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Characterisation of TAR 2 & TAR 3 fisheries and age composition of landings in 2010/11

New Zealand Fisheries Assessment Report 2012/25

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In preparation for an integrated stock assessment of east coast tarakihi (*Nemadactylus macropterus*), catch sampling programmes were carried out in the 2010 and 2011 fishing years to generate annual estimates of age composition for the commercial TAR 2 catch from the single trawl fishery, the TAR 3 single trawl fishery, and the TAR 3 Kaikoura set net fishery using market samples of landed catch. This report summarizes the catch at age for the 2011 fishing year (i.e., 2010–11). For TAR 2 and TAR 3 length and age composition of the sampled landings were scaled to the total landed catch for each fishery.

TAR 2 bottom trawl fishery – TAR 2 bottom trawl fishery samples were collected from processors landing tarakihi in Gisborne and Napier. Thirty samples of 60 fish per sample were collected, with a total of more than 1700 fish sampled for biological information and otoliths. Sampling was roughly proportional to landed catch by statistical area, and species targeted, but matched poorly the monthly trends in landings. Length distributions were unimodal with most fish 25–40 cm and no large differences were observed between sexes. The overall proportion male was 50%. The range of ages was 2–26 years (N=783), although 95% were less than 10 years old. Both male and female age distributions were unimodal with peaks at 3 or 5 years, i.e., below the ages at 50% maturity. The Mean Weighted Coefficient of Variation (MWCV) was 11% for combined sexes. Age composition for the landed catch in TAR 2 was similar to that observed in the 2010 fishing year.

TAR 3 bottom trawl fishery – TAR 3 trawl fishery samples were collected from processors in Christchurch, Timaru, and Dunedin. Twenty nine bottom trawl landings were sampled (60 fish per sample) from statistical areas 020, 022, and 024, with about 1700 fish sampled for biological information and otoliths. The overall characteristics of the sampled vessels and their fishing patterns were similar to all vessels indicating that sampling was representative of the fishery. The scaled length frequency distributions were unimodal for both males and females with peaks at 28 cm fork length, with most fish between 25 and 35 cm. The proportion male was 53%. Modal progression is evident in the seasonal scaled length frequency distributions. The range of age estimates was 2–31 years (N=599), although 96% of sampled fish were less than 8 years old. Both male and female age distributions were unimodal with peaks at about 3 years for both males and females, with the bulk of fish 3–5 years old, and most at or below the length at 50% maturity. The MWCV was 17% for combined sexes. In spring, 4 year olds were the dominant age class, but from summer to winter, and overall, 3 year olds were the dominant age class. The 2011 age composition was similar to that observed in the 2010 fishing year, although there was a much higher proportion of 3 year old fish in 2011. The TAR 3 bottom trawl catch was comprised of young fish,

TAR 3 set net fishery – TAR 3 set net fishery samples were collected from processors in Motueka (after transfer from Kaikoura). Sixteen set net landings were sampled (60 fish per sample) from statistical area 018, with about 1000 fish sampled for biological information and otoliths. The overall characteristics of the sampled vessels and their fishing patterns were similar to all vessels indicating that sampling was representative of the fishery. The scaled length frequency distributions were unimodal for both males and females, with peaks at about 33 cm and 35 cm fork length, respectively, and most fish between 30 and 40 cm. The proportion male was 39%. There is no clear seasonal signal in the scaled length frequency distributions. The range of age estimates (N = 253) was 3–24 years, although 92% of sampled fish were less than 8 years old. Both male and female age distributions were unimodal, with peaks at about 5 years, and most fish 3–6 years old. The mean weighted c.v. for combined sexes was 18%. The 2011 age composition for the landed set net trawl catch was similar to that observed in the 2010 fishing year. The older fish (7 years and older) were landed in spring and summer whereas in the autumn-winter period the oldest fish was 6 years old.

1. INTRODUCTION

This report summarises three catch sampling programmes conducted from October 2010 through to September 2011 to estimate the age composition of tarakihi (*Nemadactylus macropterus*) captured in TAR 2 single bottom trawl, TAR 3 single bottom trawl, and the TAR 3 set net fishery off Kaikoura (Figure 1). In addition, a fishery characterisation was carried out for the last ten fishing years (2002 to 2011), to assess representativeness of the sampling in each of the three areas. The report describes the catch sampling programmes separately for each fishery.

This is the second consecutive year in which these fisheries were sampled for age composition. Previous sampling programmes are reported by Beentjes (2011) and Parker & Fu (2011a). In this report, fishing year is defined as the year in which the 12-month fishing year ends *i.e.*, the October 2010–September 2011 period is referred to as the 2011 fishing year.

