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Catch-Per-Unit-Effort indices for snapper in SNA 8

New Zealand Fisheries Assessment Report 2017/45

A.D. Langley

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A standardised CPUE analysis was conducted of the SNA 8 single trawl fishery catch and effort data. The data set included individual trawl records (fishing event based data) from trawls targeting snapper, trevally and red gurnard during 1996/97–2015/16. Prior to 2007/08, most of the snapper catch was taken by trawls targeting snapper during October–December in the central region of the fishery off the Kaipara and Manukau Harbours. In the subsequent years, most of the snapper catch was taken by trawls targeting trevally over a longer fishing season (October–April) and broader area of the fishery.

A Generalised Linear Modelling (GLM) approach was used to model the occurrence of snapper catches (presence/absence) and the magnitude of positive snapper catches. The dependent variable of the catch magnitude CPUE model was the natural logarithm of catch. For the positive catch CPUE model, a lognormal error structure was adopted following an evaluation of alternative distributions. The presence/absence of snapper catch was modelled based on a binomial distribution. The range of potential explanatory variables available to both models included: vessel, fishing year, month, location, depth, target species, trawl speed, trawl gear configuration, trawl distance and duration. The data set was limited to the area north of Cape Egmont; as limited fishing effort occurred in the southern area of the fishery during the study period.

Preliminary CPUE modelling incorporated data records from October–April, the period that accounts for most of the SNA 8 catch. The preliminary lognormal CPUE models were characterised by a marked pattern in the residuals during the peak fishing season (November–December), with strong positive residuals during 2001/02–2006/07 and strong negative residuals during 2008/09–2015/16.The pattern in the residuals was indicative of a change in the operation of the fishery, related to the extent of targeting and/or avoidance of snapper. Incorporating additional complexity in the data modelling, such as the inclusion of interaction terms between key model variables (especially month, target species and month, fishing location interaction terms), did not substantially improve the fit to the November–December CPUE observations. Snapper are more highly aggregated during October–December and, hence, the effect of changes in the targeting or avoidance behaviour of the trawl fleet are likely to have a larger influence on snapper catch rates during that period. It is also considered that snapper catch rates (and hence CPUE indices) are likely to be less sensitive to changes in abundance (hyperstable) during this period. In contrast, during January–April snapper are more homogeneously distributed and snapper catch rates are likely to be less sensitive to changes in targeting/avoidance behaviour. On that basis, the final CPUE data set was restricted to records from January–April only.

One aspect of the change in fishing operation was a shift towards the targeting of red gurnard by some vessels, particularly in more recent years. These vessels typically conducted trawling at a slower speed than when targeting snapper and/or trevally. Snapper are known to be less vulnerable to trawl gear at slower speeds and, consequently, snapper catch rates would be expected to be lower from these trawls. Nonetheless, the preliminary CPUE models did not fully account for these changes in targeting behaviour, as evidenced by patterns in model residuals for individual vessels. Instead, the slower trawl speed was considered to represent a proxy for a range of fishing behaviours that have increasingly targeted red gurnard and reduced the catch rate of snapper. On that basis, records with trawl speeds less than 2.7 knots were excluded from the final data set. The final data set was further restricted to include only records from the main (core) vessels that operated in the fishery during the study period.

The annual indices derived from the January–April lognormal CPUE model were relatively constant for 1996/97–2003/04. The CPUE indices increased over the subsequent years, initially increasing by approximately 50% during 2003/04–2007/08 and then increasing considerably during 2007/08–2015/16. The annual indices derived from the binomial model also increased from 2007/08 onwards. The trend in the combined (delta-lognormal) CPUE series is similar to the lognormal CPUE series, although the magnitude of the increase in the combined CPUE series is increased by about 20% due to

the influence of the binomial indices. The NINS WG adopted the combined January–April CPUE series as an index of stock abundance for SNA 8 (22 June 2017).

Interviews were conducted with most of the current operators in the SNA 8 trawl fishery. The operators confirmed the changes in the operation of the fishery (i.e., the reduction in fishing in areas of higher snapper abundance especially during the spawning period and the change in the configuration of the trawl gear used) and emphasised that these changes were in response to a large increase in the abundance of snapper over the last 10 years. The interviews identified a range of strategies that were utilised to minimise the catch of snapper while continuing to harvest other species (trevally and/or red gurnard, John dory and tarakihi). These strategies included changes in fishing location, especially during the October–December spawning period, changing the type of trawl gear used and modifications to the configuration of the gear to enable slower trawling speeds.

The changes in fishing behaviour highlighted by the interviewees were accounted for in the CPUE analysis either by the criteria applied to the selection the final data set (especially the exclusion of the data from October–December and trawl records with a slower trawling speed) and by the inclusion of the relevant explanatory variables within the CPUE modelling (especially trawl location and trawl gear dimensions). Additional CPUE modelling that partitioned individual vessels by trawl gear category indicated that the final CPUE indices were robust to the changes in trawl gear that occurred during the study period.

1. INTRODUCTION

SNA 8 supports an important inshore trawl fishery along the west coast of the North Island. Annual commercial catches from the fishery peaked at about 4000–5000 t during the mid–late 1970s following the development of the pair trawl fishery (Ministry for Primary Industries 2016). Catches declined during the early 1980s and an initial TACC was set at 1331 t in 1986/87. The TACC was increased to 1500 t during 1992/93–2004/05 and annual catches were maintained at about that level. During this period, there was considerable rationalisation of the trawl fleet, and an increase in the dominance of the single trawl method (Kendrick & Bentley 2010).

The last stock assessment of SNA 8 was conducted in 2004/05 (Davies et al. 2013). The primary indices of stock abundance included in the assessment model were: biomass estimates from the 1990 and 2002 tagging programmes, CPUE indices from the pair trawl fishery 1974–91 (Vignaux 1993) and CPUE indices from the single trawl fishery 1996–2003 (following Davies et al. 2006). The assessment estimated that the stock biomass in 2004 was at 8.7–9.8% of the unexploited level (B_{2004}/B_0 = 8.7–9.8%). In 2005/06, the TACC was reduced from 1500 t to 1300 t to ensure a faster rebuild of the stock (MPI 2016).

During the intervening years, there has been ongoing collection of age composition data (at three year intervals) from the SNA 8 commercial catch (Walsh et al. 2017). A characterisation of the fishery, including an update of the single trawl CPUE analysis to 2007/08, was conducted by Kendrick & Bentley (2010). During 1989/90–2007/08, most of the snapper catch was taken by trawls targeting snapper during October–December in the central region of the fishery off the Kaipara and Manukau Harbours (Kendrick & Bentley 2010). Snapper are aggregated to spawn during this period and it was considered that snapper catch rates (and the resulting CPUE indices) were likely to be relatively insensitive to changes in stock abundance (hyperstable). In the absence of an accepted index of stock abundance (relative or absolute) from the recent period . the SNA 8 stock assessment has not been updated (since 2004/05).

The purpose of the current study was to investigate the feasibility of developing an accepted time-series of relative abundance based on standardised CPUE. The project was commissioned by the two main SNA 8 quota owners, Sanford Ltd and Moana New Zealand, and conducted under the auspices of Trident Systems LP.

2. DATA SETS

The CPUE analysis was based on commercial catch and effort data from the SNA 8 single bottom trawl (BT) fishery. From 1994/95, many of the inshore trawlers operating in SNA 8 reported fishing effort and catch data for individual trawls via the Trawl, Catch, Effort and Processing Return (TCEPR). In 2007/08, the Trawl, Catch and Effort Return (TCER) was introduced specifically for the inshore trawl fisheries and was adopted by many of the inshore trawl vessels within the SNA 8 fishery. The TCEPR and TCER forms record detailed fishing activity, including trawl start location and depth, and associated catches from individual trawls. Landed catches associated with trips reported on TCEPR and TCER forms are reported at the end of a trip on the Catch Landing Return (CLR).

Catch and effort data from the SNA 8 trawl fishery were also reported via the Catch Effort Landing Return (CELR), particularly prior to 1995/96 (Kendrick & Bentley 2010). The CELR form records fishing effort and catch aggregated by vessel fishing day and by target species and Statistical Area fished. The aggregated nature of the reporting means that no information is available regarding the fishing depth and location of individual trawl events. These factors are influential in the catch of snapper and were important explanatory variables in previous CPUE analyses. Following the previous studies, the current analysis was restricted to the trawl (event) based data collected via the TCEPR and TCER statutory reporting forms.

Prior to 2006/07, a significant proportion of the SNA 8 catch was caught by the pair bottom trawl method (BPT) (Kendrick & Bentley 2010). The pair trawl fishery ceased operation 2011/12 and, hence, the fishery does not provide data to monitor recent trends in snapper CPUE. The CPUE data set was limited to data from the single trawl fishery only.

In recent years, a number of vessels operating in the SNA 8 trawl fishery have participated in the development and trailing of the Precision Seafood Harvesting (PSH) trawl gear. During these trials, the fishing operation differed from the normal fishing operation and, consequently, individual fishing trips that used the PSH fishing gear were excluded from the data set.

The event based (TCEPR or TCER) catch and effort data were sourced from the Ministry for Primary Industries (MPI) database *warehou*. The data extract included the catch and effort data from any fishing trip that conducted bottom trawling within the Statistical Areas that comprise the SNA 8 fishstock area (Statistical Areas 037, 038–048) (Figure 1) and targeted snapper or a range of other inshore species that are caught in association with snapper (TAR, FLA, TRE, RCO, BAR, SKI, WAR, GUR, and JDO).

For the qualifying trips, all effort data records were sourced, regardless of whether or not snapper was landed. The estimated catches and landed catch records of all finfish species were sourced for the qualifying fishing trips. Data were complete to the end of the 2015/16 fishing year.

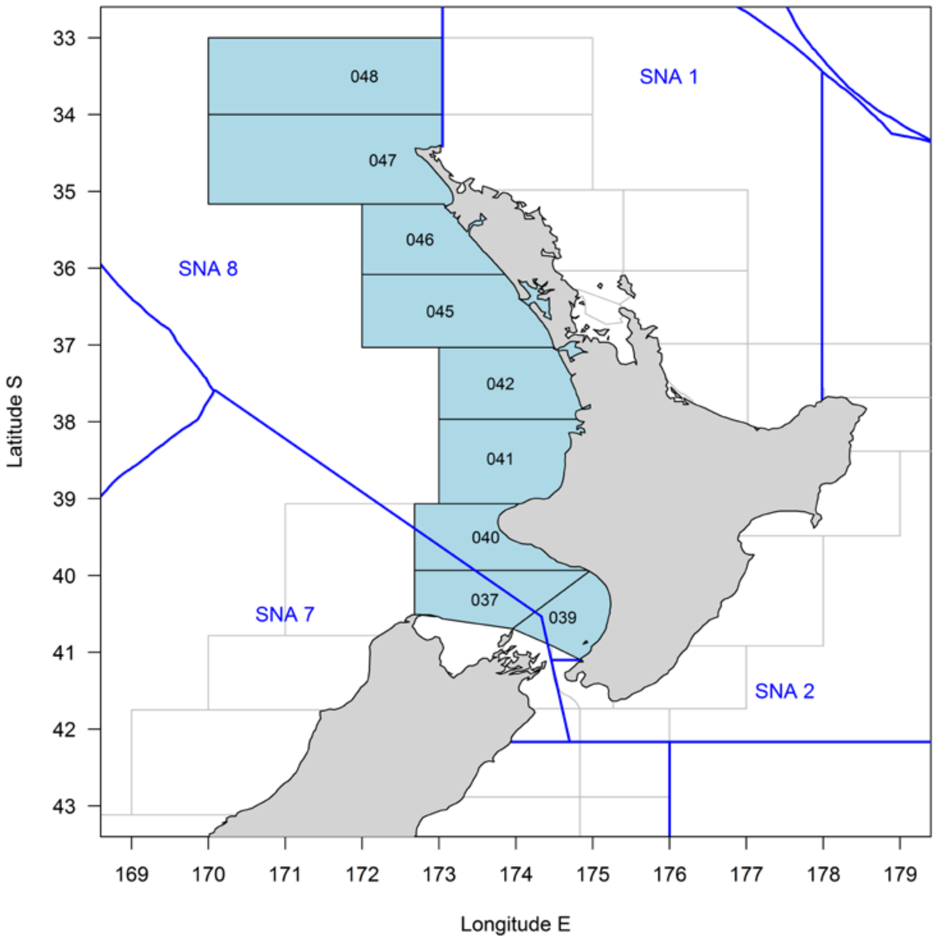

Figure 1: Map of the SNA 8 fishstock area and constituent Statistical Areas.

2.1 Data processing

The initial set of SNA 8 landed catch records was screened to retain the records that represented the final destination of the snapper catch (destination codes L, A, C, E, and O). This resulted in a trivial (<0.1%) reduction in the total snapper landed catch included in the characterisation data set.

The SNA 8 landed catches were compared to the aggregated estimated catches of snapper from individual fishing trips. In most cases, the ratio of the trip landed catch to the estimated catch approximated 1.0, indicating a good correspondence between the landed catch and estimated catch data (Figure 2). Potentially erroneous landed catch records were identified based on the ratio of the trip landed catch to the aggregated estimated catch. For these trips, the landed catches were evaluated by comparing the landed catch with the corresponding processed catch weight multiplied by the conversion factor of the associated state code. A subset of those trips had catch values derived from the processed catch data that were considerably lower than the landed catch. For these trips, the landed catches were corrected using the green weight equivalent of the processed catches. This resulted in a small reduction in the total snapper catch included in the data set.

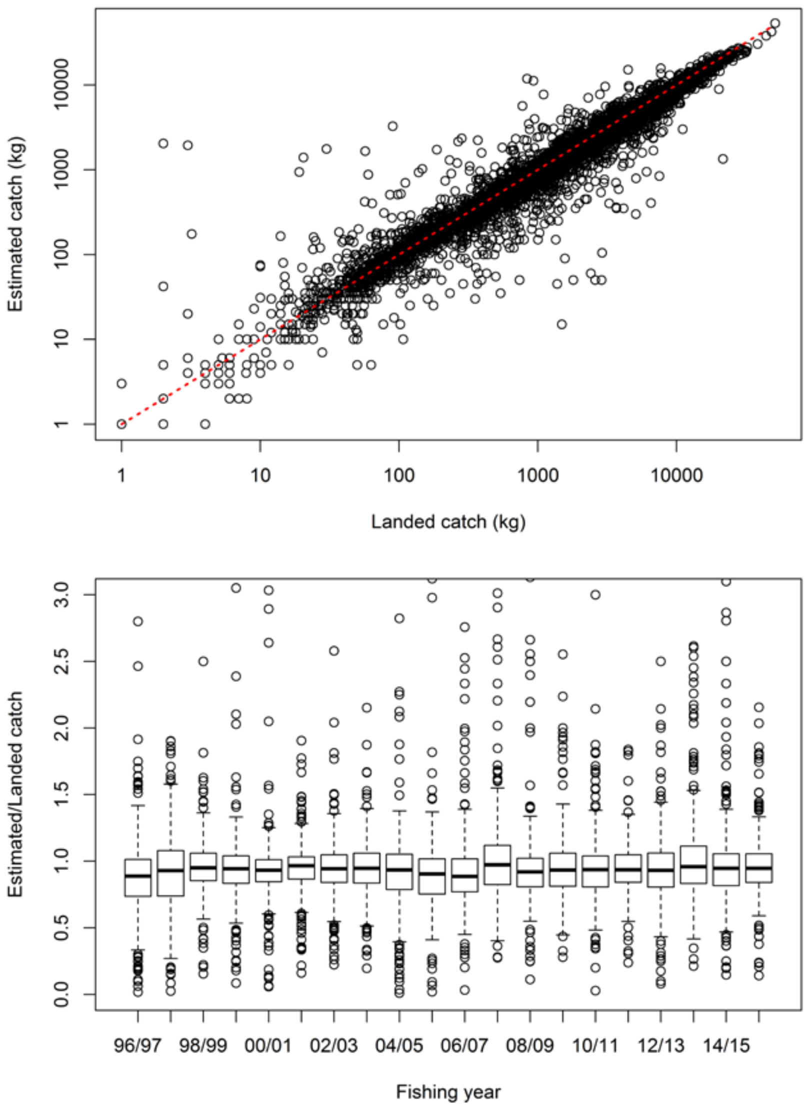

Figure 2: A comparison of snapper estimated and landed catches from individual fishing trips included in the SNA 8 single trawl data set (top panel) and boxplots of the annual ratio of estimated and landed snapper catches.

