Ministry for Primary Industries
Manatū Ahu Matua

Fishery characterisation and age composition of tarakihi in TAR 1, 2 and 3 for 2013/14 and 2014/15

New Zealand Fisheries Assessment Report 2017/36

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EXECUTIVE SUMMARY

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Catch at-age sampling of the TAR 1, 2 & 3 bottom trawl and setnet catches during the 2013–14 and 2014–15 fishing years suggest that tarakihi off the east coast of New Zealand comprise a single stock. Patterns in year class strength suggest that tarakihi recruitment to the east coast fishery largely occurs south of Banks Peninsula. Recruits then progressively move northwards up the coast such that the final destination of the majority of the older tarakihi age classes is east Northland. There is also evidence in the catch at-age data that tarakihi on the western coast of the North Island are part of a separate west New Zealand stock.

Catch sampling was temporally and spatially representative of the TAR 1, 2, & 3 commercial bottom trawl and TAR 3 setnet target fishery spatial in both fishing years. Evidence from trawl surveys suggests that older east coast tarakihi have greater prevalence at depths beyond the 80 m isobath. Catches deeper than 80m from TAR 3, the east Northland, and the Bay of Plenty were slightly over-sampled. This means that catch sampling in these areas may have over-represented older tarakihi.

Precision on fish ageing was high, with the overall percentage agreement between readers improving with increasing latitude (73% for TAR 1, 80% for TAR 2 and 86% for TAR 3).

1 INTRODUCTION

1.1 General biology, distribution and depth range

Tarakihi (*Nemadactylus macropterus, N. rex*) belong to the family Cheilodactylidae, which are also commonly known as morwongs (including several species of moki in New Zealand). *N. macropterus* are found throughout New Zealand waters including around the Snares, Chathams, and Three Kings Islands and are mostly found on the continental shelf (Ayling & Cox 1982). *N. Rex* (king tarakihi) is known from Southeast Australia, Lord Howe, Norfolk Island. In New Zealand *N. Rex* occurs mostly around the top of the North Island, Three Kings, and East Cape region (Roberts et al. 2015). Both tarakihi species are taken commercially in New Zealand. Commercial tarakihi catches are controlled by individual quota, however, fishers are not required to differentiate the two species in their catch reporting so the relative catch of each species is unknown. Difficulties is differentiating between the two species in catches have meant that it was impractical to monitor the two species separately (this report) therefore information to monitor and assess the *N. rex* in northern New Zealand is not available. It is reasonable to assume, given the limited New Zealand geographic distribution of *N. rex,* that this species is likely to make up a relatively small component of the annual reported tarakihi catch. For these reasons, stock assessment and monitoring of New Zealand tarakihi is largely assumed to apply to *N. macropterus*.

The mean depth at which tarakihi have been caught during research trawl surveys throughout New Zealand is 182 m (range 11–486 m), although this mean is biased by the large amount of survey effort directed towards deep water fisheries (Anderson et al. 1998). The median catch depth for commercial bottom trawlers landing tarakihi from the east coast of the North and South Islands is about 80 to 100 m (Beentjes 2011, Parker & Fu 2011, Beentjes et al. 2012), although capture depths vary by statistical area, gear type, and target species.

1.2 Age and growth

A number of studies assessing the age of tarakihi catch have been conducted over the years. While estimates of maximum age vary substantially by area (from 18 to 44 years), all of these studies suggest that tarakihi are relatively long-lived, and populations can be comprised of many cohorts (Vooren & Tong 1973, Beentjes et al. 2012).

1.3 Reproductive biology

Tarakihi are serial spawners that aggregate to spawn in summer-autumn, when final maturation and gonad ripening coincides with the drop in seawater temperature in April-May (Tong & Vooren 1972). Spawning is thought to occur on the outer continental shelf in areas such as the western Bay of Plenty, East Cape area (between Lottin Point and Hicks Bay and towards Mahia Peninsula), west coast South Island, and Pegasus Bay (including Conway Ridge and Cape Campbell) (Tong & Vooren 1972, Vooren & Tong 1973, Vooren 1975, Morrison et al. 2012). The seasonality of the trawl fisheries catching tarakihi along the east coast of New Zealand roughly coincides with spawning related migrations into these areas (Langley & Starr 2012).

Size at 50% maturity has been estimated at near 27 cm and 28 cm fork length (FL) for males and females respectively (Tong & Vooren 1972) and more recently by Parker & Fu (2011) at 32 and 33 cm from the East Cape area. These lengths correspond to an age at 50% maturity of between five and seven years.

1.4 Nursery areas

The location of tarakihi nursery grounds has been inferred from commercial catch sampling and trawl surveys conducted in the 1960s and 70s (Vooren 1972, 1975, Beentjes 2011, Beentjes et al. 2012). The two main areas where tarakihi smaller than 20 cm were caught were Tasman and Golden Bay (TAR 7) and off the South Canterbury Bight (TAR 3)). Smaller numbers of under 20 cm tarakihi were occasionally caught in the eastern Bay of Plenty, Hawkes Bay, along the southern Wairarapa coast, Kapiti coast, and off Kaikōura (Vooren 1975). With the exception of the Kapiti coast, very few juvenile tarakihi were caught off the west coast of the North Island, and many areas have not yet been sampled with fishing gear that would select small tarakihi. Juvenile tarakihi were only rarely caught off the east coast of the North Island, between East Cape and the western Bay of Plenty (Vooren 1975).

Inshore trawl surveys off both the east coast South Island and Tasman/Golden Bay, indicate that juvenile tarakihi are consistently abundant in these areas (MacGibbon & Stevenson 2013, Beentjes et al. 2015).

1.5 Movement

Tagging studies conducted in the Bay of Plenty revealed that tagged tarakihi only moved short distances within the first year, but some fish were recaptured up to 200 km from the tagging site after a longer period at liberty (Crossland 1976). Tarakihi were subsequently tagged off the Kaikōura coast between 1986 and 1988, but relatively few of these fish were recaptured (Annala 1988). Of those recaptured seventeen were caught off the east coast North Island, three were caught off the west coast of the North Island, and another three were recaptured south of Kaikōura. These tag recoveries suggest a stock linkage between South Island and North Island Quota Management Areas (QMAs), with a predominant northward migration of tarakihi from TAR 3 to TAR 2 and TAR 1.Small numbers of tarakihi have also been tagged during biennial west coast South Island trawl surveys in Tasman Bay, but there have been no reported recaptures of these fish to date.

1.6 Stock structure

The number and spatial extent of tarakihi biological stocks in New Zealand is not well understood, and this is a major source of uncertainty in the management of tarakihi fisheries (Ministry for Primary Industries 2016). Apart from extensive movements of adults described above, tarakihi have a long pelagic larval phase of 7–12 months, which suggests that larvae will also be widely dispersed. The stock structure of tarakihi was reviewed by Annala (Annala 1987, Annala 1988) and Hanchet & Field (2001). Although the authors put forward a range of hypotheses, there was little evidence to support any particular stock structure hypothesis. The "default" view has been that tarakihi around the main islands of New Zealand consist of one continuous stock (Ministry for Primary Industries 2016). In the absence of an accepted definition around the spatial extent of biological stocks, New Zealand tarakihi fisheries have largely been managed in relation to the eight administrative QMA boundaries, as illustrated in Figure 1.

A more recent review of the stock structure of tarakihi off the east coast of New Zealand was undertaken by Langley & Starr (2012), which was based on high spatial resolution commercial catch reporting data collected since 1996. These data were used in conjunction with other research and tagging data to assess spatial and temporal patterns in catch, length and age distributions and seasonal and annual abundance trends; and to infer spawning and nursery locations and movement patterns. Strong similarities in catch patterns and CPUE trends suggest a strong link between the Bay of Plenty (in TAR 1), TAR 2 and to some extent TAR 3 (although tarakihi in the Cook Strait region, Statistical Area 016, did not appear to be part of this north eastern stock). Regional patterns in age structure from recent catch sampling programmes show that southern TAR 3 is largely comprised of young fish (Beentjes 2011; Beentjes et al. 2012). Although the age distribution of tarakihi sampled from northern TAR 1 trawl landings are usually broad, larger older fish are generally uncommon in trawl catches from the Bay of Plenty in southern TAR 1, and TAR 2 (Parker & Fu 2011, Beentjes et al. 2012). The location of spawning areas within both TAR 2 (East Cape) and TAR 3 (Cape Campbell) also suggests that local recruitment occurs in both areas, with TAR 2 being augmented by a northward movement of fish from TAR 3.

A notable exception to the patterns described above occurs within the east Northland portion of TAR 1 (McKenzie et al. 2015). The limited age sampling conducted here indicated a predominance of older tarakihi, potentially explained by lower exploitation and reduced interaction with southern tarakihi populations (although other explanations are also possible). Overall, tarakihi stock structure is complex, with a range of hypotheses ranging from discrete stocks to substantial mixing. The lack of spatially disaggregated catch at-age observations collected over the entire east New Zealand coast at the same time was a major limiting factor in the recent TAR 1, 2, and 3 stock assessments conducted by Langley & Starr (2012). A belief that a reliable assessment of east New Zealand tarakihi stocks would not be possible until more spatial age data were collected was the main justification for the present catch sampling programme.

1.7 Tarakihi fisheries

The major tarakihi fishing grounds are: on the west and east coasts of Northland, in TAR 1; between the western Bay of Plenty and Cape Turnagain in TAR 1 and 2; from the Cook Strait to the Canterbury Bight, which mostly falls in TAR 3; and between Jackson Head and Cape Foulwind, in TAR 7 (Figure 1). About 70–80% of the tarakihi taken off the North Island is targeted, mostly by bottom trawlers.

Only about 30% of the tarakihi catch taken off the South Island is currently targeted by trawlers, with much of the remainder taken as incidental catch by bottom trawlers targeting barracouta and red cod. In addition, there is a small target tarakihi set net fishery off Kaikoura.

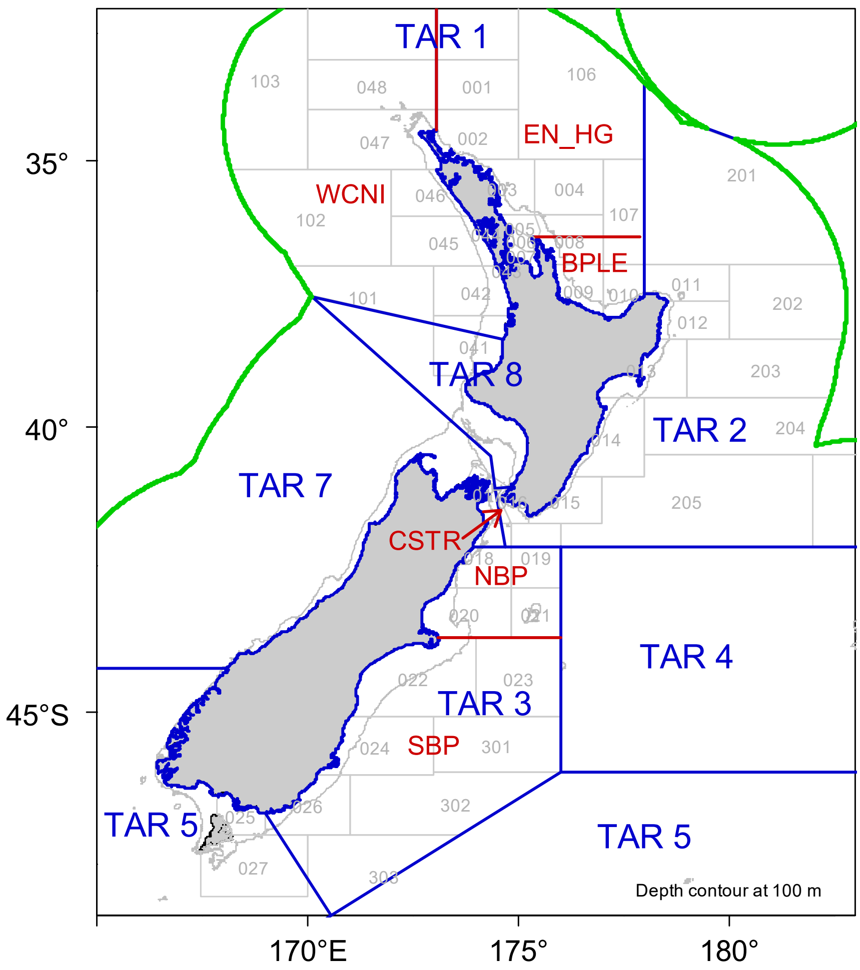

Figure 1: Map of tarakihi Quota Management Areas (in blue), sub-areas (in red), and statistical reporting areas (in grey) around New Zealand.

1.8 Monitoring of TAR stocks

Since 1990, the trends in status of most tarakihi QMAs have been inferred from standardised commercial CPUE indices and trawl survey indices of relative abundance. Commercial trawl catch per unit effort (CPUE) data are available for all the main tarakihi QMAs (1, 2, 3, 7 & 8), as continuous series since 1990. The trends in all of these CPUE indices are relatively flat, except for the east Northland/Hauraki Gulf sub-area, where a long–term gradual decline has occurred (Starr & Kendrick 2014). Research trawl survey time series are only available for two tarakihi fish stocks; TAR 7 (west coast South Island / Tasman & Golden Bay surveys (MacGibbon & Stevenson 2013)) and TAR 3 (east coast South Island survey; Ministry for Primary Industries (2016)). Both of these trawl survey programmes were initiated in 1991. In TAR 3 there has been no trend in relative biomass (Beentjes et al. in prep). Although tarakihi have been caught during trawl surveys conducted in other parts of the country, in our opinion none of these surveys have been designed to monitor tarakihi abundance, as they have been intermittent, occurred at suboptimal times of year, and/or over inappropriate depth ranges.

Catch at-age sampling of east coast New Zealand commercial trawl and setnet fisheries was undertaken in various fishing-years and areas between 2007 and 2011. Good spatial sampling coverage of TAR 2 & 3 trawl fisheries and the TAR 3 setnet fishery was achieved in the 2009–10 and 2010–11 fishing years (Beentjes 2011, Parker & Fu 2011, Beentjes et al. 2012). Catch sampling of TAR 1 trawl fisheries was undertaken in the 2007–08 and 2010–11 fishing years but in each year a full spatial coverage of TAR 1 was not achieved (McKenzie et al. 2015).

1.9 Objectives

The results presented in this report represent the first time TAR 1, 2 and core commercial fisheries have been sampled in the same fishing years and over their full spatial ranges. The specific objectives for this programme were:

1. To characterise the TAR 1, TAR 2, and TAR 3 fisheries.

2, 3, 4. To conduct representative sampling to determine the length, sex and age structure of the commercial catch of tarakihi in TAR 1, 2 & 3 during the 2013/14 and 2014/15 fishing years.

5. To age tarakihi otoliths collected during the above sampling programme.

6. To age tarakihi otoliths collected during previous trawl surveys conducted of the east coasts of both North and South Islands.

Objective 6 is covered in a standalone FAR (Beentjes et al. in prep).

2 FISHERY CHARACTERISATION AND CATCH SAMPLING DESIGN

2.1 Overview

Trawling is the predominant method for catching tarakihi commercially in TAR 1, 2, & 3. Therefore, catch sampling for age was restricted to this method in each of the three Quota Management Areas (QMAs), except in TAR 3 where the Kaikoura set-net fishery was also sampled. The design required year round sampling in each of the three tarakihi QMAs to determine the age structure of the tarakihi catch in each of two fishing years (2013–14 and 2014–15). The design also recognised formal sub-area stratification in some of the QMAs to achieve a mean weighted CV in each sub-area of 0.3 or lower. To achieve representative sampling throughout each fishing year, the years were divided into seasonal strata with an allocated number of landings to sample in each season. However, no formal seasonal stratification was incorporated in the final analysis. Because of the need to conduct sampling throughout the year a random age sampling approach was used, with the approach being to randomly collect 60 otolith pairs from each landing sampled. The number of target landings to be sampled from each tarakihi sub-area varied across the three QMAs, being largely in accordance with previous tarakihi sampling programmes (Beentjes 2011, Parker & Fu 2011, Beentjes et al. 2012).

Sampling designs used in this programme were based on a characterisation of recently reported fishing activity in TAR 1, TAR 2 and TAR 3; by fishing year, fishing method, month, and fish processing facility. Commercial catch effort data were extracted from the Ministry for Primary Industries, (MPI) catch effort database for the period October 2007 to September 2012 (hereafter referred to as the 2008–2012 fishing years). This extract included all reported effort data and associated catch weights (for all species including tarakihi) from all trips landing tarakihi from TAR 1, TAR 2, and TAR 3. Because our analysis was only performed on data reported after the 2007 fishing year, there was no need to consider changes in form types (all data were on Trawl Catch Effort Processing Return/Trawl Catch Effort Return/Net Catch Effort Returns (TCP/TCE/NCER) forms), or the increase in the number of species that fishers were required to report catch weight estimates for per tow, from 5 to 8 species.

This dataset was initially groomed so that estimates of the species catch per tow were linked to their associated effort variables, by fishing event (such as fishing location, fishing method, target species, tow speed). Individual fishing events were then linked to landed catch weights for each trip, to prorate the landed weight for each species across events, given event-based catch weight estimates. The link between the event-based estimated effort and trip-based landed catch weight tables was a common trip number field (trip_key). This allowed us to assign the catch weight from individual fishing events to particular stocks and sub-areas of interest (based on stock structure reviews (Annala 1987, Annala 1988, Hanchet & Field 2001, Langley & Starr 2012) and recommendations from the Northern Inshore Working Group (NIWG)).

Three sub-areas were considered for the TAR 1 QMA:

1. West coast North Island (WCNI - the northern part of Statistical Area 041 through to 048, plus the offshore statistical areas on the west coast),
2. East Northland/Hauraki Gulf (ENHG - Statistical Areas 001 through to 007, plus the northern part of Statistical Area 008 and associated offshore statistical areas)
3. The Bay of Plenty (BPLE - the southern part of Statistical Area 008 through to Statistical Area 010, plus the offshore statistical areas) (Figure 1).

The TAR 2 stock was sampled as a single area (Figure 1). In the TAR 3 trawl fishery, two areas were recognised for sampling purposes: north Banks Peninsula area (NBP Statistical Areas 018–021 (Figure 1)); south Banks Peninsula (SBP Statistical Areas 022 – 026 and 301 – 303 (Figure 1)). For the TAR 3 set net fishery, only catches within Statistical Area 018 (Kaikoura) were sampled. Data assigned to each QMA/sub-area were then groomed and spatially and temporally characterised.

Robertson (1978) and Annala (1987) suggested that spawning may occur from Kaikoura through to Cook Strait, but little sampling has been conducted in the area to confirm this. The fact that parts of this area spans multiple QMAs has made catch sampling programmes logistically difficult, with the result that the area was typically excluded from catch sampling plans. However, the existence of a spawning stock in the area would have implications for stock structure and therefore influence the configuration of assessment models. To investigate spawning in this area, we worked directly with fishers that targeted spawning tarakihi in Cook Strait Statistical Areas 016, 017 and 018 to sample landings, regardless of the QMA the catch was allocated to. Therefore, the sampling design in Cook Strait was not aimed at describing the age composition of the catch for a particular QMA, or to represent the entire catch coming from that area, but rather to document an aggregation of mature tarakihi in that location during the summer spawning season.

2.2 TAR 1

2.2.1 TAR 1 commercial fishery profile

The majority of tarakihi taken from the three TAR 1 sub-areas were caught by bottom trawling (Figure 2). Over half of the annual commercial harvest from TAR 1 in any given year was taken in the Bay of Plenty (BPLE), this catch almost exclusively taken by bottom trawl (Figure 2). Significant quantities of tarakihi were taken by bottom longline in the East Northland/Hauraki Gulf (EN_HG) sub-area, as a bycatch to the snapper target fishery. Longlining was conducted there due to the extensive areas of foul ground precluding the use of trawling. On the west coast of the North Island (WCNI) bottom pair trawling accounted for significant quantities of the tarakihi catch up until 2011 (Figure 2).

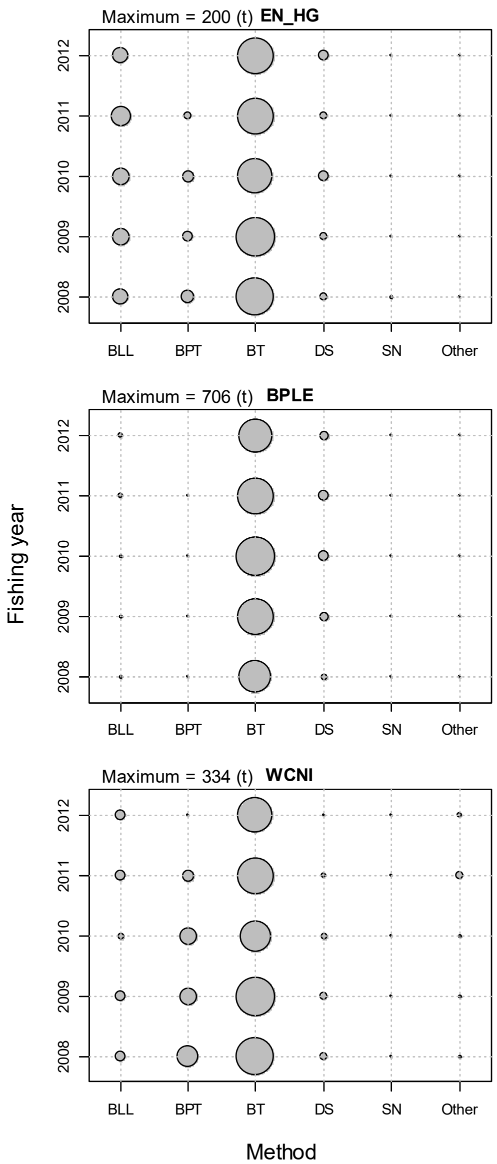

Figure 2: Tonnages of tarakihi landed annually by different fishing methods, in all three TAR 1 sub-areas between the 2008 and 2012 fishing years. The area of each bubble is proportional to the annual catch tonnage taken by each method: BLL = bottom longline, BPT = bottom pair trawl, BT = bottom trawl, DS = Danish seine, and SN = set net.

2.2.2 TAR 1 Trawl fishery profile

As the majority of TAR 1 catches are taken by bottom trawl, sampling during the 2013–14 and 2014–15 fishing years was restricted to this method.

The majority of the annual bottom trawl tarakihi catch from all three sub-areas of TAR 1 was taken whilst targeting tarakihi (Figure 3). Bottom trawlers targeting snapper and trevally in all three sub-areas also landed a much lower tarakihi bycatch during each fishing year, and modest tarakihi bycatch was also taken when targeting John dory in East Northland/Hauraki Gulf (Figure 3).

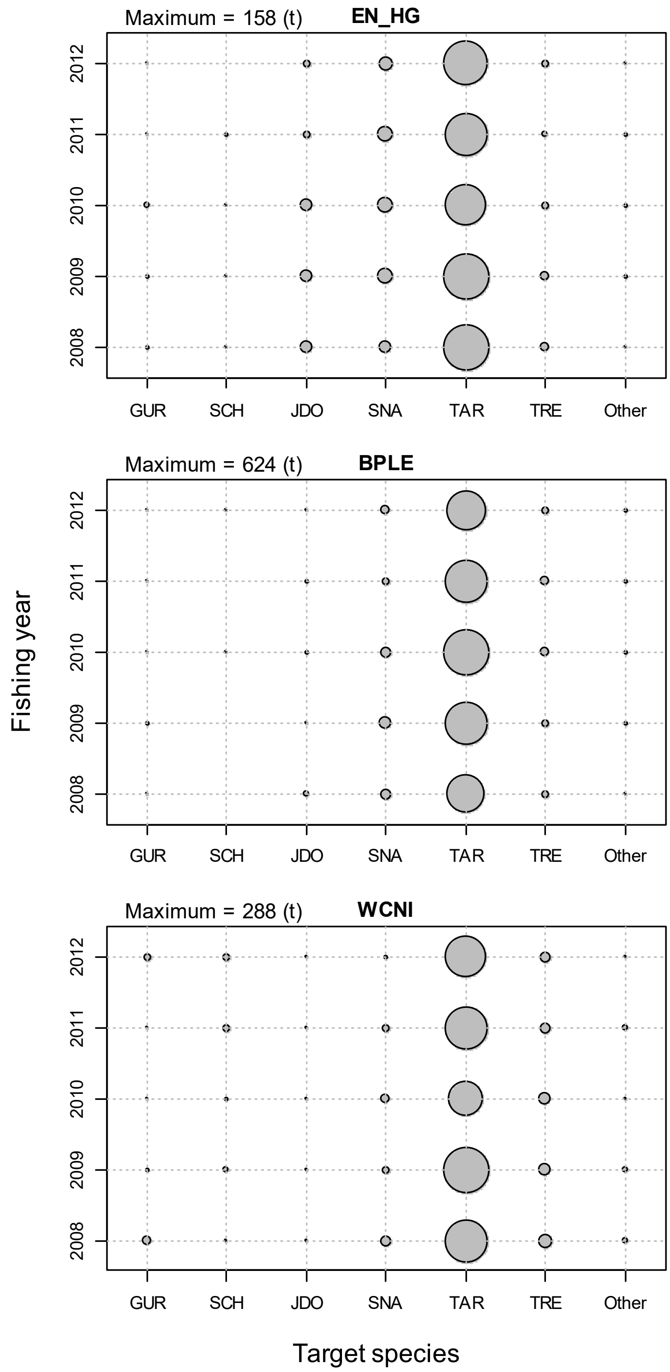

Figure 3: Tonnages of tarakihi landed annually by bottom trawlers when targeting different species between the 2008 and 2012 fishing years. The area of each bubble is proportional to the annual catch tonnage taken when targeting each species: GUR = red gurnard, SCH = school shark, JDO = John dory, SNA = snapper, TAR = tarakihi, and TRE = trevally.

There is a clear seasonality in bottom trawl catches from two of the TAR 1 sub-areas, with landings usually peaking between March and May in the Bay of Plenty and on the West Coast of the North Island (Figure 4). Monthly landings from East Northland/Hauraki Gulf peaked at different times of the year during each of the five fishing years characterised.

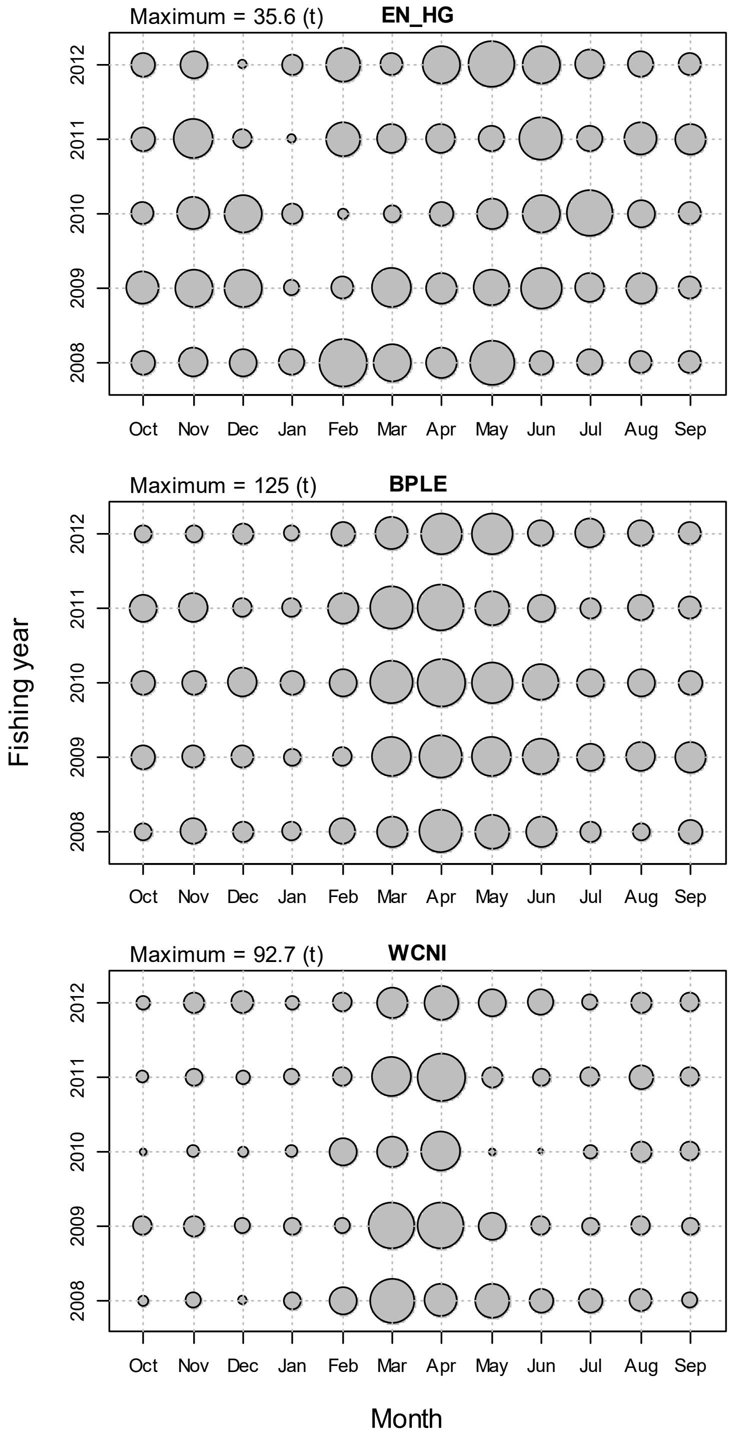

Figure 4: Monthly tonnages of tarakihi landed by bottom trawlers during the 2008 to 2012 fishing years. The area of each bubble is proportional to the monthly catch (t).

There were consistent patterns in the relative contribution of landings from each statistical area in each sub-area, across all five fishing years (Figure 5). Most of the annual bottom trawl catch from the East Northland/Hauraki Gulf sub-area was taken from areas 002 and 003, with smaller amounts taken from areas 004 and 005. The majority of the catch landed from the Bay of Plenty sub-area was taken from areas 009 and 010, with most of the remainder taken from 008. On the west coast of the North Island, almost all of the landed catch was taken north of the Manukau Harbour, in Statistical Areas 045 to 047.

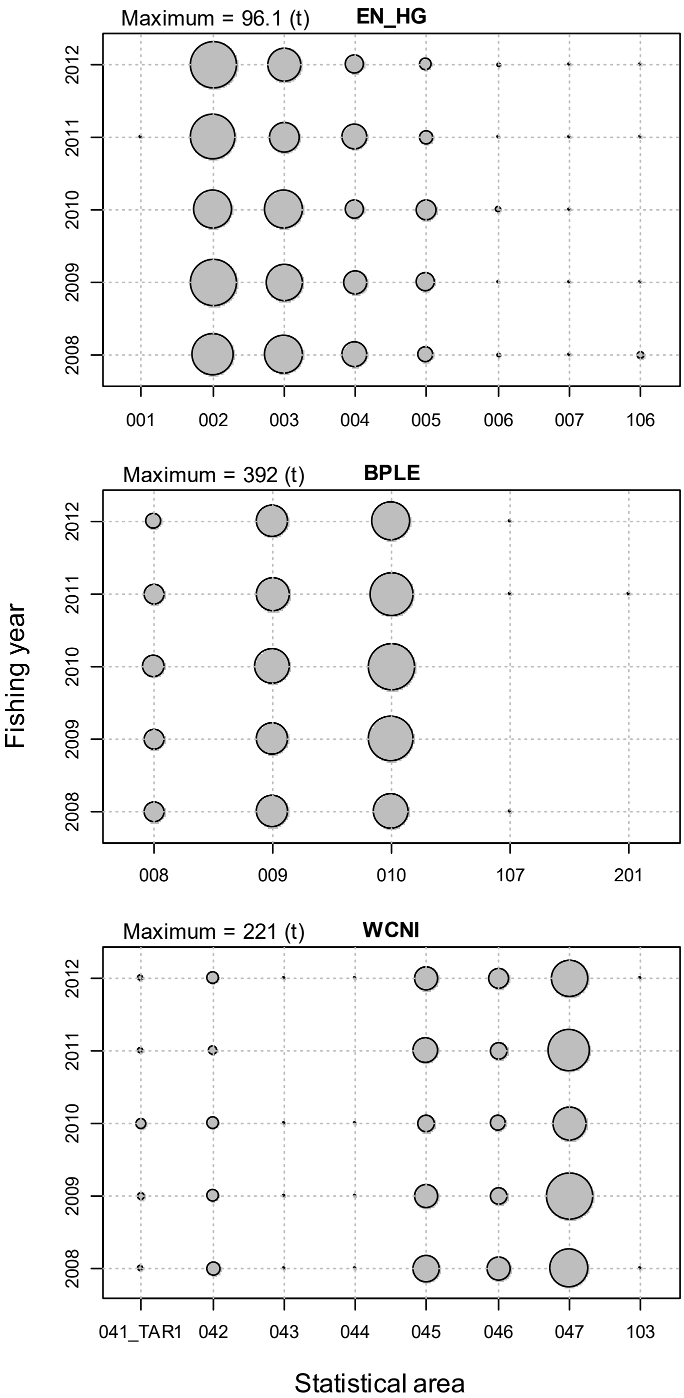

Figure 5: Tonnage of tarakihi landed annually by bottom trawlers in each sub-area, by statistical area, during the 2008 to 2012 fishing years. The area of each bubble is proportional to the annual tonnage landed in each statistical area. "041_TAR1" refers to the portion of Statistical Area 041 that is within the TAR 1 Quota Management Area.