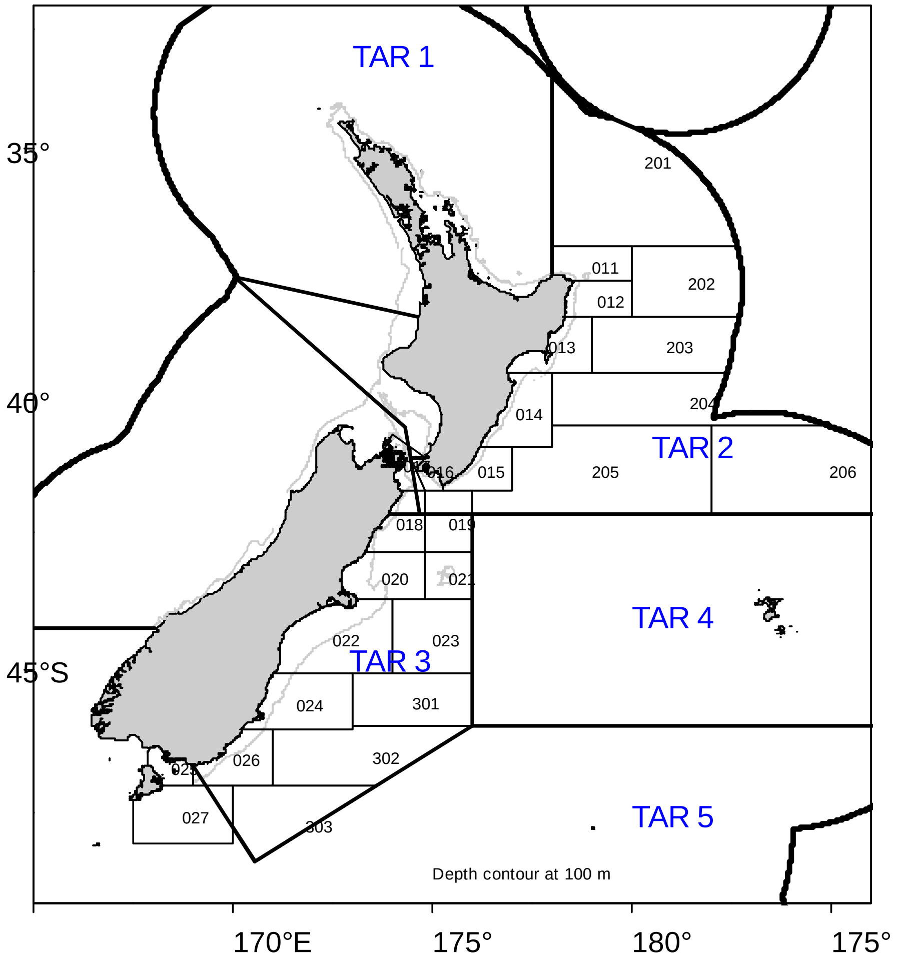


Figure 1: Map of tarakihi quota management areas and statistical areas within TAR 2 and TAR 3.

Specific objectives:

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

2. To conduct representative sampling to determine the length, sex and age structure of the commercial catch of tarakihi in TAR 2. The target coefficient of variation (c.v.) for the catch-at-age is 30% (mean weighted c.v. across all age classes).

3. To conduct representative sampling to determine the length, sex and age structure of the commercial catch of tarakihi in TAR 3. The target coefficient of variation (c.v.) for the catch-at-age is 30% (mean weighted c.v. across all age classes).

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

1.1 Biology

1.1.1 Distribution and depth range of tarakihi

Tarakihi are found throughout New Zealand including the Snares, Chatham Islands, and Three Kings Islands (Francis 2001), and are most common on the continental shelf (Ayling & Cox 1982). The mean depth of tarakihi from research trawl surveys throughout New Zealand is 182 m (range 11–486 m) (Anderson et al. 1998) although the mean is biased by the amount of deepwater survey effort. In contrast, east coast south Island (ECSI) research trawl surveys show a depth distribution of 30–250 m (Beentjes & Stevenson 2009). Catches of tarakihi, albeit small, are also taken when targeting hoki (mean depth 278 m) and elephantfish (mean depth 45 m) (Starr et al. 2009).

Off the east coast of New Zealand, median catch depth for commercial bottom trawlers landing tarakihi is about 80 to 100 m (Beentjes 2011, Parker & Fu 2011a), though this depends somewhat on statistical area and target species. A target tarakihi set net fishery in statistical area 018 operates off Kaikoura during summer/autumn. There are no published depth data from this fishery because depth is not a required field for the Catch Effort Landing Returns (CELR) or the more recent Net Catch Effort Landing Returns (NCELR) introduced in 2006–07, but anecdotal information indicates that the target set net fishery operates in depths of between 100 and 160 m (pers. comm. Dick Cleall, Kaikoura commercial set net fisher). This is distinct from the deeper water mixed species set-net fishery which operates year round and uses a larger mesh (175 mm or 200 mm), with the main catch comprising hapuku, ling, spiny dogfish, school shark, tarakihi, blue moki, and seal shark (Langley 2010).