Most of the trips with a landed catch of snapper were successfully linked to the aggregated fishing effort records. However, the number of trips was reduced by the exclusion of effort records for fishing methods that would not be expected to catch snapper (e.g. surface longline and troll) and/or target species that are unlikely to be associated with snapper (e.g. ORH, SSO, and BOE). Individual fishing effort records from outside of the SNA 8 fishstock area (mainly from SNA 1) were also excluded from the data set.

From 1996/97, fishing event based catch and effort data accounted for a substantial proportion of the total SNA 8 catch (Figure 3). Initially, these data were collected in TCEPR format and from 2007/08 a significant proportion of the data were collected in TCER format. A notable difference between the two formats is that the TCER form has the facility to record the estimated catch of the eight main species caught from the trawl, while the TCEPR format records the estimated catch of the top five species caught per trawl. This difference has the potential to result in a change in the reporting of the catch of the minor species, potentially increasing the number of small catches reported in the TCER format and, thereby, reducing the proportion of zero catch records (Langley 2014). In turn, this has the potential to influence the allocation of the landed catches amongst fishing events from a fishing trip as this is usually based on the corresponding estimated catches from individual trawls.

For the composite TCEPR/TCER data set, estimated catches of snapper were associated with the individual trawl records and the ranking of snapper amongst the estimated species catches from the individual trawl was determined based on the reported estimated catch weight. For comparability with the TCEPR trawl records, snapper estimated catches from TCER records that were ranked lower than the 5th largest catch (i.e. the 6–8th ranked species) were reassigned an estimated catch of zero (0 kg). For each fishing trip, the aggregated top 5 estimated catch of snapper was determined. The landed catch of snapper from each fishing trip was then allocated amongst the trawl records from the respective fishing trips in proportion to the estimated catches of snapper (top 5 species only) (following Starr 2007). Virtually all of the qualifying fishing trips included at least one trawl with an estimated catch of snapper, enabling all landed catches to be allocated in this manner.

3. DATA SUMMARY

From 1996/97, the bottom trawl event based data set accounted for a substantial proportion of the total SNA 8 catch (Figure 3). The overall proportion of the catch included in the data set has further increased in recent years, and from 2007/08 the data set represented at least 70% of the total annual SNA 8 catch.

This section provides a summary of the bottom trawl event based data set from 1996/97–2015/16. It is not intended to represent a full characterisation of the SNA 8 fishery, although the results will be indicative of the trends in the entire fishery, especially in the more recent years.

Overall, the catch of snapper was dominated by the snapper and trevally target trawl fisheries (Figure 4). During 2007/08–2010/11, there was a shift in the relative importance of these two fisheries, with a marked decline in the proportion of the snapper catch taken by the target snapper fishery, and a corresponding increase in the catch from the trevally fishery. The red gurnard target trawl fishery also accounted for a secondary component of the snapper catch. The proportion of the catch taken by the fishery increased in 2011/12, and accounted for 15–20% of the snapper catch in the subsequent years (Figure 4).

Annual catches were predominantly taken in Statistical Areas 045 and 042, encompassing the coastal area off the entrances to the Kaipara and Manukau Harbours (Figure 1 and Figure 5). Since 2008/09, there has also been an increase in the proportion of the catch taken off Ninety Mile Beach (Statistical Area 047) with a corresponding reduction in the magnitude of the catch from Statistical Area 045. A smaller proportion of the catch was taken from North Taranaki Bight (041), while limited catch was taken from the southern area of SNA 8 (Statistical Areas 037, 039 and 040) (Figure 1 and Figure 5).

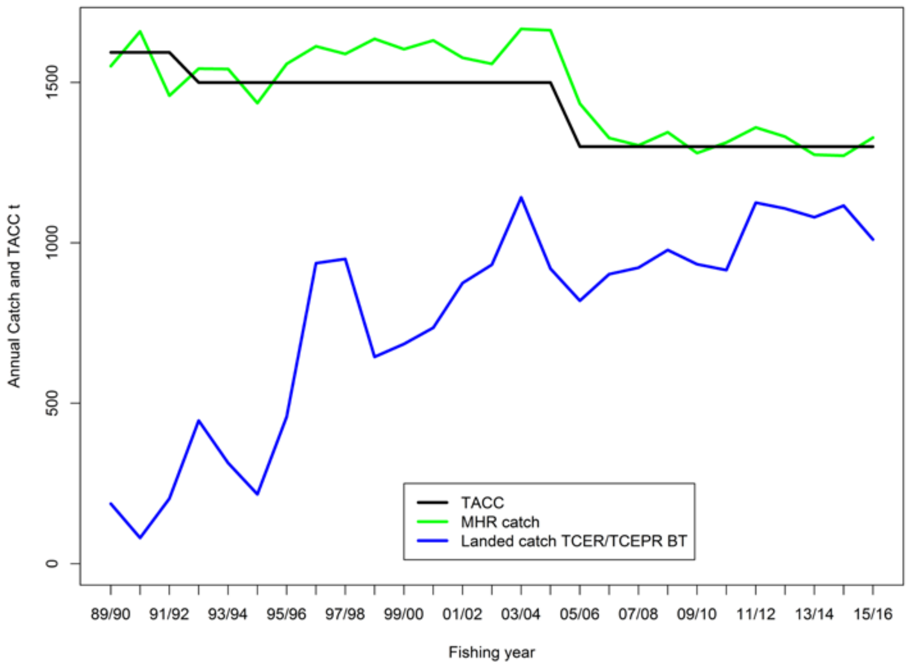

Figure 3: Annual SNA 8 reported catch (MHR catch) and Total Allowable Commercial Catch (TACC) and the landed catch included in the single trawl event based data set (associated with TCER and TCEPR reporting forms).

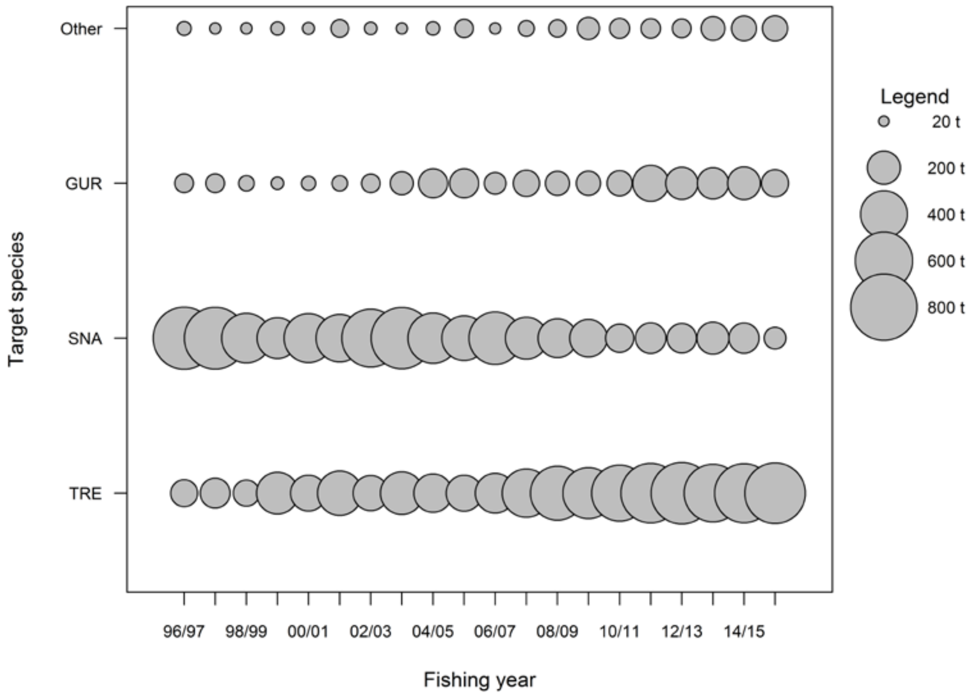

Figure 4: Annual snapper catch from the SNA 8 single trawl fishery by declared target species from the event based data set (TCEPR and TCER data only). The area of the circle is proportional to the catch.

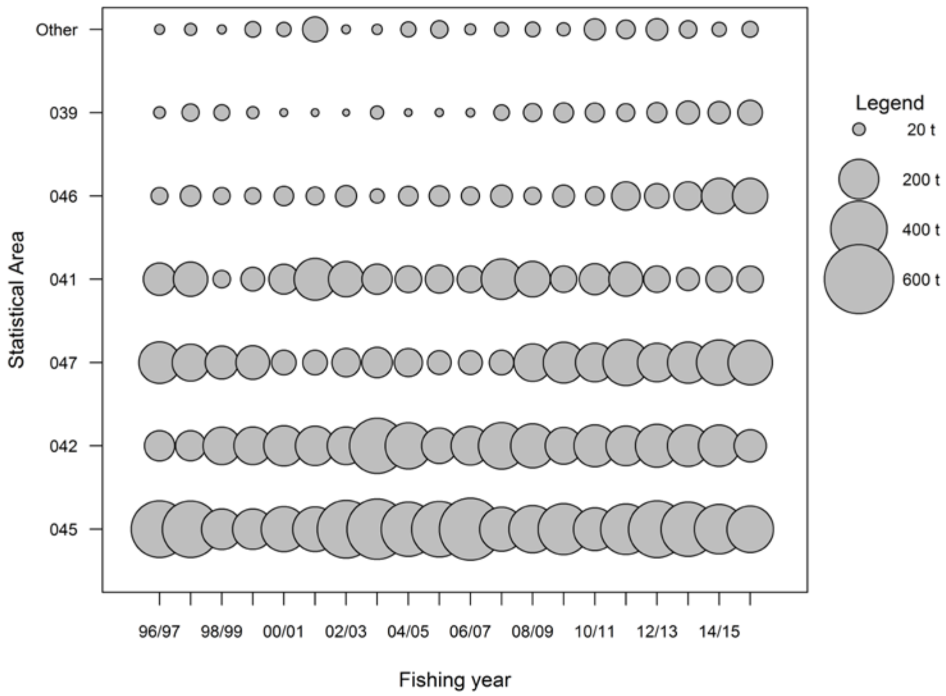

Figure 5: Annual snapper catch from the SNA 8 single trawl fishery by Statistical Area from the event based data set (TCEPR and TCER data only). The area of the circle is proportional to the catch.

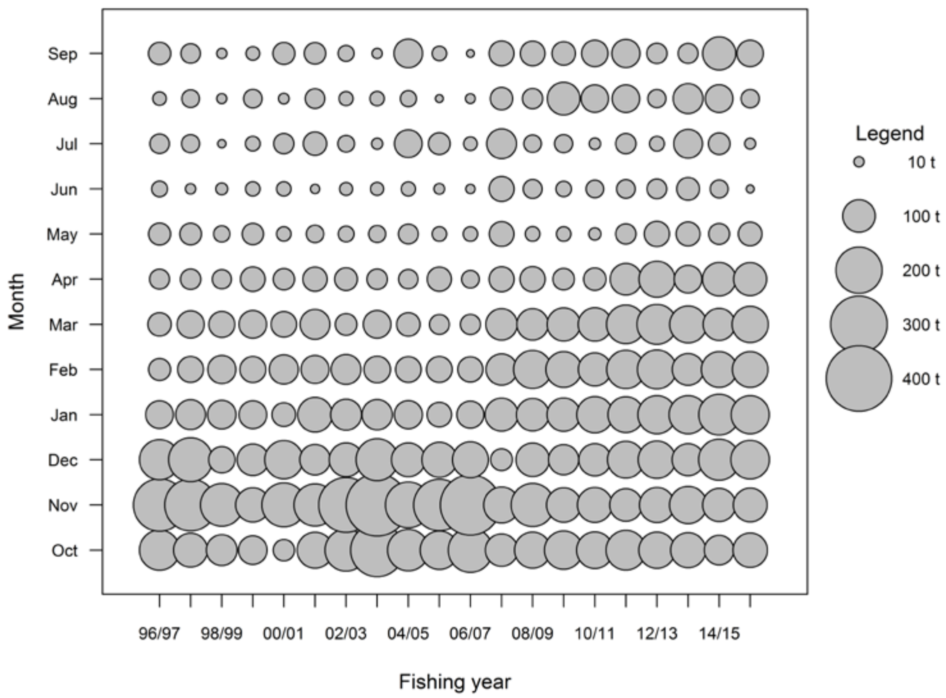

Figure 6: Annual snapper catch from the SNA 8 single trawl fishery by month from the event based data set (TCEPR and TCER data only). The area of the circle is proportional to the catch.

Prior to 2007/08, the snapper catch was concentrated in October–December and this period accounted for 41–71% of the annual catch (Figure 6). Most of the remainder of the catch was taken during January–April and catches were low during May–August. From 2007/08, snapper catches were relatively evenly distributed throughout October–April and there was an increase in catches during August–September (Figure 6).

From the initial summary of the data set, the definition of the SNA 8 trawl fishery was further restricted to include only trawls targeting snapper, trevally or red gurnard in the area north of Cape Egmont. The revised data set included 89% of the snapper catch included in the initial data set.

For this portion of the SNA 8 fishery, a number of trends are apparent in the distribution of the fishing effort, specifically:

- A restriction in the depth range fished with a lower proportion of the trawls conducted in 10–30 m during 2007/08–2015/16 (Figure 7).
- An increase in the distance trawled during 1999/2000–2004/05 (Figure 7). Since 2008/09, average trawl distance declined again, primarily due to an increase in the frequency of relatively short trawls.
- The spatial distribution of trawl effort varied over time and since 2006/07 there has been less concentration of fishing effort in the central area of the fishery off Kaipara and Manukau Harbours. Fishing effort in the North Taranaki Bight reduced in 2012/13 with a corresponding increase in effort off Raglan Harbour (Figure 7).
- From 2006/07, fishing effort was more evenly distributed throughout October–April compared to the preceding years when effort was more concentrated in October–December (Figure 7).
- There was a marked reduction in the headline height of the trawl gear during 2006/07–2013/14 (Figure 7). The reduction in the average headline height was initially driven by the entrance of two vessels into the fishery in 2006/07 and 2007/08 both of which had low opening trawl gear. More recently, in 2012/13 two of the other vessels in the fleet changed the configuration of the trawl gear (to gear with a lower headline height) (Figure 7).
- Initially, the reduction in headline height was primarily associated with the increased targeting of red gurnard from 2007/08 and a corresponding reduction in trawling speed (Figure 8). More recently, there was also a marked decline in the headline height of trawls targeting trevally and snapper; however, higher trawling speeds are used when targeting these two species (Figure 8). Since 2012/13, there was an increase in the speed of trawls targeting trevally.