A fine scale plot of the spatial distribution of tarakihi catches within TAR 1, based on the reported latitude and longitude of individual trawl shots, suggests that tarakihi are caught on the outer shelf (about 100 m depth) throughout this QMA (Figure 6). Several tarakihi catch hotspots are evident, especially offshore from: the Kaipara Harbour (area 045), 90 Mile Beach (area 047), Great Exhibition Bay and Mangonui (area 002), Great Barrier Island (areas 004 and 008), Tauranga (area 009) and off the Bay of Plenty between Opotiki and Waihau Bay (area 010; the largest catches from TAR 1 occurred here).

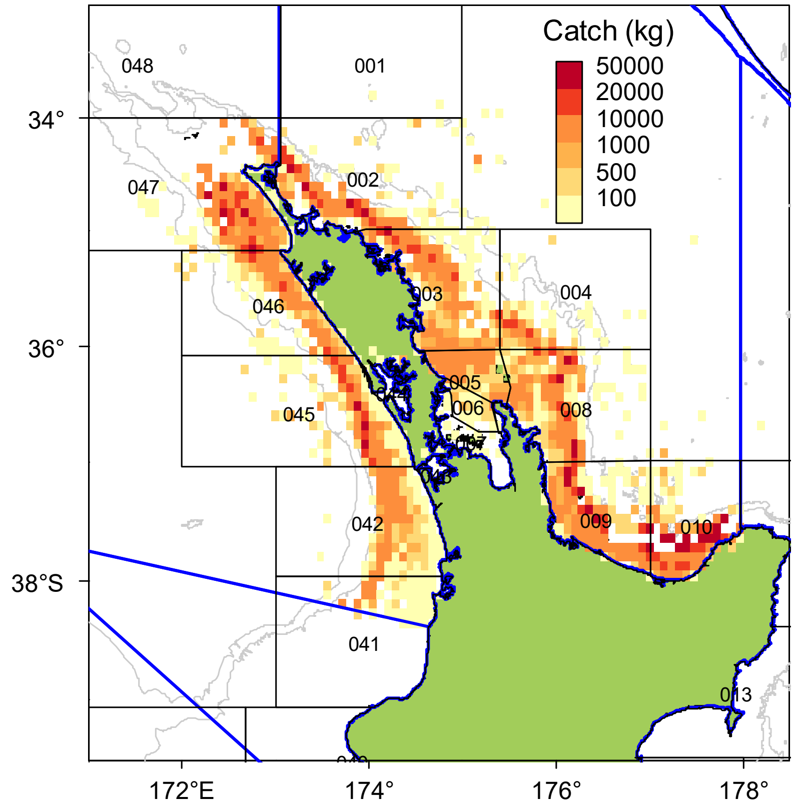

Figure 6: Spatial distribution of the catch of tarakihi within TAR 1 caught by bottom trawl between the 2008 and 2012 fishing years. The colour within each cell (0.08 of a degree of latitude) represents the total catch caught over this five year period (note: catches indicated on land most likely result from positional errors in the MPI catch reporting system).

2.2.3 TAR 1 catch sampling design

In sampling bottom trawl landings from TAR 1 a number of considerations were taken into account to ensure that sampling was undertaken in a way that represented each sub-area/fishery unit. A total of 20 landing sampling events were allocated to area-fishery for the 2013–14 and 2014–15 fishing years, i.e. 60 sampling events in each fishing year. Landings from trips that had fished across multiple stocks/areas were not sampled as it was not possible to identify fish from each area. To ensure representative temporal coverage within each fishery, the seasonal trend of catches from past years was assessed, and sampled landings distributed in accordance to these patterns. The fishing year for the west coast North Island fishery was divided into three seasons: October to January, February to May, and June to September on the basis of the seasonal pattern seen in Figure 4. The fishing year for the East Northland/Hauraki Gulf and Bay of Plenty sub-areas was divided into four seasons: October to December, January to March, April to June, and July to September based on recent seasonal patterns (Figure 4). Fishing company catching patterns were also considered in allocating sample landings across seasons. Landing weight was also taken into account in sample selection process. Only landings above an area specific weight limit were eligible for sampling.

2.2.3.1 Sample design for the west coast North Island sub-area

For the west coast North Island (WCNI) sub-area, an initial minimum landing size of 1000 kg was set, this threshold would have resulted in about 90 % of the landed catch by weight and about 40 % of the number of available landings being deemed eligible for sampling (Figure 7).

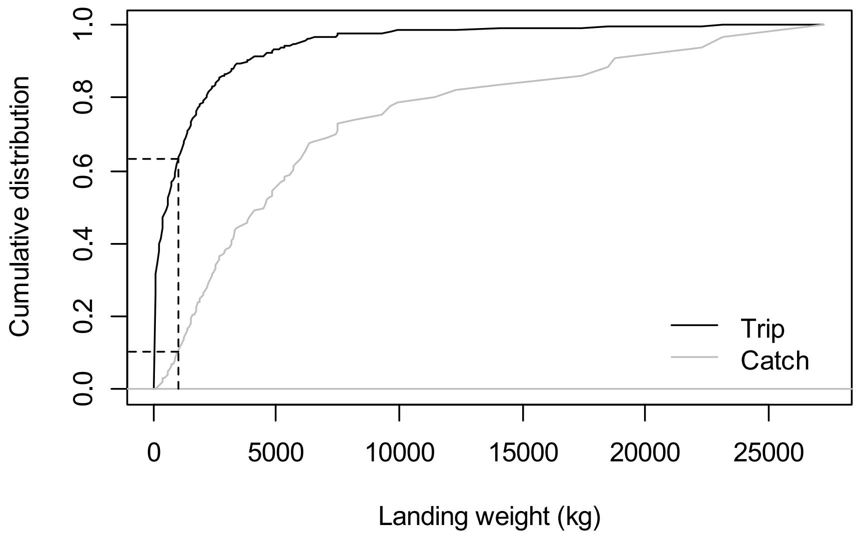

Figure 7: Cumulative distribution of landings from the west coast North Island (WCNI) TAR 1 sub-area (by weight and number of trips) for the 2011 and 2012 fishing years. The dashed vertical line denotes the 1000 kg minimum size limit for landings deemed eligible for sampling. The horizontal dashed lines denote the corresponding proportions of landings smaller than this minimum size limit, which accounted for about 10 % of the catch by weight, and about 60 % of the number of available trips.

Tarakihi landings from the west coast North Island sub-area were predominantly processed by two LFRs (Figure 8), and the 20 sampling events allocated to each of these processors for each year was based on the relative weight of catch they processed respectively.

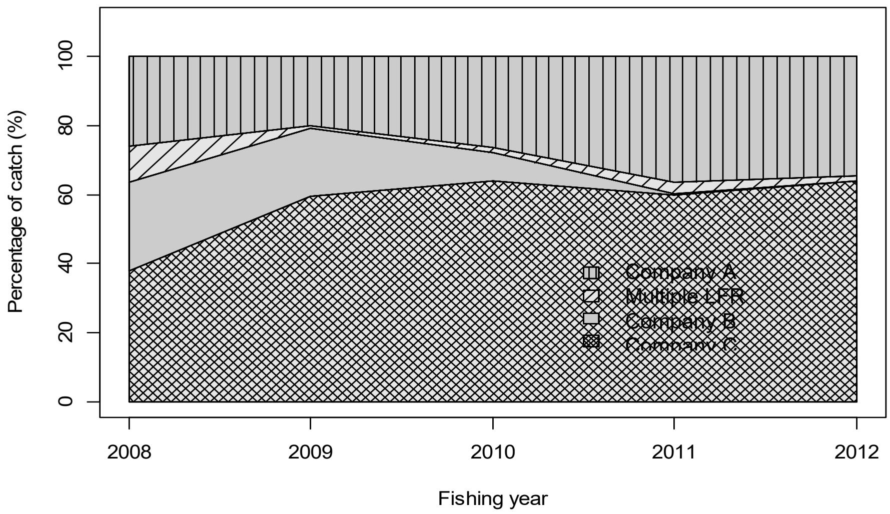

Figure 8: Percentage of the bottom trawl tarakihi catch from the west coast North Island sub-area processed annually by the main LFRs between the 2008 and 2012 fishing years

2.2.3.2 Sample design for the East Northland/Hauraki Gulf sub-area

For the East Northland/Hauraki Gulf sub-area, the minimum weight threshold for landings eligible for sampling was set to 500 kg (Figure 9). Based on data from the 2011 and 2012 fishing years, this threshold would have resulted in about 85 % of the landed catch by weight and about 20 % of the number of available landings being deemed eligible for sampling.

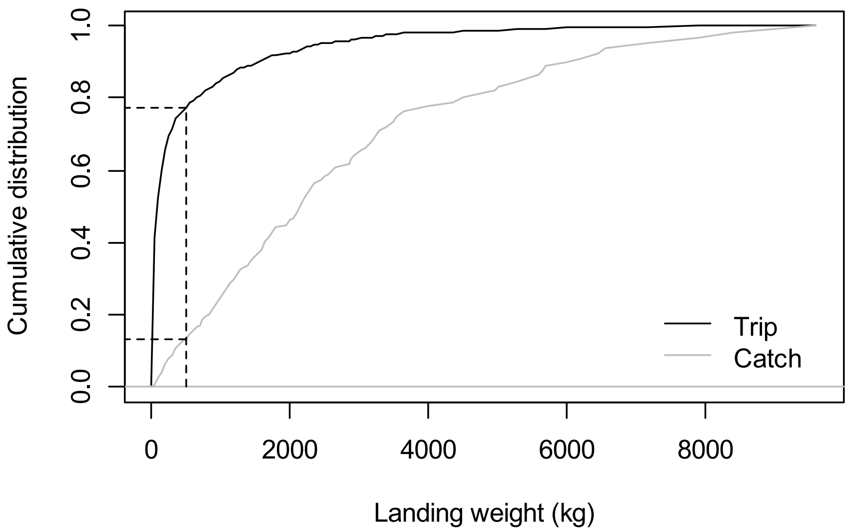

Figure 9: Cumulative distribution of landings from the East Northland/Hauraki Gulf (ENHG) TAR 1 sub-area (by weight and number of trips) for the 2011 and 2012 fishing years. The dashed vertical line denotes the 500 kg minimum size limit for landings deemed eligible for sampling. The horizontal dashed lines denote the corresponding proportions of landings smaller than this minimum size limit, which accounted for about 15% of the catch by weight, and about 80% of the number of available trips.

Landings from the East Northland/Hauraki Gulf (ENHG) sub-area were predominantly processed by two LFRs (Figure 10), and the 20 sampling events allocated to each of these processors for each year was based on the relative weight of catch they processed.

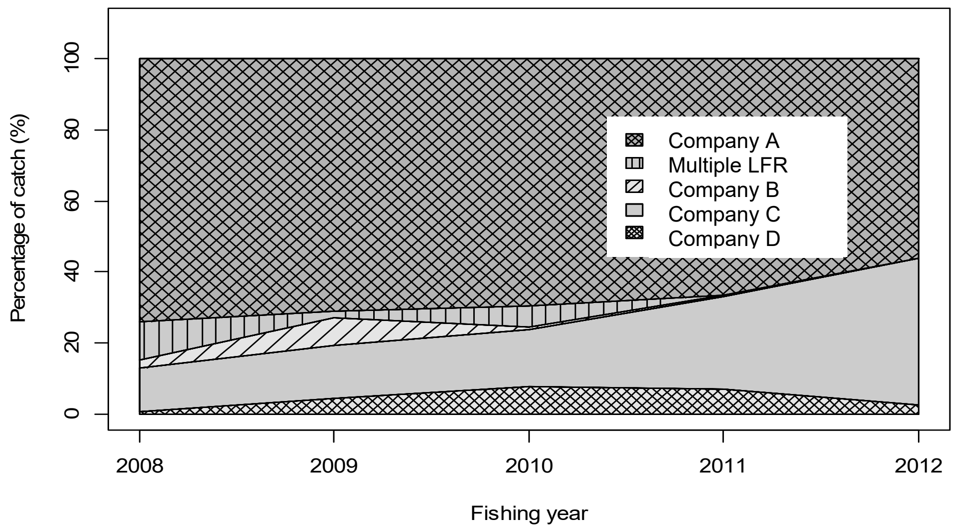

Figure 10: Percentage of the bottom trawl tarakihi catch from the East Northland/ Hauraki Gulf sub-area processed annually by the main LFRs between the 2008 and 2012 fishing years.

2.2.3.3 Sample design for the Bay of Plenty sub-area

For the Bay of Plenty sub-area, the minimum weight for a landing eligible for sampling was set to 1000 kg. Based on data from the 2011 and 2012 fishing years, this threshold would have resulted in about 85 % of the landed catch by weight and about 40 % of the number of available landings being deemed eligible for sampling (Figure 11).

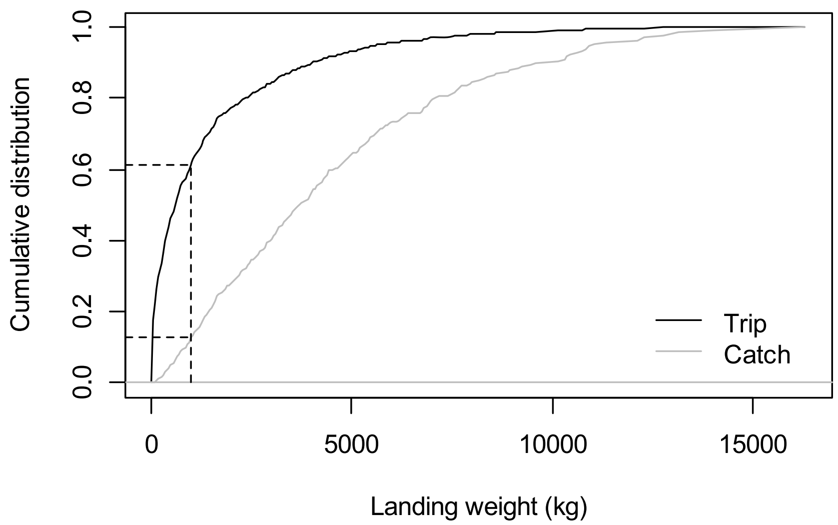

Figure 11: Cumulative distribution of landings from the Bay of Plenty (BPLE) TAR 1 sub-area (by weight and number of trips) for the 2011 and 2012 fishing years. The dashed vertical line denotes the 1000 kg minimum size limit for landings deemed eligible for sampling. The horizontal dashed lines denote the corresponding proportions of landings smaller than this minimum size limit that accounted for about 15 % of the catch by weight, and about 60 % of the number of available trips.

Bottom trawl landings of tarakihi from the Bay of Plenty were predominantly processed by three LFRs (Figure 12). The twenty samples to be collected in each year were therefore allocated to each of these LFRs in proportion to their processed catch.

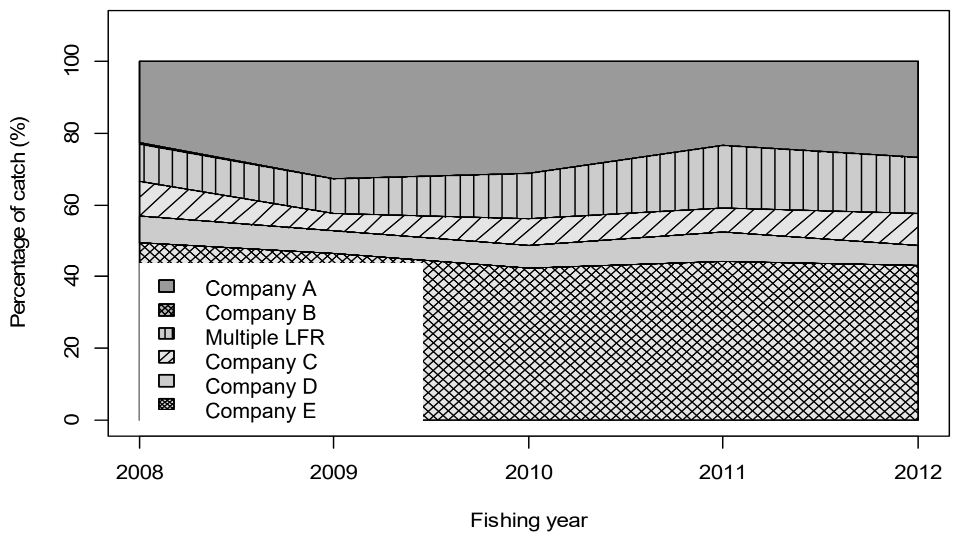

Figure 12: Percentage of the bottom trawl tarakihi catch from the Bay of Plenty sub-area processed annually by the main LFRs between the 2008 and 2012 fishing years.

2.3 TAR 2

2.3.1 TAR 2 fishery profile

The characterisation of the TAR 2 fishery focuses on bottom trawling, as this method accounts for nearly all of the landed catch (Figure 13). The TAR 2 bottom trawl fishery is predominantly a target tarakihi fishery, with a small proportion of effort also targeting red gurnard (Figure 14).

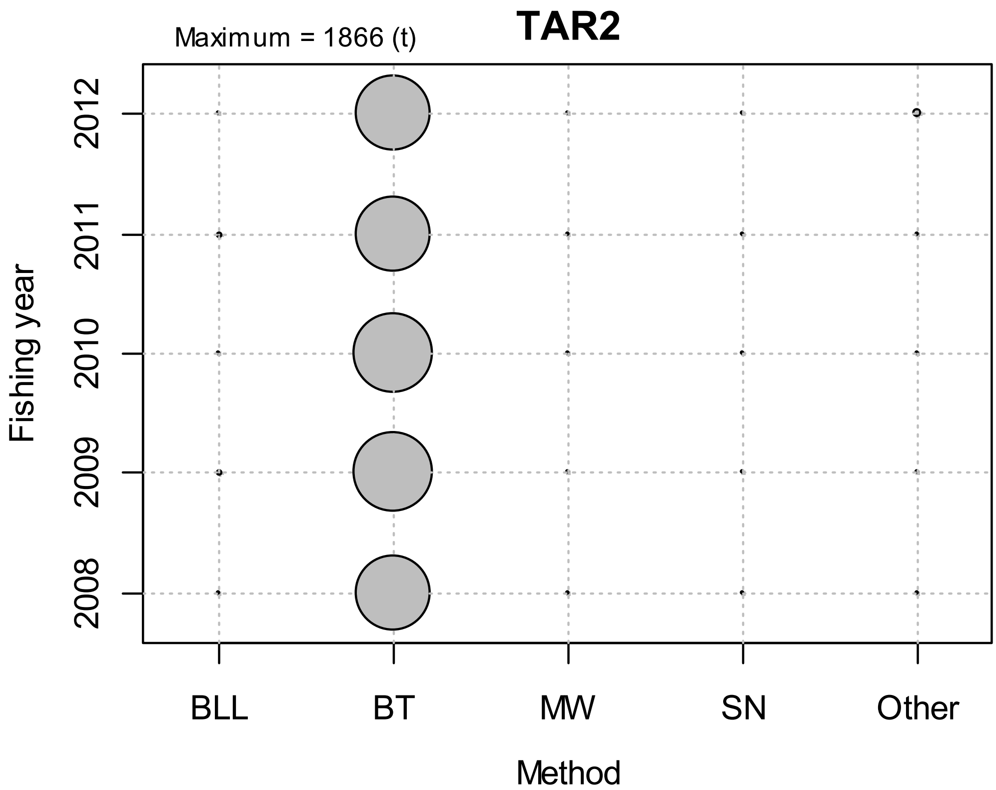

Figure 13: Annual landings of tarakihi by different fishing methods within TAR 2 between the 2008 and 2012 fishing years. The area of each bubble is proportional to the annual catch tonnage taken by each method: BLL = bottom longline, BT = bottom trawl, MW = mid water trawl, and SN = set net.

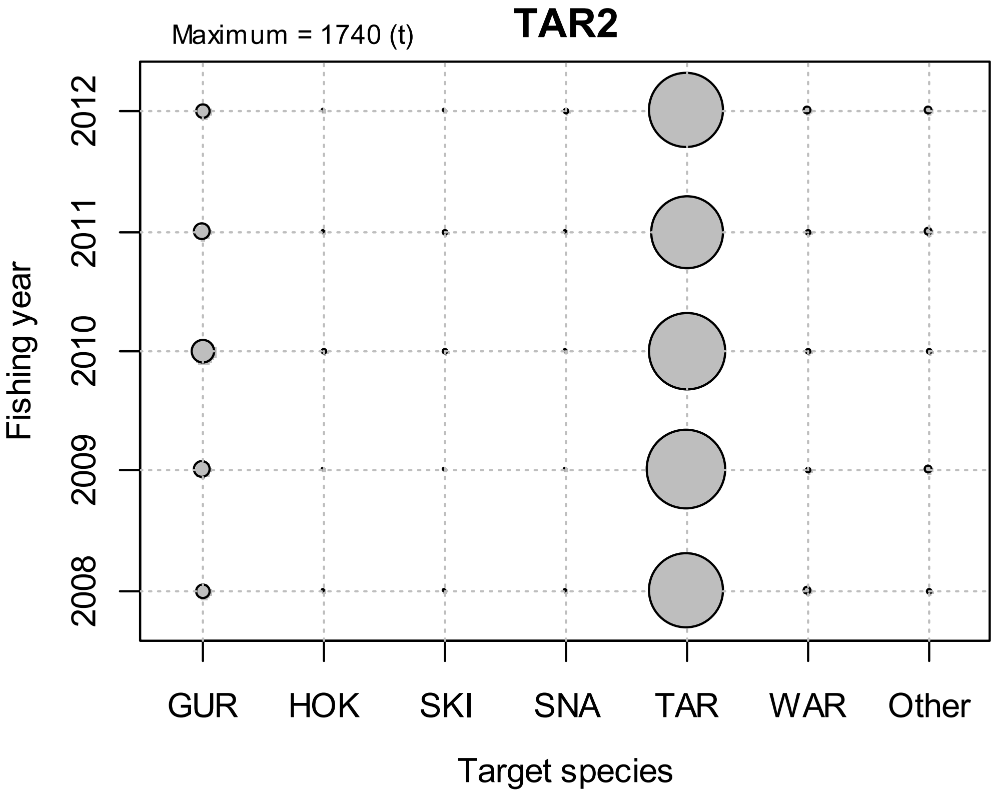

Figure 14: Annual landings of tarakihi landed by bottom trawlers when targeting different species between the 2008 and 2012 fishing years. The area of each bubble is proportional to the annual catch tonnage taken when targeting each species: GUR = red gurnard, HOK = hoki, SKI = gemfish, SNA = snapper, TAR = tarakihi, and WAR = common warehou.

The TAR 2 bottom trawl fishery generally lacks a seasonal pattern, with consistently sized landings occurring throughout the year (Figure 15).

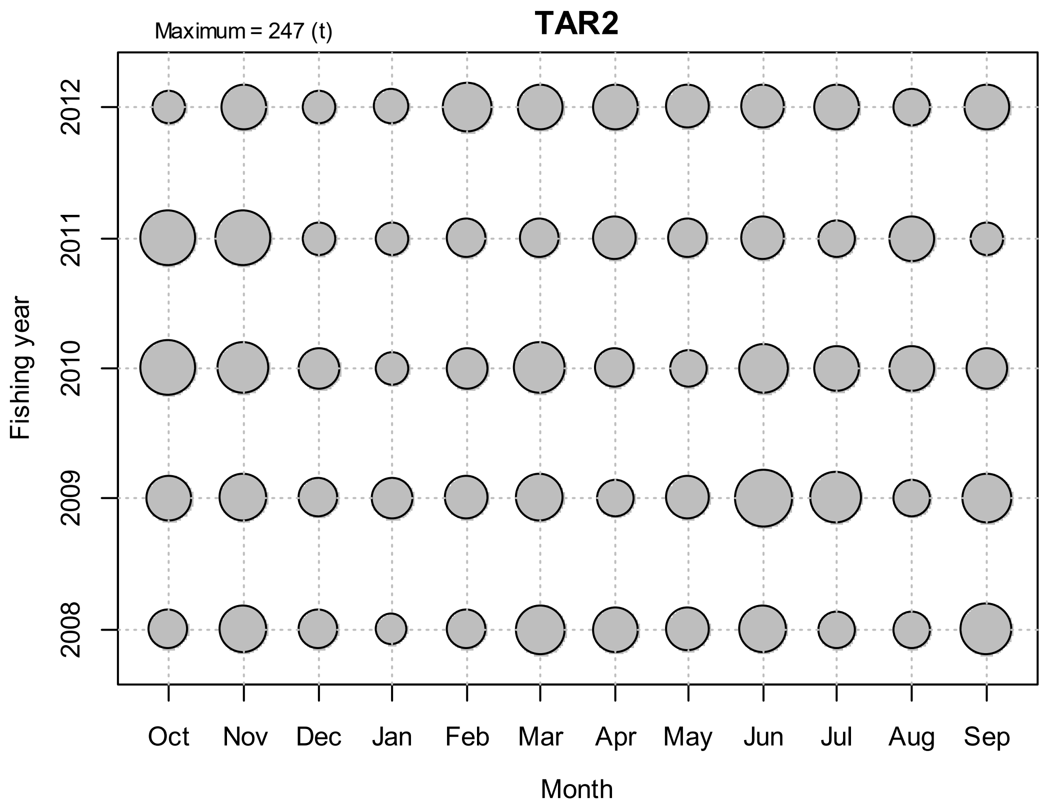

Figure 15: Monthly landings of tarakihi landed by bottom trawlers during the 2008 to 2012 fishing years. The area of each bubble is proportional to the monthly catch (t).

The majority of tarakihi catch within TAR 2 is widespread across Statistical Areas 011, 012, 013 and 014 (Figure 16). Less catch is taken from area 15, and the smaller statistical areas which fall across QMA boundaries.

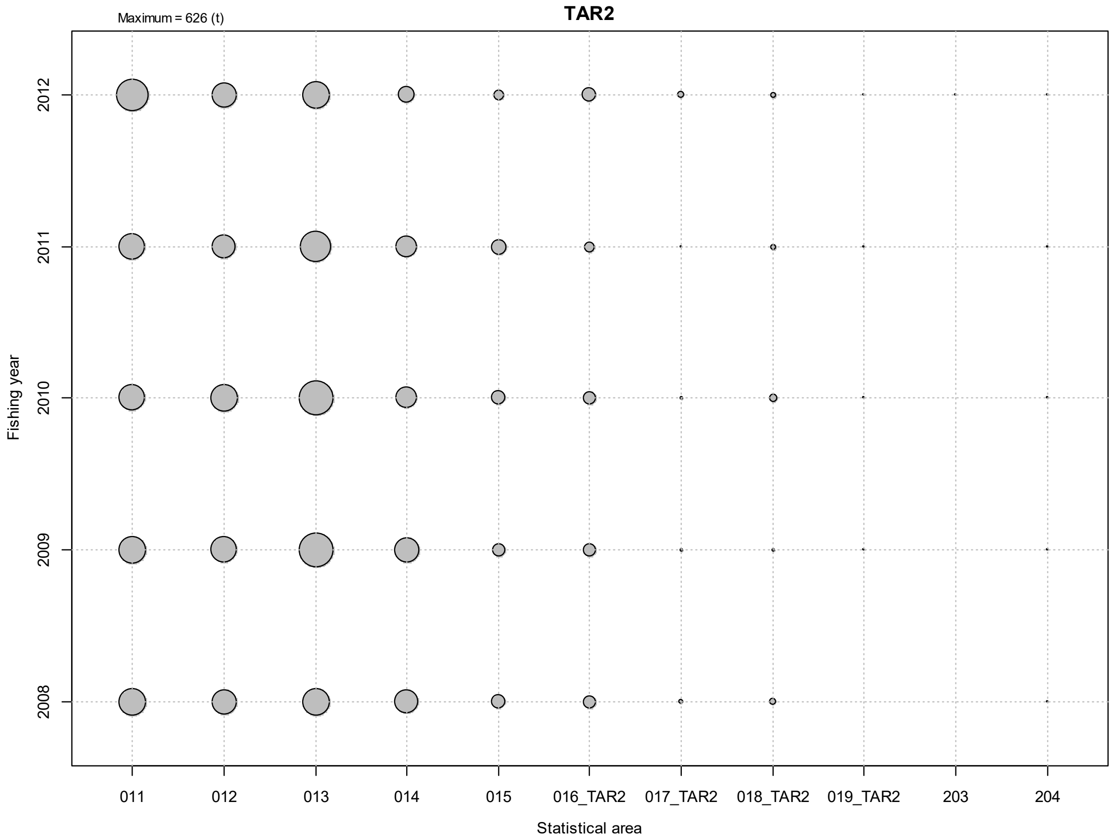

Figure 16: Annual landings of tarakihi by bottom trawlers by statistical area during the 2008 to 2012 fishing years. The area of each bubble is proportional to the annual tonnage landed in each statistical area. "016_TAR3" etc… refers to the portion of Statistical Area 016 that is within the TAR 2 Quota Management Area.

The widespread nature of tarakihi catch throughout TAR 2 is further illustrated in Figure 17, although the highest catch rates appear constrained to the north of Mahia Peninsula.

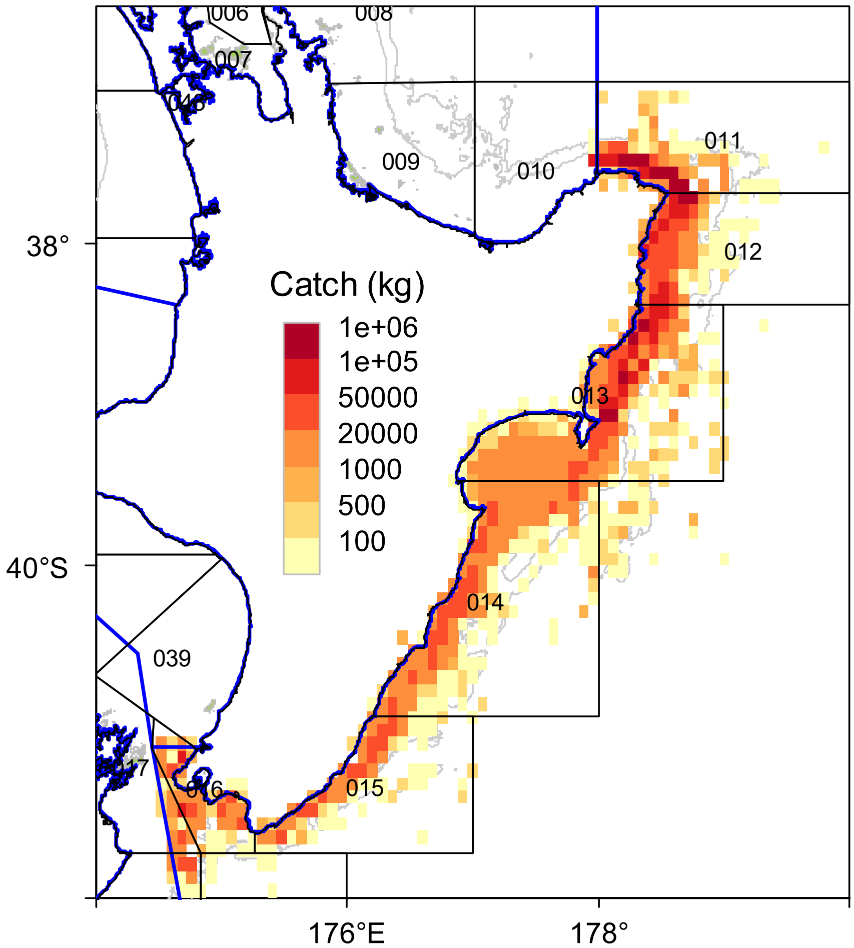

Figure 17: Spatial distribution of the catch of tarakihi within TAR 2 caught by bottom trawl between the 2008 and 2012 fishing years. The colour within each cell (0.08 of a degree of latitude) represents the total catch tonnage caught over this five year period, as defined by the legend (note: catches indicated on land most likely result from positional errors in the MPI catch reporting system).

2.3.2 TAR 2 catch sampling design

TAR 2 was not divided into sub-areas for sampling and in accordance with sampling in previous years (Beentjes et al. 2012) and an annual sampling allocation was set at 30 landings.

The catch sampling design for TAR 2 was constrained to the main statistical areas fished. First, the majority of TAR 2 catch comes from the northern statistical areas (011, 012, 013 and to some extent 014). The southernmost statistical areas overlap multiple QMAs, making it difficult to ascertain clean landings (i.e. consisting of catch from just TAR 2). For these reasons, we only assessed catches from Statistical Areas 011, 012, 013 and 014 when setting minimum catch limits and allocating sampling effort across LFRs. The Cook Strait area was sampled separately as described below.

An initial minimum landing size of 1200 kg was set, this threshold would have resulted in about 90 % of the landed catch by weight and about 40 % of the number of available landings being deemed eligible for sampling (Figure 18).