1.1.2 Age and growth

Using whole otoliths, Vooren & Tong (1973) recorded a maximum age of about 18 years for tarakihi males and 22 years for females from the East Cape fishery in 1971. Vooren (1977) subsequently studied age and growth of tarakihi from the west coast of the South Island and the Chatham Islands, areas considered to be lightly exploited at that time, and estimated maximum ages of 33 years for males and 35 years for females for the west coast, and 39 and 41 years for the Chatham Islands. In 1987 a research trawl survey between Cook Strait and Banks Peninsula using R.V. *James Cook* was undertaken specifically to study the biology of tarakihi (Annala et al. 1990), and maximum ages of tarakihi were estimated at 42 years for both males and females. More recently an ageing project with the objective of validating the ageing methodology and assessing the between reader precision for otolith annual increment readings was carried out by Stevenson & Horn (2004). They found that tarakihi from the west coast of the South Island had maximum ages of 38 and 44 years for males and females, respectively, although there were few fish sampled in the fishery older than 15 years. Hence, tarakihi are relatively long-lived and populations are likely to comprise many cohorts.

1.1.3 Spawning

Tarakihi spawn in summer/autumn off the outer continental shelf (McKenzie 1961, Ayling & Cox 1982), but freshly fertilized eggs have also been found in shallow coastal waters (Robertson 1973). Known spawning areas include Bay of Plenty (Vooren & Tong 1973), outer Pegasus Bay, Conway Ridge, Cape Campbell, Cook Strait (Tong & Vooren 1972, Robertson 1973, Fenaughty & Bagley 1981), and the west coast South Island (Vooren 1975). Robertson (1973) was of the view that spawning did not occur south of Banks Peninsula, although this was not the conclusion of Vooren (1975). A summary of known spawning areas is given in Annala (1987) and Hanchet & Field (2001).

Juvenile tarakihi (less than 3 years old and 24 cm) are known to aggregate in nursery grounds in 20–100 m depth in Tasman Bay, the south west coast of the North Island, the Chatham Islands, and the east coast of the South Island (Vooren 1975). Catches of tarakihi from ECSI *Kaharoa* trawl surveys are consistent with this observation (Beentjes & Stevenson 2000, 2001, 2008, Beentjes et al. 2010) with individuals generally smaller than those from the WCSI trawl survey (Stevenson & Hanchet 2000b). Indeed most tarakihi caught on the ECSI trawl surveys are less than 30 cm in length (Beentjes & Stevenson 2008, Beentjes et al. 2010). Size at 50% maturity was estimated at around 27 cm and 28 cm for males and females respectively (Tong & Vooren 1972) and more recently by Parker & Fu (2011a) at 32 and 33 cm from the East Cape area. This indicates that most tarakihi caught in the ECSI surveys are immature pre-spawning fish.

1.1.4 Movement

Tagging studies of tarakihi around the Bay of Plenty indicate that tagged fish moved only short distances within the first year, but later recaptures showed much greater movements with some fish recaptured up to 200 km from the tagging site, but no fish moved out of TAR 2 QMA (Crossland 1982). Tagging of tarakihi in the Kaikoura area by Annala (1988) from 1986 to 1988 resulted in few returns, but of the recoveries, 17 were from the east coast North Island, 3 were from the west coast North Island, and 3 recoveries had moved south. This suggests a stock linkage between South and North Island QMAs with northward migration of tarakihi predominantly from TAR 3 into TAR 1 and TAR 2. Tagging of tarakihi is carried out every two years during the WCSI trawl surveys, but no recoveries have been reported yet.

1.2 Summary of catches

1.2.1 TAR 2

Tarakihi landings have been reported for both domestic and foreign fleets since 1968. The east coast of the North Island (TAR 2) has been the largest fishery since 1984. Biomass estimates of TAR 2 are not available. The total allowable commercial catch (TACC) for TAR 2 was 1 633 t from 1993 to 2004, and was slightly exceeded in the period 2000–2004. The TACC was raised by 10% to 1 796 t in 2005 under an AMP (Ministry of Fisheries 2008a), and was exceeded in 2006, 2009, and 2010. Since 2001, TAR 2 catches have averaged 1 766 t but have ranged between 1 638 t and 1 986 t (Figure 2). Landed catch decreased by about 300 tons in 2011.