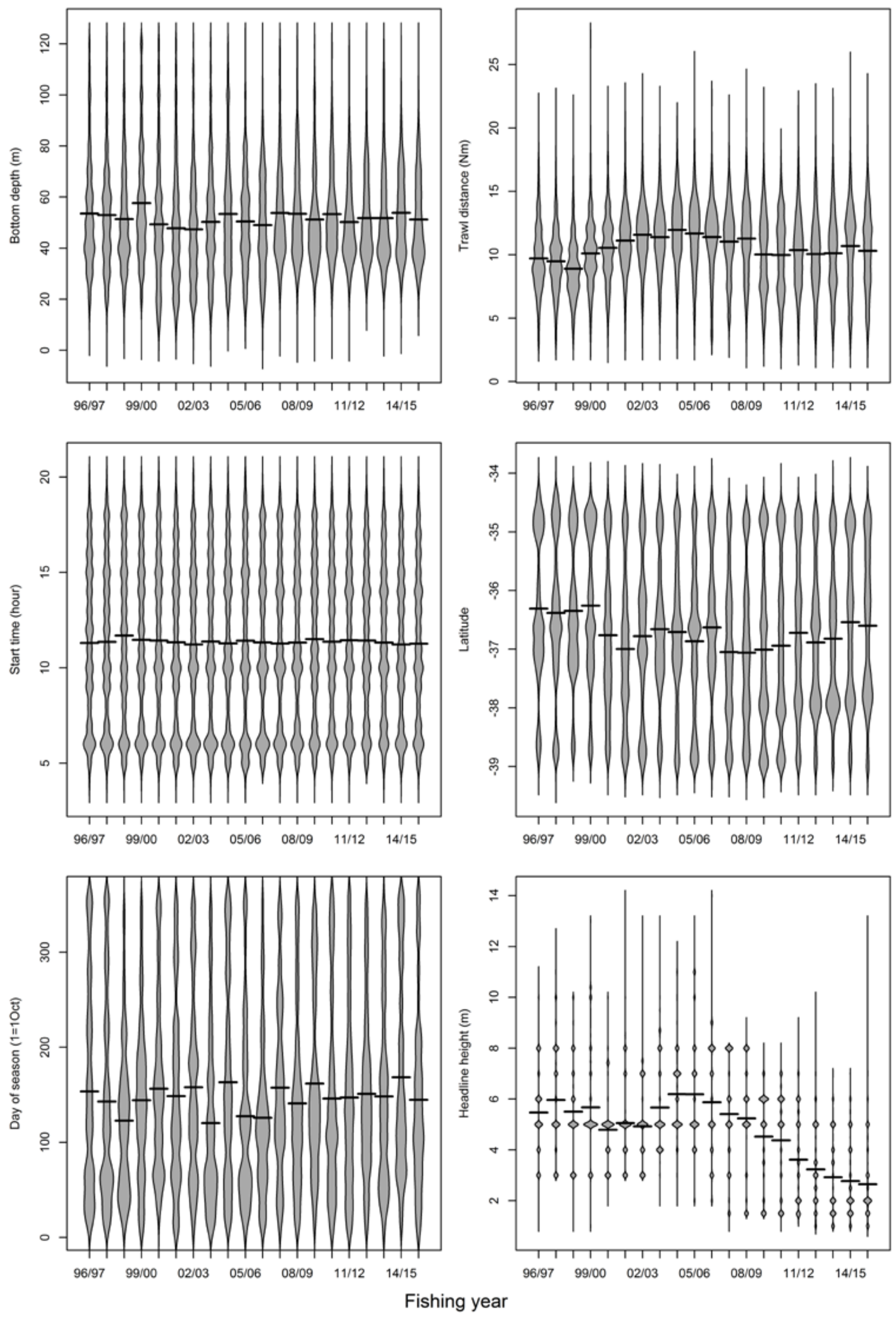

Figure 7: Bean plots of the annual distribution of selected variables included within a subset of the event based data set including trawls targeting snapper, trevally and red gurnard in the area of SNA 8 north of Cape Egmont. The horizontal lines represent the annual means.

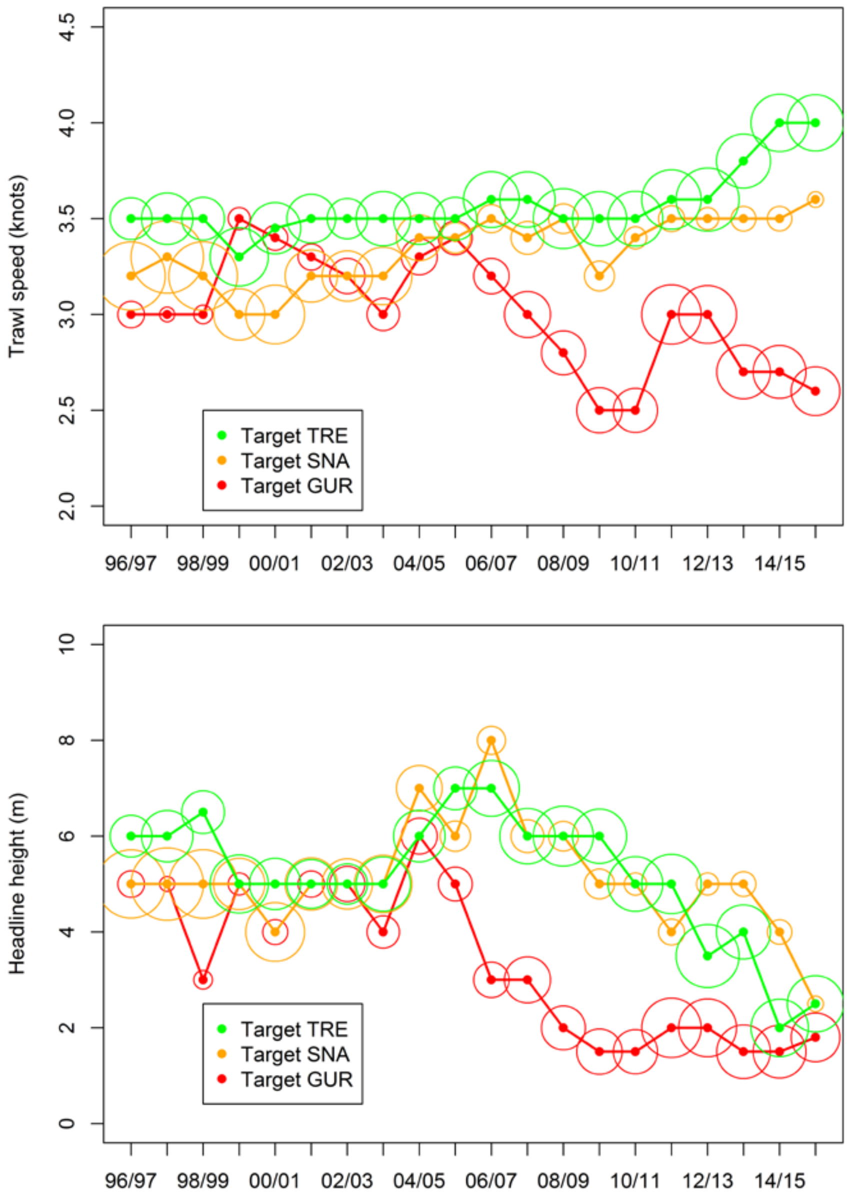

Figure 8. Annual trend in median trawl speed (top panel) and median trawl headline height (bottom panel) by target species, for a subset of the event based data set including trawls targeting snapper, trevally and red gurnard in the area of SNA 8 north of Cape Egmont. The area of the circle is proportional to the number of records (maximum = 2030).

There is a strong seasonal pattern in the relative catch rate of snapper along the west coast (Figure 9 and Figure 10). Catch rates were highest in October–December in the Kaipara/Manukau area. In recent years (2008/09–2015/16), there was limited fishing in this area during October–November (Figure 10). During January–April, catch rates were generally lower and more homogeneous throughout the area of the fishery. Catch rates from January–April were generally higher during 2008/09–2015/16 compared to the preceding period (Figure 9 and Figure 10). During 2008/09–2015/16, relatively high catch rates of snapper were achieved off Ninety Mile Beach in March–April (Figure 10).

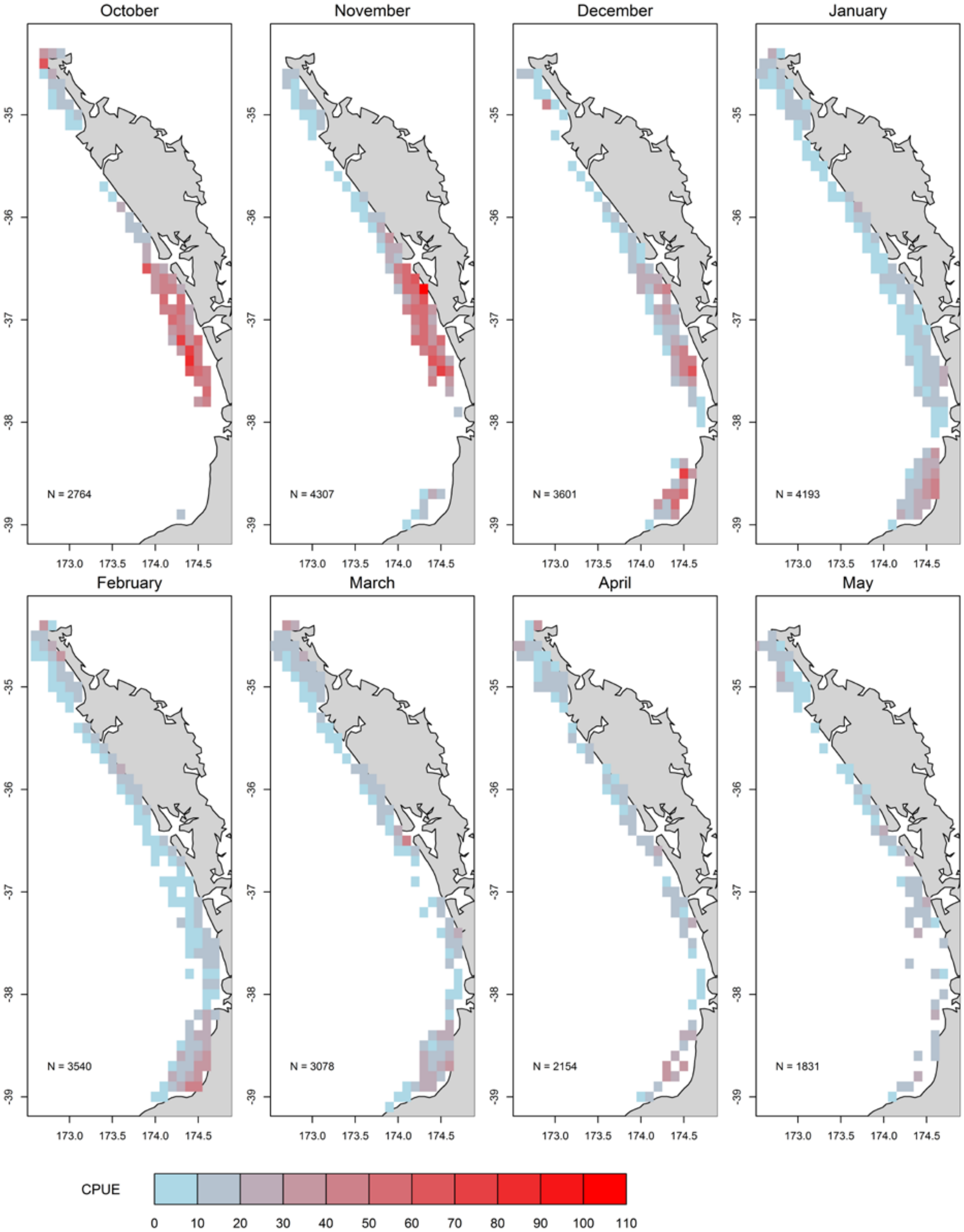

Figure 9: Median catch rate (kilograms per nautical mile) of snapper aggregated by month (October–May) and 0.1 degree of latitude/longitude from 1996/97–2007/08 (target SNA, TRE, GUR). Only cells with a minimum of 10 trawls are presented. N represents the total number of trawls included in the plot.

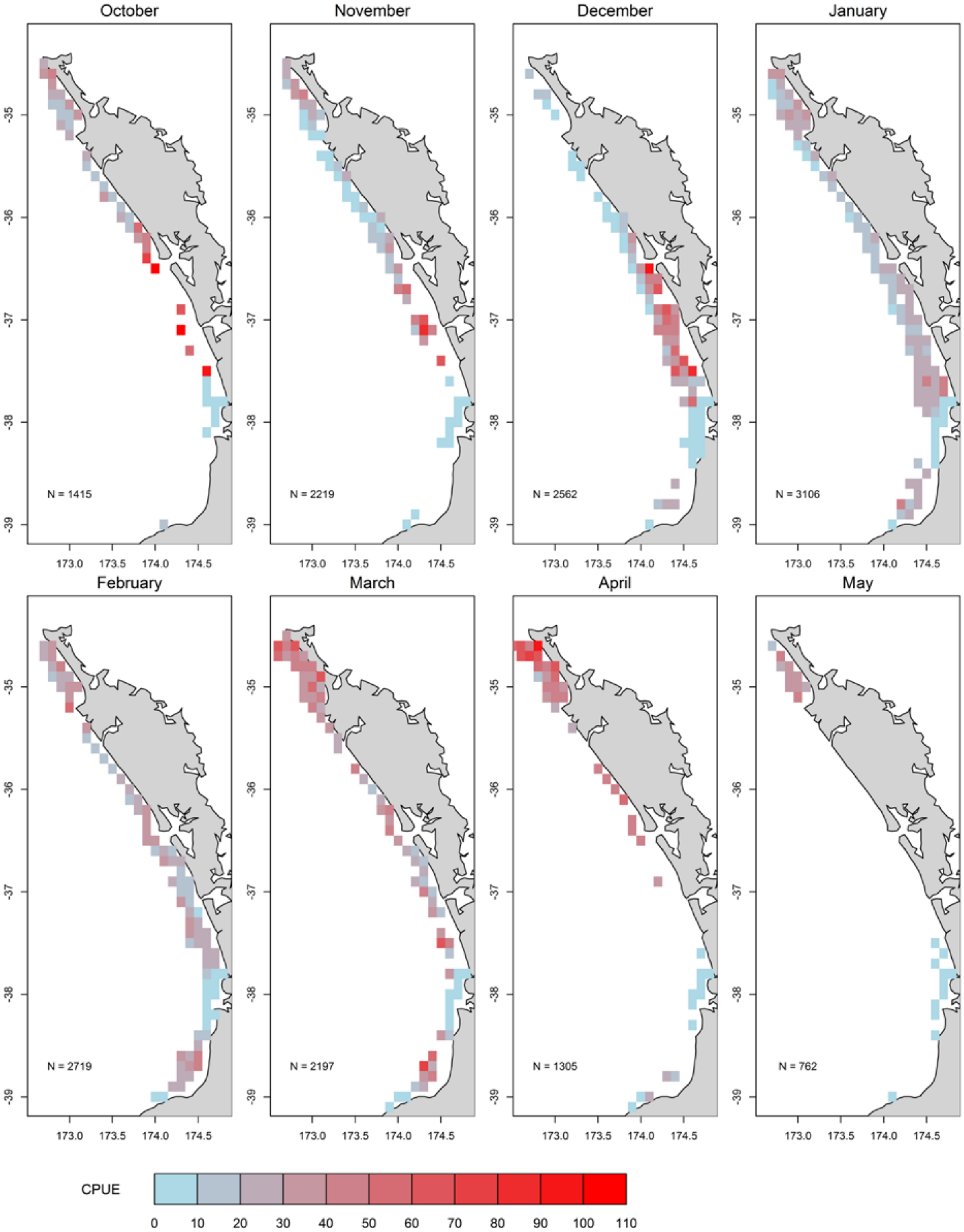

Figure 10: Median catch rate (kilograms per nautical mile) of snapper aggregated by month (October–May) and 0.1 degree of latitude/longitude from 2008/09–2015/16 (target SNA, TRE, GUR). Only cells with a minimum of 10 trawls are presented. N represents the total number of trawls included in the plot.

4. CPUE ANALYSIS

4.1 Methodology

A Generalised Linear Modelling (GLM) approach was used to model the occurrence of snapper catches (presence/absence) and the magnitude of positive snapper catches. The dependent variable of the catch magnitude CPUE models was the natural logarithm of catch. For the positive catch CPUE models, a lognormal error structure was adopted following an evaluation of alternative distributions (Log logistic, Weibull, Gamma). The presence/absence of snapper catch was modelled based on a binomial distribution.

The potential explanatory variables available for inclusion in the CPUE models are specified in Table 1.

Table 1: The variables included in the SNA 8 trawl event based CPUE data set. The data range restriction was applied to the final January–April data set.