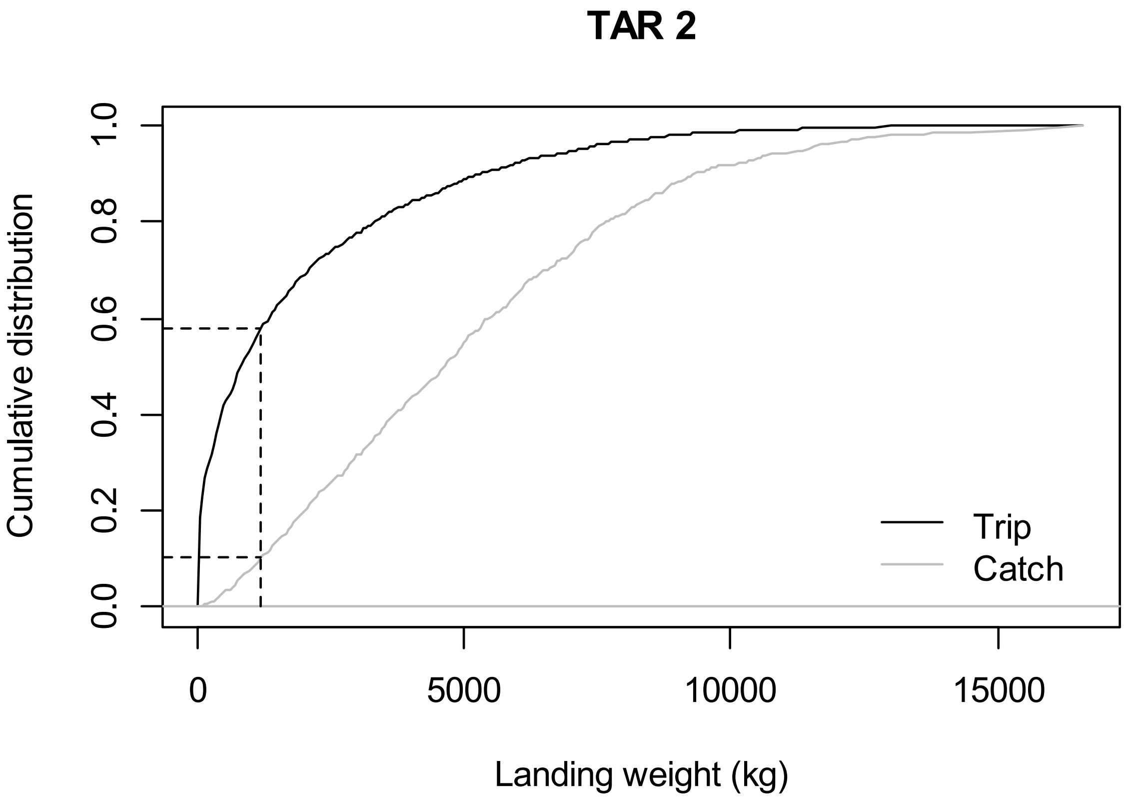

Figure 18: Cumulative distribution of landings from the TAR 2 bottom trawl fishery (by weight and number of trips) for the 2011 and 2012 fishing years. The dashed vertical line denotes the 1200 kg minimum size limit for landings deemed eligible for sampling. The horizontal dashed lines denote the corresponding proportions of landings smaller than this minimum size limit that accounted for about 10 % of the catch by weight, and about 60 % of the number of available trips.

Bottom trawl landings of tarakihi from TAR 2 were predominantly processed by four LFRs (Figure 19). Sampling effort (30 samples for each year) was therefore allocated to each of these LFRs, in proportion to their typical processed catch.

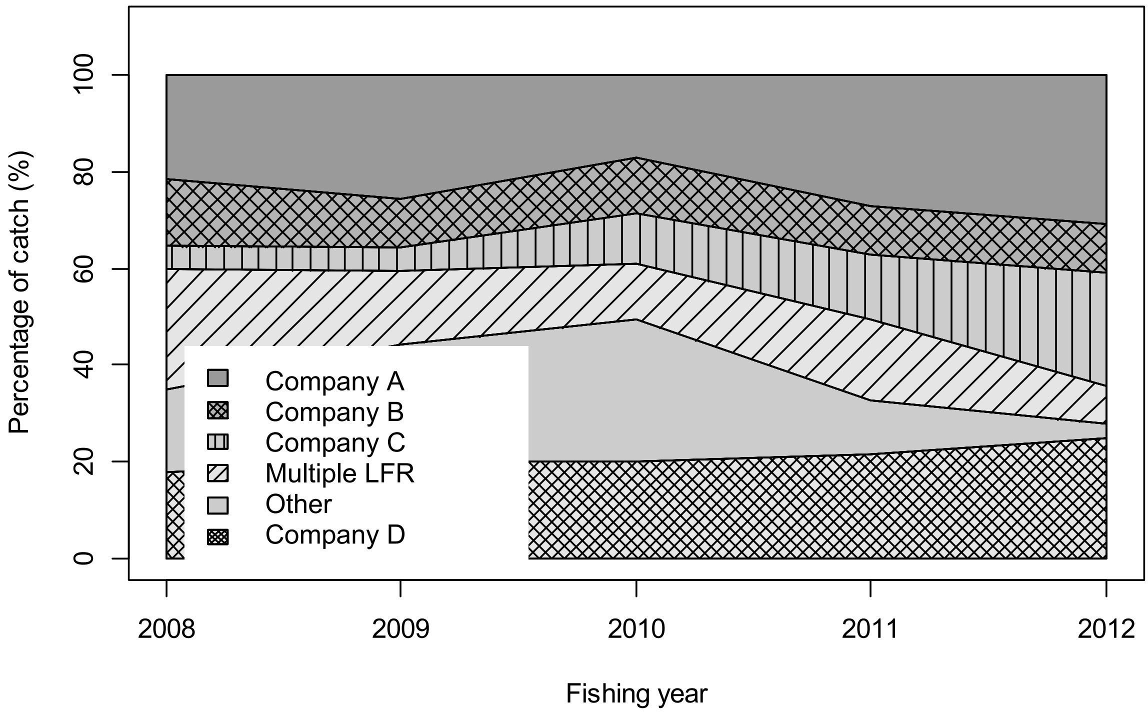

Figure 19: Percentage of the bottom trawl tarakihi catch from TAR 2 processed annually by the main LFRs between the 2008 and 2012 fishing years.

2.4 Cook Strait

Cook Strait sampling included portions of Statistical Areas 016, 017 and 018. The purpose of sampling Cook Strait was to describe the length and age structure of a potential spawning aggregation. The catch from this area is targeted by a bottom trawl fishery and specifically targets large, aggregated, pre-spawning fish. The catches occur typically over the summer months, the period when tarakihi are in spawning condition. As such, we constrained sampling to January through to early March so we could specifically target spawning adult tarakihi. We did this by coordinating directly with skippers on the vessels that typically target these aggregations to determine when they would fish in Cook Strait, and when and where they would land the catch. The fishers target an area called “12-mile”, as it was near the 150 m depth contour 12-miles off Cape Campbell, or “26-mile”, as the same location was 26 miles from Wellington. Catch was sampled in Nelson and in Wellington. The size of tarakihi catches from this region are predominantly large, with 80 % of landings being greater than 2500 kg. We therefore set a minimum landing size of 1000 kg. The majority of catch from this region in the 2011 and 2012 fishing years was processed by three LFR’s, which together received an allocation of 10 landings to be sampled in each of the 2013–14 and 2014–15 fishing years. Note that representativeness of the total catch coming from these statistical areas was not the objective of this sampling, and therefore a targeted period and vessel arrangement was appropriate.

2.5 TAR 3

2.5.1 TAR 3 fishery profile

The majority of the catch taken from TAR 3 between 2008 and 2012 was caught by bottom trawling, with significant catches also taken by set net and Danish seine (Figure 20).

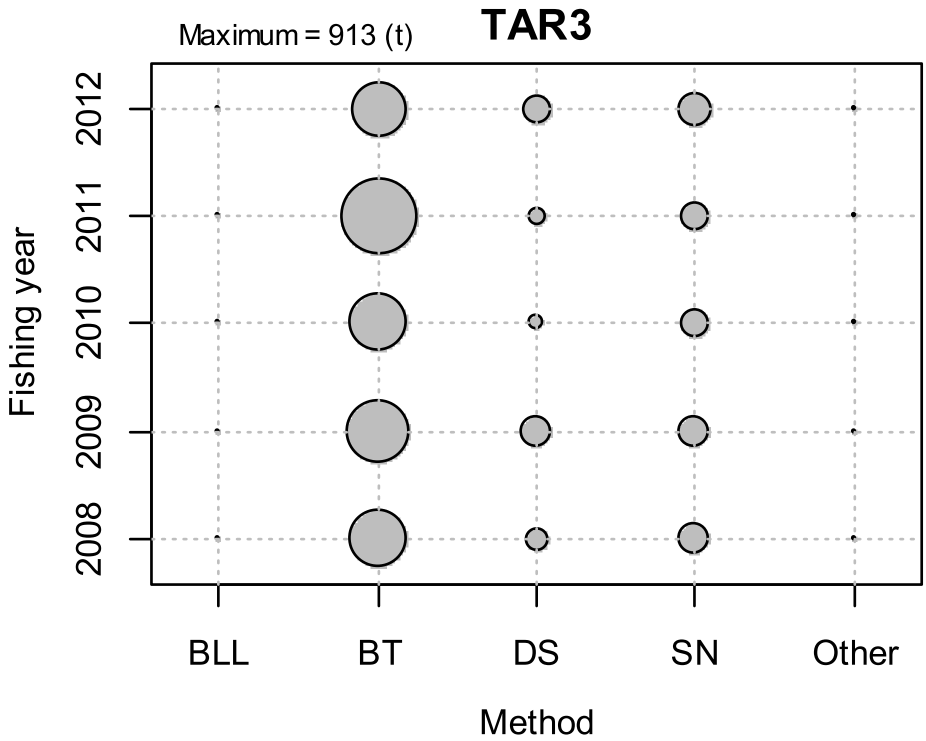

Figure 20: **Tonnages of tarakihi landed annually by different fishing methods within TAR 3 between the 2008 and 2012 fishing years. The area of each bubble is proportional to the annual catch tonnage taken by each method: BLL = bottom longline, BT = bottom trawl, DS = Danish seine, and SN = set net.**

2.5.1.1 Fishery profile for the bottom trawl fishery

The majority of the annual bottom trawl tarakihi catch from TAR 3 was taken targeting tarakihi (Figure 21). Bottom trawlers targeting barracouta, flatfish and red cod landed a small tarakihi bycatch during each fishing year.

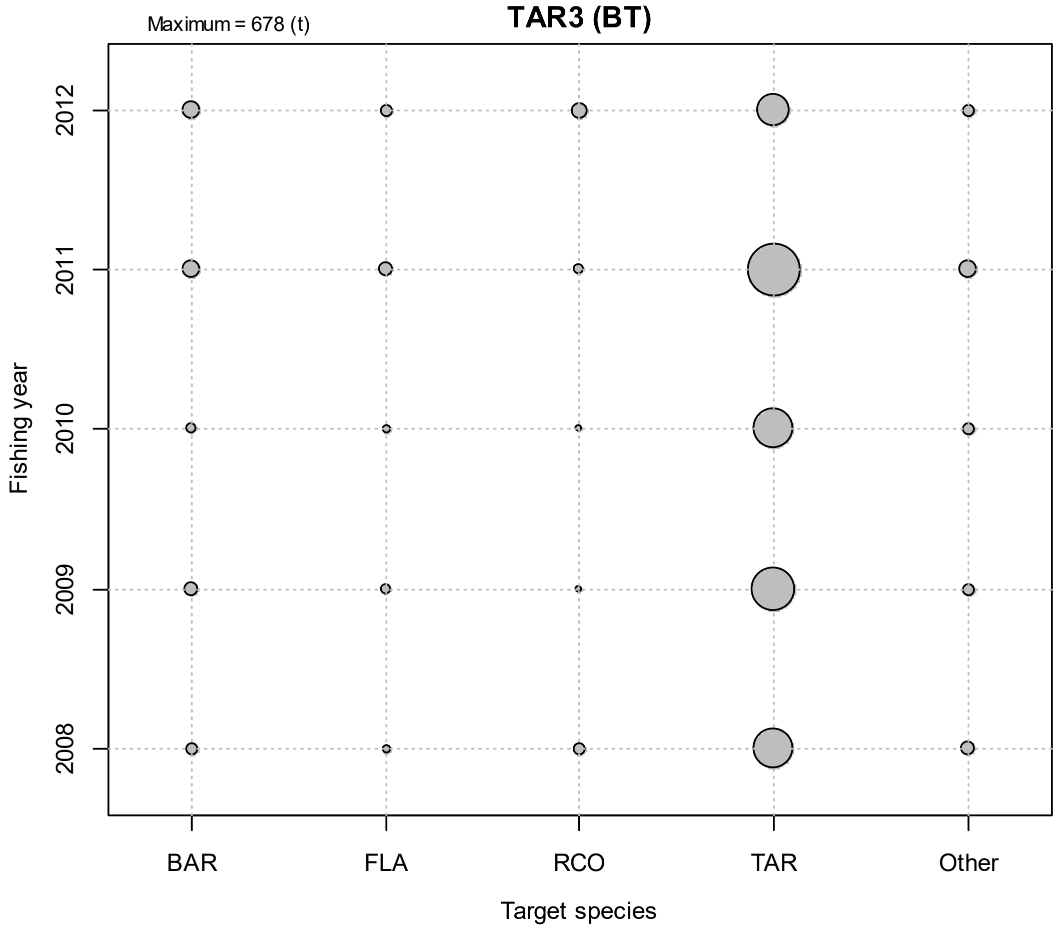

Figure 21: Tonnage of tarakihi landed annually by bottom trawlers when targeting different species between the 2008 and 2012 fishing years. The area of each bubble is proportional to the annual catch tonnage taken when targeting each species: BAR = barracouta, FLA = flatfish, RCO = red cod, and TAR = tarakihi.

There is a clear seasonality in bottom trawl catches within TAR 3, with landings usually peaking between January and June in most years (Figure 22).

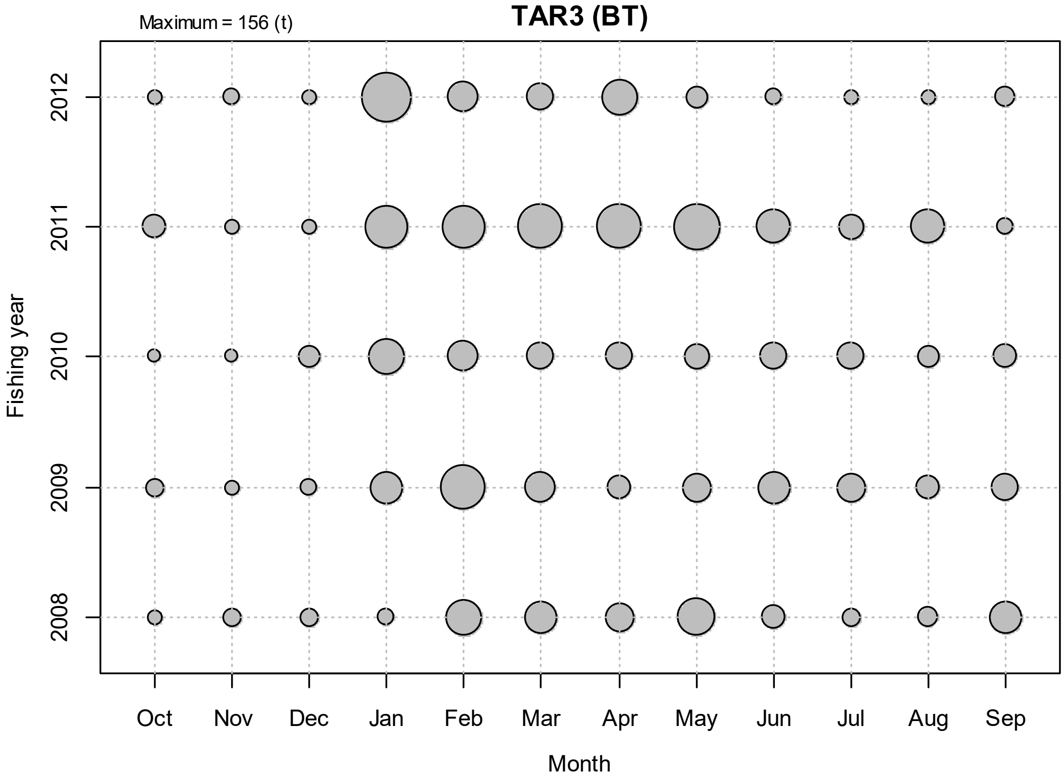

Figure 22: Monthly tonnages of tarakihi landed by bottom trawlers during the 2008 to 2012 fishing years. The area of each bubble is proportional to the monthly catch (t).

There were consistent patterns in the relative contribution of TAR 3 bottom trawl landings from each statistical area between 2008 and 2012 (Figure 23). The areas contributing the most tarakihi catch were Statistical Areas 022, 020 and 024.

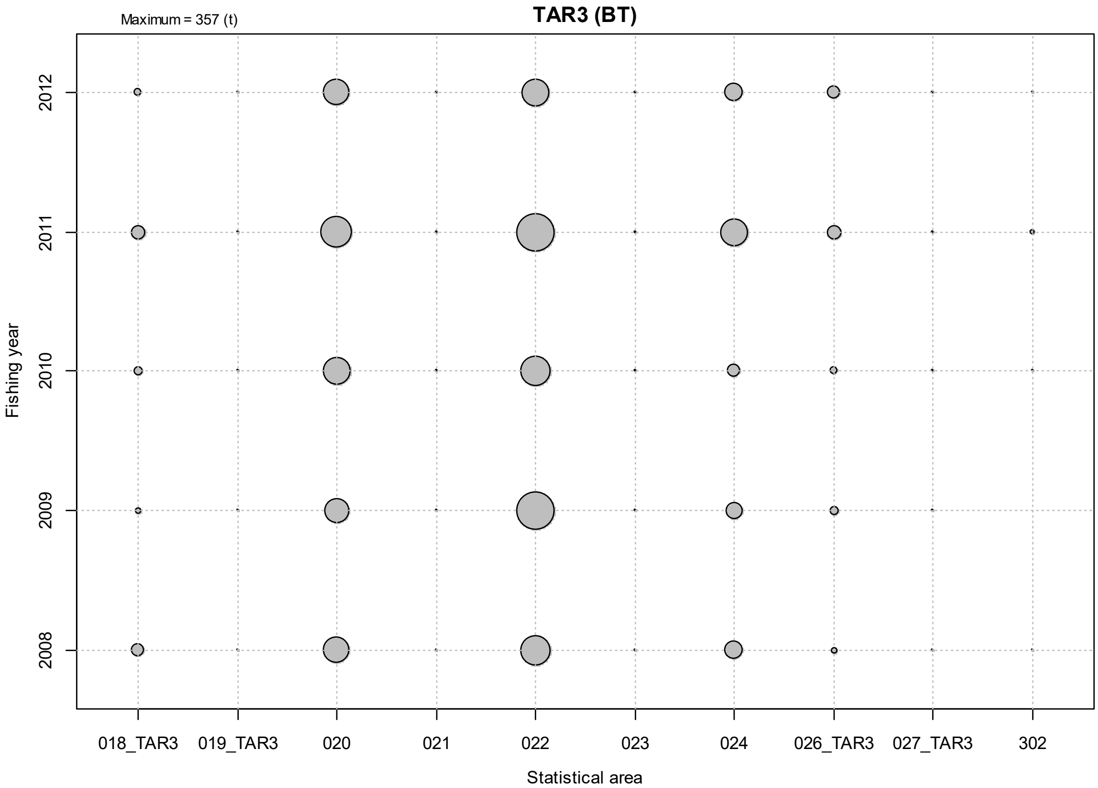

Figure 23: Tonnage of tarakihi landed annually by bottom trawlers by statistical area during the 2008 to 2012 fishing years. The area of each bubble is proportional to the annual tonnage landed in each statistical area. "018_TAR3" etc… refers to the portion of Statistical Area 018 that is within the TAR 3 Quota Management Area.

A fine scale plot of the spatial distribution of tarakihi catches within TAR 3, based on the reported latitude and longitude of individual trawl shots, suggests that tarakihi are caught across a broad shelf west of Banks Peninsula area (areas 020 and 022) (Figure 24). Both north and south of Banks Peninsula, however, the continental shelf is narrower and tarakihi are subsequently caught much closer to the coast (i.e. to the south of Otago Peninsula within areas 024 and 026 and around the Kaikoura Peninsula within areas 020 and 018). As a result, the total area fished is more extensive near Banks Peninsula (i.e. statistical areas 020 and 022), which corresponds with the higher landed weights from these areas (Figure 23).

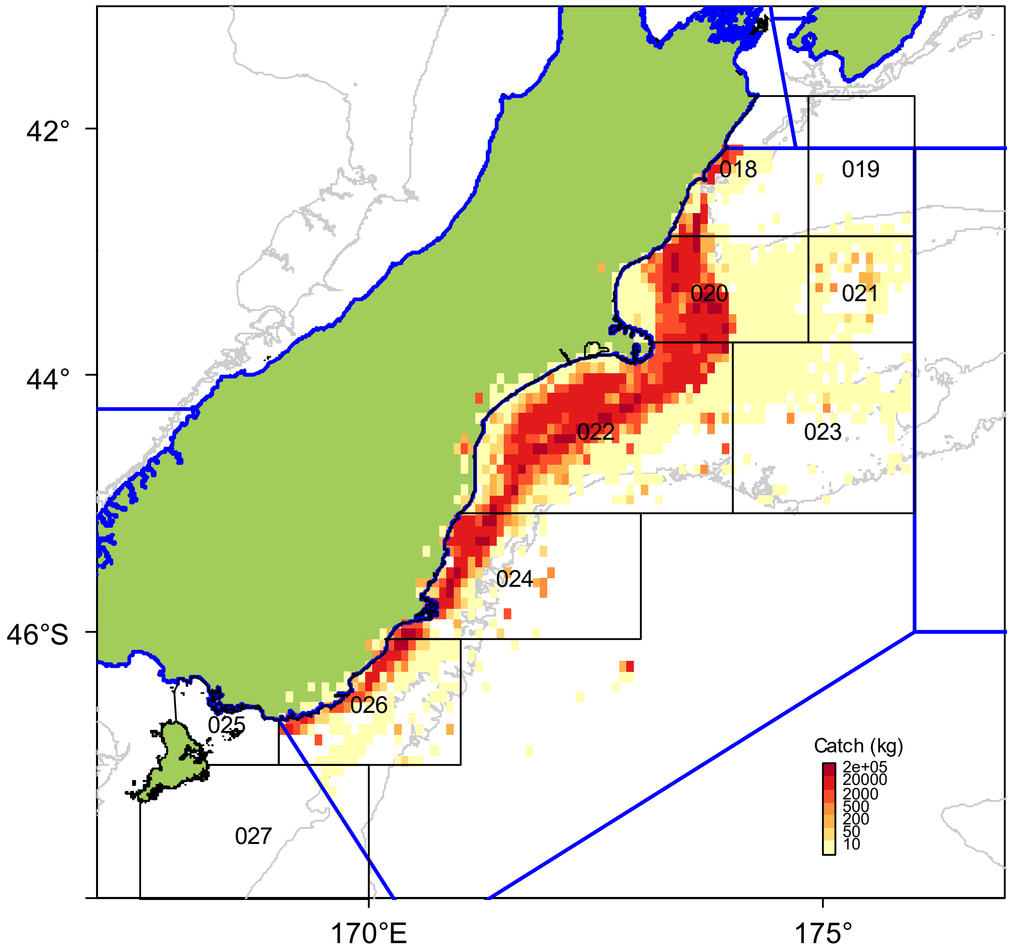

Figure 24: Spatial distribution of the catch of tarakihi within TAR 3 caught by bottom trawl between the 2008 and 2012 fishing years. The colour within each cell (0.08 of a degree of latitude) represents the total catch tonnage caught over this five year period, as defined by the legend (note: catches indicated on land most likely result from positional errors in the MPI catch reporting system).

2.5.1.2 Fishery profile for the set net fishery

Almost all of the annual set net tarakihi catch from TAR 3 has been taken while targeting tarakihi (Figure 25).

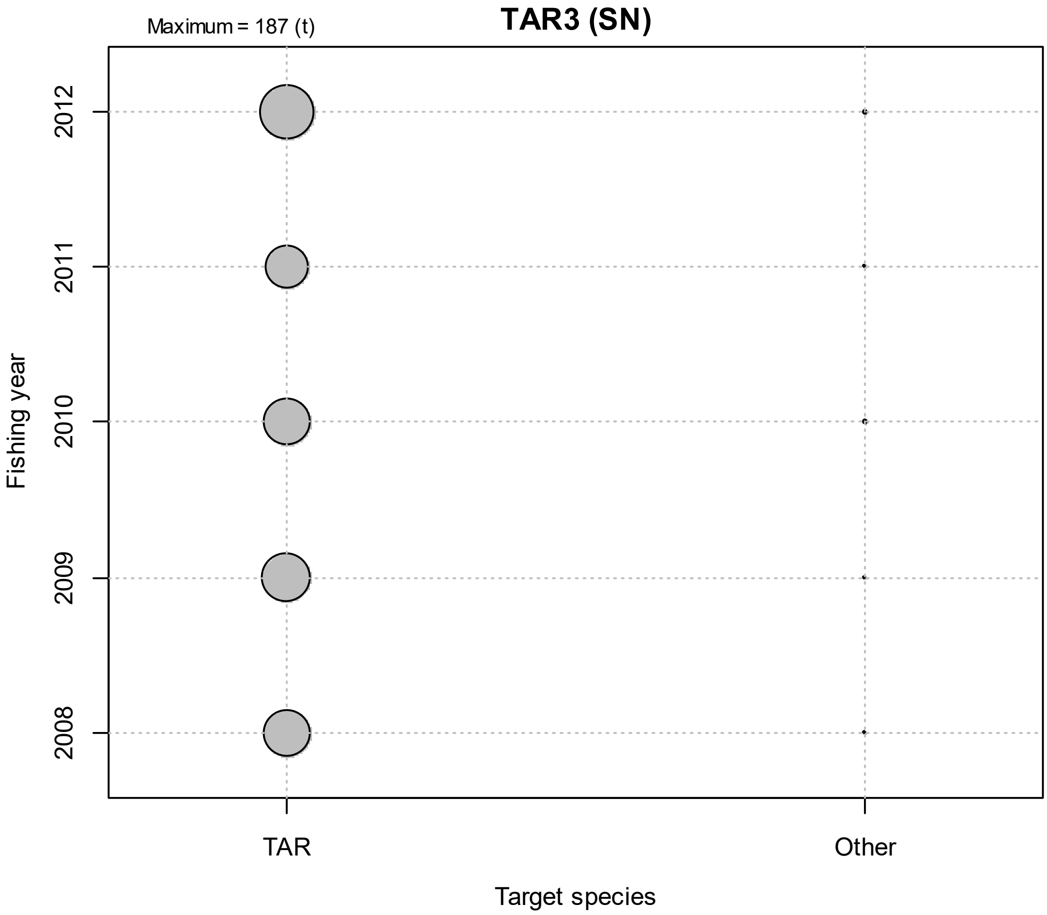

Figure 25: Tonnage of tarakihi landed annually by set net when targeting different species between the 2008 and 2012 fishing years. The area of each bubble is proportional to the annual catch tonnage taken when targeting each species: TAR = tarakihi.

There is a clear seasonality in set net catches within TAR 3. Tarakihi set net catch largely occurs between December and June (Figure 26). January and May consistently have the highest tarakihi catches, with lower catches occurring between these months.

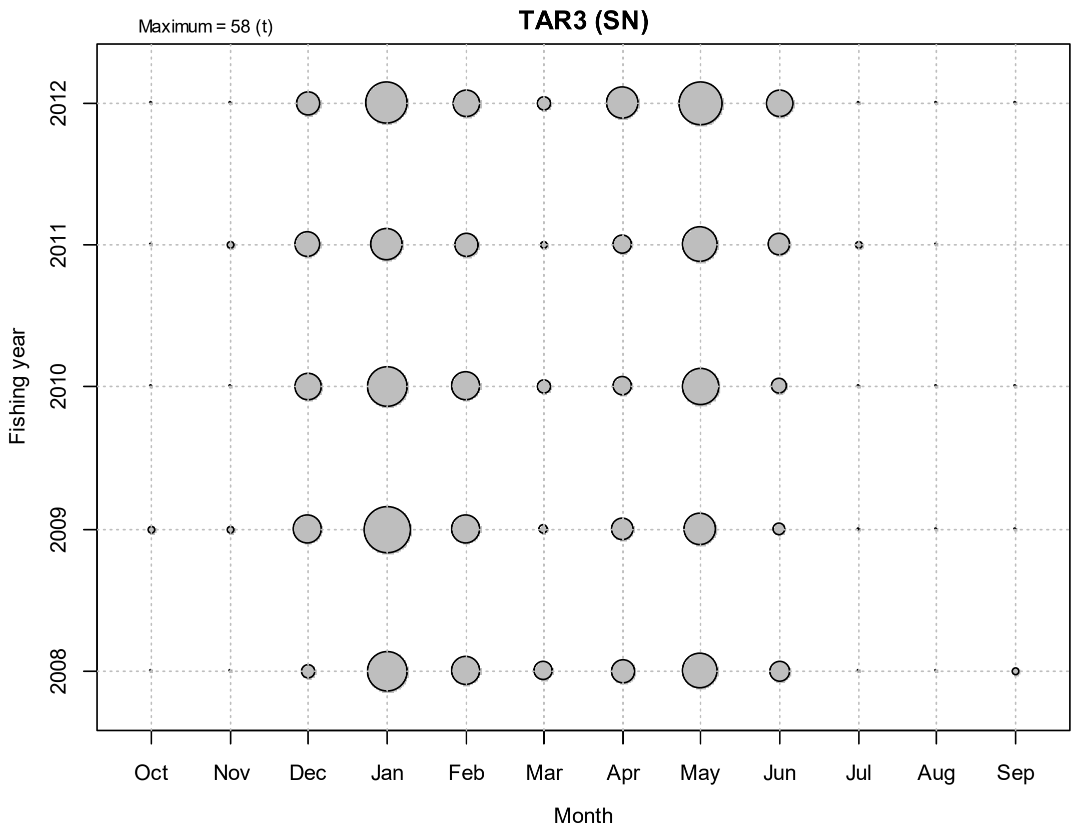

Figure 26: Monthly tonnages of tarakihi landed by set net during the 2008 to 2012 fishing years. The area of each bubble is proportional to the monthly catch (t).

Tarakihi set net catch within TAR 3 mainly occurs within Statistical Area 018 (Figure 27). A small amount of tarakihi is also caught by set net from Statistical Area 024.

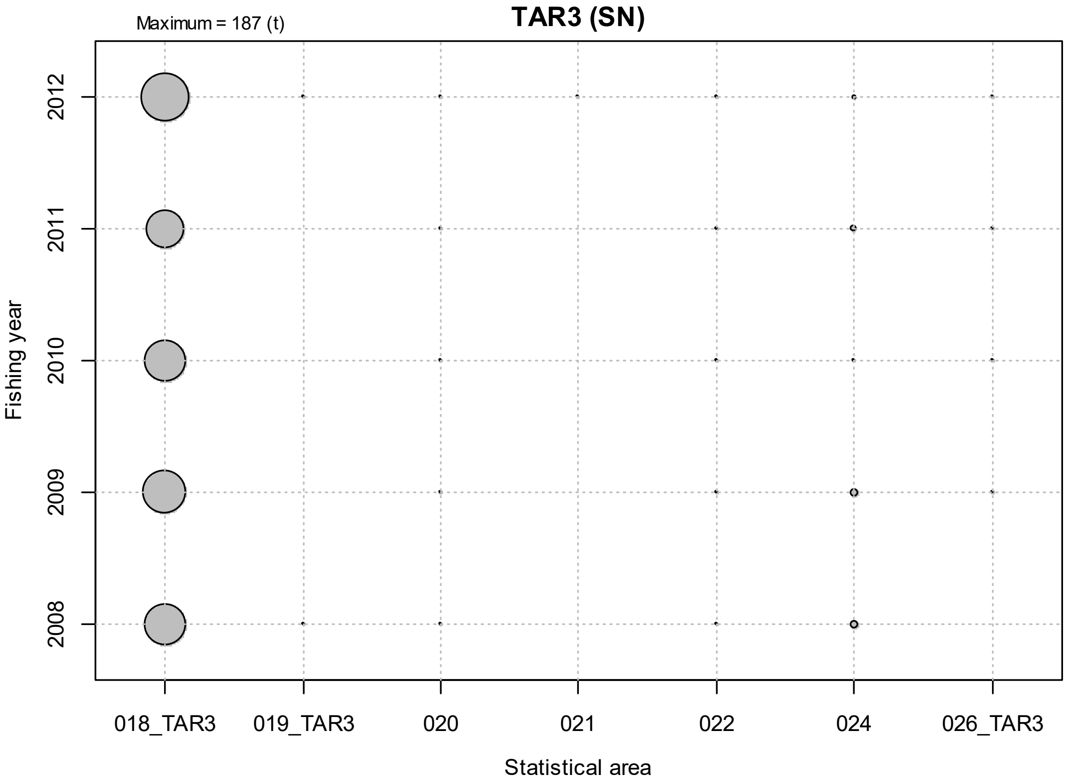

Figure 27: Tonnage of tarakihi landed annually by set net by statistical area during the 2008 to 2012 fishing years. The area of each bubble is proportional to the annual tonnage landed in each statistical area. "018_TAR3" etc… refers to the portion of Statistical Area 018 that is within the TAR 3 Quota Management Area.

A fine scale plot of the spatial distribution of tarakihi set net catches within TAR 3, based on the reported latitude and longitude of individual net sets, suggests that the majority of set net catches of tarakihi are taken from near Kaikoura (area 018) (Figure 28). Set netting is also conducted further to the south near Oamaru (area 024), but tarakihi catches are much lower than the set net fishery from area 018 (Figure 28).