Variable	Definition	Data type	Range
Vessel	Fishing vessel category	Categorical (16)	
FishingYear	Fishing year	Categorical (20)	
Month	Month	Categorical (4)	Jan–Apr
Latitude	Latitude at the start location of trawl.	Continuous	34.0–39.33S
Longitude	Longitude at the start location of trawl.	Continuous	
TargetSpecies	Declared target species for trawl.	Categorical (3)	SNA,TRE,GUR
Duration	Natural logarithm of trawl duration (hours)	Continuous	ln(1–6)
Distance	Natural logarithm of distance trawled (N. miles)	Continuous	ln(1–30)
Depth	Fishing depth (m)	Continuous	1–120
StartTime	Hour at the start of trawl.	Continuous	3–21
Speed	Trawl speed (knots)	Continuous	2.75–5.0
GearWidth	Wingspread of trawl gear (m)	Continuous	0–50
GearHeight	Headline height of trawl gear (m)	Continuous	0.5–15
GearRatio	Ratio *GearWidth/GearHeight*	Continuous	0–30
SNAcatch	Scaled estimated SNA trawl catch (kg).	Continuous	0–5000
SNAbin	Presence (1) or absence (0) of SNA catch in trawl.	Categorical	

A step-wise fitting procedure was implemented to configure each of the CPUE models. The fitting procedure initially considered the range of potential explanatory variables (Table 1) with the continuous variables typically parameterised as a third order polynomial function, although a more flexible parameterisation (7^{th} order polynomial) was used for the *Latitude* variable to account for spatial variation in snapper catch rates. The categorical variable *FishingYear* was included in the initial model and subsequent variables were included in the model based on the improvement in the AIC. Additional variables were included in the model until the improvement in the Nagelkerke pseudo-R^2 was less than 0.5%.

The influence of each of the main variables in the CPUE models was examined following the approach of Bentley et al. (2011). Annual trends in the residuals of each model were examined with respect to month, target species, Statistical Area and vessel.

The final (combined) indices were determined from the product of the positive catch CPUE indices and the binomial indices following the approach of Stefansson (1996). A recent study highlighted the importance of incorporating both components in the derivation of the final indices, particularly for bycatch fisheries where the reporting of smaller catches may be variable (particularly over time) (Langley 2015). The confidence intervals associated with the combined indices were determined using a bootstrapping approach.

4.2 Preliminary analysis

Initial CPUE models incorporated data records from October–April, the period that accounts for most of the SNA 8 catch. The preliminary models were characterised by a marked pattern in the residuals from the lognormal CPUE models, specifically from November–December, with strong positive residuals during 2001/02–2006/07 and strong negative residuals during 2008/09–2015/16 (Figure 11). This pattern may indicate a change in the operation of the snapper fishery during the main spawning period related to the extent of targeting and/or avoidance of snapper aggregations.

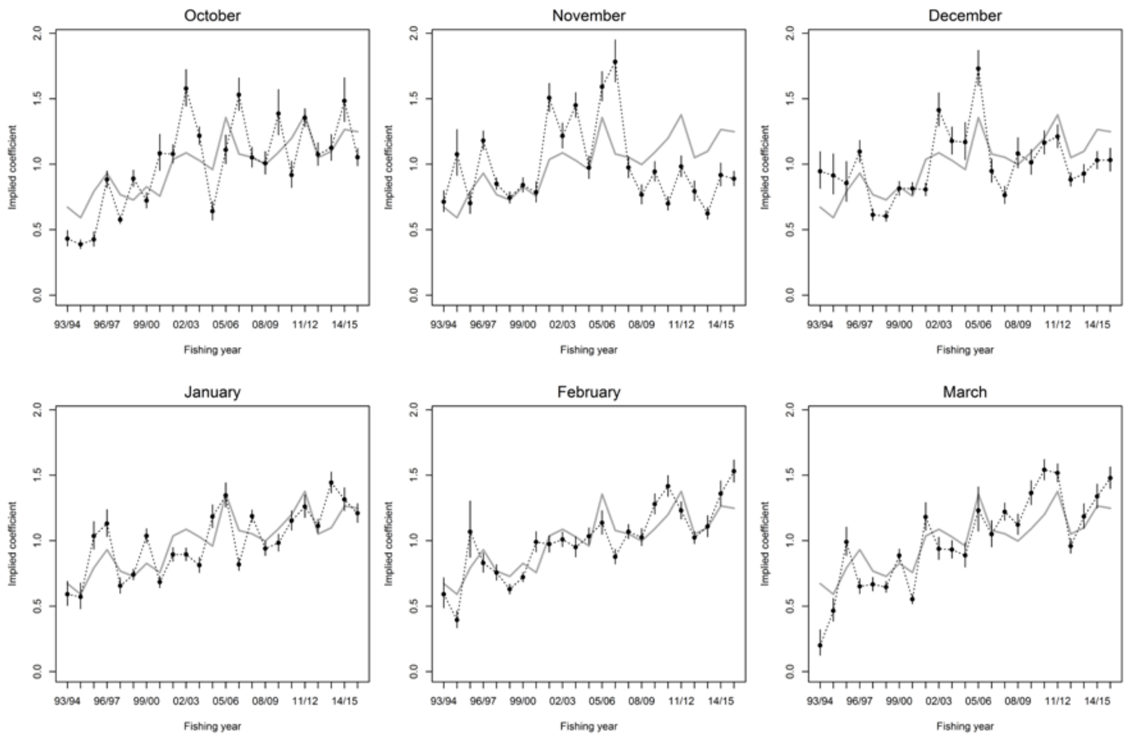

Figure 11: Annual implied coefficients (points) for the individual *Months* included in a preliminary lognormal CPUE model. The grey line represents the annual CPUE indices derived from the model. The confidence intervals represent the standard error of the annual residuals.

The CPUE models were further refined to more adequately account for changes in targeting behaviour, including the inclusion of interactions among key model variables, specifically *Vessel* and *TargetSpecies*, *Month* and *TargetSpecies*, and *Month* and *Latitude*. Of these interaction terms, *Month:Latitude* had the greatest explanatory power as it enabled the CPUE models to account for the changes in the spatial distribution of snapper associated with the spawning period.

The estimated *Month:Latitude* coefficients were consistent with the seasonal patterns in the unstandardised CPUE (see Figure 9 and Figure 10). The model predicts that snapper CPUE is highest in the Kaipara/Manukau area during October and November (Figure 12). The spatial effect is reduced in December and during January–April monthly catch rates are predicted to be relatively consistent throughout the main area of the fishery. Nonetheless, during this period snapper catch rates are predicted to be higher in the southern (North Taranaki Bight) and northern (Ninety Mile Beach) areas of the fishery (Figure 12).

The inclusion of the *Month:Latitude* interaction term in the CPUE model reduced the magnitude of the temporal trend in the residuals during November–December, although the underlying trend persisted.

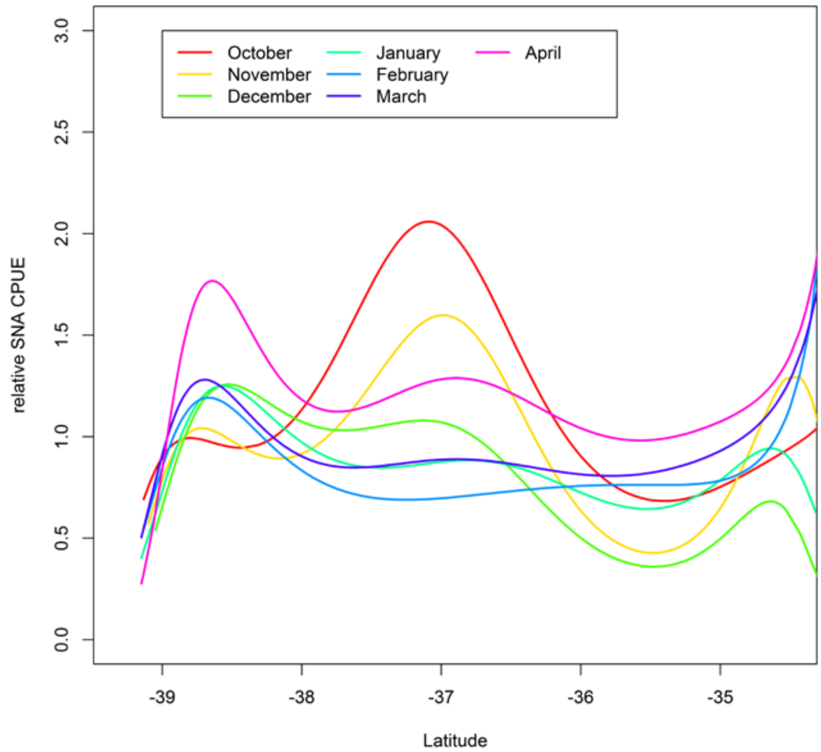

Figure 12: Relative snapper CPUE predicted from the *Month:Latitude* interaction term included in a preliminary lognormal CPUE model.

From the preliminary CPUE models, there were also strong temporal patterns in the model residuals for individual fishing vessels. Most notably, there was a declining trend in the residuals for two vessels (coded 959275579 and 1463970646), both of which predominantly targeted red gurnard. For these vessels, the proportion of snapper caught in the target red gurnard trawls declined during recent years indicating that the vessels were becoming more proficient at targeting red gurnard and avoiding snapper (Figure 13). These vessels were also trawling at slower speeds than other vessels in the fleet (typically less than 2.75 knots). While trawl speed and target species were both included as explanatory variables in the preliminary CPUE models, the patterns in the residuals indicate that these variables were not fully accounting for the changes in the fishing operation of these vessels.

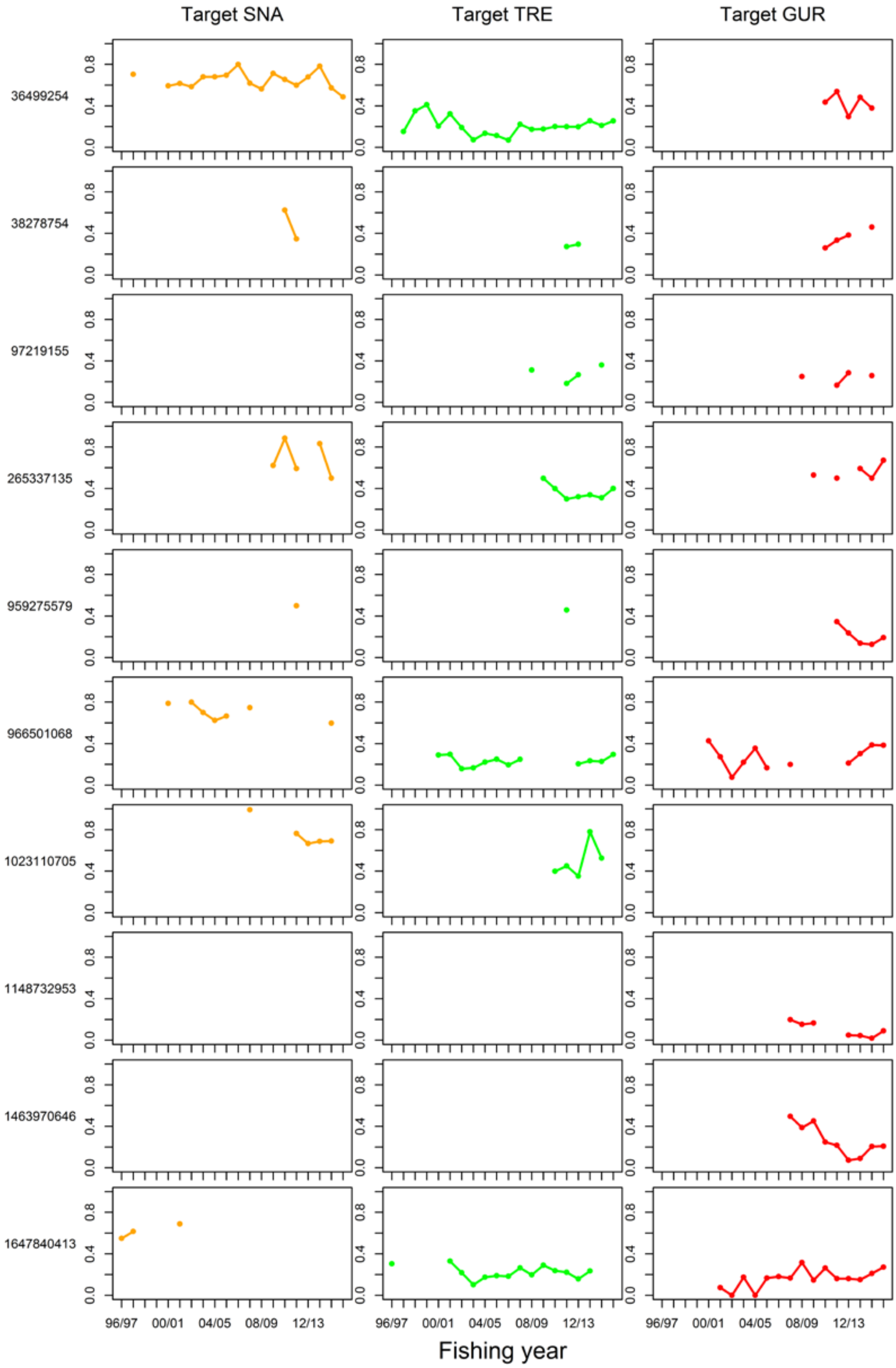

Figure 13: Proportion of snapper caught in the trawl catches (snapper, trevally and red gurnard combined) by vessel (rows) and target species (columns) for the ten main vessels operating in the SNA 8 fishery during 2008/09–2015/16.

4.3 CPUE models

The results from the preliminary CPUE modelling suggested that there had been considerable changes in the operation of the SNA 8 trawl fishery during the late 2000s. There were some corresponding trends in a number of the main effort variables (see Section 3); however, it was apparent that the data modelling was unlikely to fully account for the influence of such changes on the catch rate of snapper due to the complex nature of the fishery and the relatively limited data collected via statutory reporting forms. The changes in fishing operation were most apparent during the October–December period. Snapper are more highly aggregated at that time and, hence, the effect of changes in the targeting or avoidance behaviour of the trawl fleet are likely to have a larger influence on snapper catch rates in that period. It is also considered that snapper catch rates (and hence CPUE indices) are likely to be less sensitive to changes in abundance (hyperstable) during this period. In contrast, the spatial distribution of snapper during January–April appears to be more homogeneous and snapper catch rates during that period are likely to be less sensitive to changes in targeting/avoidance behaviour. On that basis, the final CPUE data set was restricted to records from January–April only.

One aspect of the change in fishing operation was a shift towards targeting red gurnard by some of the vessels in the fleet (as described in the previous Section). The slower trawl speed associated with the increased targeting red gurnard was considered to represent a proxy for a range of fishing behaviours that have resulted in increased avoidance of snapper. On that basis, the trawl records with a slower trawl speed were also excluded from the final data set.

The final CPUE data set (Appendix 1 Table A2) was defined by the following criteria:

- Fishing method BT.
- Declared target species SNA, TRE or GUR.
- Fishing years 1996/97–2015/16.
- Fishing season January–April.
- Fishing effort was restricted to the main depth range of the snapper catch (less than 120 m).
- Fishing location north of Cape Egmont as there was limited trawling in the southern area of SNA 8 during 1996/97–2015/16.
- Trawls conducted with a slower trawl speed (less than 2.75 knots) were excluded.
- Fishing effort limited to (core) vessels completing a minimum of 8 trips in at least five years based on records meeting the specified criteria.

The core fleet, defined based on the continuity criteria, accounted for 86% of the total snapper catch included in the January–April data set. The criteria resulted in the selection of 16 unique vessels including 6 vessels that operated in the fishery for at least 10 of the 20 years (Figure 14). Approximately half of the snapper catch included in the core vessel data set was taken by three vessels with a single vessel accounting for 38% of the catch.

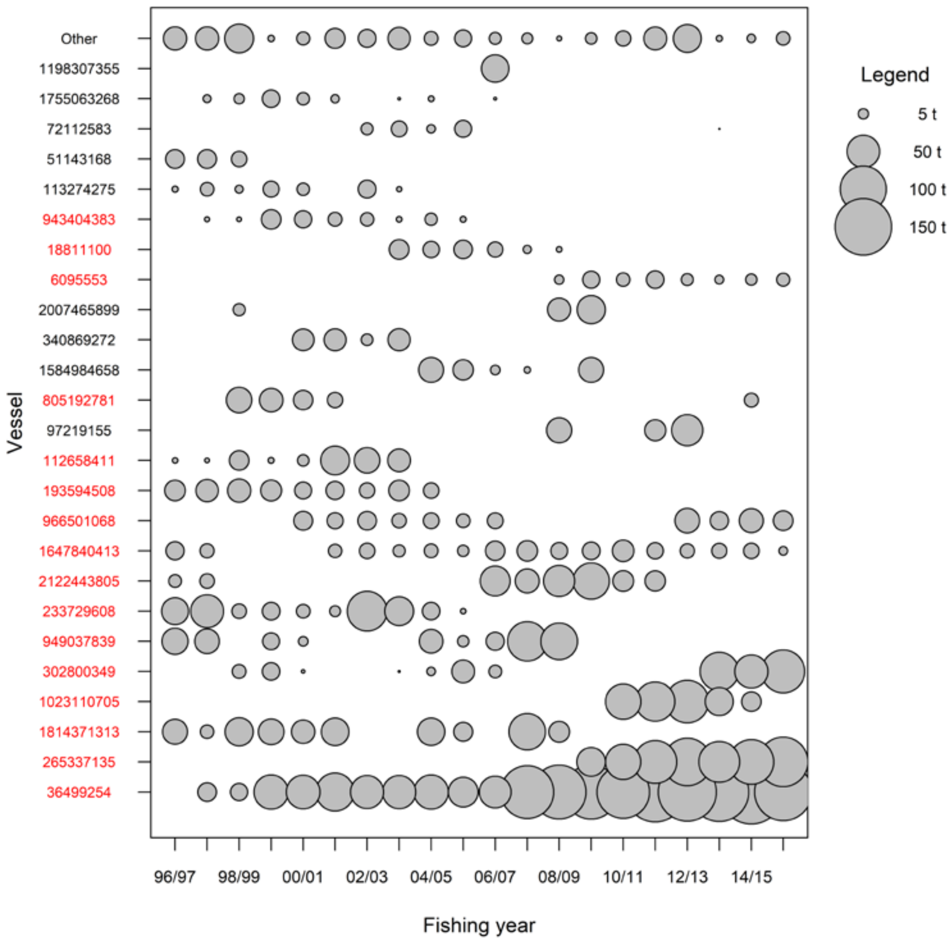

Figure 14: Annual snapper catch during January-April from the event based bottom trawl data set. The area of the circle is proportional to the snapper catch. The vessels included in the core vessel data set are highlighted in red.

The number of vessels included in the core fleet declined during the early 2000s and the core fleet was comprised of a relatively small number (about 6) of vessels operating in the fishery each year during 2010/11–2015/16 (Figure 15). During 2001/02–2015/16, fishing effort (number of trawls) by the core fleet fluctuated between 600–800 trawls per annum. The annual snapper catches included in the January–April core vessel data set were about 130–200 t during 1996/97–2006/07 and then increased to a peak of about 350–400 t during 20011/12–2012/13. Catches in the two most recent years were slightly below the peak level (Figure 15, Appendix 1 Table A2).

Most of the core vessels operating in the fishery have continued to report catch and effort via TCEPR form, rather than changing to reporting via the TCER form (from 2007/08). Almost all (99.7%) of the snapper catch was allocated to the fishing effort records based on the distribution of the estimated catch within individual fishing trips. For most (77%) of the fishing event records, snapper was included within the three main species recorded in the estimated catch. There was no appreciable change in the recording of snapper catches associated with the introduction of the TCER reporting form i.e., there was no apparent difference in the frequency of zero catches of snapper reported from the TCER and TCEPR forms and there was no difference in the ranking of snapper in the catch of species reported from individual trawls between the two form types.

Trawls with no associated snapper catch represented 8–26% of the records during 1996/97–2006/07. Over the subsequent years, there was a steady decline in the proportion of zero catch records to only 2–3% in 2011/12–2015/16 (Figure 15).

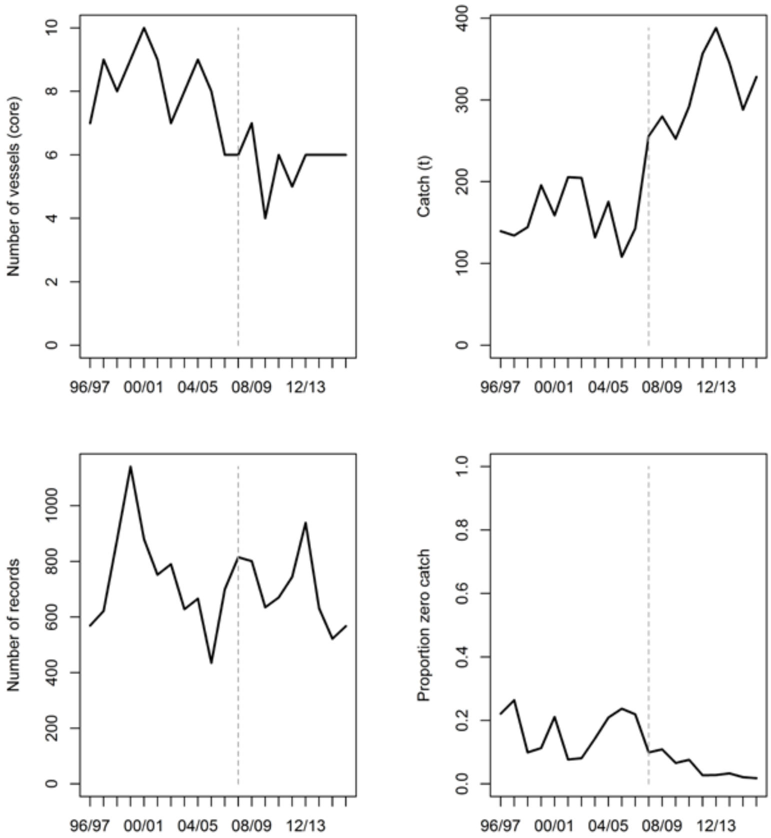

Figure 15: A summary of the data included in the January-April SNA 8 core vessel data set by fishing year. The dashed vertical line represents the year the TCER reporting form was introduced.

The positive catch CPUE model included the predictor variables *FishingYear*, *Vessel*, *Latitude*, *Depth*, the natural logarithm of *Distance* and *TargetSpecies* (Table 2). Overall, the model explained 37.0% of the variation in the positive catch of snapper (Nagelkerke pseudo-R^2), while the *FishingYear* variable accounted for a considerable proportion of the variation (13.1%).

Table 2: Summary of stepwise selection of variables in the SNA 8 lognormal catch CPUE model. Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: term included in final model.

Term	DF	Log likelihood	AIC	Nagelkerke pseudo-R^2
FishingYear	19	-18 374	36 789.1	0.131 *
Vessel	15	-17 364	34 799.3	0.266 *
Latitude	7	-16 962	34 010.3	0.314 *
Depth	3	-16 640	33 371.2	0.350 *
Distance	3	-16 510	33 117.6	0.364 *
TargetSpecies	2	-16 457	33 015.9	0.370 *
Month	3	-16 428	32 963.3	0.373
GearHeight	3	-16 420	32 954.1	0.374
GearRatio	3	-16 411	32 942.7	0.375
StartTime	3	-16 405	32 935.6	0.376
Duration	3	-16 401	32 934.1	0.376

While the distribution of the CPUE model residuals approximates the assumption of normality, the deviation of the residuals is lower than expected from a normal distribution (Figure 16). Alternative error structures, especially the Weibull distribution, were investigated in the modelling fitting procedure; however, the alternative error structures did not result in an improvement in the fit to the data (measured by AIC) or the model diagnostics. Regardless, the resulting annual CPUE indices were similar for each of the model configurations investigated.

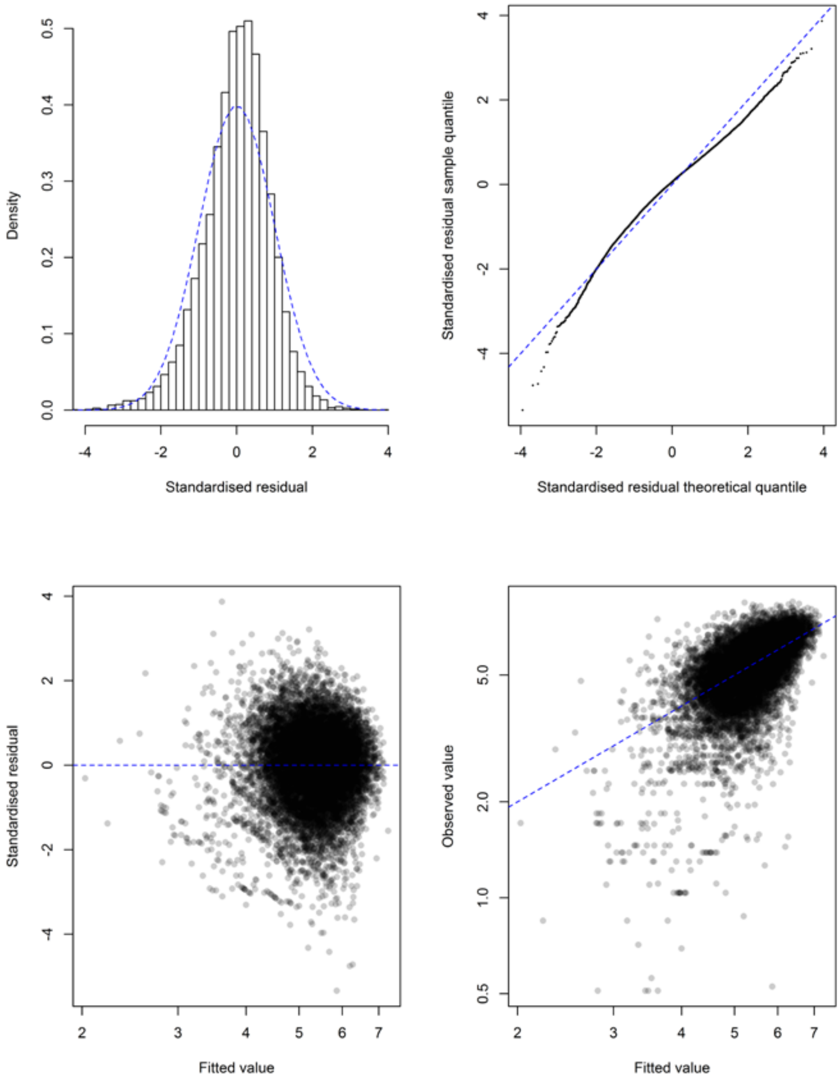

Figure 16: Residual diagnostics for the lognormal positive catch CPUE model for the SNA 8 trawl fishery. Top left: histogram of standardised residuals compared to a standard normal distribution. Bottom left: quantile-quantile plot of standardised residuals. Top right: fitted values versus standardised residuals. Bottom right: observed values versus fitted values.

The annual indices derived from the positive catch CPUE model were relatively constant during 1996/97–2003/04 (Figure 17). The CPUE indices increased over the subsequent years, initially increasing by approximately 50% during 2003/04–2007/08, and then increasing considerably during 2007/08–2015/16. The trend in the CPUE indices was generally comparable to the trend in the nominal (unstandardized) catch rates of snapper (Figure 17).

The *Latitude* and *Depth* were the most influential variables included in the CPUE model. The inclusion of both variables resulted in some deviation in the standardised CPUE indices from the nominal CPUE from 2010/11 onwards (Figure 17 and Figure 18). During this period, a higher proportion of the fishing effort occurred in depths greater than 50 m, with a lower expected catch of snapper (Figure 18, Appendix 3 Figure A3). There was also a shift in the spatial distribution of fishing effort with a reduction in the proportion of effort conducted in the North Taranaki Bight in recent years. The CPUE model predicted that this area has a higher catch rate of snapper during January–April (Figure 18, Appendix 3 Figure A2).

An examination of the residuals from the CPUE model revealed that the CPUE trends are generally comparable among three main target fisheries (snapper, trevally and red gurnard), the four months (January–April) and the Statistical Areas that encompass the spatial domain of the CPUE data set (Appendix 3 Figures A6–8). The trends in the residuals were also examined for a subset of five of the core vessels that had each operated in the fishery during the two periods of contrasting CPUE indices (pre and post 2007/08) (Appendix 3 Figure A9). For each of these vessels, the trend in the vessel specific CPUE was generally consistent with the base CPUE indices.

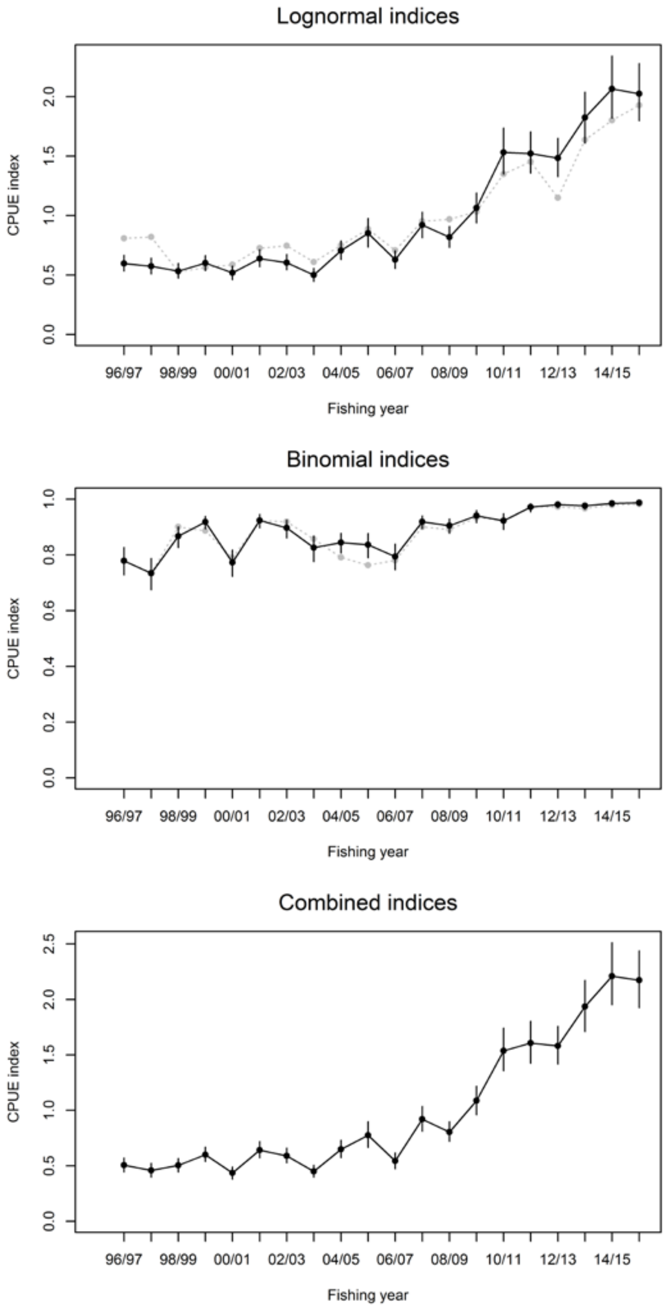

Figure 17: A comparison of: (top panel) the SNA 8 single trawl positive index and the geometric mean of the annual catch per day (grey line); (middle panel) the binomial index and the annual proportion of positive catch records (grey line) in the data set; and (bottom panel) the combined index. The error bars represent the 95% confidence intervals associated with each index. The annual indices are provided in Table A3 (Appendix 2).