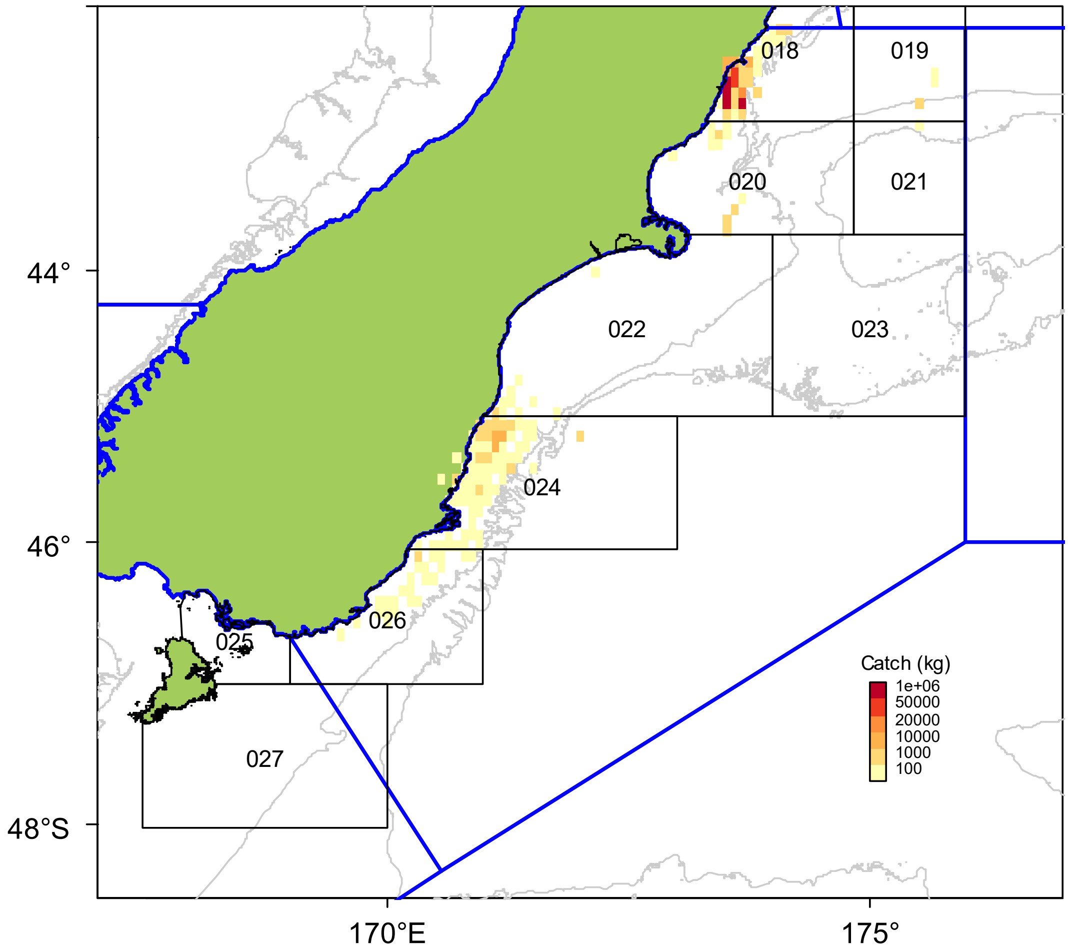

Figure 28: Spatial distribution of the catch of tarakihi within TAR 3 caught by set net between the 2008 and 2012 fishing years. The colour within each cell (0.08 of a degree of latitude) represents the total catch tonnage caught over this five year period, as defined by the legend (note: catches indicated on land likely result from positional errors in the MPI catch reporting system).

2.5.2 TAR 3 catch sampling design

As mentioned above, all sampling of tarakihi within TAR 3 was conducted from the bottom trawl and set net fishery landings. For the bottom trawl fishery, the working group agreed that finer spatial resolution in age structure information was desirable, as it may provide a better understanding of stock structure along the east coast of the South Island. As such, the TAR 3 bottom trawl fishery was subdivided into northern Banks Peninsula (NBP), and southern Banks Peninsula (SBP) sub-areas (see Figure 1), with separate sampling effort allocated to each. In past TAR 3 sampling programmes, 30 landings were annually sampled from the TAR 3 trawl fishery and 16 from the Kaikoura region set net fishery (Beentjes et al. 2012). The revised sampling design saw 20 trawl samples allocated to NBP and 10 to SBP. As in previous years, 16 annual samples were allocated to the Kaikoura set net fishery.

In sampling landings from TAR 3 a number of considerations were taken into account to ensure that sampling was undertaken in a way that represented each sub-area/fishery unit. Landings from trips that had fished across multiple stocks/areas were not sampled as we would not be able to distinguish which parts of the catch should be associated with each area. To ensure representative temporal coverage within each fishery, the seasonal trend of catches from past years was assessed, and sampled landings distributed in accordance to these patterns. Within the NBP bottom trawl fishery, sampling was conducted across four seasons: October to December, January to March, April to June, and July to September. A similar seasonality was followed for the SBP bottom trawl fishery, although only three of the above seasons were sampled (October to December was not sampled). For the TAR 3 set net fishery, only two seasons were sampled, being December to February and April to June.

The size and number of landings within each fishery was also assessed, with a minimum landing size that would be sampled established (only landings above a certain size limit were deemed representative of each fishery). The distribution of eligible landings across the major LFRs was also examined, so that these sampling events could be allocated between processors in a representative manner.

2.5.2.1 Sample design for the bottom trawl fishery

For the NBP bottom trawl fishery an initial minimum landing size of 500 kg was set, this threshold would have resulted in about 90 % of the landed catch by weight and about 30 % of the number of available landings being deemed eligible for sampling (Figure 29).

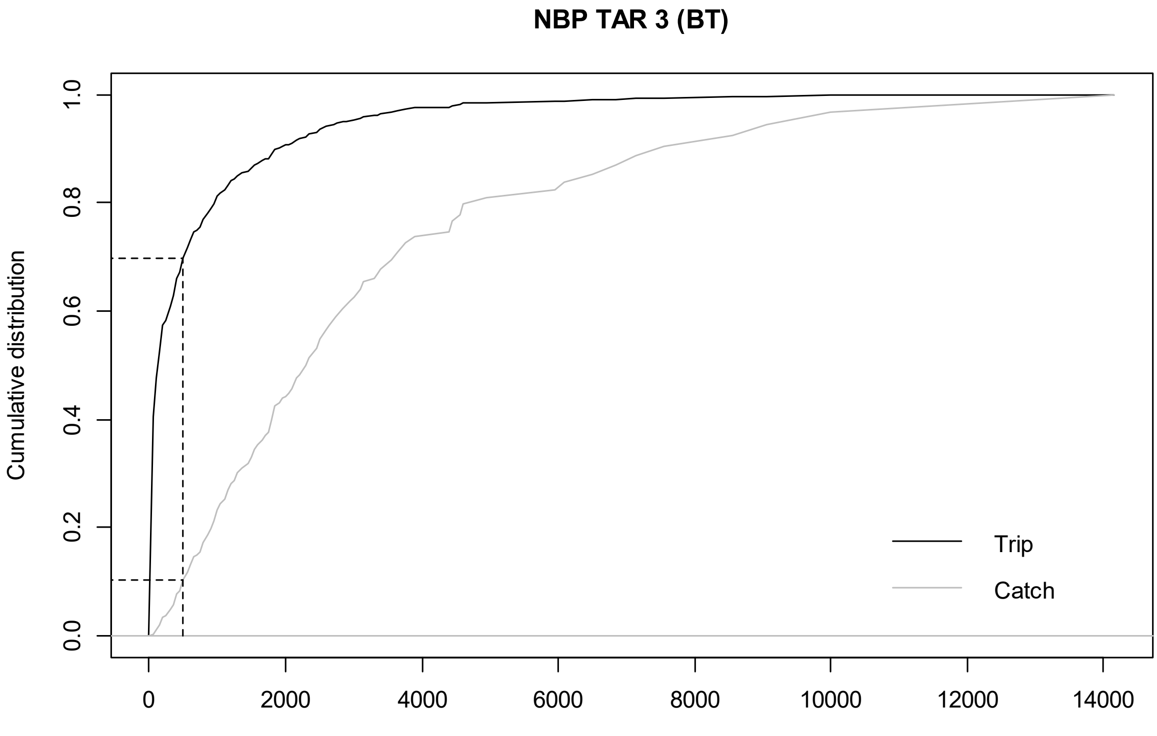

Figure 29: Cumulative distribution of bottom trawl landings from the northern Banks Peninsula TAR 3 sub-area (by weight and number of trips) for the 2011 and 2012 fishing years. The dashed vertical line denotes the 500 kg minimum size limit for landings deemed eligible for sampling. The horizontal dashed lines denote the corresponding proportions of landings smaller than this minimum size limit that accounted for about 10 % of the catch by weight, and about 70 % of the number of available trips.

For the SBP bottom trawl fishery an initial minimum landing size of 300 kg was set, this threshold would have resulted in about 90 % of the landed catch by weight and about 30 % of the number of available landings being deemed eligible for sampling (Figure 30).

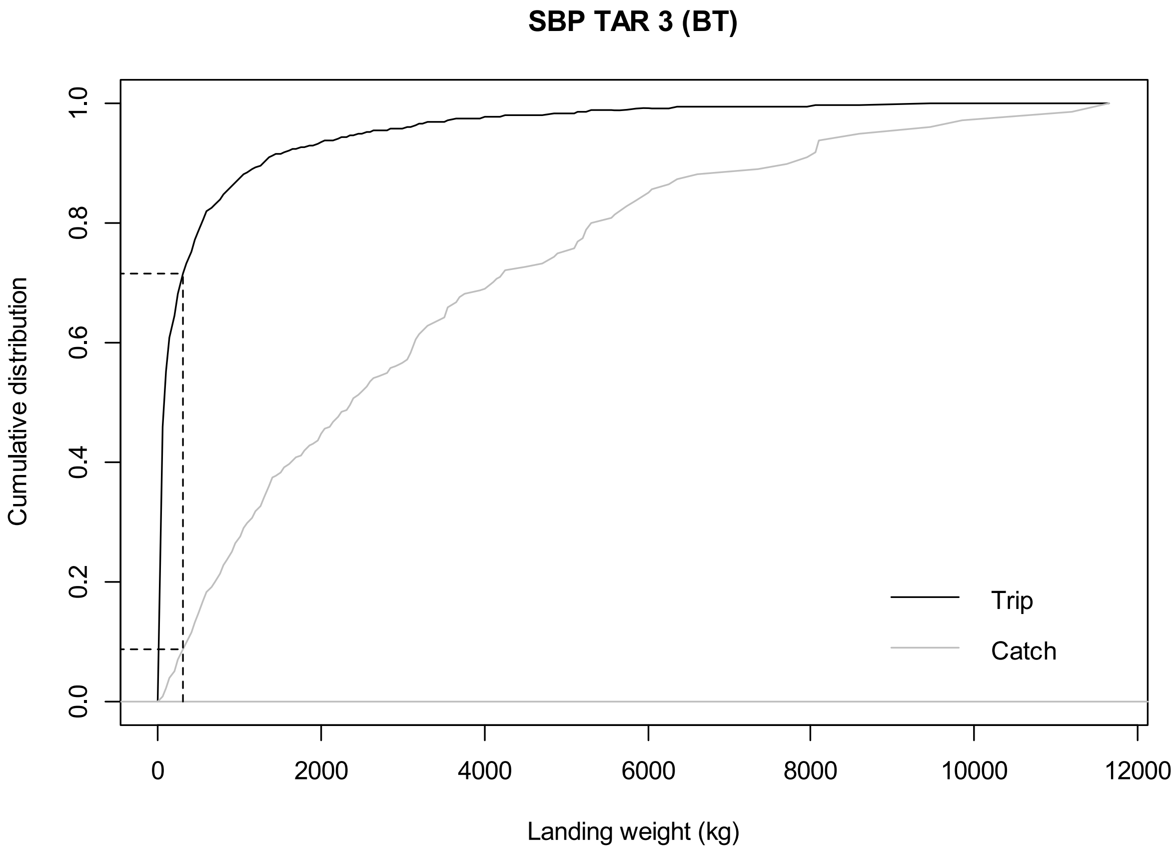

Figure 30: Cumulative distribution of bottom trawl landings from the southern Banks Peninsula TAR 3 sub-area (by weight and number of trips) for the 2011 and 2012 fishing years. The dashed vertical line denotes the 300 kg minimum size limit for landings deemed eligible for sampling. The horizontal dashed lines denote the corresponding proportions of landings smaller than this minimum size limit that accounted for about 10 % of the catch by weight, and about 70 % of the number of available trips.

Tarakihi landings from NBP were predominantly processed by one LFR (Figure 31), which was consequently allocated all 20 landings to be sampled.

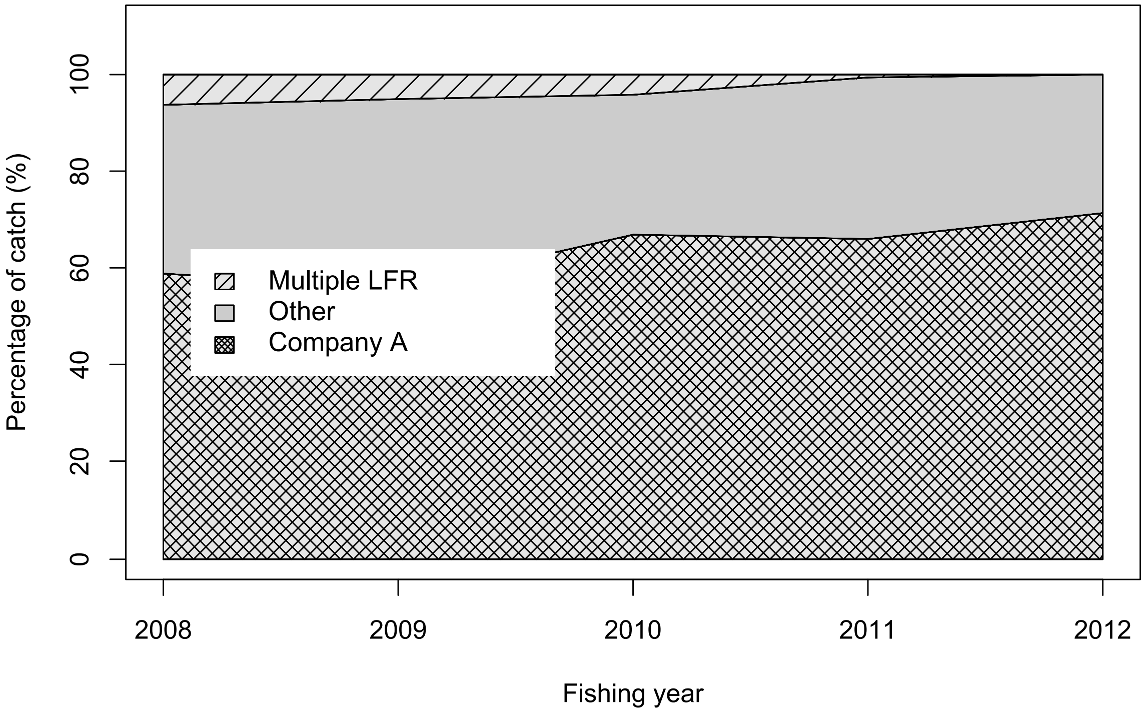

Figure 31: Percentage of the bottom trawl tarakihi catch from the northern Banks Peninsula sub-area of TAR 3 processed annually by the main LFRs between the 2008 and 2012 fishing years.

Tarakihi landings from SBP were predominantly processed by three LFRs (Figure 32), with the ten landings to be sampled allocated in proportion to their processed catch weight.

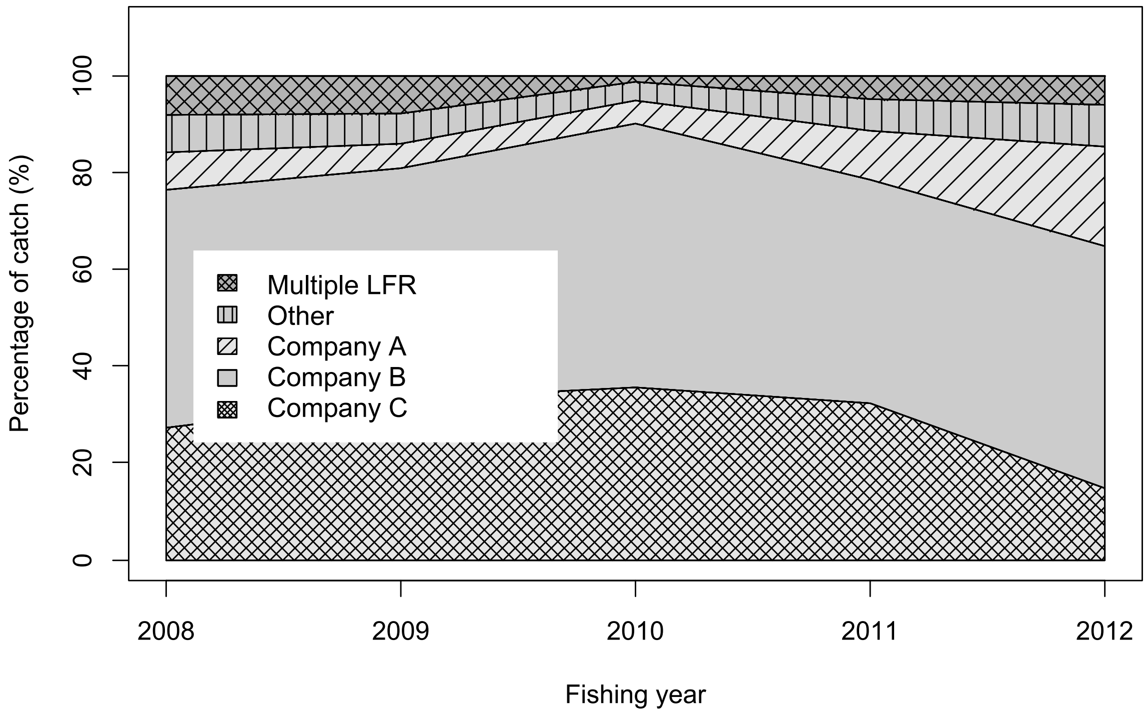

Figure 32: Percentage of the bottom trawl tarakihi catch from the southern Banks Peninsula sub-area of TAR 3 processed annually by the main LFRs between the 2008 and 2012 fishing years.

2.5.2.2 Sample design for the set net fishery

For the TAR 3 set net fishery an initial minimum landing size of 250 kg was set, this threshold would have resulted in about 93 % of the landed catch by weight and about 45 % of the number of available landings being deemed eligible for sampling (Figure 33).

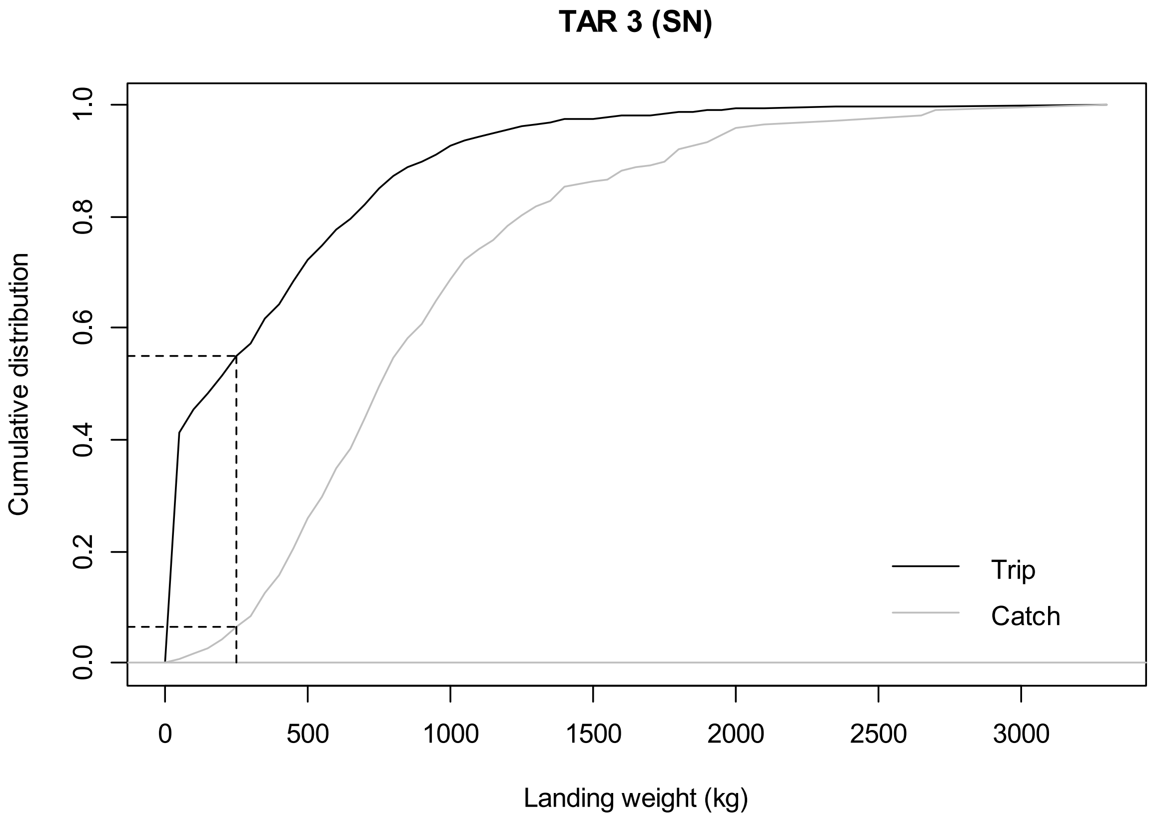

Figure 33: Cumulative distribution of landings from the TAR 3 set net fishery (by weight and number of trips) for the 2011 and 2012 fishing years. The dashed vertical line denotes the 250 kg minimum size limit for landings deemed eligible for sampling. The horizontal dashed lines denote the corresponding proportions of landings smaller than this minimum size limit that accounted for about 7 % of the catch by weight, and about 55 % of the number of available trips.

Tarakihi landings from the TAR 3 set net fishery were predominantly processed by three LFRs (Figure 34), with the sixteen landings to be sampled allocated in proportion to their processed catch weight.

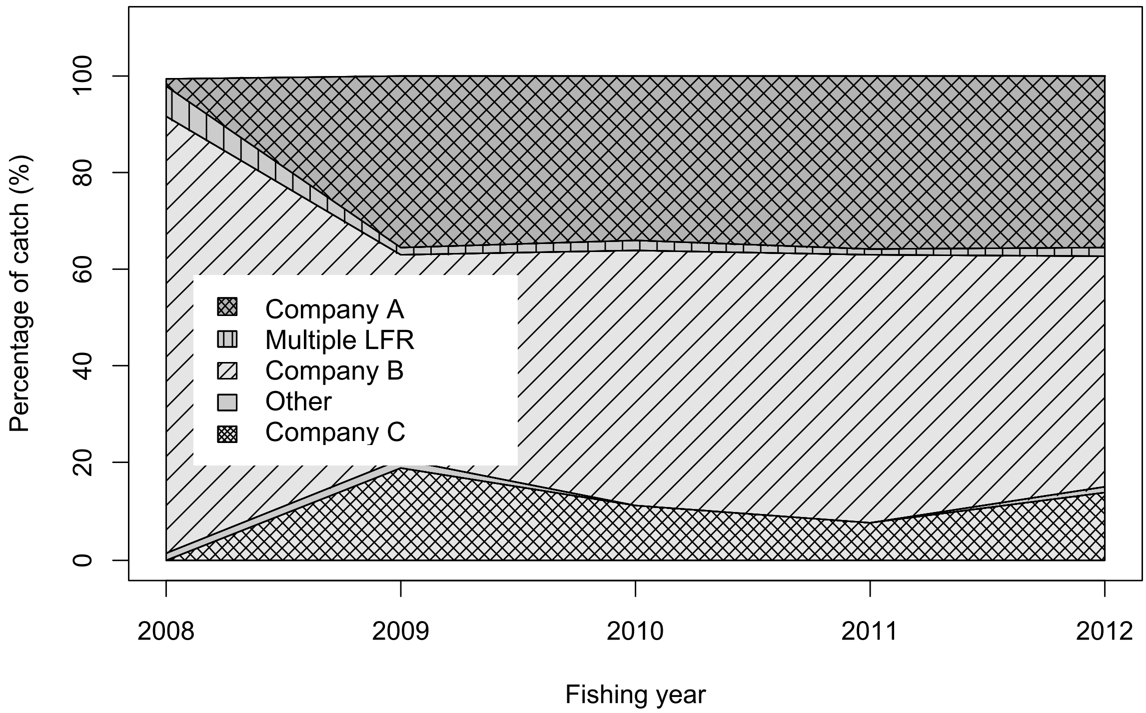

Figure 34: Percentage of the set net tarakihi catch from TAR 3 processed annually by the main LFRs between the 2008 and 2012 fishing years.

3 METHODS

3.1 Random Age Frequency (RAF) sampling methods

The random age frequency (RAF) approach requires randomly selecting a small number (typically 30–60) of fish from the sampled landing for subsequent ageing using otoliths (Davies et al. 2003). The number of otoliths collected from a fishery using the RAF approach is usually higher than that required under the age-length key (ALK) approach for the same target precision (Davies et al. 2003). Because fewer fish are typically measured for length under the RAF approach the precision on the length frequency estimates are typically less than with ALK methods. RAF is primarily used when samples are to be collected over a protracted period of time (e.g., one year) such that fish growth during the sampling period is likely to introduce bias (Davies et al. 2003).

Otolith ageing targets were defined for each tarakihi QMA sub-area on the basis of previous catch sampling programmes (Beentjes et al. 2012) (Table 1), with the intention of achieving a mean weighted CV of 0.3 or lower on the sub-area proportion at-age estimates.

Table 1: Target number of annual (fishing-year) aged otoliths in accordance with the spatial programme design.

QMA	Method	Area	Annual No. otoliths aged
TAR 1	BT	WCNI	600
		EN_HG	600
		BPLE	600
TAR 2	BT	TAR 2	700
Cook Strait	BT	Cook Strait	300
TAR 3	BT	NBP	600
		SBP	550
	SN	NBP (Kaikoura)	450

The main challenge with collecting a small number of fish (about 60) from a trawl landing of several thousand fish (i.e., 1–6 tonnes) is in ensuring that the fish sample is "random", i.e. representative of the age composition of the landing. The basic sampling approach, used to sample trawl landings in past tarakihi and snapper RAF sampling programmes, has been to "randomly" sub-sample 12 approximately 35kg bins from the total number of landed bins and to further 'randomly' sample 5 fish from each of the 12 bins (Davies et al. 2003, Beentjes et al. 2012).

The fishing industry research company Trident conducted all catch sampling in TAR 1 and about half of TAR 2 catch sampling. The Trident sampling approach relied on the use of factory staff to measure fish and to remove and collect otoliths. NIWA undertook regular audits of the Trident samplers during the course of the programme to ensure that data quality was maintained. The remaining TAR 2 catch sampling and all of TAR 3 sampling was undertaken by experienced NIWA technical staff. The use of both experienced NIWA fisheries technicians and Trident fish factory staff for the tarakihi sampling required two sampling approaches. The initial bin selection procedure was the same for Trident and NIWA sampling, being a haphazard selection of bins across the range of all the landed bins; the base requirement being that samplers had access to all bins from the landing during the selection process. The subsequent process followed by experienced NIWA staff for randomly selecting 5 fish from each of the 12 bins was to sequentially work down the left hand bottom corner of each bin removing from each the first five fish with heads closest to the corner of the bin. Trident samplers were required to measure all fish in each of the 12 bins. Fish to be selected for ageing were randomly marked on the Trident length frequency forms. The Trident sampler tasked with selecting fish for measurement did not know beforehand if a fish would be selected for ageing.

The RAF selection process results in the collection of more otoliths than required from each sub-area (Table 1). An initial random sample of 15 otoliths was selected from each sampled landing. The remaining required number of otoliths (Table 1) were then drawn from across all the landings in proportion to the landed weight for the landing.

3.2 Ageing methods

A standardised procedure for the preparation and reading of tarakihi otoliths has been previously documented in an age determination protocol for tarakihi (Walsh et al. 2016). In short, up to five tarakihi otoliths are embedded in epoxy resin and sectioned along a dorsal-ventral line directly through the core using a Struers Secotom-10 digital sectioning machine to a thickness of approximately 350 μm. Section wafers were cleaned and embedded on microscope slides under a few drops of epoxy resin with a coverslip and oven cured at 50ºC. Otoliths were viewed with a compound microscope under transmitted light and the number of opaque zones counted.

A total of four readers were used in ageing tarakihi otolith samples collected from the TAR 1, 2 and 3 stocks in 2013–14 and 2014–15 (reader 1 read all stock samples and readers 2 to 4 each read a single stock) with each reader having no prior knowledge of the other's zone count obtained or of the fish length. For otoliths where both readers agreed on the zone count, the age was determined from this count. When readers disagreed, the otolith was re-examined together with a third experienced otolith reader present to determine the likely source of disagreement and a final count agreed upon. The forced margin method was implemented to anticipate the otolith margin type (wide, line, narrow) *a priori* based on the month in which the fish was sampled to provide guidance in determining age (Walsh et al. 2016). To determine the "fishing year age class" of fish using the forced margin, 'wide' readings are increased by 1 year (e.g., 3W is aged as a 4 year old) while 'line' and 'narrow' readings remain the same as the zone count (e.g., 4L or 4N are aged as a 4 year old), meaning that regardless of whether the fish was caught before or after the nominal birth date of 1 May, age remains the same throughout, unlike that which would be used for age groups/age classes or in growth rate estimation (see Walsh et al. 2016).

Otolith reading precision was quantified by carrying out between-reader comparison tests after Campana et al. (1995), including those between each reader and the agreed age. The Index of Average Percentage Error, IAPE (Beamish & Fournier 1981), and mean coefficient of variation (CV) (Chang 1982), were calculated for each test.

3.3 Age composition

For each fishery (set net and bottom trawl for TAR 3, and bottom trawl for the TAR 1 and TAR 2 fisheries), estimated scaled numbers-at-age were calculated using the NIWA program Catch-at-length-and-age (CALA, NIWA 2011). Age data were scaled in the same way as length data, i.e., by landed weights of tarakihi from the sampled vessels, and by commercial catch from the sampling strata. Scaled age-frequency distributions were estimated by sex, season, and overall for all strata combined. The mean-weighted coefficients of variation (MWCV) were estimated by sex and overall using a bootstrapping routine (500 bootstraps).

4 RESULTS

4.1 Reader comparison tests for TAR 1, 2 and 3 readings

Approximately 99% of tarakihi otolith samples selected for ageing from the TAR 1, 2 and 3 stock collections in 2013–14 and 2014–15 were successfully aged. Between-reader tests, based on statistical comparisons, are given in Figure 35, Figure 36, and Figure 37, and show that some inconsistency exists between readers. The overall percentage agreement between readers improved with increasing latitude of the stocks and was 73% for TAR 1, 80% for TAR 2 and 86% for TAR 3. There appeared to be some relatively minor systematic differences (bias) in first counts of tarakihi otoliths between the readers. For TAR 1, the slight positive weighting of the histogram, the relative clustering of plotted points about the zero line, and the slight deviation from the one-to-one line on the age-bias plots (Figure 35 (a–c)) indicate that reader 2 tended to estimate a younger age, particularly for very young and old fish. For TAR 2 and 3, the slight negative weighting of the histograms, the relative clustering of plotted points about the zero line, and the slight deviation from the one-to-one line on the age-bias plot, indicate an overestimation of age (Figure 36 and Figure 37 (a-c)). For reader 3 this was most apparent for old fish, while for reader 4 this was across age classes ((a–c)). The between-reader CVs ranged from 1.70 to 2.56% and IAPEs ranged from 1.20 to 1.81% (Figure 35, Figure 36, and Figure 37 (c)) and the profiles show that precision varied across age classes in all stock collections, being lowest for TAR 1, followed by TAR 2 and highest for TAR 3 (Figure 35, Figure 36, and Figure 37 (d)). Comparisons of the age-bias plots for all four readers with the agreed age indicates that reader 1 showed a high level of precision and consistency in estimating age with CV and IAPE estimates less than 0.6% (Figure 35, Figure 36, and Figure 37 (e)). For readers 2 to 4, precision was lower, with CVs and IAPEs closer to the between-reader estimates (Figure 35, Figure 36, and Figure 37 (c)), and ranging from 1.57 to 2.15% (CV) and 1.11 to 1.52% (IAPE) (Figure 35, Figure 36, and Figure 37 (e) and (f)).