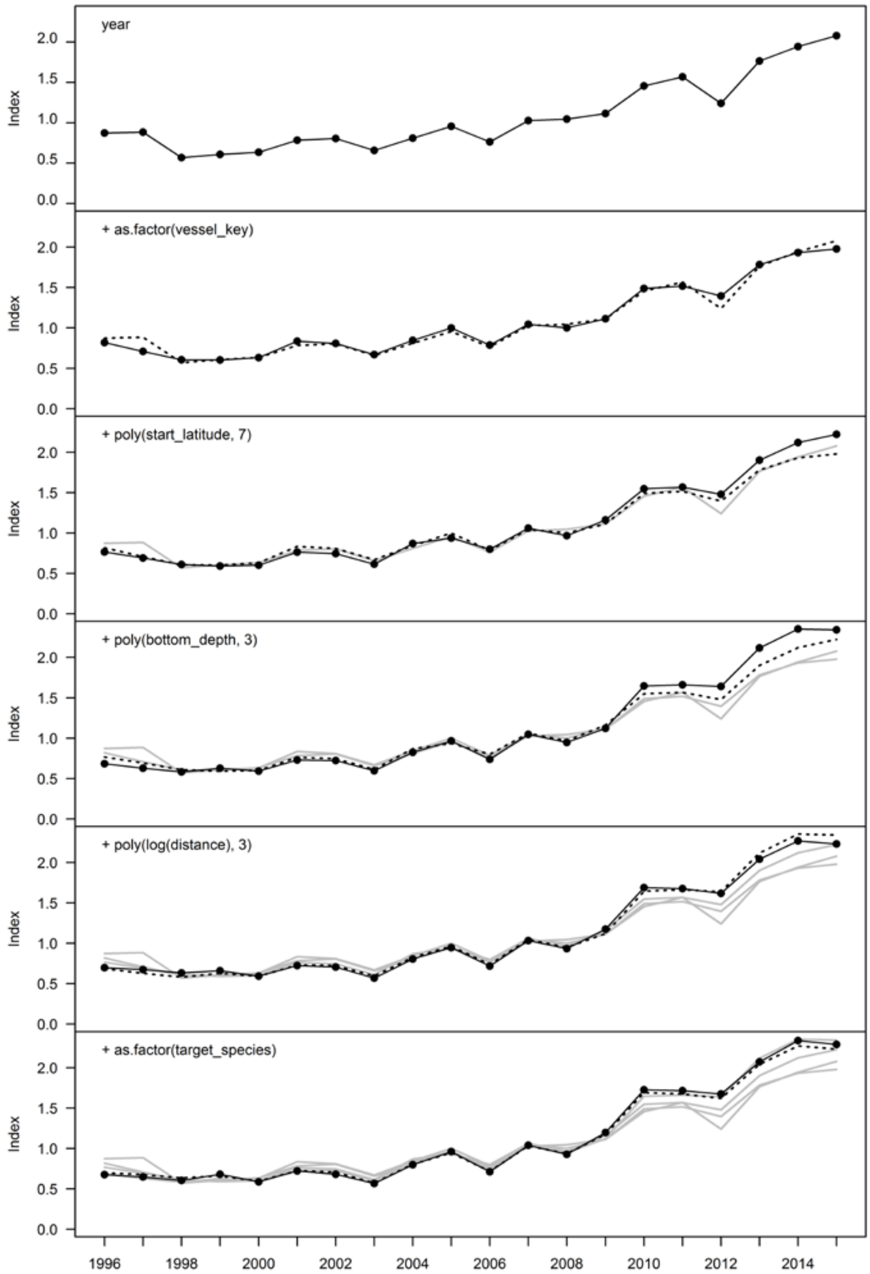

Figure 18: The change in the annual coefficients with the step-wise inclusion of each of the significant variables in the positive catch CPUE model for the SNA 8 trawl fishery (from top to bottom panel). The solid line and points represent the annual coefficients at each stage. The fishing year is denoted by the calendar year at the beginning of the fishing year (e.g. 1996 denotes the 1996/97 fishing year).

The occurrence of snapper in the SNA 8 trawl catch was predicted by the binomial model including the explanatory variables *FishingYear*, *Depth*, *Vessel*, *TargetSpecies*, *Latitude* and *StartTime* (Table 3). The resulting annual indices derived from the binomial model are generally comparable to the annual proportion of positive catch records, with an increased probability of catching snapper from 2007/08 onwards (Figure 17).

The trend in the combined CPUE series is similar to the lognormal CPUE series, although the magnitude of the increase in the combined CPUE series is increased by about 20% with the inclusion of the increase in the binomial series (Appendix 2 Table A3).

Table 3: Summary of stepwise selection of variables in the SNA 8 catch occurrence model (binomial model). Model terms are listed in the order of acceptance to the model. AIC: Akaike Information Criterion; *: term included in final model.

Term	DF	Log likelihood	AIC	Nagelkerke pseudo-R^2
FishingYear	19	-4 712	9 463.8	0.108 *
Depth	3	-4 408	8 861.2	0.185 *
Vessel	15	-4 217	8 510.2	0.232 *
TargetSpecies	2	-4 158	8 395.9	0.246 *
Latitude	4	-4 129	8 346.2	0.253 *
StartTime	3	-4 105	8 303.5	0.259 *
Month	3	-4 089	8 279.0	0.262
Distance	3	-4 078	8 262.1	0.265
GearHeight	3	-4 072	8 255.5	0.266
GearRatio	3	-4 066	8 249.5	0.268
GearWidth	3	-4 053	8 230.3	0.271

Since 2006/07, a single vessel has accounted for 25–35% of the records included in the CPUE data set. The configuration of the trawl gear used by this vessel changed considerably in 2012/13. Trawl gear metrics were included as potential explanatory variables in the CPUE modelling, although these variables were not incorporated in the final CPUE models. Nonetheless, there is concern that the change in gear configuration may have influenced snapper CPUE and could potentially bias the CPUE indices.

To investigate the potential influence of the change in the trawl gear, the data from this vessel were partitioned by time period (pre and post 2012/13) and the CPUE models were refitted treating the two time blocks as separate vessel effects. There was no appreciable change in the resulting CPUE indices compared to the base CPUE indices, indicating that the change in gear configuration was not significantly biasing the CPUE indices.

5. DISCUSSION

There have been considerable changes in the operation of the SNA 8 trawl fishery, especially since the mid-late 2000s, including changes in the seasonality of catches, changes in the areas and depth fished, and changes in trawl gear and trawl operation. Most of these changes are related to a shift away from the direct targeting of snapper during the October–December period. The changes in fishing operation coincided with a reduction in the TACC in 2005/06 and an increase in snapper abundance, indicated by the considerable increase in the CPUE indices from 2007/08.

Interviews with the main commercial operators highlighted that the changes in fishing behaviour were necessary to ensure that sufficient snapper ACE was available to account for the increased snapper catch taken in association with the other main fisheries within the SNA 8 fishstock area, especially trevally (TRE 7) and red gurnard, John dory and, to a lesser extent, tarakihi (Appendix 4). A range of different fishing strategies have been developed to minimise the catch of snapper while targeting these species:

- avoiding fishing in the areas of higher snapper abundance, especially during the period when snapper are aggregated during the spawning (October–December);

- targeting trevally in areas of lower snapper abundance and shifting trawl location (or fishing depth) in response to the magnitude of snapper caught (relative to the catch of trevally);
- a shift towards using trawl gear with a lower headline height (e.g. scraper trawl) that is generally considered to reduce the catch of snapper (and trevally), while maintaining the catches of other demersal species (red gurnard and John dory); and
- modifying trawl gear to conduct trawling at slower speeds (about 2.5 knots) to minimise the catch of snapper while targeting red gurnard and John dory.

These general trends are evident in the catch and effort data collected from the fishery and these variables (trawl speed, location, fishing depth, trawl gear dimensions) were also available for inclusion as parameters in the modelling of snapper CPUE. However, the diagnostics from the preliminary CPUE models indicated that the modelling approach was not accounting for the magnitude of the change(s) in the fishing behaviour, especially during the spawning period (October–December). This is likely to reflect the limitations of the data collected from the fishery (e.g. related to fishing gear), variation in local scale distributions of snapper and associated species, and the assumption of independence of individual fishing events.

Snapper are more highly aggregated during October–December and, hence, the effect of changes in the targeting or avoidance behaviour of the trawl fleet are likely to have a larger influence on snapper catch rates during that period. In contrast, during January–April snapper are more homogeneously distributed and snapper catch rates are likely to be less sensitive to changes in targeting/avoidance behaviour, and also less hyperstable. This rationale was the basis for limiting the CPUE analysis to the January–April period. Further, a number of vessels progressively developed fishing strategies that reduced the catch of snapper relative to the catch of red gurnard (and other species). These vessels were excluded from the final CPUE analysis.

A number of the vessels that have continued to catch snapper in association with trevally had changed the trawl net during the study period, adopting trawl nets with a considerably lower headline height (e.g. scraper trawls compared to balloon trawls). The dimensions of the trawl net were included as potential explanatory variables in the CPUE models although the variables were not included in the final models, suggesting that the change in net configuration was not greatly influencing the catch rate of snapper during January–April. Further CPUE modelling was conducted to investigate these changes in trawl gear configuration by estimating separate vessel effects for each trawl gear classification. The resulting CPUE indices did not differ appreciably from the base CPUE indices, supporting the previous observation that the change in trawl gear was not having a substantial influence on the catch rate of snapper.

The final set of CPUE indices are characterised by a strong increase in the CPUE indices from 2007/08–2015/16. This increase is consistent with the available age composition data from the SNA 8 single trawl fishery (Walsh et al. 2017); which indicate the recruitment of a strong year class in 2008/09 (the 2005 year class at age 4 years) followed by the recruitment of an even stronger (2006) year class in 2009/10. The latter year class persisted in the age composition of the catch over the subsequent years (to 2015/16), and the age structure was further augmented by the recruitment of strong 2009 and 2010 year classes (Walsh et al. 2017).

The CPUE indices were derived from catch and effort data from the area of SNA 8 from Cape Egmont to North Cape. There has been limited inshore trawling in the area of SNA 8 south of Cape Egmont during the last 20 years and, consequently, insufficient catch and effort data are available to monitor CPUE trends from this area.

The CPUE indices derived from the current analysis (January–April only) were comparable to the SNA 8 CPUE indices from the previous studies (Davies et al. 2013, Kendrick & Bentley 2010), for corresponding years.

6. MANAGEMENT IMPLICATIONS

The Northern Inshore Working Group accepted the January–April combined CPUE series as an index of relative abundance for SNA 8 (at a meeting held on 22 June 2017). The last stock assessment for

SNA 8 was conducted in 2004/05 (Davies et al. 2013). There has been no stock assessment in the interim period as the fishery has been in a rebuilding phase and no accepted index of abundance has been available for the recent period. Previously, standardised CPUE indices had not been accepted as an index of stock abundance as the indices were derived from fishing that primarily targeted spawning aggregations of snapper and, hence, catch rates were considered to be relatively insensitive to changes in stock abundance (hyperstable). Further, there has not been a direct estimate of stock biomass since the last tagging programme in 2002. Nevertheless, routine sampling of the age composition of the SNA 8 commercial catch has been undertaken and these data are available for 2005/06–2009/10, 2012/13 and 2015/16 (7 years) (Walsh et al. 2017).

The NINSWG discussed options for scheduling the next SNA 8 stock assessment. A key consideration was the requirement to have recent age composition data available to enable the estimation of recent recruitment and, thereby, inform the model regarding trends in stock biomass over a five year projection period. Currently, the next catch sampling project is scheduled for spring–summer 2018/19 and, on that basis, the stock assessment would be conducted in 2020. This assessment would also include an estimate of recreational harvest derived from a survey conducted in 2017/18. Alternatively, there may be an opportunity to reschedule the catch sampling for 2017/18 and conduct the assessment in the following year. There is also scope to use the interim period to conduct a preliminary assessment and then update the assessment immediately when the next age composition data become available.

7. ACKNOWLEDGMENTS

This study was funded by Sanford Ltd and Moana New Zealand Ltd and the project was coordinated by David Middleton (Trident Systems LP), with input from Alison Undorf-Lay (Sanford Ltd) and Nathan Reid (Moana New Zealand). Many of the main SNA 8 trawl vessel skippers provided very useful insights into the operation of the fishery. Members of the Northern Inshore Fishery Assessment Working Group reviewed the analysis. Software developed by Nokome Bentley was utilised for the presentation of CPUE model diagnostics.

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APPENDIX 1 CPUE DATA SET

Table A1: Summary of the SNA 8 catch and effort data from the entire single trawl CPUE data set (all months, all vessels) from the area north of Cape Egmont.

Fishing year	Number records	Number vessels	Number trips	Catch (t)	Number trawls	Duration (hrs)	Percent zero catch
1996/97	2 782	27	325	838.9	2 782	8 136	17.6
1997/98	3 225	24	347	851.8	3 225	9 303	14.3
1998/99	2 674	21	230	605.1	2 674	7 250	8.3
1999/2000	2 531	15	235	558.3	2 531	7 875	8.6
2000/01	2 792	22	344	659.8	2 792	8 925	11.4
2001/02	2 324	19	352	683.3	2 324	7 750	7.7
2002/03	2 299	18	264	787.6	2 299	8 054	14.7
2003/04	3 016	18	297	1055.3	3 016	10 440	13.4
2004/05	2 642	16	272	821.6	2 642	9 345	15.5
2005/06	1 830	14	201	657.0	1 830	6 379	14.0
2006/07	2 010	12	207	739.0	2 010	6 573	15.3
2007/08	2 522	15	298	736.7	2 522	8 355	9.6
2008/09	2 503	15	274	743.8	2 503	8 432	11.3
2009/10	2 299	17	280	698.6	2 299	7 040	7.7
2010/11	2 133	17	288	704.9	2 133	6 463	9.8
2011/12	3 003	14	352	948.6	3 003	9 380	5.6
2012/13	3 035	15	369	923.7	3 035	9 060	8.0
2013/14	2 526	18	351	865.0	2 526	7 525	10.5
2014/15	2 606	21	351	913.0	2 606	8 049	7.9
2015/16	2 262	16	298	797.3	2 262	6 852	2.9

Table A2: Summary of the SNA 8 catch and effort data from the January–April single trawl CPUE data set (core vessels only).

Fishing year	Number records	Number vessels	Number trips	Catch (t)	Number trawls	Duration (hrs)	Percent zero catch
1996/97	569	7	59	139.6	569	1 754	22.1
1997/98	622	9	60	134.2	622	1 770	26.4
1998/99	878	8	72	144.5	878	2 408	9.9
1999/2000	1 141	9	82	195.7	1 141	3 552	11.3
2000/01	880	10	78	158.9	880	2 894	21.1
2001/02	752	9	91	205.5	752	2 534	7.7
2002/03	790	7	79	204.6	790	2 701	8.1
2003/04	628	8	71	131.9	628	2 225	14.3
2004/05	666	9	73	175.5	666	2 301	20.9
2005/06	435	8	50	108.1	435	1 477	23.7
2006/07	700	6	64	142.8	700	2 337	21.9
2007/08	815	6	71	255.9	815	2 679	9.9
2008/09	801	7	73	279.9	801	2 718	10.9
2009/10	635	4	63	252.5	635	1 926	6.6
2010/11	670	6	72	292.1	670	2 095	7.6
2011/12	744	5	72	356.6	744	2 281	2.7
2012/13	939	6	86	388.1	939	2 981	2.8
2013/14	631	6	70	345.0	631	2 014	3.3
2014/15	522	6	56	288.0	522	1 612	2.1
2015/16	567	6	53	328.2	567	1 774	1.8

APPENDIX 2 TABULATED CPUE INDICES

Table A3: Annual SNA 8 trawl CPUE indices and the lower (LCI) and upper (UCI) bounds of the 95% confidence intervals.