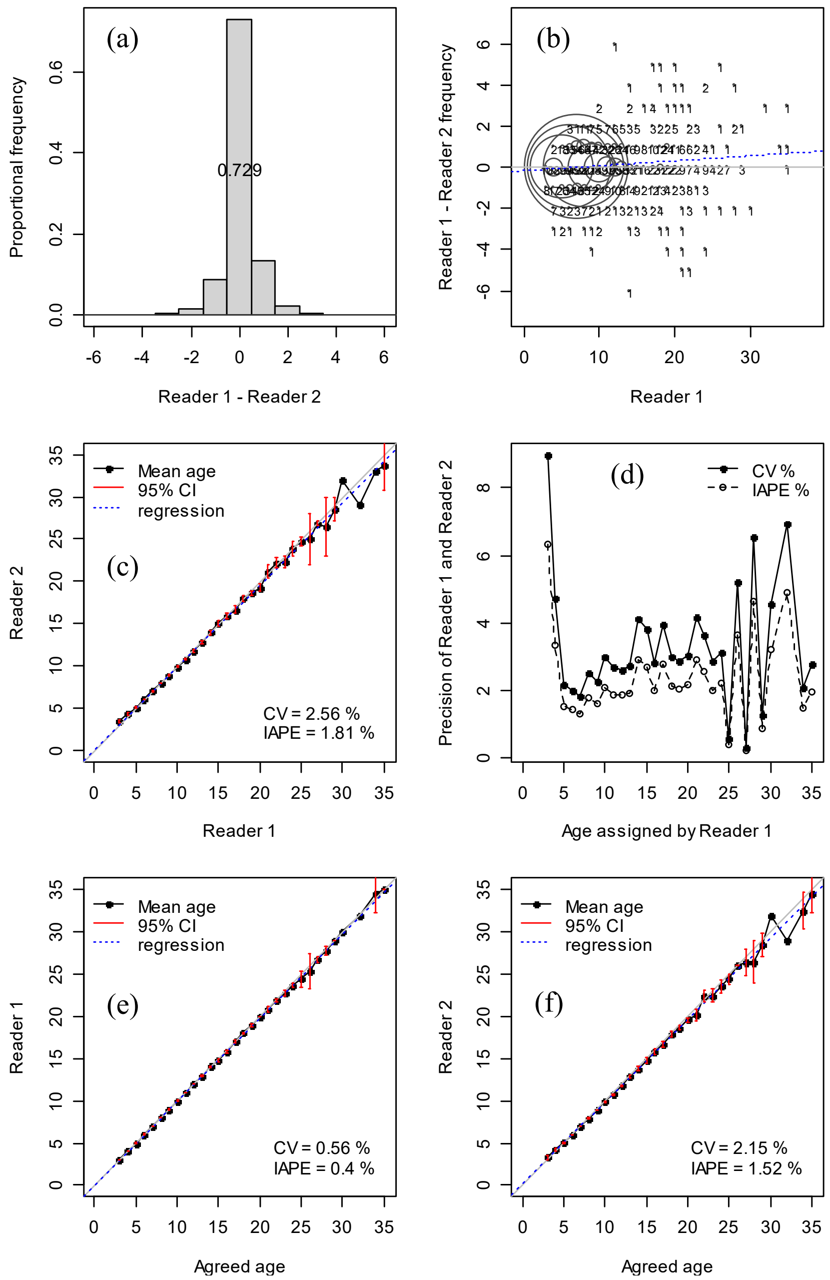

Figure 35: **Results of between-reader comparison test (reader 1 and 2) for TAR 1 otoliths collected in 2013–14 and 2014–15 (n = 3422): (a) histogram of differences between readings for the same otolith; (b) differences between readers for a given age assigned by reader 1; (c) bias plot between readers; (d) CV and IAPE profiles (precision) relative to the age assigned by reader 1; (e) bias plot between reader 1 ((f) reader 2) and agreed age. The expected one-to-one (solid line) and actual relationship (dashed line) between readers are overlaid on (b) and (c), and between reader 1 and 2 and the agreed age on (e) and (f).**

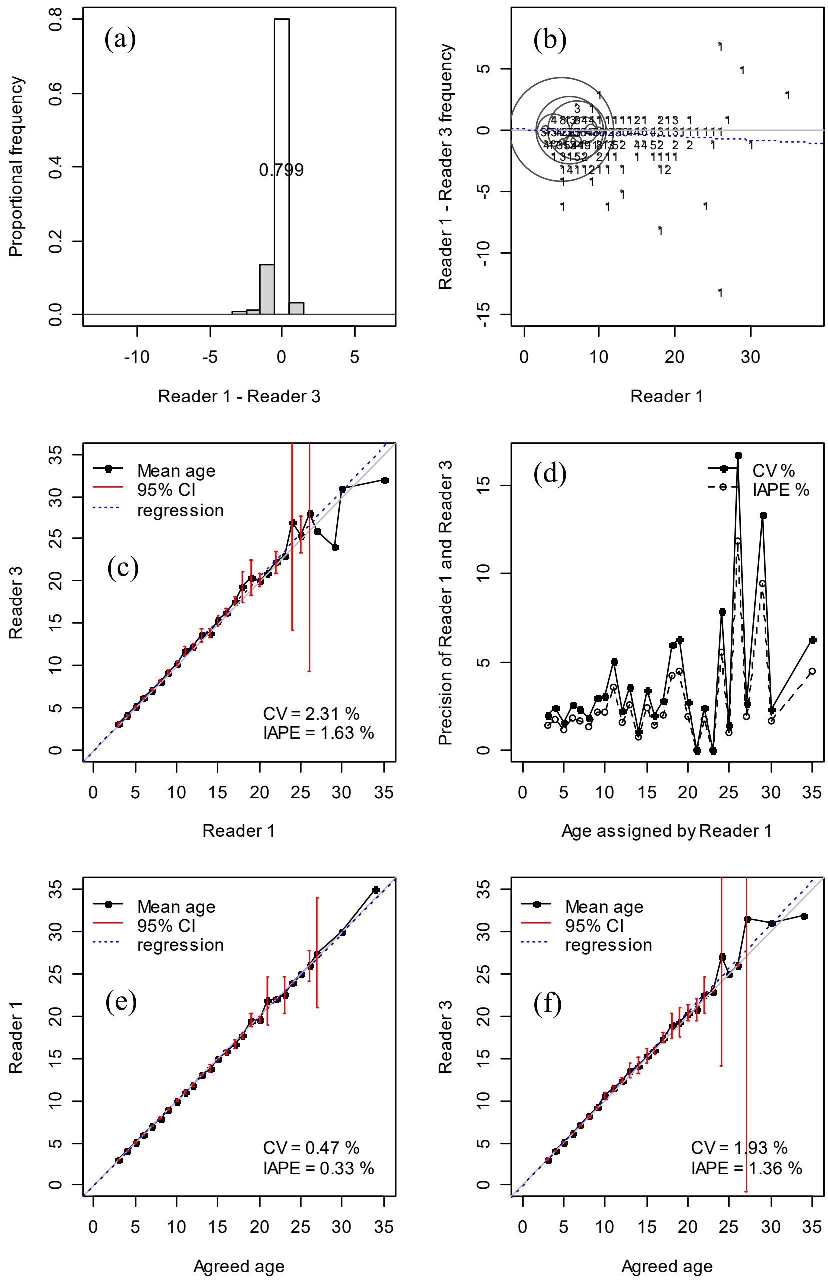

Figure 36: **Results of between-reader comparison test (reader 1 and 3) for TAR 2 otoliths collected in 2013–14 and 2014–15 (n = 1682): (a) histogram of differences between readings for the same otolith; (b) differences between readers for a given age assigned by reader 1; (c) bias plot between readers; (d) CV and IAPE profiles (precision) relative to the age assigned by reader 1; (e) bias plot between reader 1 ((f) reader 3) and agreed age. The expected one-to-one (solid line) and actual relationship (dashed line) between readers are overlaid on (b) and (c), and between reader 1 and 3 and the agreed age on (e) and (f).**

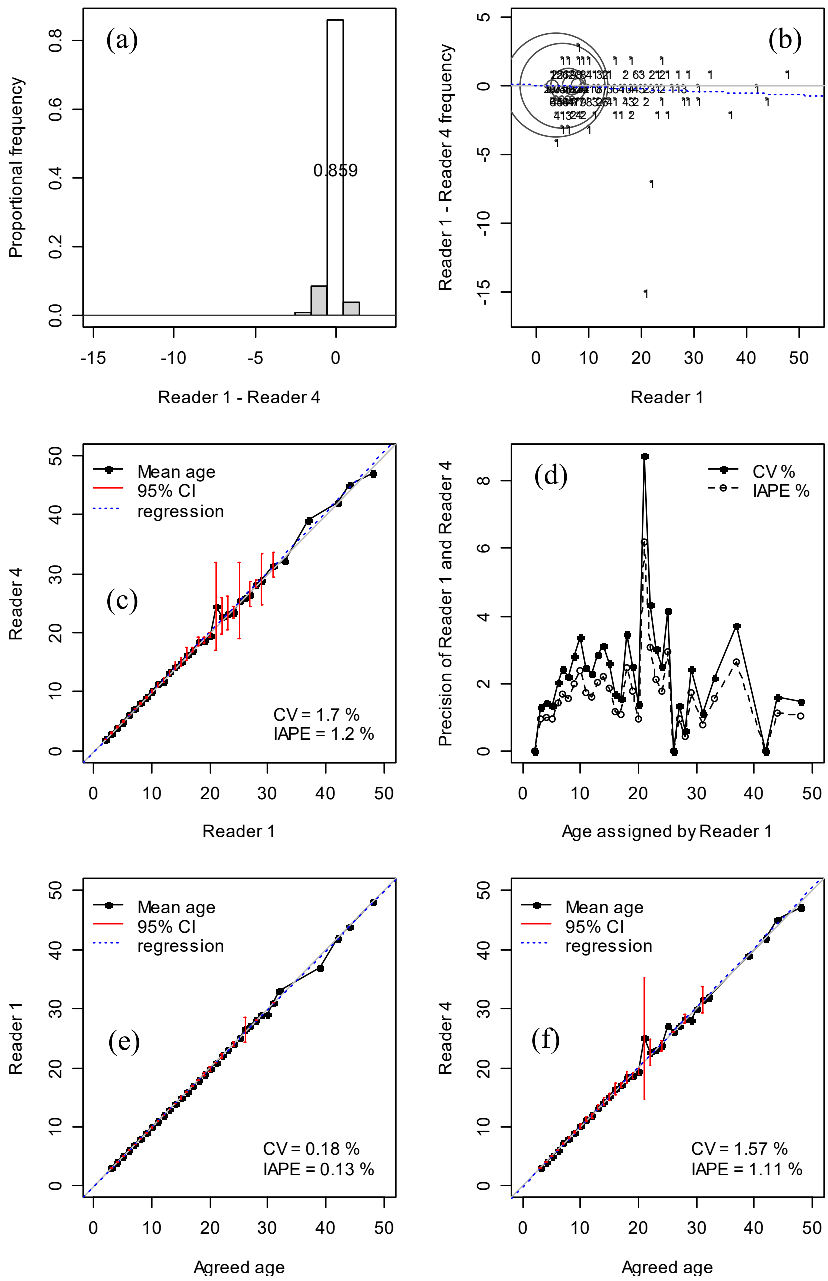

Figure 37: Results of between-reader comparison test (reader 1 and 4) for TAR 3 otoliths collected in 2013–14 and 2014–15 (n = 2926): (a) histogram of differences between readings for the same otolith; (b) differences between readers for a given age assigned by reader 1; (c) bias plot between readers; (d) CV and IAPE profiles (precision) relative to the age assigned by reader 1; (e) bias plot between reader 1 ((f) reader 4) and agreed age. The expected one-to-one (solid line) and actual relationship (dashed line) between readers are overlaid on (b) and (c), and between reader 1 and 4 and the agreed age on (e) and (f).

4.2 TAR 1

The target number of 20 landings sampled was almost met on the WCNI during both fishing years, but the number of eligible sampled landings was short of target levels for the ENHG sub-area in 2014–15 and the BPLE sub-area in 2013–14 (Table 2). The under-sampling in ENHG during 2014–15 was because some sampled landings were ultimately rejected, when a review of TCPER/CLR returns for these trips highlighted the fact that these landings would have also included tarakihi caught on the WCNI.

The shortfall in the BPLE in 2013–14 was because a high proportion of fishing events occurred in the southern half of Statistical Area 008 in that year (which was not initially included as part of this sub-area) and because some fishing trips spanned TAR 1 and TAR 2. These problems were identified early on in the fishing year, and the spatial extent of this sub-area was expanded to include the southern half of Statistical Area 008, and attempts were made at sea to tag and separate out TAR 1 catches when fishing also occurred in TAR 2 during the same trip. Only eleven eligible landings were sampled despite these measures in 2013–14, but landings from trips occurring solely in Statistical Areas 009 and 010 were more readily available in 2014–15.

Table 2: Number of TAR 1 landings targeted and actually sampled by fishing year and sub-area. The temporal representativeness of sampling within each of these years can be inferred from Figure 38.

Area	Fishing year	Target	Sampled	Otoliths aged
WCNI	2013–14	20	21	564
	2014–15	20	21	655
ENHG	2013–14	20	19	519
	2014–15	20	14	535
BPLE	2013–14	20	11	540
	2014–15	20	13	515

4.2.1 Sampling representativeness

Landings from the bottom trawl fisheries from all three sub-areas were sampled in a broadly similar manner in 2013–14 and 2014–15. The temporal distribution of sampled landings mostly followed the trend seen for all landings throughout the year, although there were some abrupt jumps in the cumulative weight of the sampled catch when one or more large landings were sampled in a month (Figure 38). Peaks and troughs in the weight of sampled landings and of all landings are also broadly similar when the data are aggregated into seasonal strata (Figure 39).

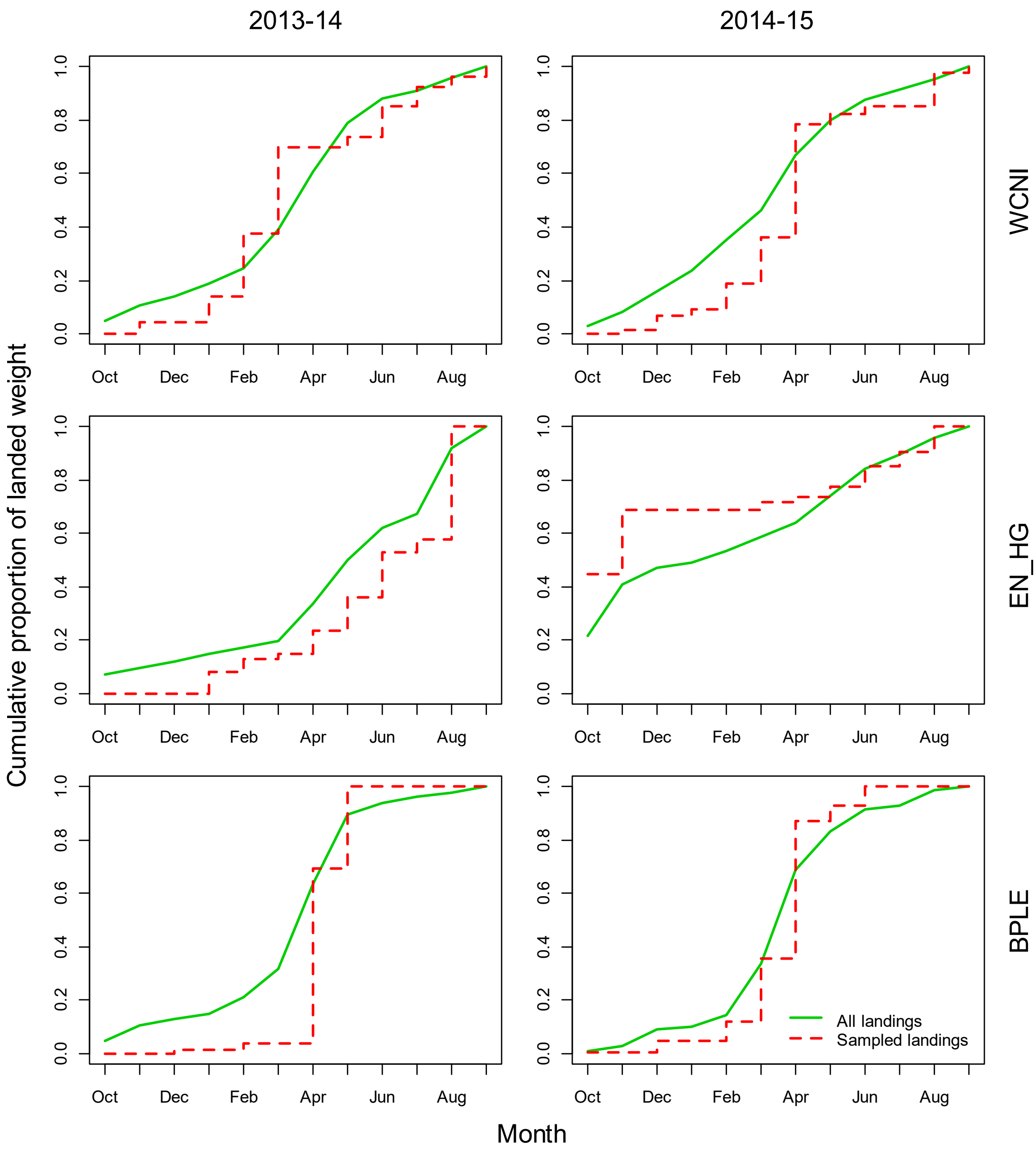

Figure 38: The cumulative proportion of the weight of sampled tarakihi landings, and of all landings, from the west coast North Island (WCNI), East Northland/Hauraki Gulf (EN_HG), and Bay of Plenty (BPLE) sub-areas, by bottom trawlers during the 2013–14 and 2014–15 fishing years.

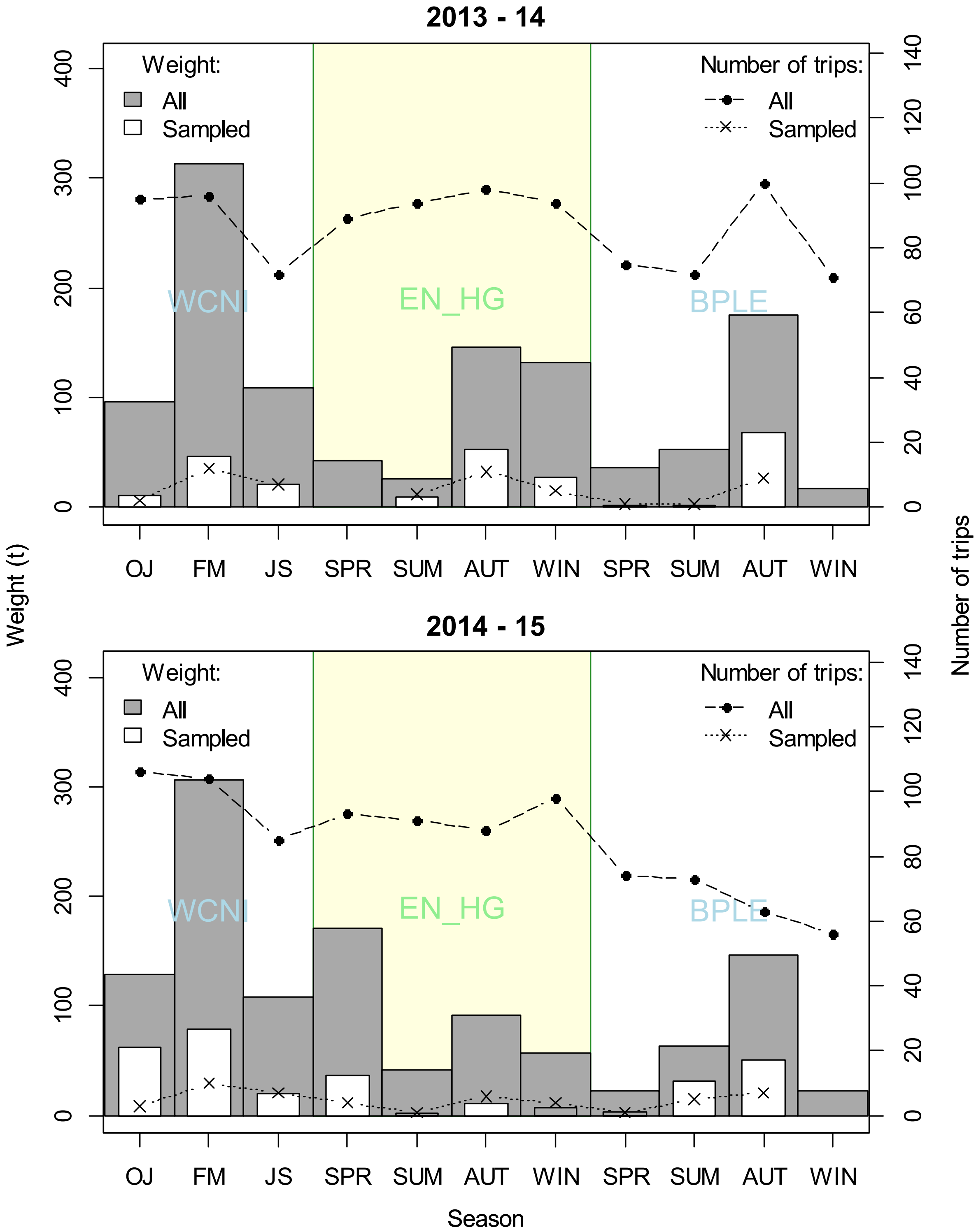

Figure 39: Comparison of the seasonal distribution of the sampled and total landed weight (histograms) and numbers of landings (lines) of tarakihi within the three TAR 1 sub-areas during the 2013–14 and 2014–15 fishing years; for the sampling seasons: OJ = October to January, FM = February to May, JS = June to September, SPR = October to December, SUM = January to March, AUT = April to June, and WIN = July to September.

The distribution of sampled catches between statistical areas was also broadly representative of the spatial distribution of all catches landed by bottom trawlers in each sub-area in each year, with two exceptions (Figure 40). There was some under and over sampling (relative to the fishery) in two statistical areas from the WCNI in 2013–14 and again in ENHG in 2014–15.

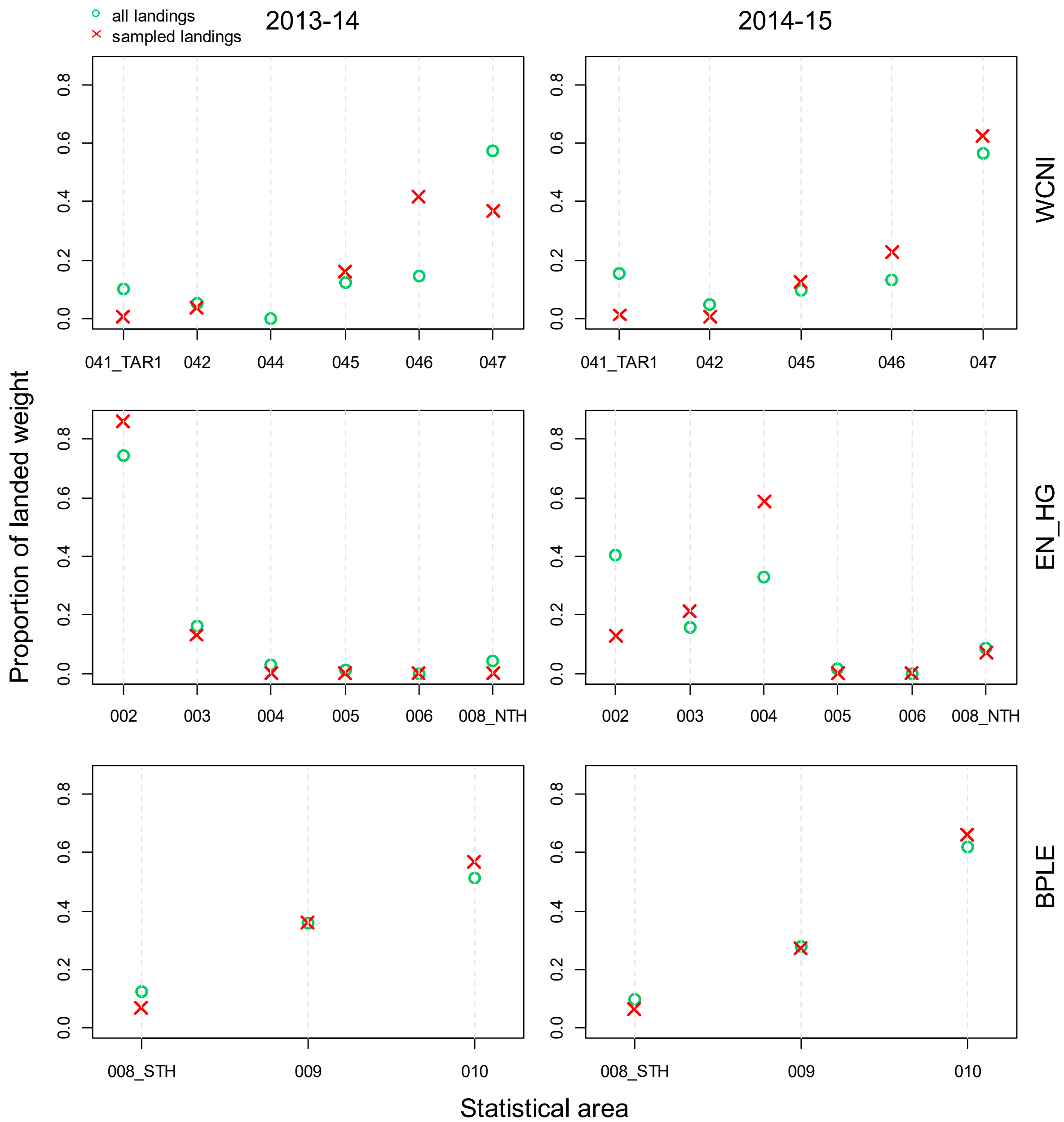

Figure 40: Comparison of the proportional distribution of the estimated bottom trawl catch and the sampled component by statistical area for the three TAR 1 stocks in 2013–14 and 2014–15.

The distribution of sampled landings by fishing depth was similar to that of the wider fishery for the WCNI sub-area, but samples obtained from 100 to 300 m depth were overrepresented for the ENHG and BPLE sub-areas (Figure 41). The depth range of the Bay of Plenty catch shows a distinct bimodal pattern in both the 2013–14 and 2014–15 fishing years which catch sampling was better able to reflect in 2014–15 (Figure 41).

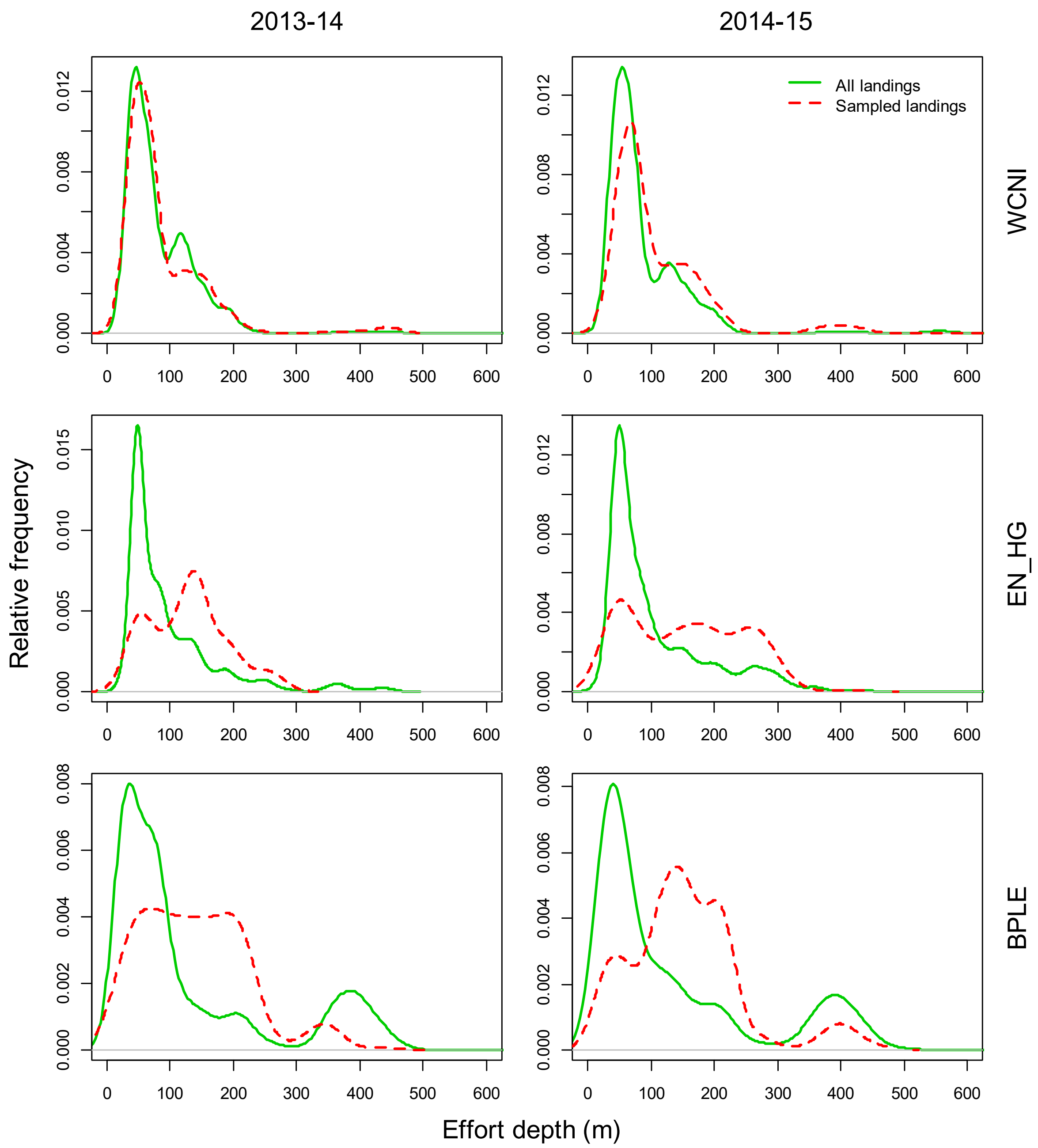

Figure 41: Depth distribution of the overall frequency of tarakihi bottom trawl landings compared to sampled landings for the three TAR 1 sub-areas between 2013–14 and 2014–15.

4.2.2 Length and age frequency distributions

The length compositions of tarakihi from TAR 1 were broadly similar between sub-areas and the two years of sampling (Figure 42). The only exception was a higher proportion of smaller fish from ENHG in 2014–15 compared to 2013–14. Overall the majority of tarakihi sampled were between 25 and 55 cm Fork Length (FL), with a mode of around 35 cm FL.

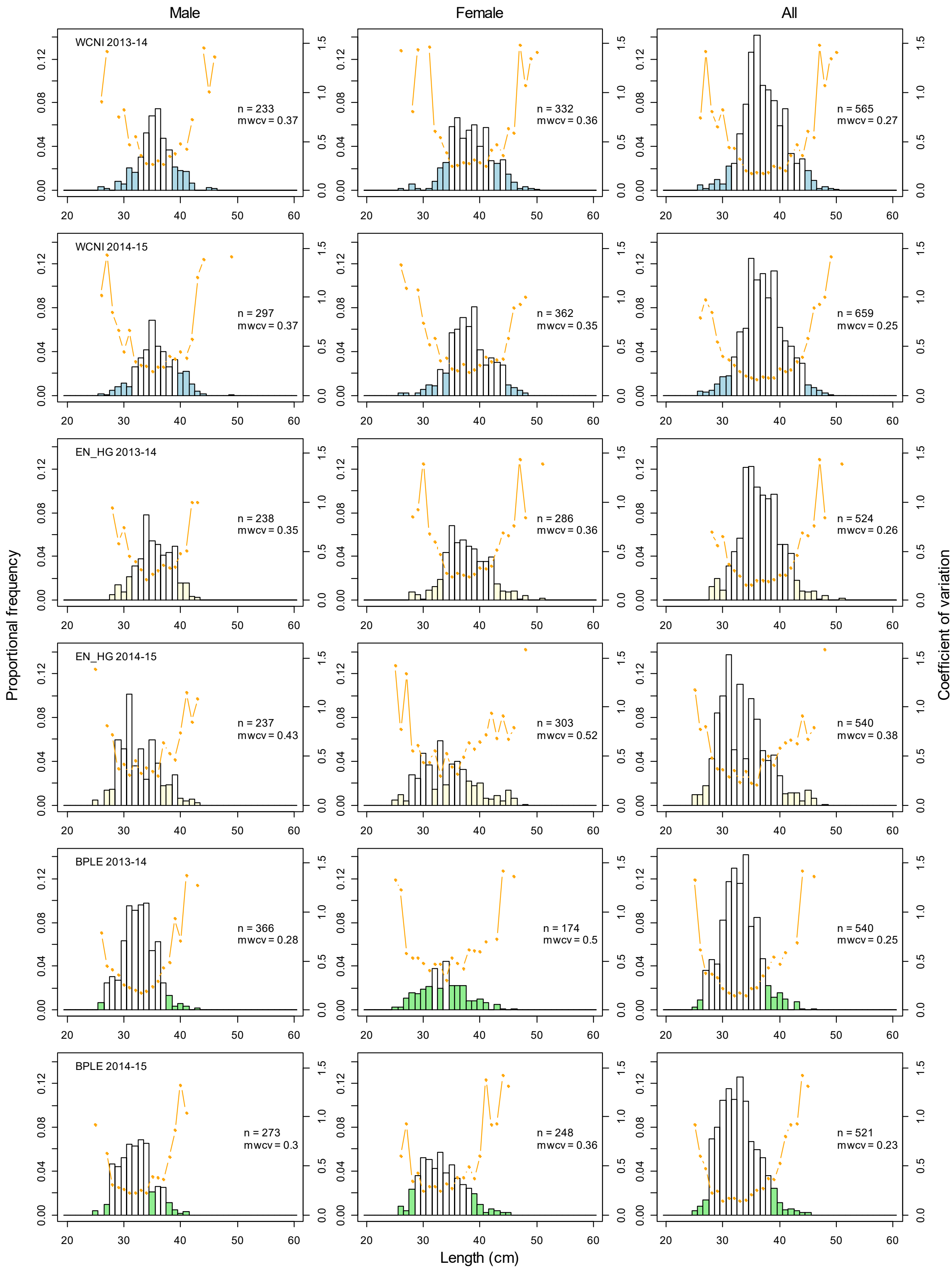

Figure 42: Length frequency distributions for samples of tarakihi bottom trawl landings for the three TAR 1 sub-areas and the whole TAR 1 stock for separate sexes and combined between 2013–14 and 2014–15.