Fishing	Combined			Binomial			Lognormal		
year	Index	LCI	UCI	Index	LCI	UCI	Index	LCI	UCI
96/97	0.780	0.686	0.881	0.779	0.728	0.827	1.000	0.895	1.118
97/98	0.706	0.612	0.805	0.734	0.675	0.788	0.962	0.857	1.077
98/99	0.776	0.686	0.874	0.868	0.827	0.901	0.895	0.797	1.002
99/00	0.925	0.832	1.030	0.919	0.894	0.939	1.008	0.903	1.113
00/01	0.672	0.588	0.754	0.773	0.723	0.818	0.869	0.776	0.965
01/02	0.989	0.884	1.108	0.924	0.897	0.945	1.071	0.957	1.197
02/03	0.908	0.812	1.018	0.897	0.861	0.925	1.013	0.914	1.130
03/04	0.693	0.612	0.781	0.826	0.776	0.868	0.839	0.749	0.934
04/05	1.000	0.886	1.126	0.844	0.807	0.878	1.185	1.058	1.319
05/06	1.195	1.027	1.386	0.837	0.790	0.877	1.428	1.234	1.636
06/07	0.839	0.729	0.951	0.794	0.747	0.839	1.056	0.932	1.182
07/08	1.420	1.253	1.597	0.919	0.894	0.940	1.545	1.366	1.724
08/09	1.241	1.110	1.385	0.905	0.878	0.929	1.371	1.231	1.524
09/10	1.678	1.481	1.880	0.940	0.916	0.959	1.784	1.575	1.996
10/11	2.369	2.093	2.687	0.923	0.892	0.948	2.568	2.263	2.911
11/12	2.478	2.200	2.782	0.972	0.954	0.983	2.550	2.278	2.858
12/13	2.437	2.187	2.711	0.981	0.970	0.988	2.485	2.226	2.768
13/14	2.986	2.639	3.350	0.977	0.964	0.986	3.057	2.697	3.417
14/15	3.409	3.013	3.877	0.985	0.974	0.992	3.461	3.051	3.928
15/16	3.352	2.970	3.761	0.987	0.977	0.994	3.394	3.012	3.820

APPENDIX 3 CPUE MODEL DIAGNOSTICS

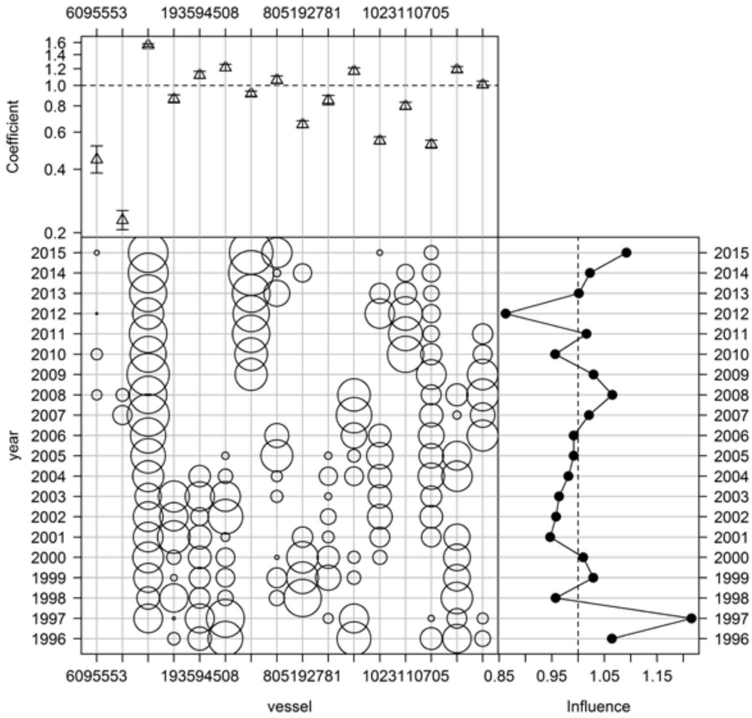

Figure A1: Influence plot of the *Vessel* variable in the SNA 8 January–April lognormal CPUE model.

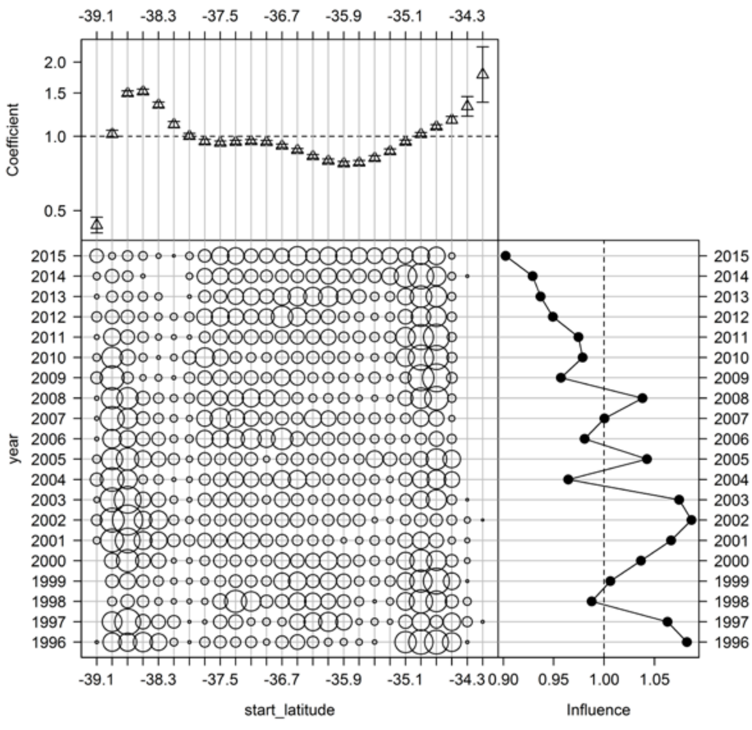

Figure A2: Influence plot of the *Latitude* variable in the SNA 8 January–April lognormal CPUE model.

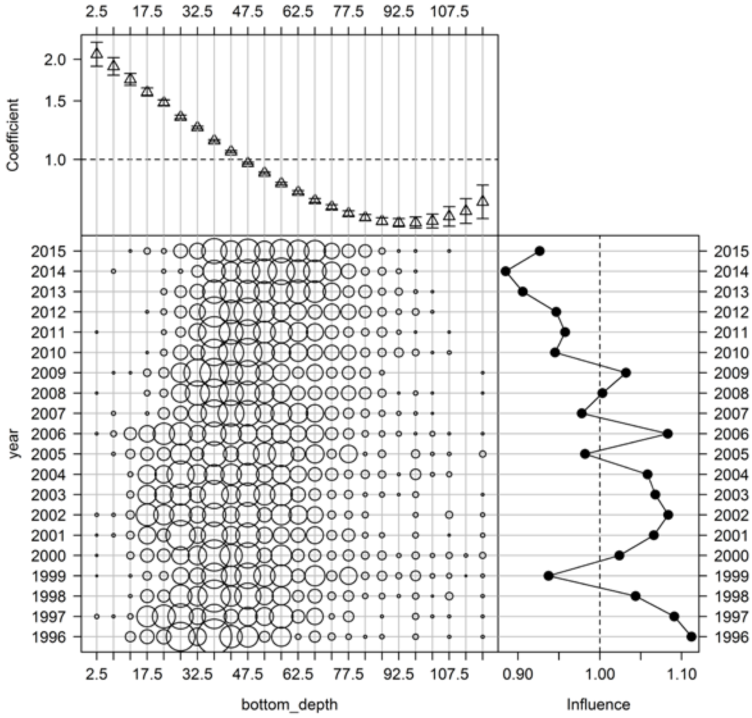

Figure A3: Influence plot of the *Depth* variable in the SNA 8 January–April lognormal CPUE model.

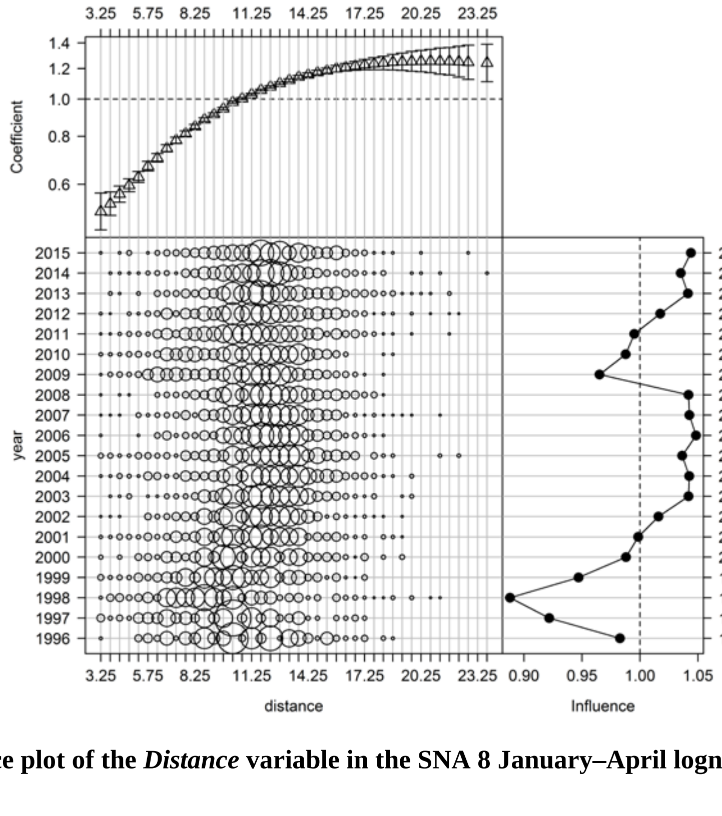

Figure A4: Influence plot of the *Distance* variable in the SNA 8 January–April lognormal CPUE model.

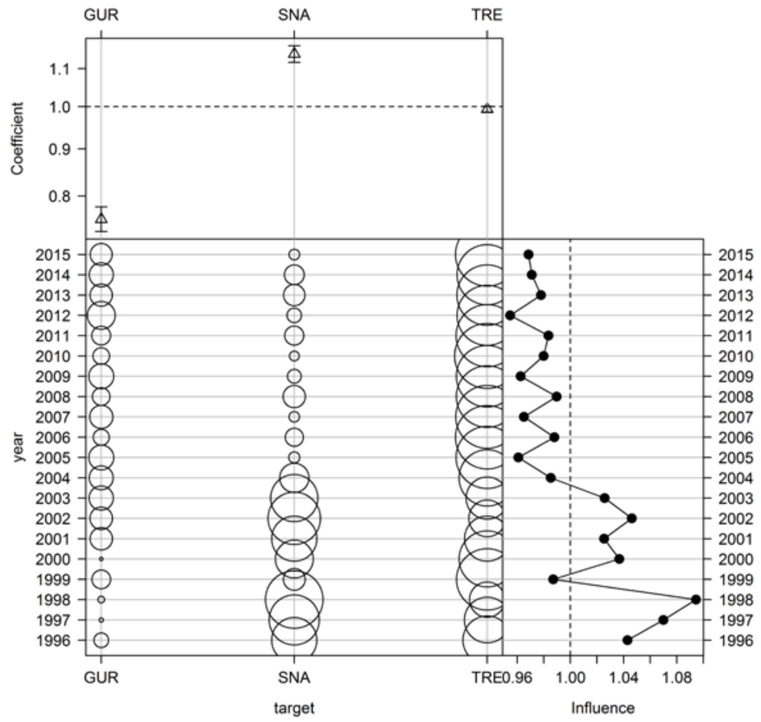

Figure A5: Influence plot of the *TargetSpecies* variable in the SNA 8 January–April lognormal CPUE model.

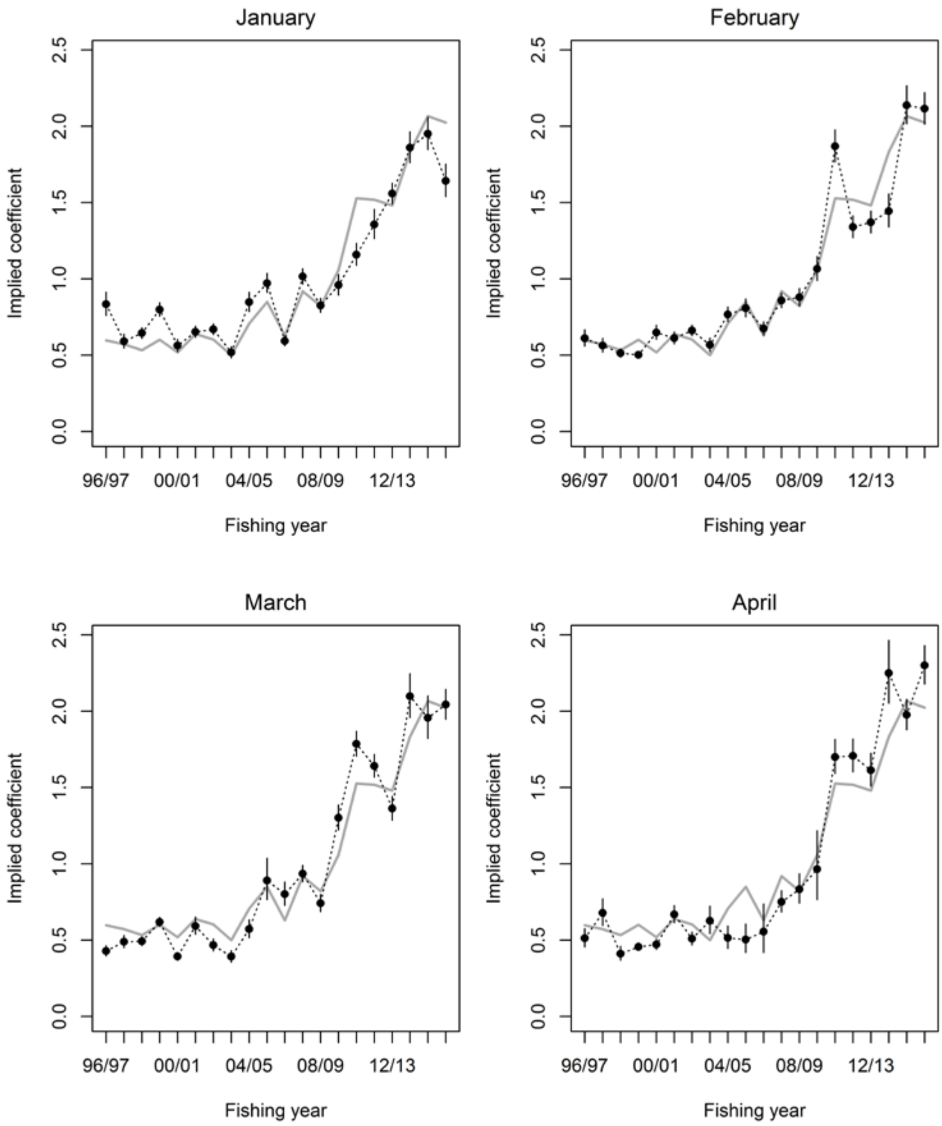

Figure A6: Annual implied coefficients (points) for the individual *Months* included in the SNA 8 January–April lognormal CPUE model. The grey line represents the annual CPUE indices derived from the model. The confidence intervals represent the standard error of the annual residuals.