Age data from the three TAR 1 sub-areas demonstrate consistent patterns in year class strength within sub-areas across the two years sampled, but also some differences in both the overall age composition and individual year class strengths between sub-areas (Figure 43). For example, the WCNI has a broad age distribution, with clear evidence of strong 2005 and 2007 year classes. The ENHG sub-area also has a broad age distribution and a strong 2007 year class, but there is no evidence of the strong 2005 year class seen on the WCNI. Furthermore, sampling of the ENHG sub-area conducted in 2014–15 also revealed a strong 2009 year class, which potentially explains the influx of smaller fish seen in 2014–15 and not 2013–14 length compositions for this area (Figure 42). The BPLE sub-area is almost entirely composed of fish younger than 15 years old and the strong 2007 and 2009 age classes are evident in both years that the BPLE sub-area was sampled.

Despite both the number of fish aged and number of landings being less than the targets, MWCVs on total proportional at-age were less than the target 0.3 for most areas (Figure 43).

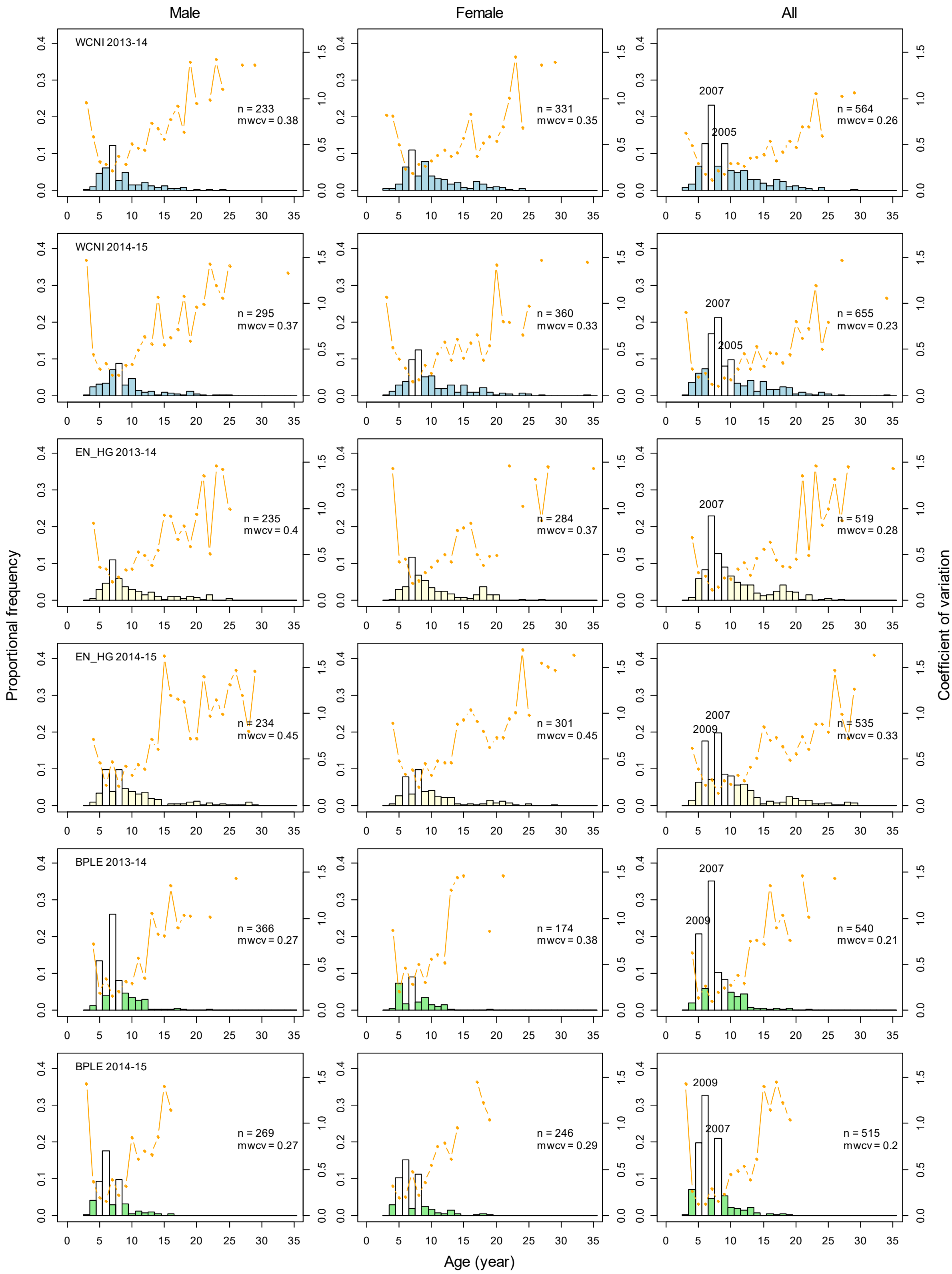

Figure 43: Age frequency distributions for samples of tarakihi bottom trawl landings for the three TAR 1 sub-areas and the whole TAR 1 stock for separate sexes and combined between 2013–14 and 2014–15.

4.3 TAR 2

The target number of 30 landings was met for TAR 2 during both fishing years (Table 3).

Table 3: Number of TAR 2 landings targeted and actually sampled by fishing year. The temporal representativeness of sampling within each of these years can be inferred from Figure 44.

Area	Fishing year	Target	Sampled	Otoliths aged
TAR 2	2013–14	30	30	638
	2014–15	30	32	692

4.3.1 Sampling representativeness

The temporal trend in fishery landings indicated a near constant rate of landed catch weight throughout the fishing year. There was no indication of a seasonal pattern of larger landings during a particular season or of ramping up landings to attain the allocated quota in the last few weeks of the fishing year. The pattern was matched fairly well by the sampled landings throughout each year, though the landings were somewhat under sampled in the autumn of 2015 (Figure 44).

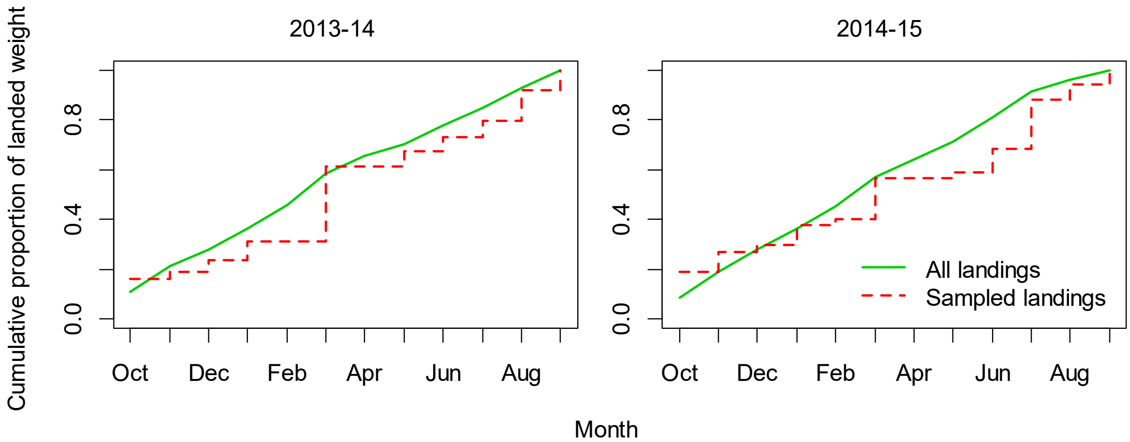

Figure 44: The cumulative proportion of the weight of tarakihi landings and samples taken from TAR 2 bottom trawl fisheries in 2013–14 and 2014–15.

The seasonal distribution of the landings and sampled landings supported a uniform distribution of sampling effort. A small percentage (under 10%) of the total number of trips were targeted for sampling and although a 1200 kg threshold landing weight was used, a small proportion of the total catch weight was sampled. This is the result of many landings of low catch weight (more than 800 trips landed a total of less than 2000 t of TAR 2 catch) (Figure 45).

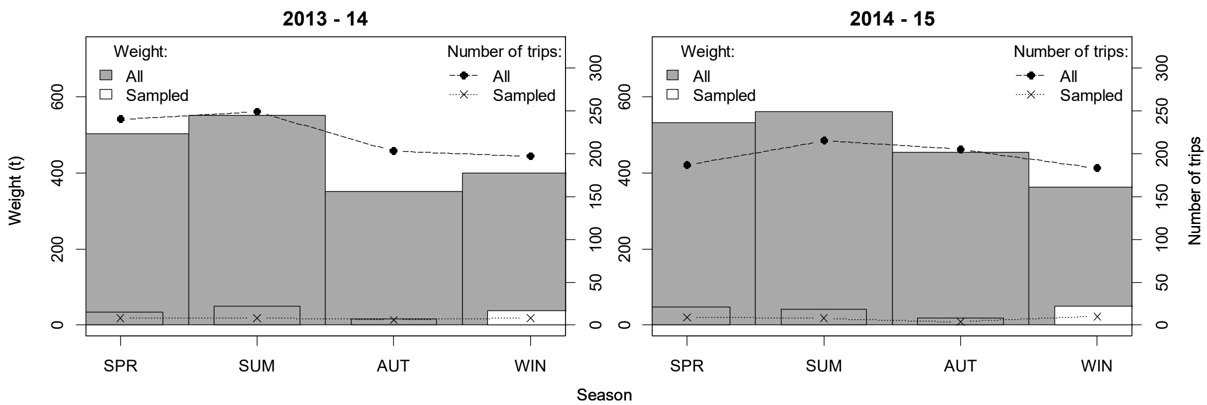

Figure 45: Comparison of the seasonal distribution of landed weight (histograms) and numbers of landings (lines) of tarakihi within TAR 2 from 2013–14 to 2014–15 (Note: histograms and lines overlaid; SPR= October-December, Sum = January–March, Aut = April–June, Win = July–September.)

In both sampling years most of the catch was derived from Statistical Areas 011, 012, and 013, and to a lesser extent 014 (Figure 46). The sampled landings were distributed mainly across landings of the same areas, but tended to over sample those areas as few landings were made from more southern or offshore statistical areas in each year. Given the large numbers of small landings from some statistical areas, and the small number of landings sampled, this result was expected.

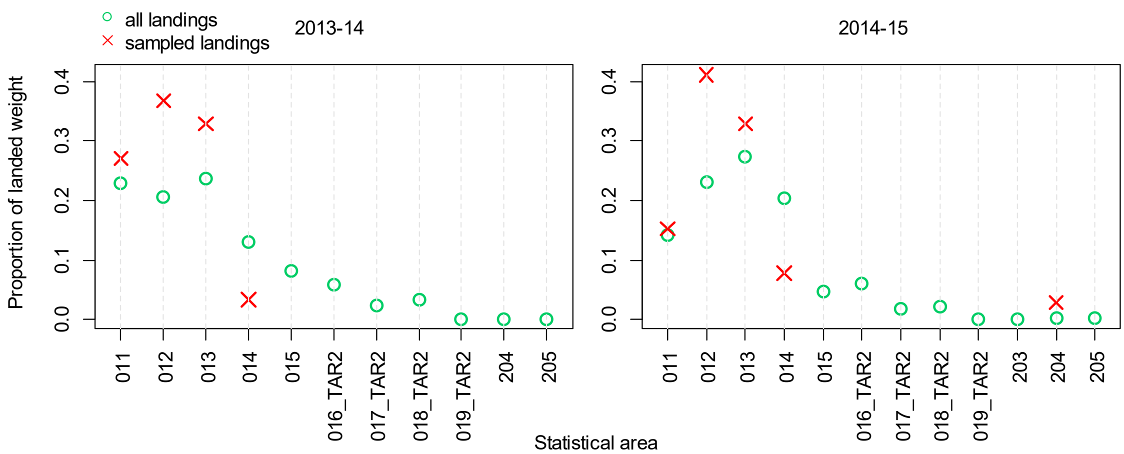

Figure 46: Comparison of the proportional distribution of the estimated bottom trawl catch and the sampled component by statistical area for TAR 2 in 2013–14 and 2014–15.

The depth distribution of the fishery and of the sampled trips were similar, showing most fishing at depths less than 100 m and almost all catch from less than 200 m in both years (Figure 47).

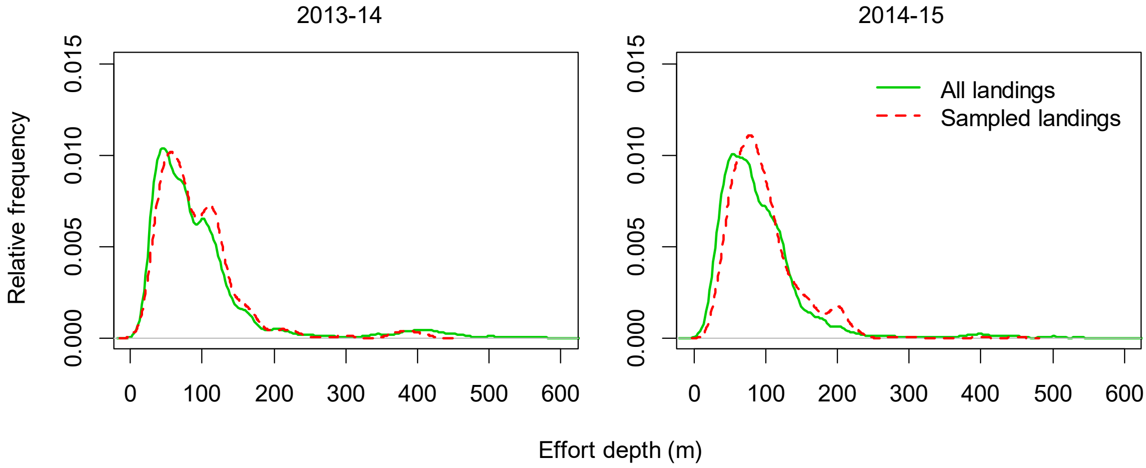

Figure 47: Depth distribution of tarakihi bottom trawl landings and samples for TAR 2 during the 2013–14 and 2014–15 fishing years.

Overall, catch sampling conducted in TAR 2 was representative of the fishery by catch weight, time and depth, and at a coarse level by area (although catch from southern statistical areas was not sampled and catches from the areas with the most catch were oversampled).

4.3.2 Age and length frequency distributions

The length frequency distribution of the TAR 2 catch in each year was similar, comprised of a unimodal distribution with a minimum size of 25 cm, a peak size near 32 cm, and a small distribution tail extending to about 45 cm (Figure 48). 25 cm is minimum marketable size and the commercial catch will necessarily be truncated at that length. The length distributions were similar when split by sex, but with males being a few centimetres smaller than females in both years. The MWCV was about 16% in both years for all fish combined.

The TAR 2 age composition was also similar in each year sampled, with a range of 3–27 years observed, and most fish in the 5–8 year old age classes (Figure 49). Two strong year classes were present in both sexes and in each year sampled, and they showed year class progression between years. The strong year classes were 2007 and 2009, as observed in the other QMAs. Very few fish were more than 10 years old. The MWCV of the age composition in each year was about 12%.

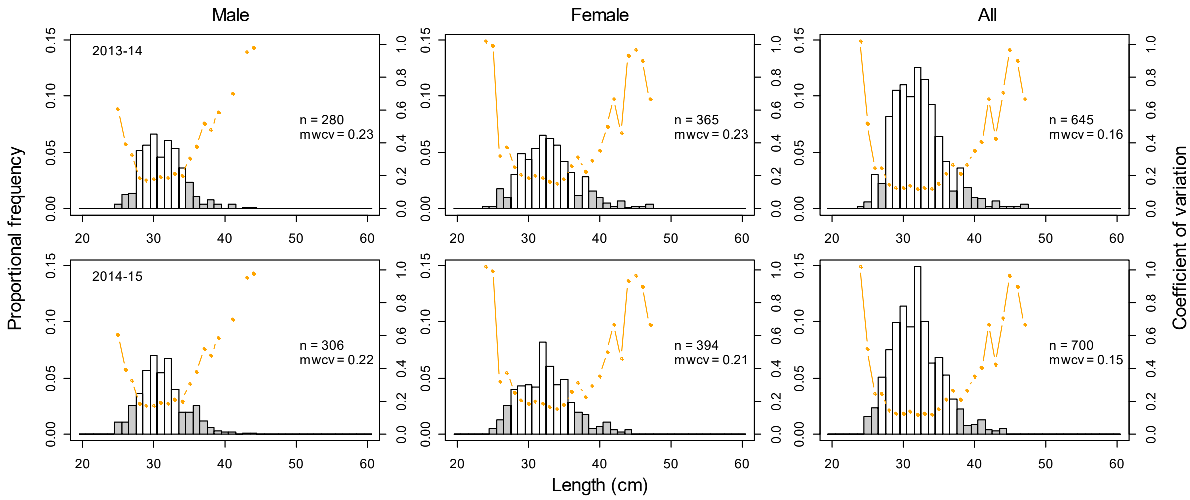

Figure 48: Scaled length frequency distributions and coefficient of variation for each length class for bottom trawl landings of TAR 2 for each sex and combined sexes during 2013–14 and 2014–15.

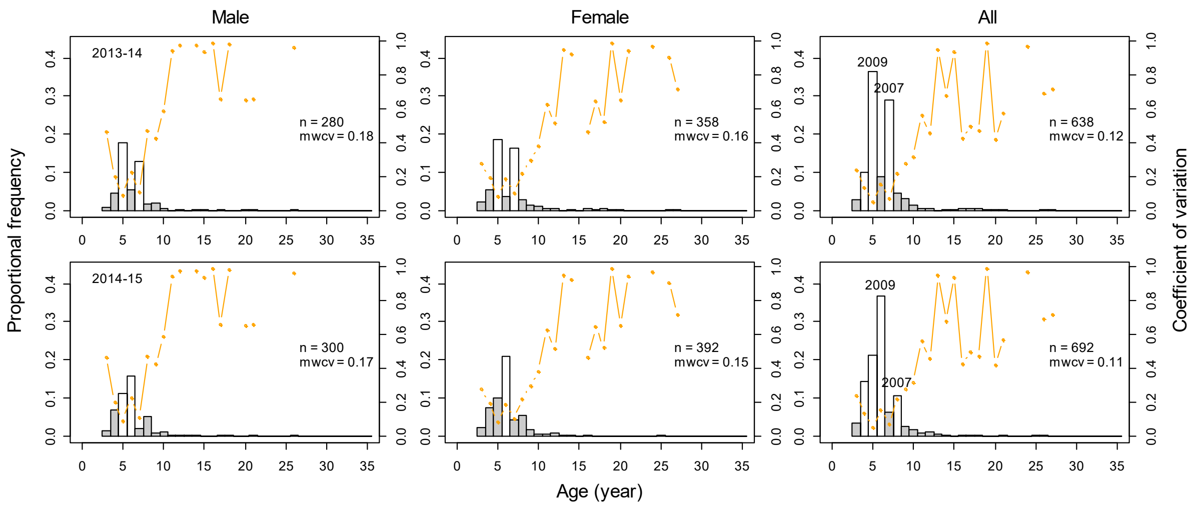

Figure 49: Scaled age frequency distributions and coefficient of variation for each age class for bottom trawl landings of TAR 2 for each sex and combined sexes during 2013–14 and 2014–15.

4.4 Cook Strait

The Cook Strait sample target was largely achieved in 2013–14, but not 2014–15 due to the target fishery not operating as it had in previous years (most landings were from the west coast in 2014–2015 and little Cook Strait fishing occurred). As a result, there was insufficient data to proceed with analysis for the 2014–15 fishing year (Table 4).

Table 4: Number of Cook Strait landings targeted and actually sampled by fishing year.

Area	Fishing year	Target	Sampled	Otoliths aged
Cook Strait	2013–14	10	9	297
	2014–15	10	3	Not aged

4.4.1 Sampling representativeness

Although bottom trawl catch in Cook Strait occurs year round, it is typically inshore and targets smaller fish. To document the presence and age composition of spawning fish in Cook Strait, sampling was undertaken during the summer months (late January–early March). The sampling was therefore not designed to be representative of the landings in the area for the entire year.

The area of aggregated spawning tarakihi targeted by fishers is on the 150 m contour off Cape Campbell, and was therefore close to the boundary of TAR 2 and TAR 7 as well as the boundaries between Statistical Areas 016, 017, and 018. As a result fishery landings from this area had not been previously sampled. The targeted sampling period, mix of small management areas and objective of simply documenting that catches of large adults aggregated during the spawning season makes the evaluation of "representativeness" of the sampling unnecessary.

4.4.2 Age and length frequency distributions

The length composition of the sampled catches included larger fish than in the remainder of TAR 2, or in TAR 3, with the bulk of the fish in the 30–40 cm range, and some fish over 50 cm (Figure 50). Some small and probably immature tarakihi (under 30 cm) were present in the landings. These fish were likely to be from shallower water tows made during trips targeting the spawning aggregation, as fishers reported that during wind events, they would sometimes move shallower to a more sheltered location and catch smaller tarakihi.

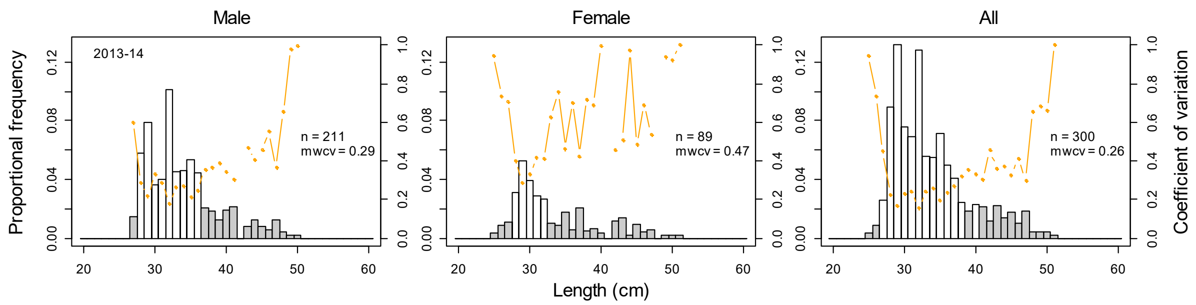

Figure 50: Scaled length frequency distributions and coefficient of variation for each length class for bottom trawl landings from Cook Strait for each sex and combined sexes during 2013–14.

The age composition contained more old fish compared to the rest of TAR 2 or TAR 3 samples. Significant portions of the catch showed ages of greater than 10 years, and fish more than 30 years old were observed. Interestingly, the strong 2007 and 2009 year classes were both present in the Cook Strait samples, as these fish were then 5 and 7 years old, near the age at 50% maturity (Beentjes et al. 2012) . The sex ratio was dominated by males (72%) (Figure 51).

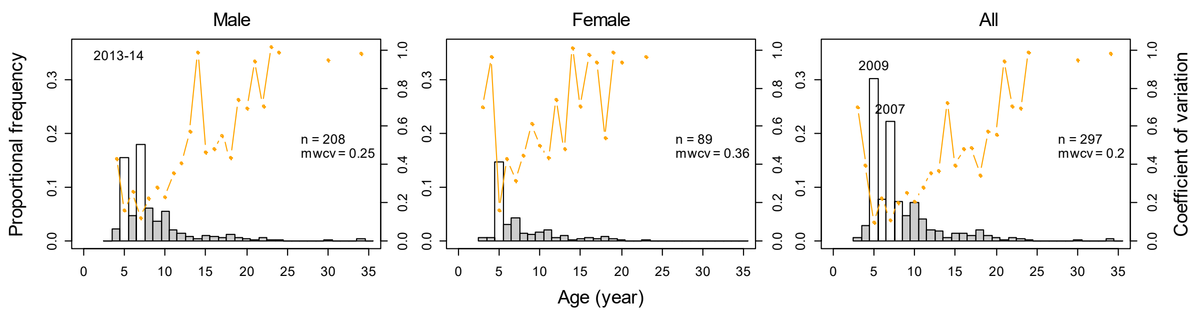

Figure 51: Scaled age frequency distributions and coefficient of variation for each age class for bottom trawl landings from Cook Strait for each sex and combined sexes during 2013–14.

4.5 TAR 3

Target landings were generally achieved/overachieved for the SBP bottom trawl fishery and the Kaikoura set net fishery in both years of sampling (Table 5). Sampling for the NBP fishery, however was below targets in both years. This was largely due to stratification of sampling effort by processor, under the assumption that catch at certain processors was exclusively from either the NBP or SBP sub-area. The end result was that more landings from SBP were sampled than anticipated, and eight other landings had to be discarded as they contained mixed catches (i.e., with effort in both NBP and SBP).

Table 5: Number of TAR 3 landings targeted and actually sampled by fishing year. The temporal representativeness of sampling within each of these years can be inferred from Figure 52.

Method	Area	Fishing year	Target	Sampled	Otoliths aged
BT	NBP	2013–14	20	11	334
		2014–15	20	8	386
	SBP	2013–14	10	13	710
		2014–15	10	15	599
SN	Kaikoura	2013–14	16	11	448
		2014–15	16	14	449

4.5.1 Sampling representativeness

4.5.1.1 Bottom trawl

The temporal trend in fishery landings in the NBP sub-area indicated a near constant rate of landed catch weight throughout the fishing year, while the SBP sub-area exhibited reduced catch accumulation over late winter and spring (Figure 52). These patterns were matched fairly well by the sampled landings throughout each year, although SBP landings were somewhat under sampled between February and August in the 2014–15 fishing year (Figure 52). The temporal pattern of landings and samples was also similar when aggregated at the seasonal level (Figure 53).

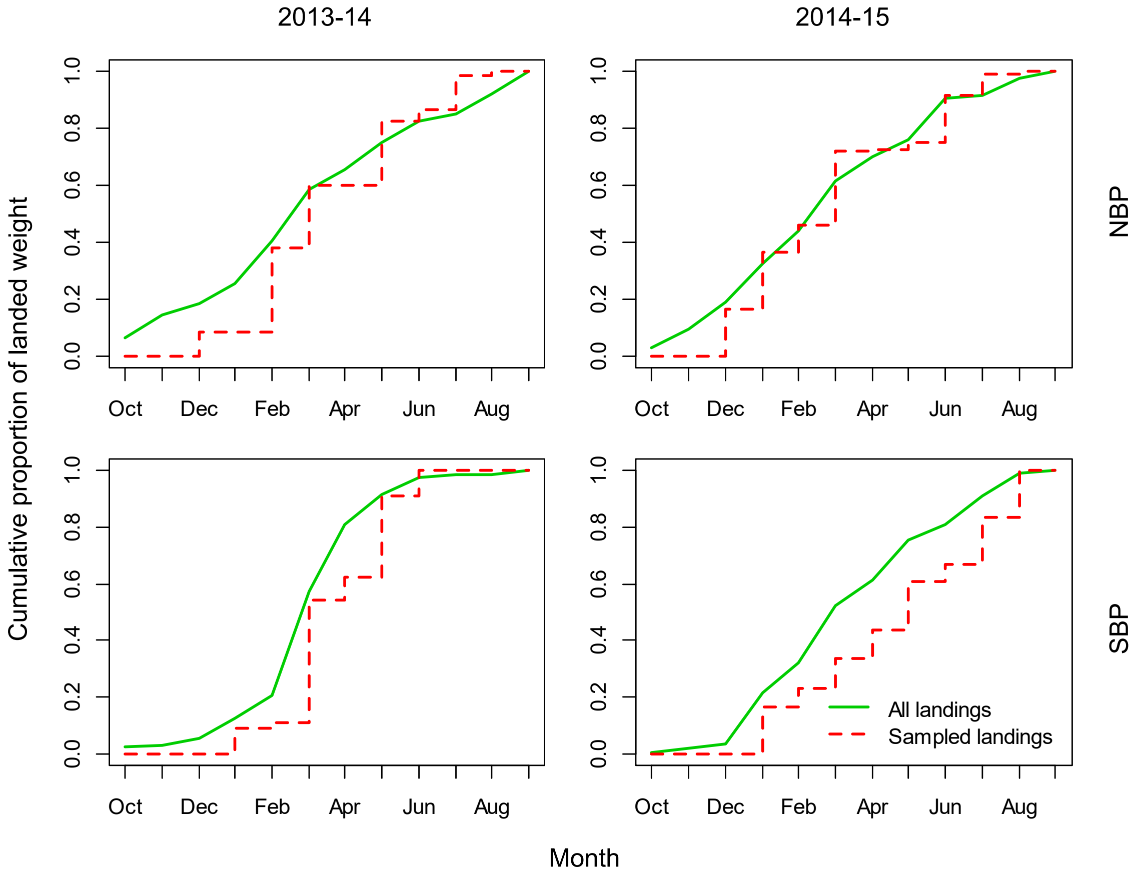

Figure 52: The cumulative proportion of the weight of tarakihi landings and samples taken from the NBP and SBP bottom trawl fisheries within TAR 3 in 2013–14 and 2014–15.

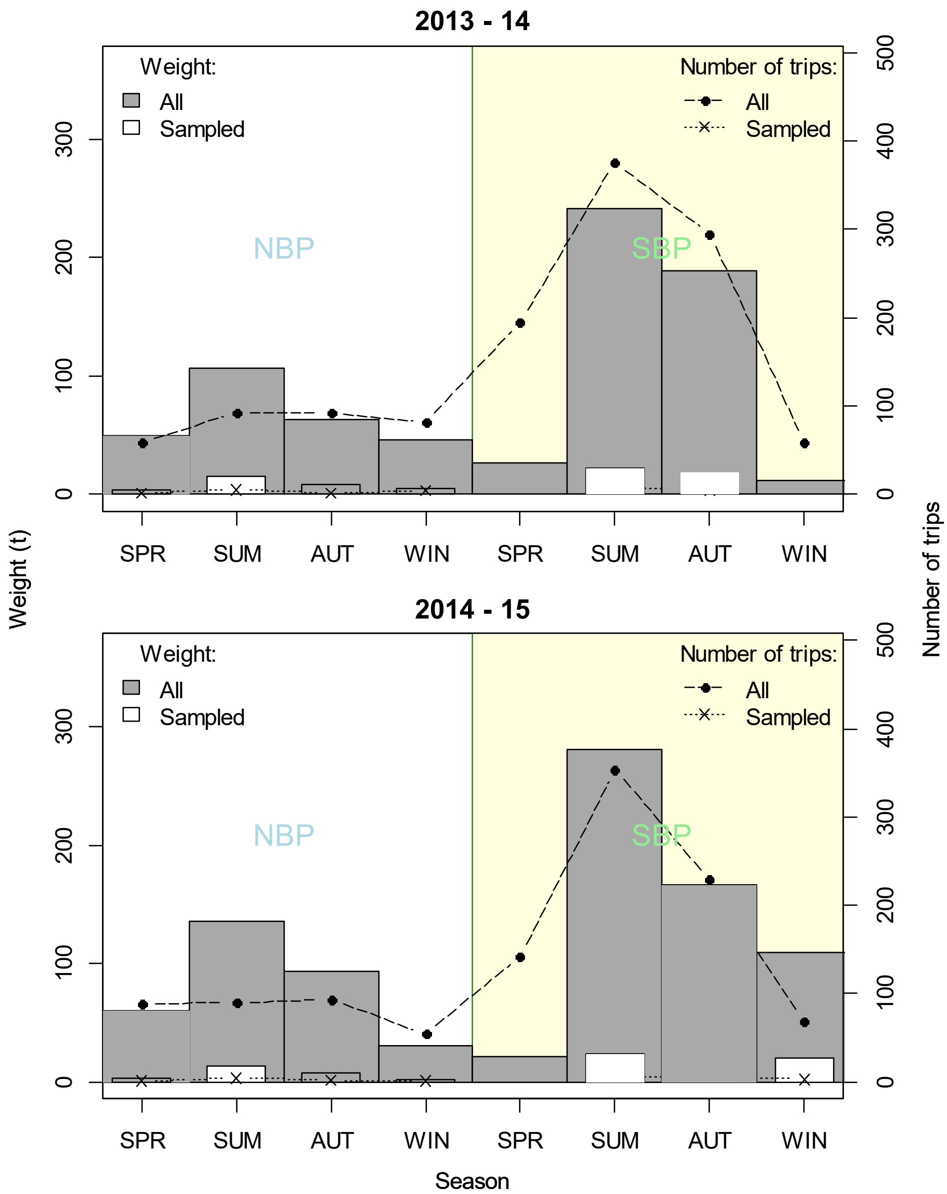

Figure 53: Comparison of the seasonal distribution of landed weight (histograms) and numbers of landings (lines) of tarakihi within the NBP and SBP bottom trawl fisheries within TAR 3 in 2013–14 and 2014–15 (Note: histograms and lines overlaid; SPR= October-December, Sum = January–March, Aut = April–June, Win = July–September).

For NBP, Statistical Area 020 and to a lesser extent Statistical Area 018 contributed the majority of the catch. This pattern was well represented by sampled landings in the 2014–15 fishing year, but area 018 was under sampled in the 2013–14 fishing year (Figure 54). For SBP, areas 022, 024 and 026 contributed the most catch (in decreasing order of importance). In both sampling years the relative importance of areas 022 and 024 was well reflected in the sampled landings, however catches from area 026 were not sampled in either fishing year (Figure 54).