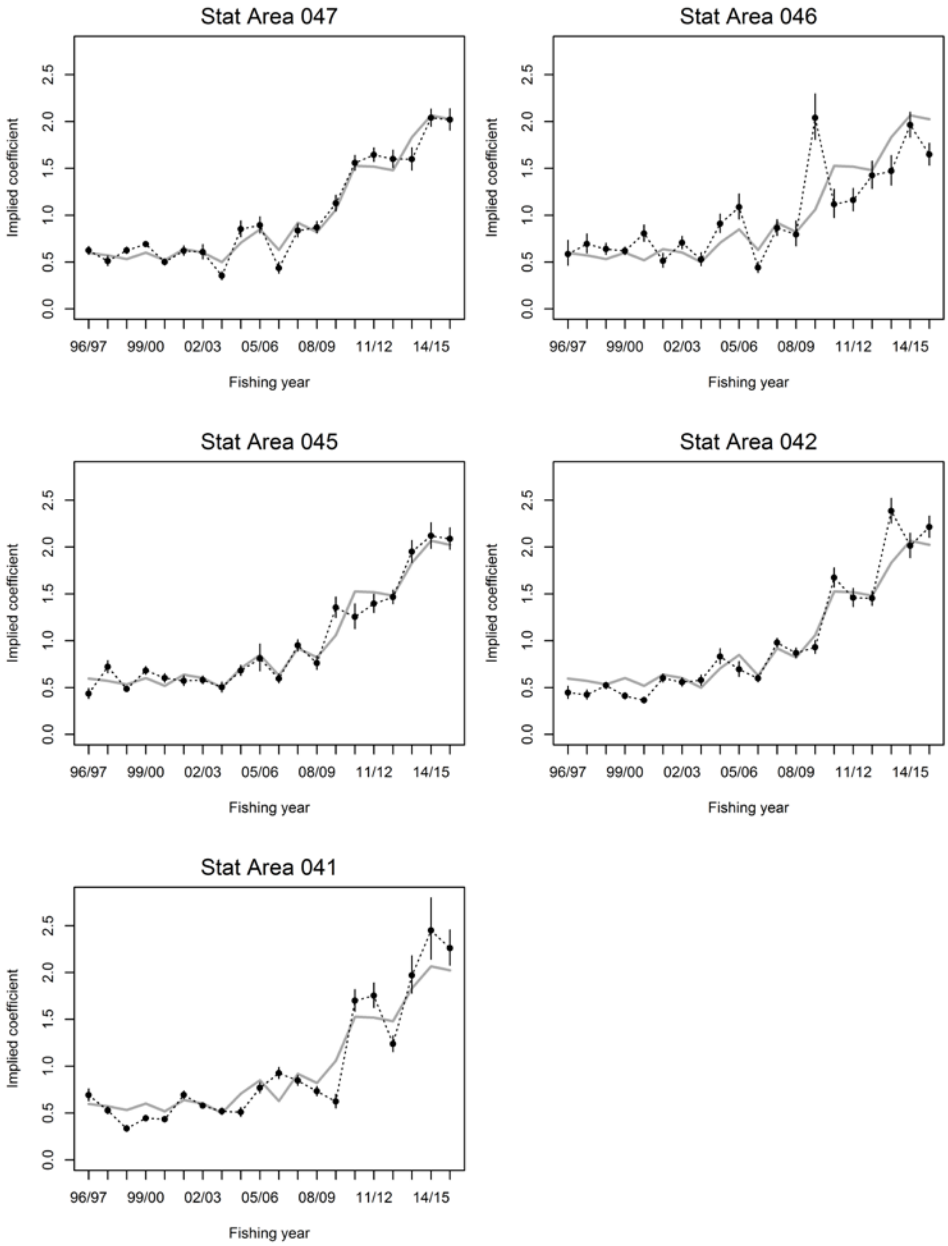

Figure A7: Annual implied coefficients (points) for the individual Statistical Areas that encompass the area included in the SNA 8 January–April lognormal CPUE model. The grey line represents the annual CPUE index derived from the model. The confidence intervals represent the standard error of the annual residuals.

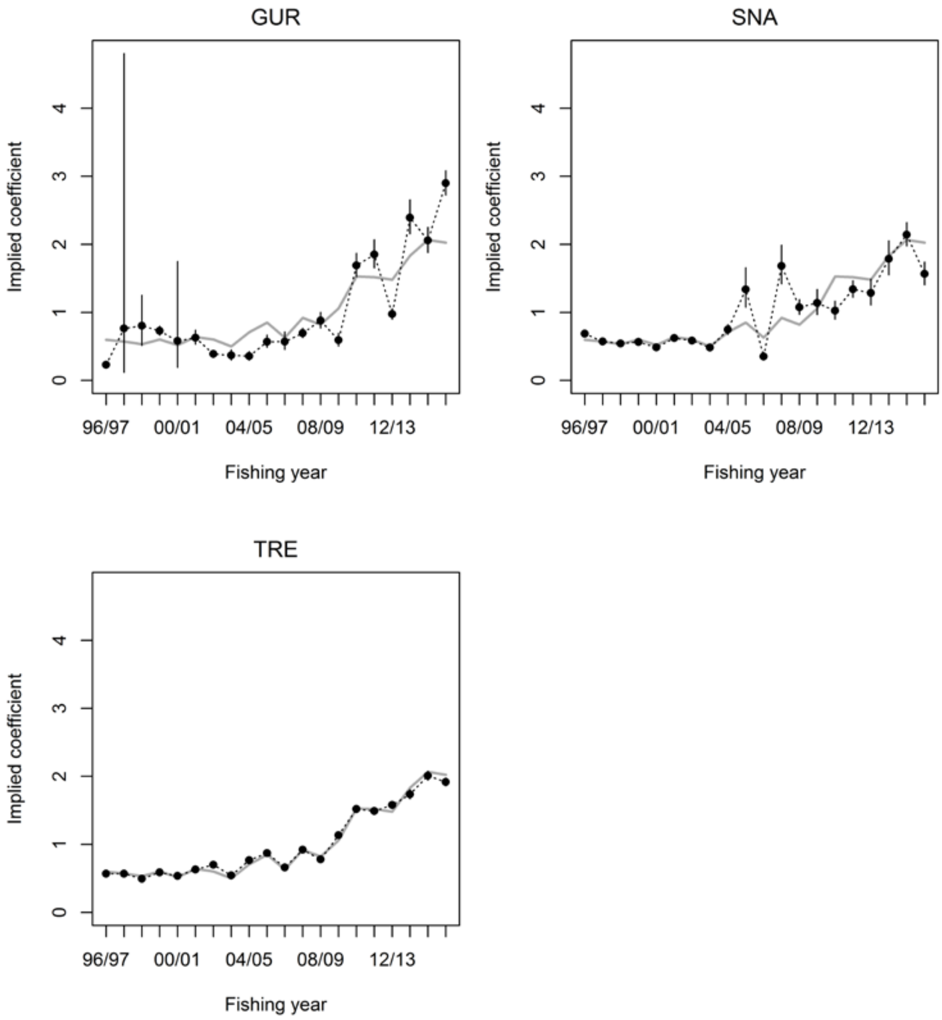

Figure A8: Annual implied coefficients (points) for the individual target species included in the SNA 8 January–April lognormal CPUE model. The grey line represents the annual CPUE index derived from the model. The confidence intervals represent the standard error of the annual residuals.

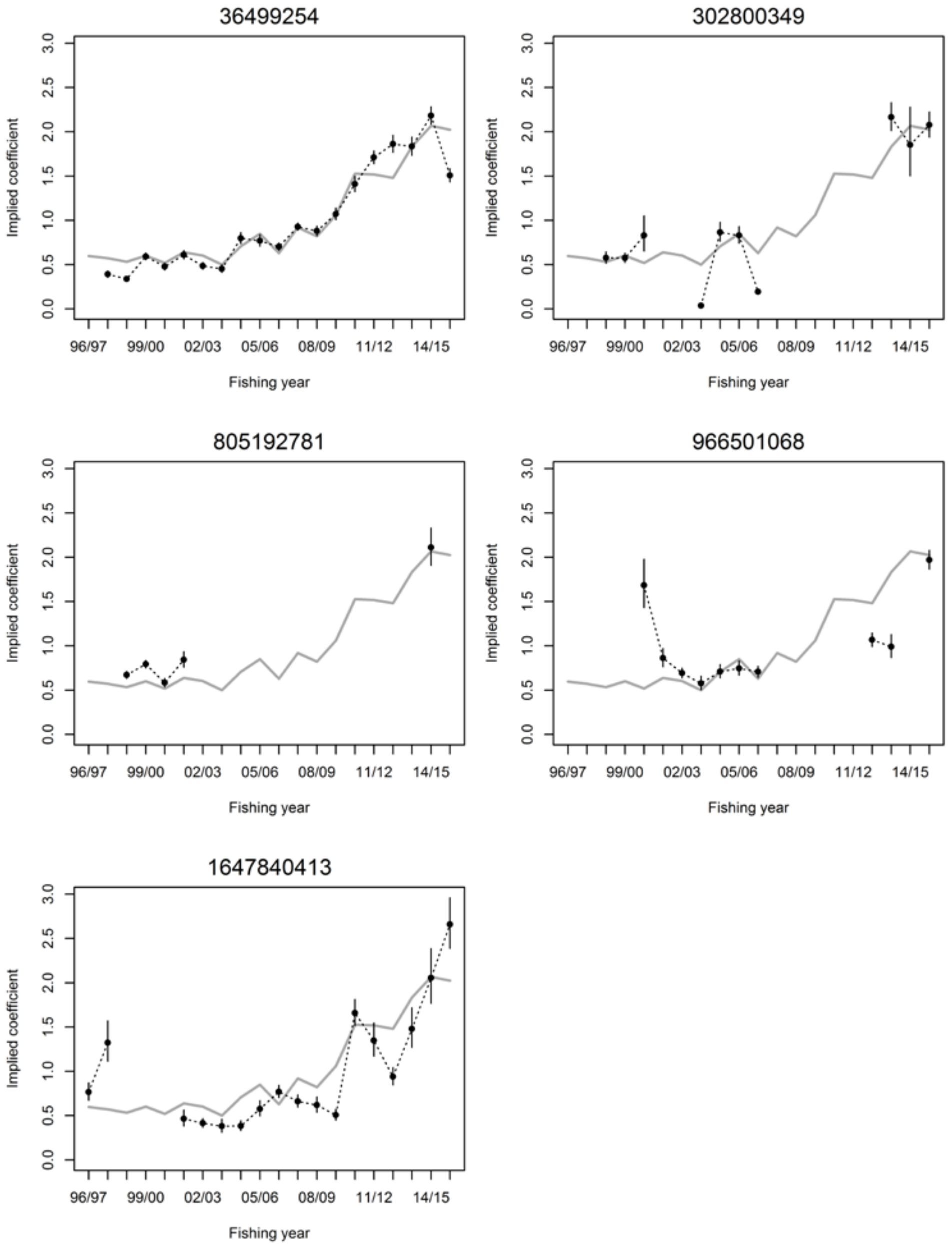

Figure A9: Annual implied coefficients (points) for a subset of the individual Vessels included in the SNA 8 January–April lognormal CPUE model. The grey line represents the annual CPUE index derived from the model. The confidence intervals represent the standard error of the annual residuals.

APPENDIX 4 SUMMARY OF INTERVIEWS WITH VESSEL SKIPPERS OPERATING IN THE SNA 8 TRAWL FISHERY

Skipper A

- Operating vessel for the last 10 years. Fishes inshore area from Port Waikato to Tirua Point (south of Kawhia Harbour).
- Primarily target GUR and JDO and attempt to minimise SNA bycatch. Limited SNA 8 ACE available.
- Initially fished with inshore trawl net designed for targeting FLA (120 ft ground rope) but changed gear to minimise SNA catch. Currently using Milligans Scraper trawl net with 75 ft ground rope and low headline height (1.0–1.5 m).
- Also changed trawl doors from V doors to smaller, more efficient Thyboron Type 11 doors, increased sweep length (85 m sweeps and 20 m bridles), smaller floats on headline.
- These gear changes and modifications have been made to increase spread of the gear at lower trawl speed (2.5 knot) to minimise catch of SNA. These changes substantially reduced the ratio of SNA catch relative to GUR catch.
- Investigated other gear modifications but limited further refinements possible.
- Vessel can only fish effectively when swell less than 1.5 m to ensure adequate bottom contact of gear. Sea conditions limit fishing to about 100 days per year.
- Operates one of the vessels excluded from the final CPUE analysis as predominantly GUR target vessel.

Skipper B

- Fished in SNA 8 for 36 years, and skipper of current vessel for the last 25 years. The company owns a small parcel of SNA 8 quota.
- Primarily fishes in area to the north-east of New Plymouth in the southern North Taranaki Bight. Main target species are GUR, JDO and TAR.
- Fishing operation has evolved to increasingly avoid SNA as the abundance of the species has increased. Fishing in deeper water has minimised SNA catch although the catch rate of other species is also lower in this area. Fishing in these areas is economically viable as the trawl gear has been modified with an increase in the length of sweeps and a change in trawl doors. Also, increasingly fishing at night when SNA catch rates are lower and catch rates of tarakihi are generally higher.
- Usually able to minimise SNA catch in the summer months by fishing in deeper water (beyond 50 m). Snapper are more widely distributed in winter and since the abundance of SNA has increased it has become more difficult to avoid snapper during winter months.
- The vessel has recently installed a new two-panel trawl net with a headline height of 1.5–2 m. It is anticipated that the net will reduce catches of SNA while maintaining catch of the other demersal species.
- Noted the high abundance of SNA in the South Taranaki Bight. There is insufficient SNA 8 quota available for trawl vessels to operate in this area.
- Operates one of the vessels excluded from the final CPUE analysis as it predominantly targets species other than SNA and/or TRE.

Skipper C

- Has been involved in SNA 8 fishery for many years. Has operated several vessels single trawling and pair trawling.
- Current vessel operates on the west coast catching trevally and snapper.

- Changed trawl net to scraper trawl in the last few years. Previously, the vessel was using a trawl net from the older 95 foot vessels.
- Large increase in SNA abundance over the last 10 years. No longer fishes in the Kaipara/Manukau area during September-December as large marks of fish are evident on the echo sounder when steaming through the area. Has generally fished to the north of the Kaipara Harbour to avoid snapper since about 2010.
- No longer targeting SNA and increasingly difficult to target TRE without catching too much snapper. The vessel is fishing deeper to avoid snapper and increased fishing off Ninety Mile Beach.

Skipper D

- Has 25 years experience in the SNA 8 fishery. The fishery has changed markedly in that time. Up to about 10 years ago the fishery primarily targeted SNA during October-November. Now primarily targets TRE and avoids the main SNA fishing grounds in Kaipara/Manukau area. The vessel increasingly fishes along the Hokianga coast and off Ninety Mile Beach.
- The vessel used to target TRE in prime fishing grounds off Port Waikato; however, the abundance of SNA in the area means that limited fishing now occurs in this area. This has impacted the ability to catch TRE.
- The vessel is usually operating with a trip limit of SNA (about 10 t) and skippers are required to operate inside the limit. To minimise snapper catch, subsequent trawls will shift to slightly deeper water (+5 m) from previous trawls. The strategy of moving locations is less effective as there may be more SNA at the new location (relative to TRE).
- Trawl gear is fitted with a catch sensor to minimise the risk of a large SNA catch (> 5 t). A headline monitor is also used but it is difficult to distinguish SNA in the signal.
- In 2012, the vessel changed trawl net from a balloon trawl with 7–8 m headline to a lower headline scraper trawl. The lower headline probably reduces the catch of SNA and TRE, to some extent. The vessel has maintained the same length of sweeps and the gear has a doorspread of about 180 m.

Skipper E

- Long involvement in the SNA 8 trawl fishery trawling and also Danish seining.
- Increase in abundance of snapper throughout SNA 8; large increase in abundance in North Taranaki Bight and no longer fishes in that area.
- Primarily targeting TRE. Vessel has access to reasonable amount of SNA 8 ACE; however, attempts to minimise the catch of snapper to ensure sufficient ACE is available to catch TRE 7.
- When targeting TRE, the vessel will remain in the area if catching a good mix of TRE (1/3 catch) and other species (1/3 catch) relative to SNA (1/3 catch), rather than moving to another area where there is a risk that snapper could represent a higher proportion of catch.
- Early morning is the best time to catch TRE. Maximise TRE catch by completing morning trawl in good TRE fishing locations.
- Vessel has been changing its gear set up to minimise snapper catch. Currently using a flatfish trawl for part of the fishing trip to optimise catch of mix species (GUR, JDO, etc) as this reduces the catch of snapper and trevally. Changes trawl gear later in the trip to switch to targeting of trevally.

Skipper F

- Operating in the SNA 8 fishery for the last 5 years.
- Vessel has a limit on the amount of SNA per trip and attempts to minimise the catch of snapper relative to trevally and other species. The vessel will tend to move between areas to minimise snapper catches.

- When the vessel started operating in the fishery it was using a balloon trawl with 5–6 m headline height. Since then, the vessel has switched to a scraper trawl with a low headline height to reduce the catch of snapper.