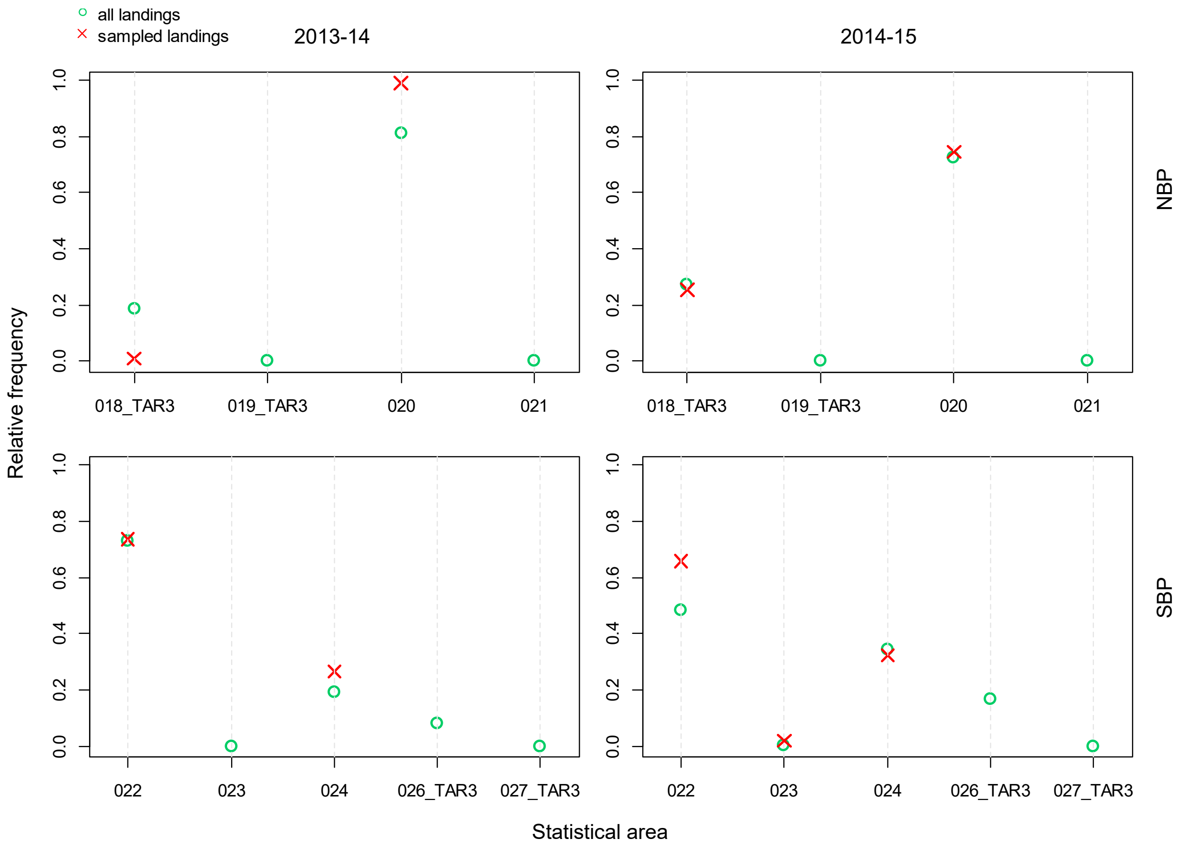

Figure 54: Comparison of the proportional distribution of the estimated bottom trawl catch and the sampled component by statistical area for NBP and SBP within TAR 3 in 2013–14 and 2014–15.

The depth distributions of tarakihi bottom trawl catch within TAR 3 peaked at about 100 m in NBP, and less than 100 m in SBP (Figure 55). The distribution of landings that were sampled in both areas also peaked at about 100 m depth, matching overall landings well for NBP, and oversampling deeper landings for SBP (Figure 55).

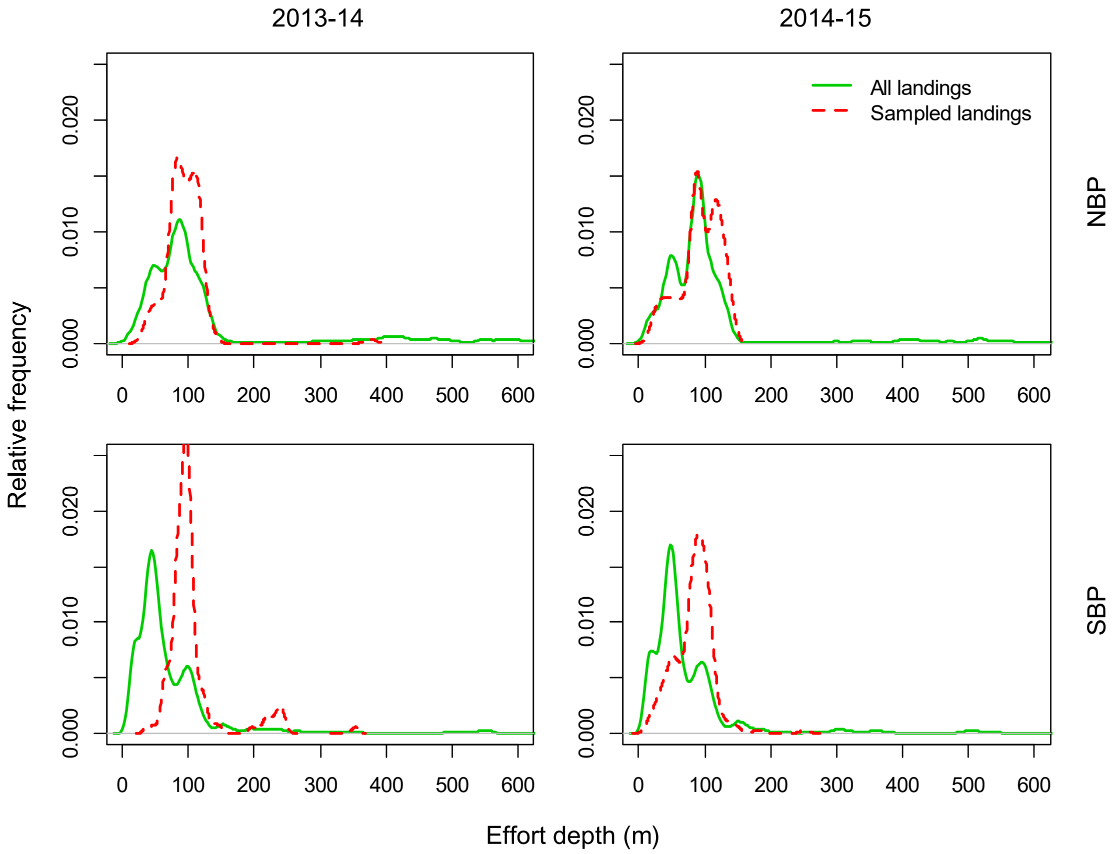

Figure 55: Depth distribution of tarakihi bottom trawl landings and samples for the NBP and SBP sub-areas within TAR 3 during the 2013–14 and 2014–15 fishing years.

4.5.1.2 Set net

The temporal trend in set net landings in both years demonstrated a gradual accumulation until June, when landings ceased. This pattern was matched fairly well by sampled landings in both years, although the accumulation of samples was more stepped than actual landings (Figure 56). When the temporal pattern of landings and samples was aggregated to the seasonal level they were also well matched (Figure 57).

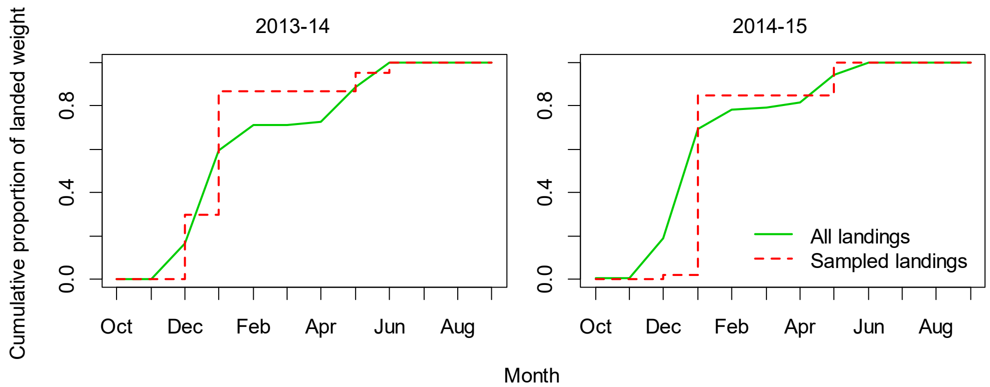

Figure 56: The cumulative proportion of the weight of tarakihi landings and samples taken from the TAR 3 set net fishery in 2013–14 and 2014–15.

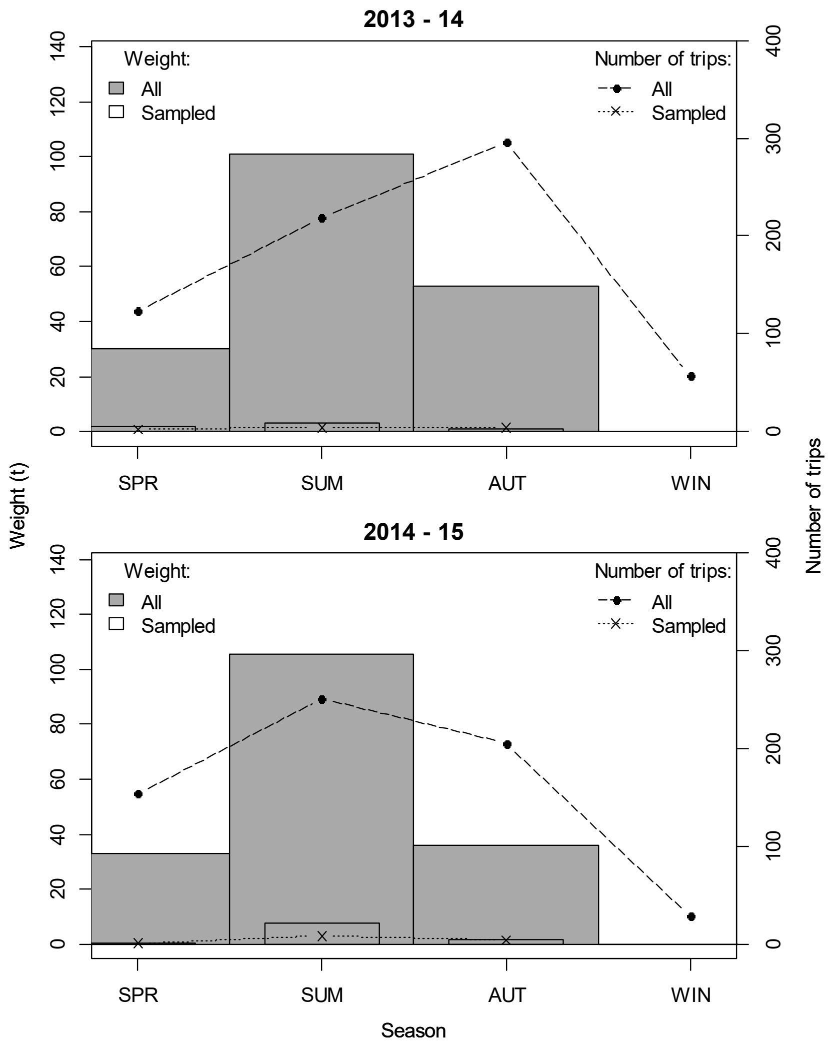

Figure 57: Comparison of the seasonal distribution of landed weight (histograms) and numbers of landings (lines) of tarakihi within the TAR 3 set net fishery from 2013–14 to 2014–15 (Note: histograms and lines overlaid; SPR= October-December, Sum = January–March, Aut = April–June, Win = July–September).

Set net landings from TAR 3 were almost entirely from Statistical Area 018; this pattern was also true of sampled landings (Figure 58).

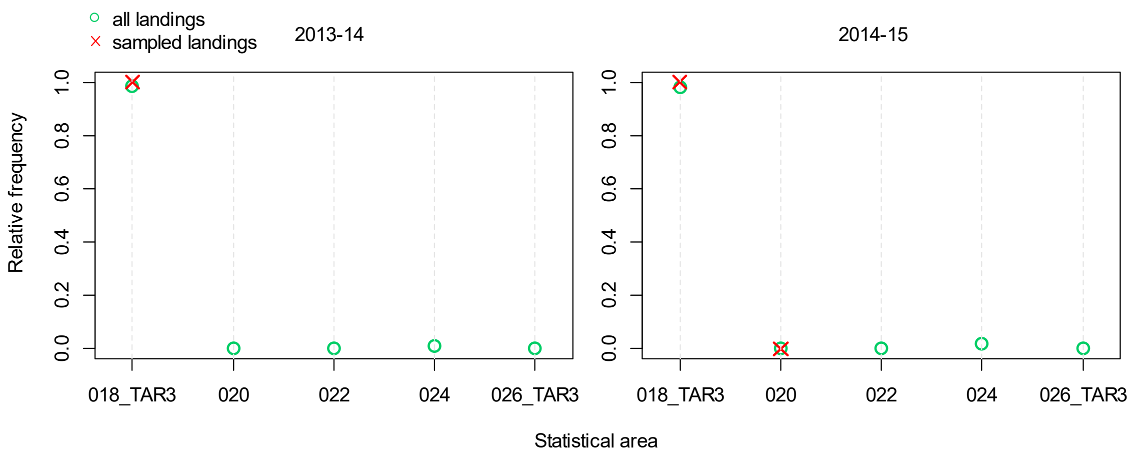

Figure 58: Comparison of the proportional distribution of the estimated tarakihi set net catch and the sampled component by statistical area for TAR 3 in 2013–14 and 2014–15.

4.5.2 Age and length frequency distributions

4.5.2.1 Bottom trawl

The length compositions of tarakihi from both the NBP and SBP bottom trawl fisheries were consistent across both years of sampling and between sexes. Both sub-areas had a mode size of just less than 30 cm FL, although the NBP length composition contained more large fish (range: 25 to 50 cm FL) compared to the SBP sub-area (range: 25 to 40 cm FL) (Figure 59).

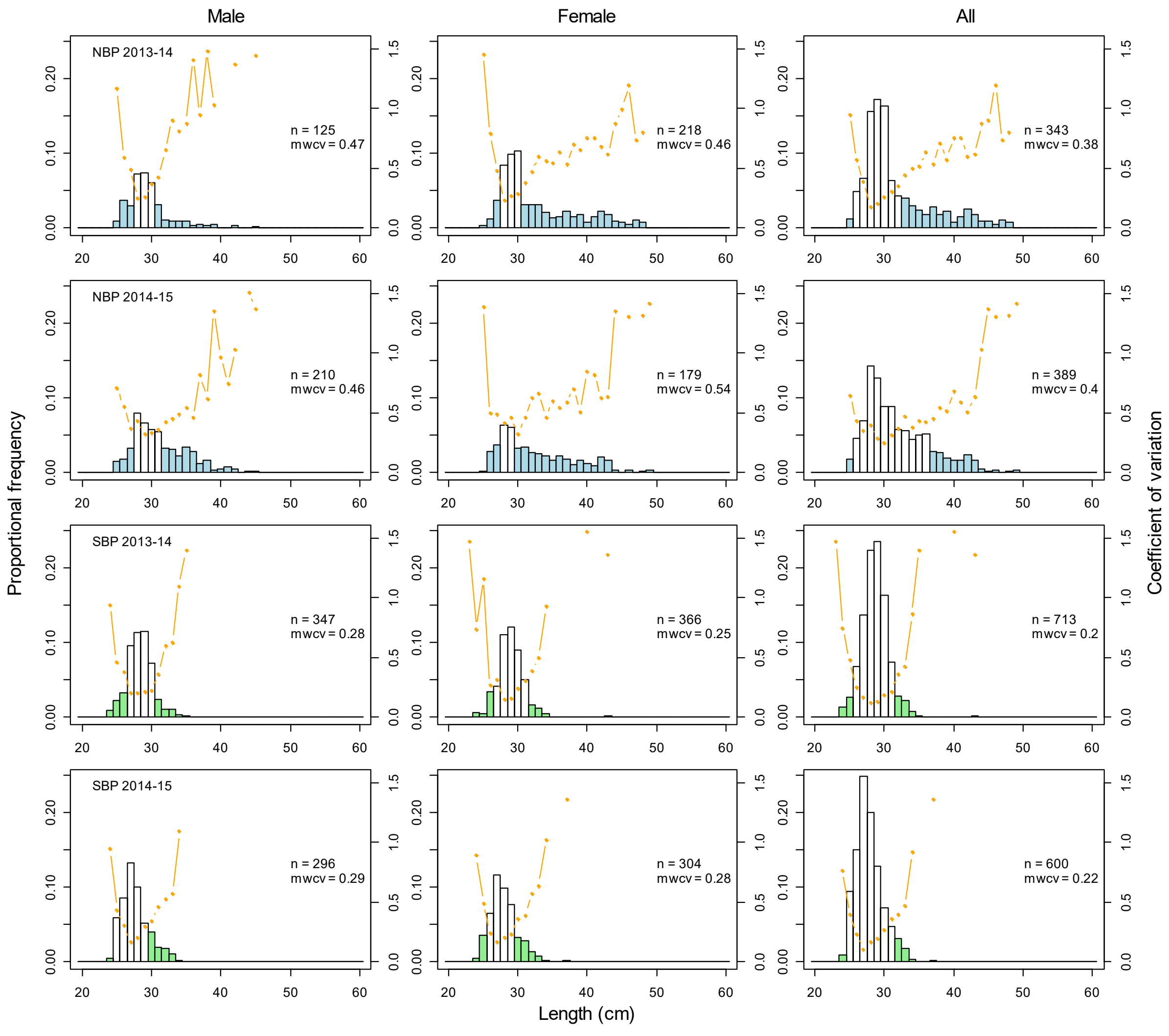

Figure 59: Scaled length frequency distributions and coefficient of variation for each length class for bottom trawl landings (NBP and SBP) of TAR 3 by sex and for combined sexes during 2013–14 and 2014–15.

The NBP bottom trawl fishery was largely comprised of young fish (age 3 to 7 years), but small amounts of older years classes were also present (total range: 3–32 years). The 2009 year class was dominant in the 2013–14 sampling year. By 2014–15 the 2009 year class was still important, but the 2011 year class was dominant. The SBP bottom trawl fishery had a much narrower age distribution, with a total age range of 3 to 9 years. The 2009 year class was again important in the 2013–14 sampling year, but was all but replaced by the 2011 year class in the 2014–15 sampling year (Figure 60).

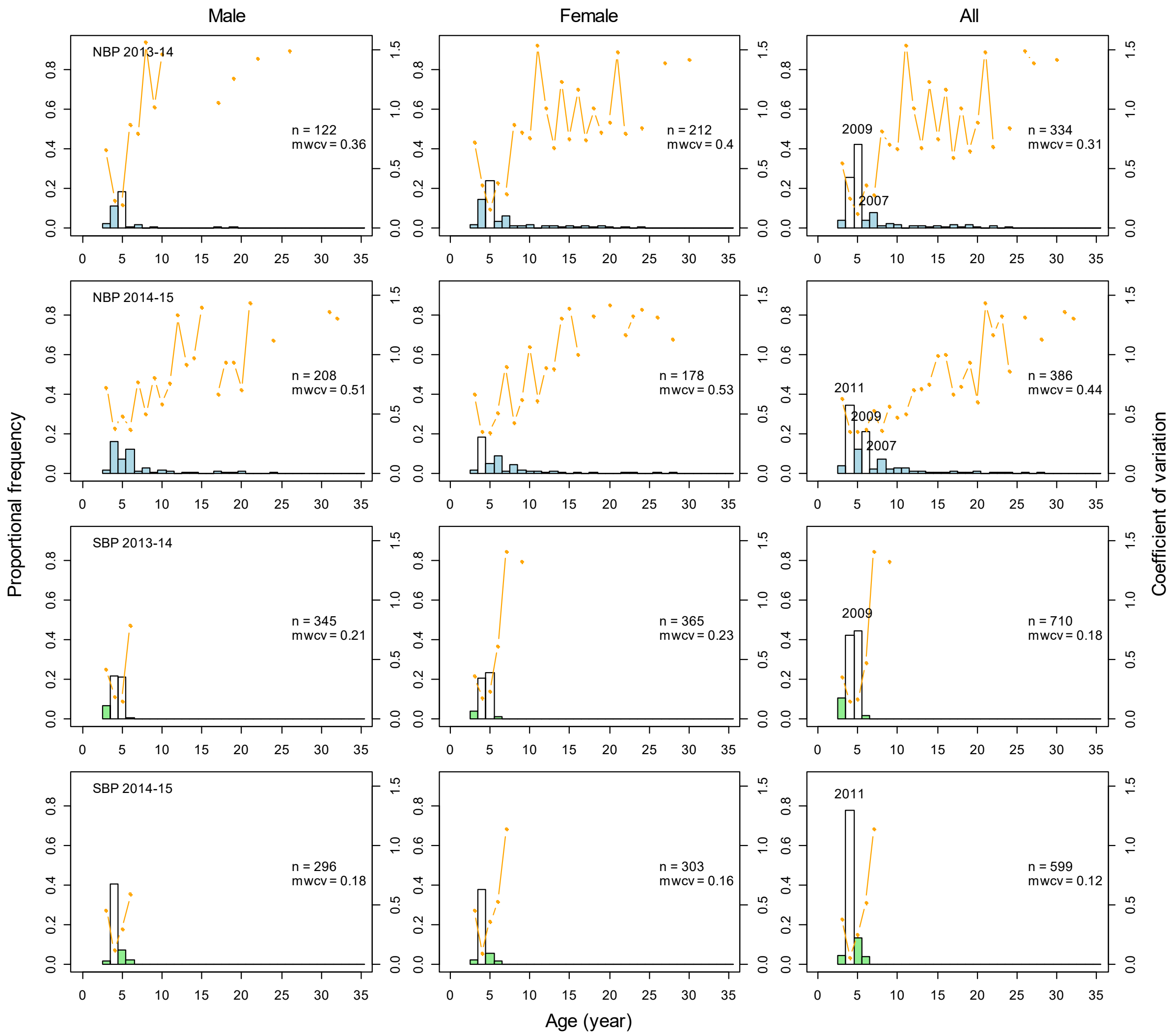

Figure 60: Scaled age frequency distributions and coefficient of variation for each age class for bottom trawl landings (NBP and SBP) of TAR 3 by sex and for combined sexes during 2013–14 and 2014–15.

4.5.2.2 Set net

The length composition of the TAR 3 set net fishery was similar across both years of sampling and sexes. The length distribution was unimodal with little skew, had a mode of around 35 cm FL, and a range of 25 to 48 cm FL (Figure 61).

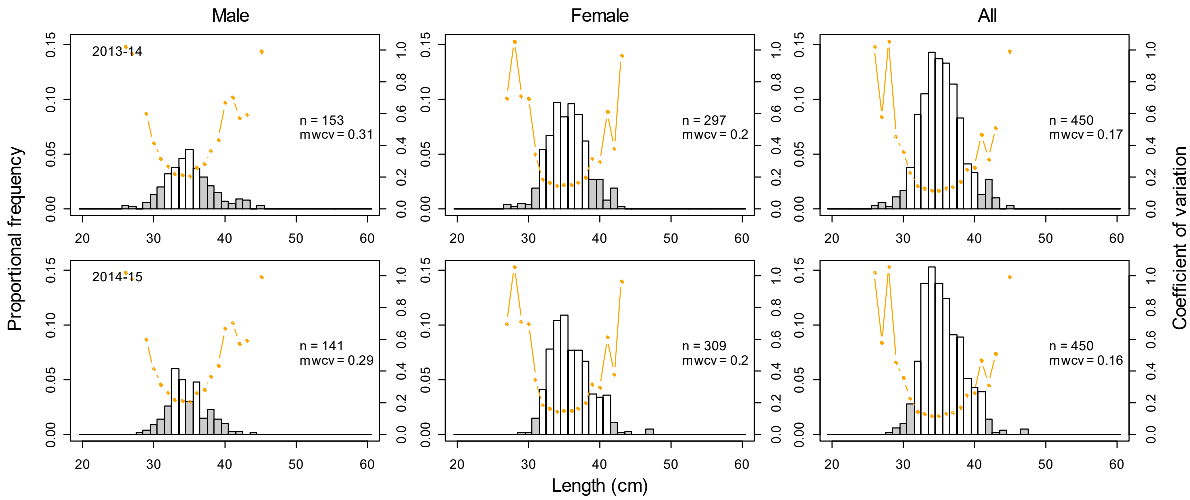

Figure 61: Scaled length frequency distributions and coefficient of variation for each length class for set net landings of TAR 3 during 2013–14 and 2014–15, plotted for each sex and sexes combined.

The TAR 3 set net fishery is dominated by fish between 5 and 10 years old, but also contains some very old fish, with an overall range of 3 to 48 years. The 2007 and 2009 year classes dominate the age composition and can be seen to progress through the age distribution across the two sampling years (Figure 62).

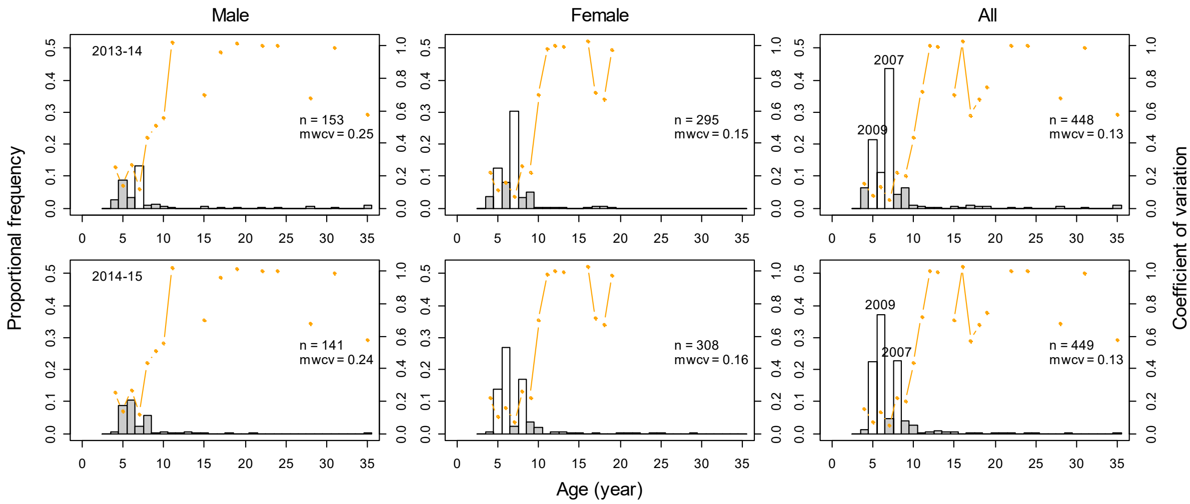

Figure 62: Scaled age frequency distributions and coefficient of variation for each age class for set net landings of TAR 3, by sex and for combined sexes during 2013–14 and 2014–15. NB: fish of 35 years or older are combined into one bar at 35.

5 DISCUSSION

This report represents the first time that the length and age structure of tarakihi populations from the entire east coast of New Zealand have been systematically and comprehensively described. As such, the results presented here help to synoptically characterise east coast New Zealand stock structure. Uncertainty in stock structure, particularly information to quantify movement, has prevented achieving previous stock assessments (Langley & Starr 2012).

A strong pattern is present in the age composition of tarakihi sub-areas along the east coast of New Zealand with latitude. In the southernmost sub-area, the SBP portion of TAR 3, landings from the bottom trawl fishery were comprised of only four age classes, with a mode of less than 5 years old. Bottom trawl landings from the northern most sub-area (the ENHG portion of TAR 1) by contrast are comprised of about 20 age classes, with a modal age of about 7 years. This trend of an increasing breadth in the age structure from south to north is apparent from SBP→NBP→TAR 2→BPLE→ENHG (Figure 63).

In addition to a broader age composition, the progression of individual age classes can also be seen from south to north. For example, in the 2013–14 sampling year the strong 2009 year class (5 year old fish at that time) is most prevalent in the southern most sub-area catch, and generally decreases in prevalence through the northern sub-areas. For the 2014–15 sampling year, the 2009 year class was less prevalent in the southern sub-area catch, but had increased in prevalence for the more northern sub-stock catch (Figure 63). In addition, a strong 2011 year class (4 year olds at that time) had recruited to the fishery in 2014–15, dominating the southern sub-stock catch, but decreasing in importance towards the north (Figure 63). Together these results suggest that on the east coast of New Zealand a major component of the recruitment of young tarakihi occurs in the south, with fish progressively moving northwards as they get older. This also implies that connectivity along east coast of New Zealand is high, suggesting that there is a single tarakihi stock in this area.

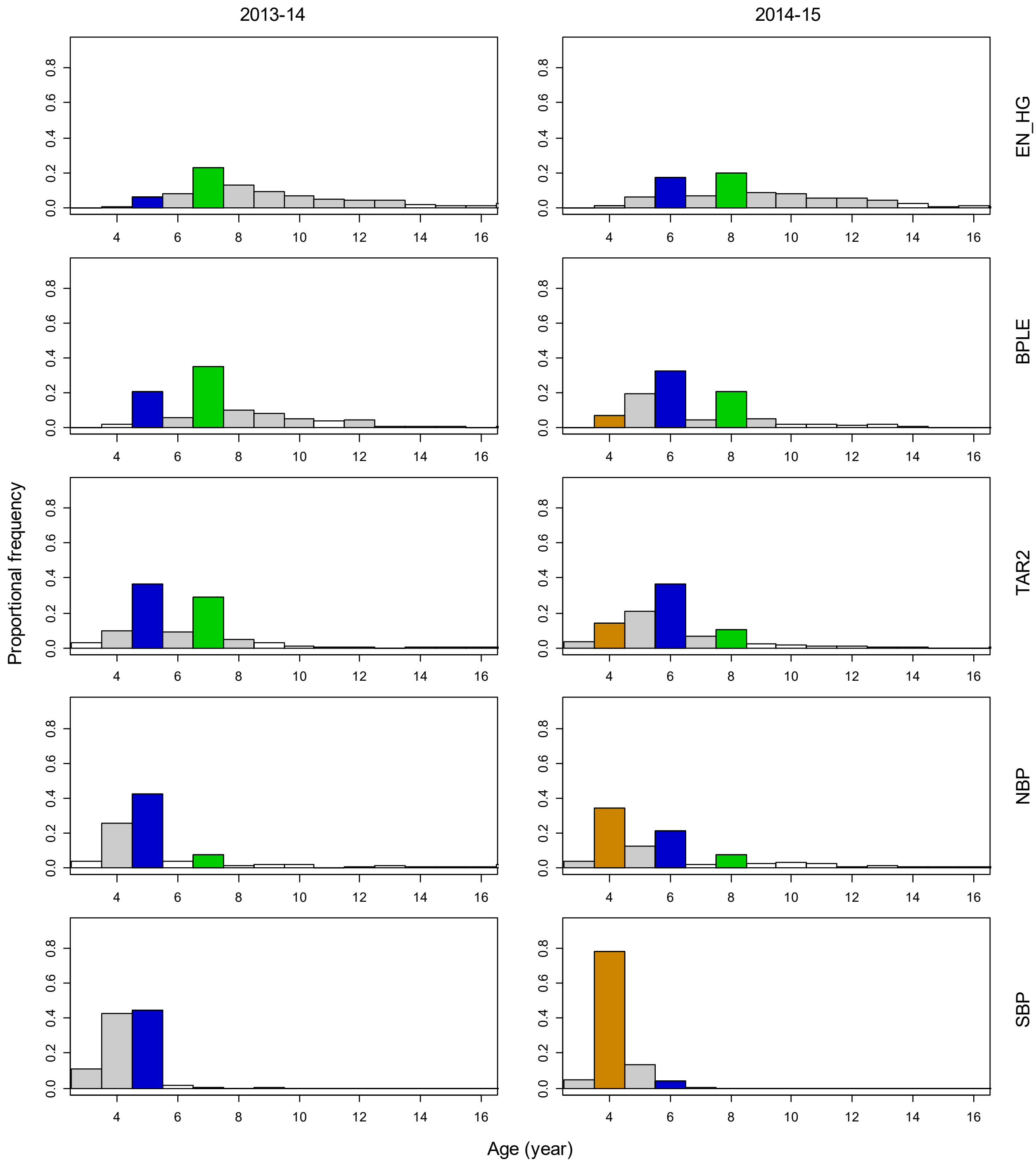

Figure 63: Age frequency compositions of tarakihi for the east coast of New Zealand ordered from north (top) to south (bottom) in 2013–14 and 2014–15. The strong 2007 (green), 2009 (blue) and 2011 (orange) years classes are highlighted.

The age composition of the TAR 3 set net fishery, the Cook Strait spawning aggregation, and the WCNI sub-area should also be interpreted relative to the trends described above. For the Kaikoura set net fishery within TAR 3, and the Cook Strait spawning aggregation, the age structure was generally consistent with that of the NBP and TAR 2 bottom trawl fisheries which occur at similar latitudes. Specifically, these fisheries were dominated by fish between 5 and 10 years old, with the presence of older age classes (compare Figure 51, Figure 62 with Figure 63). The dominant 2007 and 2009 year classes were also important for both the Kaikoura set net and Cook Strait spawning aggregation fisheries. For the Cook Strait spawning aggregation, the older age classes that were present occurred at higher frequency than in the surrounding TAR 2 and TAR 3 bottom trawl fisheries. This might be expected considering that it is comprised of a concentration of mature, and therefore older, spawning fish.

For the WCNI bottom trawl fishery, there were some similarities and dissimilarities with the closest east coast sub-area, ENHG. Landings sampled from both sub-areas were dominated by tarakihi between 5 and 10 years old, and included a significant proportion of older age classes. However, some major differences were apparent. For example, while the strong 2009 age class common to the east coast sub-areas was also dominant in the WCNI sub-area, the strong 2007 year class was not present in the WCNI catch. Furthermore, the WCNI showed a strong 2005 year class that did not feature on the east coast (Figure 43). These results provide some indication of reduced connectivity between east coast New Zealand and WCNI tarakihi populations.

It is important to consider alternative explanations for the hypothesis of connectivity and northwards progression of tarakihi recruitment on the east coast of New Zealand. One such alternative is that older tarakihi are present in the south, but were under sampled by the present study as they occur in deeper water. An analysis of tarakihi age and length distribution by depth from six east coast South Island research trawl surveys found that tarakihi were consistently larger by about four to eight cm and older by about 1 to 2 years in depths over 80 m, with few fish older than about six years below 80 m (Beentjes in prep). In this catch sampling programme, commercial catches from deeper water (more than 80 m) were over-represented and it is therefore more likely that the commercial sampling data over-represented, as opposed to under-represented, the proportion of older age classes in TAR 3 (Figure 55). Therefore, we consider it unlikely that there is a large component of older tarakihi on the south east shelf of New Zealand.

Overall, the results presented in this report are generally consistent with those of previous studies in that they suggest: (1) a strong link between east coast stocks/sub-areas (Langley & Starr 2012), (2) the dominance of young fish in southern TAR 3 (Beentjes 2011, Beentjes et al. 2012) and (3) the presence of older fish in northern TAR 1 and a general absence of these older fish from southern TAR 1 (Parker & Fu 2011, Beentjes et al. 2012, McKenzie et al. 2015). The present study represents the first time that the age composition of all east coast tarakihi stocks has been simultaneously described which has enabled a better understanding of connectivity and therefore stock linkages along the east coast. These results will inform future catch sampling designs and also provide testable hypotheses for configurations of stock assessments.

5.1 Recommendations

- Future catch sampling of the TAR 1, 2 & 3 trawl fisheries should take place concurrently as these QMAs are likely to form part of one east coast New Zealand stock (in line with age monitoring of other MPI tier 1 stocks, we recommend sampling should occur over two consecutive years in every five).
- All tarakihi QMAs throughout New Zealand should be concurrently sampled in the next tarakihi catch sampling programme to better understand the tarakihi stock structure over both coasts.
- Ageing otoliths collected as part of the recent west coast South Island trawl survey may be a useful interim measure for understanding connectivity between west and east coasts tarakihi populations, especially to look for the 2005 and 2009 year classes in that area.
- Movement of adult tarakihi as inferred from the age data does not in itself constitute definitive proof of the single east coast stock hypothesis. Tarakihi movement patterns should ideally be independently ratified; perhaps using a tagging programme, or with other appropriate biological markers such as otolith microchemistry.
- The next east coast tarakihi stock assessment should account for the spatially disaggregated nature of the TAR stocks on the east coast of New Zealand.

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8 APPENDICES

Appendix 1: TAR 1 bottom trawl proportion at age by sub-area for the 2013–14 and 2014–15 fishing years for males.

males	2013–14						2014–15					
Age	WCNI		ENHG		BOP		WCNI		ENHG		BOP	
(years)	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV
1	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-
2	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-
3	0.003	0.96	0.000	-	0.000	-	0.001	1.47	0.000	-	0.002	1.43
4	0.011	0.59	0.005	0.84	0.014	0.73	0.023	0.45	0.009	0.72	0.041	0.36
5	0.047	0.31	0.031	0.37	0.136	0.19	0.031	0.29	0.035	0.47	0.093	0.19
6	0.063	0.28	0.046	0.34	0.041	0.35	0.034	0.35	0.098	0.23	0.176	0.16
7	0.122	0.21	0.111	0.21	0.261	0.16	0.070	0.23	0.038	0.48	0.028	0.39
8	0.027	0.37	0.059	0.26	0.081	0.20	0.088	0.22	0.098	0.21	0.097	0.22
9	0.048	0.29	0.038	0.33	0.048	0.31	0.029	0.33	0.045	0.43	0.031	0.32
10	0.014	0.51	0.031	0.34	0.035	0.30	0.045	0.34	0.040	0.33	0.004	0.85
11	0.016	0.46	0.025	0.53	0.027	0.57	0.014	0.50	0.030	0.45	0.011	0.61
12	0.024	0.44	0.017	0.49	0.030	0.35	0.008	0.64	0.036	0.40	0.008	0.70
13	0.013	0.74	0.024	0.38	0.004	1.05	0.012	0.56	0.020	0.72	0.009	0.66
14	0.007	0.67	0.011	0.55	0.005	0.83	0.002	1.06	0.018	0.61	0.004	0.86
15	0.013	0.56	0.004	0.93	0.004	0.81	0.010	0.55	0.001	1.62	0.001	1.40
16	0.006	0.78	0.009	0.92	0.003	1.35	0.008	0.63	0.005	1.19	0.004	1.15
17	0.005	0.92	0.010	0.67	0.006	0.90	0.005	0.72	0.004	1.15	0.000	-
18	0.008	0.64	0.006	0.81	0.002	1.04	0.002	1.08	0.005	1.13	0.000	-
19	0.001	1.40	0.012	0.59	0.002	1.03	0.011	0.59	0.010	0.73	0.000	-
20	0.003	0.95	0.008	0.94	0.000	-	0.003	0.97	0.013	0.72	0.000	-
21	0.000	-	0.003	1.36	0.000	-	0.003	0.99	0.003	1.40	0.000	-
22	0.003	0.98	0.015	0.51	0.002	1.01	0.001	1.43	0.006	0.97	0.000	-
23	0.001	1.42	0.001	1.46	0.000	-	0.002	1.20	0.002	1.14	0.000	-
24	0.002	1.10	0.001	1.42	0.000	-	0.003	1.06	0.005	0.99	0.000	-
25	0.000	-	0.005	0.99	0.000	-	0.001	1.41	0.002	1.32	0.000	-
26	0.000	-	0.000	-	0.001	1.44	0.000	-	0.003	1.47	0.000	-
27	0.001	1.36	0.000	-	0.000	-	0.000	-	0.001	1.20	0.000	-
28	0.000	-	0.000	-	0.000	-	0.000	-	0.009	0.81	0.000	-
29	0.001	1.37	0.000	-	0.000	-	0.000	-	0.003	1.46	0.000	-
30	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-
31	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-
32	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-
33	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-
34	0.000	-	0.000	-	0.000	-	0.001	1.33	0.000	-	0.000	-
35+	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-
n	233		235		366		295		234		269	
mwcv	0.38		0.40		0.27		0.37		0.45		0.27	

Appendix 2: TAR 1 bottom trawl proportion at age by sub-area for the 2013–14 and 2014–15 fishing years for females.

females	2013–14						2014–15					
Age	WCNI		ENHG		BOP		WCNI		ENHG		BOP	
(years)	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV
1	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-
2	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-
3	0.005	0.82	0.000	-	0.000	-	0.002	1.07	0.000	-	0.000	-
4	0.006	0.81	0.003	1.44	0.006	0.87	0.013	0.53	0.005	0.89	0.029	0.32
5	0.018	0.50	0.029	0.43	0.073	0.21	0.029	0.39	0.028	0.49	0.103	0.19
6	0.064	0.24	0.036	0.46	0.018	0.46	0.039	0.30	0.078	0.34	0.151	0.21
7	0.110	0.19	0.118	0.18	0.092	0.29	0.098	0.16	0.032	0.39	0.018	0.47
8	0.039	0.29	0.068	0.22	0.023	0.50	0.123	0.17	0.098	0.21	0.112	0.22
9	0.080	0.27	0.055	0.31	0.036	0.30	0.052	0.32	0.039	0.46	0.023	0.36
10	0.041	0.33	0.035	0.36	0.015	0.56	0.053	0.24	0.042	0.33	0.016	0.54
11	0.033	0.39	0.024	0.43	0.011	0.61	0.019	0.46	0.025	0.49	0.007	0.74
12	0.030	0.44	0.025	0.50	0.015	0.52	0.019	0.58	0.021	0.46	0.005	0.79
13	0.018	0.37	0.018	0.42	0.004	1.31	0.029	0.39	0.022	0.47	0.013	0.61
14	0.023	0.42	0.008	0.76	0.001	1.44	0.009	0.62	0.004	0.88	0.004	0.96
15	0.008	0.57	0.008	0.79	0.001	1.46	0.028	0.41	0.003	0.94	0.000	-
16	0.006	0.83	0.005	0.84	0.000	-	0.010	0.57	0.006	1.04	0.000	-
17	0.025	0.38	0.015	0.50	0.000	-	0.010	0.66	0.003	0.91	0.002	1.45
18	0.017	0.52	0.037	0.38	0.000	-	0.021	0.39	0.005	0.81	0.003	1.23
19	0.009	0.59	0.014	0.48	0.003	0.86	0.010	0.54	0.013	0.63	0.003	1.04
20	0.010	0.54	0.016	0.49	0.000	-	0.001	1.42	0.007	0.74	0.000	-
21	0.007	0.70	0.000	-	0.001	1.46	0.006	0.80	0.011	0.74	0.000	-
22	0.004	1.01	0.001	1.47	0.000	-	0.005	0.80	0.008	0.95	0.000	-
23	0.001	1.45	0.000	-	0.000	-	0.000	-	0.003	1.02	0.000	-
24	0.006	0.68	0.003	1.03	0.000	-	0.007	0.66	0.001	1.69	0.000	-
25	0.000	-	0.000	-	0.000	-	0.004	0.97	0.005	0.99	0.000	-
26	0.000	-	0.002	1.32	0.000	-	0.000	-	0.000	-	0.000	-
27	0.001	1.37	0.004	0.87	0.000	-	0.002	1.47	0.001	1.55	0.000	-
28	0.000	-	0.002	1.45	0.000	-	0.000	-	0.001	1.51	0.000	-
29	0.002	1.39	0.000	-	0.000	-	0.000	-	0.003	1.47	0.000	-
30	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-
31	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-
32	0.000	-	0.000	-	0.000	-	0.000	-	0.001	1.63	0.000	-
33	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-
34	0.000	-	0.000	-	0.000	-	0.002	1.45	0.000	-	0.000	-
35+	0.000	-	0.001	1.43	0.000	-	0.000	-	0.000	-	0.000	-
n	331		284		174		360		301		246	
mwcv	0.35		0.37		0.38		0.33		0.45		0.29	

Appendix 3: TAR 1 bottom trawl proportion at age by sub-area for the 2013-14 and 2014-15 fishing years for both sexes combined.

all	2013–14						2014–15					
Age	WCNI		ENHG		BOP		WCNI		ENHG		BOP	
(years)	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV
1	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-
2	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-
3	0.008	0.63	0.000	-	0.000	-	0.003	0.90	0.000	-	0.002	1.43
4	0.017	0.49	0.008	0.69	0.020	0.62	0.036	0.29	0.014	0.62	0.070	0.27
5	0.065	0.29	0.060	0.30	0.209	0.14	0.060	0.21	0.062	0.40	0.196	0.13
6	0.127	0.18	0.083	0.27	0.058	0.26	0.073	0.24	0.176	0.22	0.327	0.13
7	0.232	0.12	0.230	0.12	0.353	0.10	0.169	0.12	0.070	0.28	0.046	0.29
8	0.067	0.22	0.127	0.15	0.103	0.20	0.212	0.11	0.196	0.14	0.209	0.15
9	0.128	0.18	0.092	0.25	0.084	0.24	0.080	0.19	0.084	0.27	0.054	0.23
10	0.055	0.29	0.067	0.24	0.049	0.28	0.098	0.17	0.081	0.23	0.020	0.45
11	0.049	0.29	0.049	0.34	0.037	0.38	0.033	0.29	0.055	0.33	0.018	0.48
12	0.054	0.27	0.042	0.41	0.044	0.30	0.027	0.45	0.057	0.27	0.013	0.53
13	0.030	0.35	0.042	0.28	0.008	0.75	0.041	0.29	0.042	0.42	0.022	0.39
14	0.030	0.36	0.019	0.46	0.006	0.76	0.011	0.54	0.022	0.52	0.007	0.62
15	0.021	0.39	0.012	0.56	0.005	0.73	0.039	0.32	0.004	0.85	0.001	1.40
16	0.012	0.54	0.015	0.63	0.003	1.35	0.018	0.47	0.011	0.71	0.004	1.15
17	0.029	0.32	0.025	0.44	0.006	0.90	0.016	0.45	0.007	0.74	0.002	1.45
18	0.025	0.42	0.042	0.37	0.002	1.04	0.023	0.36	0.009	0.64	0.003	1.23
19	0.010	0.54	0.026	0.36	0.006	0.76	0.021	0.44	0.023	0.50	0.003	1.04
20	0.013	0.47	0.024	0.45	0.000	-	0.005	0.80	0.020	0.57	0.000	-
21	0.007	0.70	0.003	1.36	0.001	1.46	0.009	0.62	0.014	0.75	0.000	-
22	0.006	0.69	0.016	0.49	0.002	1.01	0.006	0.73	0.014	0.61	0.000	-
23	0.002	1.06	0.001	1.46	0.000	-	0.002	1.20	0.004	0.88	0.000	-
24	0.008	0.60	0.004	0.82	0.000	-	0.010	0.51	0.005	0.88	0.000	-
25	0.000	-	0.005	0.99	0.000	-	0.005	0.80	0.006	0.79	0.000	-
26	0.000	-	0.002	1.32	0.001	1.44	0.000	-	0.003	1.47	0.000	-
27	0.002	1.03	0.004	0.87	0.000	-	0.002	1.47	0.002	1.00	0.000	-
28	0.000	-	0.002	1.45	0.000	-	0.000	-	0.010	0.73	0.000	-
29	0.002	1.06	0.000	-	0.000	-	0.000	-	0.007	1.26	0.000	-
30	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-
31	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-
32	0.000	-	0.000	-	0.000	-	0.000	-	0.001	1.63	0.000	-
33	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-
34	0.000	-	0.000	-	0.000	-	0.003	1.05	0.000	-	0.000	-
35+	0.000	-	0.001	1.43	0.000	-	0.000	-	0.000	-	0.000	-
n	564		519		540		655		535		515	
mwcv	0.26		0.28		0.21		0.23		0.33		0.20	

Appendix 4: TAR 2 and Cook Strait bottom trawl proportion at age for the 2013-14 and 2014-15 fishing years for males.

males	2013–14				2014–15	
Age	TAR2		CSTR		TAR2	
(years)	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV
1	0.000	-	0.000	-	0.000	-
2	0.000	-	0.000	-	0.000	-
3	0.007	0.46	0.000	-	0.012	0.37
4	0.044	0.20	0.022	0.43	0.069	0.15
5	0.177	0.09	0.154	0.16	0.112	0.12
6	0.054	0.22	0.047	0.26	0.158	0.09
7	0.128	0.11	0.179	0.12	0.020	0.28
8	0.017	0.47	0.060	0.22	0.051	0.17
9	0.019	0.42	0.036	0.28	0.007	0.38
10	0.004	0.58	0.055	0.23	0.010	0.42
11	0.000	0.94	0.020	0.35	0.003	0.68
12	0.001	0.97	0.014	0.41	0.003	0.65
13	0.000	-	0.007	0.57	0.003	0.54
14	0.001	0.97	0.004	0.99	0.001	0.94
15	0.002	0.93	0.009	0.47	0.000	-
16	0.000	0.99	0.008	0.48	0.000	0.98
17	0.001	0.66	0.006	0.55	0.002	0.99
18	0.000	0.98	0.012	0.44	0.001	0.97
19	0.000	-	0.005	0.74	0.000	-
20	0.001	0.65	0.004	0.70	0.000	-
21	0.002	0.66	0.002	0.94	0.002	0.98
22	0.000	-	0.006	0.71	0.000	-
23	0.000	-	0.002	1.02	0.000	-
24	0.000	-	0.002	0.99	0.000	-
25	0.000	-	0.000	-	0.000	-
26	0.001	0.96	0.000	-	0.001	0.89
27	0.000	-	0.000	-	0.000	-
28	0.000	-	0.000	-	0.000	-
29	0.000	-	0.000	-	0.000	-
30	0.000	-	0.002	0.95	0.000	-
31	0.000	-	0.000	-	0.000	-
32	0.000	-	0.000	-	0.000	-
33	0.000	-	0.000	-	0.000	-
34	0.000	-	0.003	0.98	0.000	-
35+	0.000	-	0.000	-	0.000	-
n	280		208		300	
mwcv	0.18		0.25		0.17	

Appendix 5: TAR 2 and Cook Strait bottom trawl proportion at age for the 2013–14 and 2014–15 fishing years for females.

females	2013–14				2014–15	
Age	TAR 2		CSTR		TAR 2	
(years)	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV
1	0.000	-	0.000	-	0.000	-
2	0.000	-	0.000	-	0.000	-
3	0.021	0.27	0.006	0.70	0.021	0.27
4	0.055	0.19	0.006	0.97	0.075	0.14
5	0.186	0.08	0.147	0.16	0.100	0.13
6	0.035	0.18	0.029	0.43	0.209	0.08
7	0.163	0.10	0.043	0.32	0.043	0.19
8	0.028	0.22	0.013	0.45	0.055	0.15
9	0.013	0.30	0.012	0.61	0.017	0.30
10	0.009	0.38	0.015	0.50	0.006	0.53
11	0.004	0.62	0.021	0.43	0.005	0.53
12	0.004	0.51	0.006	0.74	0.008	0.42
13	0.000	0.94	0.010	0.48	0.002	0.68
14	0.002	0.92	0.002	1.01	0.001	0.89
15	0.000	-	0.004	0.70	0.000	-
16	0.004	0.46	0.006	0.97	0.001	0.95
17	0.003	0.64	0.003	0.94	0.000	-
18	0.004	0.52	0.008	0.54	0.000	-
19	0.002	0.98	0.003	0.99	0.000	-
20	0.001	0.65	0.002	0.94	0.000	-
21	0.000	0.94	0.000	-	0.000	-
22	0.000	-	0.000	-	0.000	-
23	0.000	-	0.002	0.97	0.000	-
24	0.000	0.96	0.000	-	0.000	-
25	0.000	-	0.000	-	0.002	0.92
26	0.001	0.90	0.000	-	0.000	-
27	0.002	0.72	0.000	-	0.000	-
28	0.000	-	0.000	-	0.000	-
29	0.000	-	0.000	-	0.000	-
30	0.000	-	0.000	-	0.000	-
31	0.000	-	0.000	-	0.000	-
32	0.000	-	0.000	-	0.000	-
33	0.000	-	0.000	-	0.000	-
34	0.000	-	0.000	-	0.000	-
35+	0.000	-	0.000	-	0.000	-
n	358		89		392	
mwcv	0.16		0.36		0.15	

Appendix 6: TAR 2 and Cook Strait bottom trawl proportion at age for the 2013–14 and 2014–15 fishing years for both sexes combined.

all				2013–14		2014–15
Age		TAR 2		CSTR		TAR 2
(years)	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV
1	0.000	-	0.000	-	0.000	-
2	0.000	-	0.000	-	0.000	-
3	0.028	0.23	0.006	0.70	0.033	0.21
4	0.099	0.13	0.028	0.39	0.144	0.09
5	0.363	0.05	0.301	0.10	0.212	0.08
6	0.090	0.15	0.077	0.22	0.367	0.05
7	0.291	0.07	0.221	0.11	0.064	0.16
8	0.045	0.22	0.073	0.20	0.105	0.11
9	0.031	0.28	0.047	0.25	0.024	0.24
10	0.014	0.32	0.070	0.21	0.016	0.33
11	0.004	0.56	0.041	0.28	0.008	0.41
12	0.005	0.46	0.019	0.36	0.011	0.35
13	0.000	0.94	0.017	0.37	0.005	0.42
14	0.003	0.68	0.006	0.73	0.002	0.66
15	0.002	0.93	0.013	0.40	0.000	-
16	0.004	0.42	0.014	0.48	0.001	0.74
17	0.005	0.49	0.010	0.49	0.002	0.99
18	0.004	0.47	0.021	0.34	0.001	0.97
19	0.002	0.98	0.009	0.57	0.000	-
20	0.002	0.42	0.006	0.56	0.000	-
21	0.003	0.57	0.002	0.94	0.002	0.98
22	0.000	-	0.006	0.71	0.000	-
23	0.000	-	0.004	0.69	0.000	-
24	0.000	0.96	0.002	0.99	0.000	-
25	0.000	-	0.000	-	0.002	0.92
26	0.003	0.69	0.000	-	0.001	0.89
27	0.002	0.72	0.000	-	0.000	-
28	0.000	-	0.000	-	0.000	-
29	0.000	-	0.000	-	0.000	-
30	0.000	-	0.002	0.95	0.000	-
31	0.000	-	0.000	-	0.000	-
32	0.000	-	0.000	-	0.000	-
33	0.000	-	0.000	-	0.000	-
34	0.000	-	0.003	0.98	0.000	-
35+	0.000	-	0.000	-	0.000	-
n	638		297		692	
mwcv	0.12		0.20		0.11	

Appendix 7: TAR 3 bottom trawl proportion at age by sub-area for the 2013–14 and 2014–15 fishing years for males.

males	2013–14				2014–15			
Age	NBP		SBP		NBP		SBP	
(years)	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV
1	0.000	-	0.000	-	0.000	-	0.000	-
2	0.000	-	0.000	-	0.000	-	0.000	-
3	0.023	0.66	0.069	0.42	0.019	0.73	0.020	0.46
4	0.111	0.24	0.216	0.19	0.163	0.38	0.404	0.12
5	0.183	0.20	0.212	0.15	0.075	0.49	0.074	0.30
6	0.008	0.87	0.008	0.79	0.124	0.37	0.023	0.59
7	0.014	0.79	0.000	-	0.012	0.77	0.000	-
8	0.001	1.56	0.000	-	0.029	0.50	0.000	-
9	0.007	1.02	0.000	-	0.008	0.80	0.000	-
10	0.003	1.46	0.000	-	0.019	0.58	0.000	-
11	0.000	-	0.000	-	0.013	0.76	0.000	-
12	0.000	-	0.000	-	0.003	1.33	0.000	-
13	0.000	-	0.000	-	0.005	0.92	0.000	-
14	0.000	-	0.000	-	0.004	0.97	0.000	-
15	0.000	-	0.000	-	0.001	1.40	0.000	-
16	0.000	-	0.000	-	0.000	-	0.000	-
17	0.006	1.06	0.000	-	0.009	0.66	0.000	-
18	0.000	-	0.000	-	0.005	0.94	0.000	-
19	0.006	1.26	0.000	-	0.006	0.94	0.000	-
20	0.000	-	0.000	-	0.010	0.70	0.000	-
21	0.000	-	0.000	-	0.001	1.43	0.000	-
22	0.003	1.42	0.000	-	0.000	-	0.000	-
23	0.000	-	0.000	-	0.000	-	0.000	-
24	0.000	-	0.000	-	0.006	1.12	0.000	-
25	0.000	-	0.000	-	0.000	-	0.000	-
26	0.002	1.49	0.000	-	0.000	-	0.000	-
27	0.000	-	0.000	-	0.000	-	0.000	-
28	0.000	-	0.000	-	0.000	-	0.000	-
29	0.000	-	0.000	-	0.000	-	0.000	-
30	0.000	-	0.000	-	0.000	-	0.000	-
31	0.000	-	0.000	-	0.002	1.37	0.000	-
32	0.000	-	0.000	-	0.003	1.31	0.000	-
33	0.000	-	0.000	-	0.000	-	0.000	-
34	0.000	-	0.000	-	0.000	-	0.000	-
35+	0.000	-	0.000	-	0.000	-	0.000	-
n	122		345		208		296	
mwcv	0.36		0.21		0.51		0.18	

Appendix 8: TAR 3 bottom trawl proportion at age by sub-area for the 2013–14 and 2014–15 fishing years for females.

females	2013–14				2014–15			
Age	NBP		SBP		NBP		SBP	
(years)	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV
1	0.000	-	0.000	-	0.000	-	0.000	-
2	0.000	-	0.000	-	0.000	-	0.000	-
3	0.017	0.72	0.040	0.36	0.018	0.66	0.024	0.45
4	0.146	0.36	0.209	0.17	0.182	0.35	0.378	0.09
5	0.239	0.15	0.234	0.23	0.048	0.34	0.057	0.37
6	0.032	0.38	0.010	0.61	0.087	0.51	0.019	0.53
7	0.063	0.28	0.000	1.41	0.010	0.90	0.001	1.14
8	0.009	0.87	0.000	-	0.045	0.43	0.000	-
9	0.013	0.80	0.002	1.33	0.015	0.62	0.000	-
10	0.015	0.76	0.000	-	0.012	1.07	0.000	-
11	0.002	1.54	0.000	-	0.014	0.61	0.000	-
12	0.009	1.01	0.000	-	0.007	0.89	0.000	-
13	0.011	0.68	0.000	-	0.009	0.88	0.000	-
14	0.004	1.23	0.000	-	0.003	1.31	0.000	-
15	0.010	0.75	0.000	-	0.003	1.39	0.000	-
16	0.005	1.17	0.000	-	0.004	1.00	0.000	-
17	0.013	0.74	0.000	-	0.000	-	0.000	-
18	0.005	1.01	0.000	-	0.003	1.32	0.000	-
19	0.012	0.81	0.000	-	0.000	-	0.000	-
20	0.007	0.89	0.000	-	0.003	1.42	0.000	-
21	0.002	1.48	0.000	-	0.000	-	0.000	-
22	0.006	0.80	0.000	-	0.007	1.17	0.000	-
23	0.000	-	0.000	-	0.003	1.32	0.000	-
24	0.007	0.84	0.000	-	0.002	1.38	0.000	-
25	0.000	-	0.000	-	0.000	-	0.000	-
26	0.000	-	0.000	-	0.003	1.32	0.000	-
27	0.003	1.39	0.000	-	0.000	-	0.000	-
28	0.000	-	0.000	-	0.007	1.13	0.000	-
29	0.000	-	0.000	-	0.000	-	0.000	-
30	0.002	1.41	0.000	-	0.000	-	0.000	-
31	0.000	-	0.000	-	0.000	-	0.000	-
32	0.000	-	0.000	-	0.000	-	0.000	-
33	0.000	-	0.000	-	0.000	-	0.000	-
34	0.000	-	0.000	-	0.000	-	0.000	-
35+	0.000	-	0.000	-	0.000	-	0.000	-
n	212		365		178		303	
mwcv	0.40		0.23		0.53		0.16	

Appendix 9: TAR 3 bottom trawl proportion at age by sub-area for the 2013–14 and 2014–15 fishing years for both sexes combined.

Age	2013–14				2014–15			
	NBP		SBP		NBP		SBP	
(years)	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV
1	0.000	-	0.000	-	0.000	-	0.000	-
2	0.000	-	0.000	-	0.000	-	0.000	-
3	0.040	0.55	0.109	0.36	0.037	0.63	0.044	0.38
4	0.257	0.25	0.425	0.15	0.345	0.35	0.782	0.06
5	0.422	0.12	0.446	0.16	0.123	0.35	0.131	0.25
6	0.040	0.36	0.018	0.47	0.211	0.37	0.041	0.52
7	0.077	0.28	0.000	1.41	0.022	0.53	0.001	1.14
8	0.010	0.82	0.000	-	0.074	0.37	0.000	-
9	0.020	0.70	0.002	1.33	0.023	0.56	0.000	-
10	0.018	0.67	0.000	-	0.030	0.47	0.000	-
11	0.002	1.54	0.000	-	0.027	0.51	0.000	-
12	0.009	1.01	0.000	-	0.009	0.70	0.000	-
13	0.011	0.68	0.000	-	0.014	0.71	0.000	-
14	0.004	1.23	0.000	-	0.007	0.75	0.000	-
15	0.010	0.75	0.000	-	0.004	1.00	0.000	-
16	0.005	1.17	0.000	-	0.004	1.00	0.000	-
17	0.019	0.59	0.000	-	0.009	0.66	0.000	-
18	0.005	1.01	0.000	-	0.008	0.74	0.000	-
19	0.018	0.65	0.000	-	0.006	0.94	0.000	-
20	0.007	0.89	0.000	-	0.013	0.60	0.000	-
21	0.002	1.48	0.000	-	0.001	1.43	0.000	-
22	0.009	0.69	0.000	-	0.007	1.17	0.000	-
23	0.000	-	0.000	-	0.003	1.32	0.000	-
24	0.007	0.84	0.000	-	0.008	0.86	0.000	-
25	0.000	-	0.000	-	0.000	-	0.000	-
26	0.002	1.49	0.000	-	0.003	1.32	0.000	-
27	0.003	1.39	0.000	-	0.000	-	0.000	-
28	0.000	-	0.000	-	0.007	1.13	0.000	-
29	0.000	-	0.000	-	0.000	-	0.000	-
30	0.002	1.41	0.000	-	0.000	-	0.000	-
31	0.000	-	0.000	-	0.002	1.37	0.000	-
32	0.000	-	0.000	-	0.003	1.31	0.000	-
33	0.000	-	0.000	-	0.000	-	0.000	-
34	0.000	-	0.000	-	0.000	-	0.000	-
35+	0.000	-	0.000	-	0.000	-	0.000	-
n	334		710		386		599	
mwcv	0.31		0.18		0.44		0.12	

Appendix 10: TAR 3 Set net proportion at age by sub-area for the 2013–14 and 2014–15 fishing years for males

males	2013–14		2014–15	
Age	NBP		NBP	
(years)	*P.j.*	CV	*P.j.*	CV
1	0.000	-	0.000	-
2	0.000	-	0.000	-
3	0.000	-	0.000	-
4	0.027	0.25	0.006	0.58
5	0.089	0.14	0.086	0.14
6	0.032	0.27	0.104	0.13
7	0.131	0.12	0.024	0.31
8	0.009	0.43	0.057	0.20
9	0.012	0.51	0.002	0.96
10	0.006	0.56	0.007	0.56
11	0.003	1.02	0.002	0.95
12	0.000	-	0.002	1.00
13	0.000	-	0.005	0.71
14	0.000	-	0.002	1.01
15	0.006	0.70	0.002	1.03
16	0.000	-	0.000	-
17	0.003	0.96	0.000	-
18	0.000	-	0.002	1.00
19	0.003	1.02	0.000	-
20	0.000	-	0.000	-
21	0.000	-	0.002	0.94
22	0.002	1.00	0.000	-
23	0.000	-	0.000	-
24	0.003	1.01	0.000	-
25	0.000	-	0.000	-
26	0.000	-	0.000	-
27	0.000	-	0.000	-
28	0.005	0.68	0.000	-
29	0.000	-	0.000	-
30	0.000	-	0.000	-
31	0.003	0.99	0.000	-
32	0.000	-	0.000	-
33	0.000	-	0.000	-
34	0.000	-	0.000	-
35+	0.009	0.57	0.002	0.98
n	153		141	
mwcv	0.25		0.24	

Appendix 11: TAR 3 Set net proportion at age by sub-area for the 2013–14 and 2014–15 fishing years for females.

females	2013–14		2014–15	
Age	NBP		NBP	
(years)	*P.j.*	CV	*P.j.*	CV
1	0.000	-	0.000	-
2	0.000	-	0.000	-
3	0.000	-	0.000	-
4	0.035	0.22	0.007	0.50
5	0.126	0.11	0.139	0.11
6	0.081	0.16	0.269	0.08
7	0.304	0.07	0.022	0.31
8	0.033	0.26	0.169	0.10
9	0.052	0.22	0.037	0.24
10	0.004	0.70	0.019	0.33
11	0.002	0.98	0.000	-
12	0.003	1.00	0.005	0.71
13	0.002	1.00	0.005	0.70
14	0.000	-	0.002	1.00
15	0.000	-	0.003	1.01
16	0.003	1.03	0.000	-
17	0.006	0.71	0.002	1.03
18	0.005	0.67	0.000	-
19	0.002	0.97	0.000	-
20	0.000	-	0.002	1.01
21	0.000	-	0.002	1.03
22	0.000	-	0.002	1.00
23	0.000	-	0.000	-
24	0.000	-	0.002	0.91
25	0.000	-	0.003	1.02
26	0.000	-	0.000	-
27	0.000	-	0.000	-
28	0.000	-	0.000	-
29	0.000	-	0.002	0.90
30	0.000	-	0.000	-
31	0.000	-	0.000	-
32	0.000	-	0.000	-
33	0.000	-	0.000	-
34	0.000	-	0.000	-
35+	0.000	-	0.000	-
n	295		308	
mwcv	0.15		0.16	

Appendix 12: TAR 3 Set net proportion at age by sub-area for the 2013–14 and 2014–15 fishing years for both sexes combined.

all	2013–14		2014–15	
Age	NBP		NBP	
(years)	*P.j.*	CV	*P.j.*	CV
1	0.000	-	0.000	-
2	0.000	-	0.000	-
3	0.000	-	0.000	-
4	0.063	0.15	0.013	0.38
5	0.215	0.08	0.225	0.08
6	0.112	0.13	0.372	0.06
7	0.435	0.05	0.046	0.22
8	0.042	0.22	0.226	0.09
9	0.063	0.20	0.039	0.23
10	0.009	0.43	0.026	0.28
11	0.005	0.72	0.002	0.95
12	0.003	1.00	0.007	0.58
13	0.002	1.00	0.010	0.50
14	0.000	-	0.005	0.73
15	0.006	0.70	0.005	0.70
16	0.003	1.03	0.000	-
17	0.009	0.57	0.002	1.03
18	0.005	0.67	0.002	1.00
19	0.005	0.74	0.000	-
20	0.000	-	0.002	1.01
21	0.000	-	0.004	0.73
22	0.002	1.00	0.002	1.00
23	0.000	-	0.000	-
24	0.003	1.01	0.002	0.91
25	0.000	-	0.003	1.02
26	0.000	-	0.000	-
27	0.000	-	0.000	-
28	0.005	0.68	0.000	-
29	0.000	-	0.002	0.90
30	0.000	-	0.000	-
31	0.003	0.99	0.000	-
32	0.000	-	0.000	-
33	0.000	-	0.000	-
34	0.000	-	0.000	-
35+	0.009	0.57	0.002	0.98
n	448		449	
mwcv	0.13		0.13	