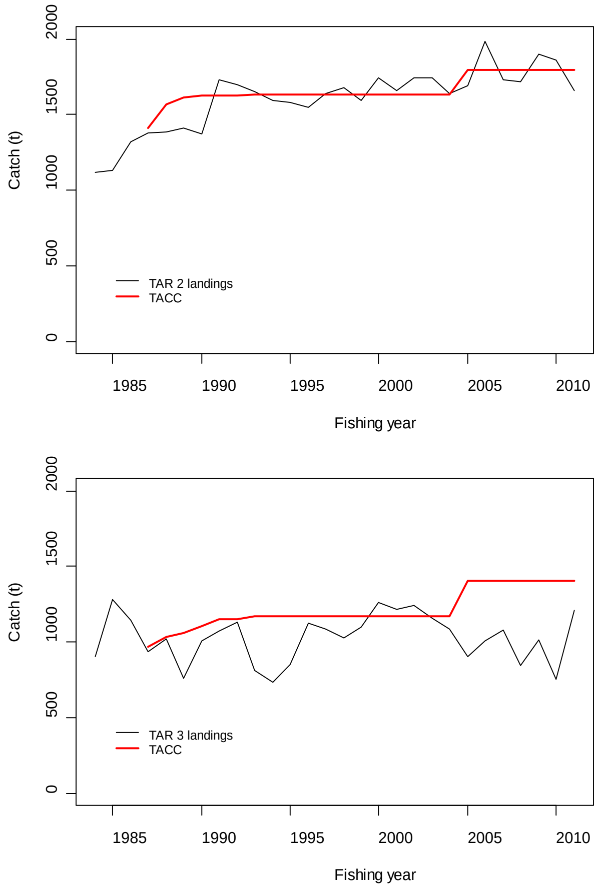


Figure 2: Reported catch of tarakihi in TAR 2[top] and TAR 3 [bottom] and TACC from 1984 to 2011. Landings (thin black line) and TACCs (thick red line) are from the tarakihi plenary summary document (Table 3) (Ministry of Fisheries 2011a). 2010 = 2009–10 fishing year.

1.2.2 TAR 3

TAR 3 is the third largest Quota Management Area (QMA) for tarakihi in terms of quota. A reconstructed catch history back to 1931 indicates that catches peaked in the mid-1940s to the mid-1960s with annual catches that were close to or exceeding 2000 t (Starr et al. 2009). Since tarakihi was introduced into the Quota Management System (QMS) in 1986, catches in TAR 3 have ranged from between 757 t and 1244 t and have averaged just over 1 000 t over the last 10 years (Figure 2).

The TACC was exceeded in three consecutive years (2000, 2001, and 2002) and then was subsequently increased by 20% in 2004–05 (1 169 to 1 403 t) under the Adaptive Management Programme (AMP) (Ministry of Fisheries 2008a). Following this increase, catches have been substantially less than the revised TACC in all fishing years (Figure 2).

2. METHODS

2.1 Catch and effort data sources

Catch and effort data for both TAR 2 and TAR 3 were extracted for the purpose of characterising the commercial fishery to design catch sampling programmes. Further, catch effort data for 2011 were used to assess the representativeness of the sampling conducted in the same year.

Catch and effort data were requested from the Ministry of Fisheries catch-effort database *warehou* as extract 8340. Analyses were conducted using the statistical software R. The data consist of all fishing and landing events associated with a set of fishing trips that reported a positive landing of tarakihi in TAR 2 or TAR 3 between 1 October 2001 and 30 September 2011. The fishing year extends from October 1 through September 30 of the next calendar year.

The estimated catch associated with the fishing events were reported on the Ministry of Fisheries Catch Effort Landing Returns (CELR), Trawl Catch Effort Returns (TCER), Trawl Catch Effort and Processing Return (TCEPR), and Net Catch Effort Returns (NCER). The green weight associated with landing events is reported on the bottom part of the CELRs and NCERs, or where fishing is reported on the two other forms it is recorded on the associated Catch Landing Return (CLR). TCEPR and TCER forms record tow-by-tow data and summarise the estimated catch for the top five species and eight species respectively (by weight) for individual tows together with latitude and longitude of the tow. CELR forms summarise daily fishing effort and catch, which are further stratified by statistical area, method of capture and target species and provide estimates of the top five species. NCER forms record set-by-set data and summarise the estimated catch for the top eight species (by weight) for individual sets together with latitude and longitude. Before October 2007 trawl vessels less than 28 m in length could use either CELR or TCEPR forms, whereas trawl vessels over 28 m were required to use TCEPR forms. From 1 October 2007 TCER forms were used by vessels over 6 m and less than 28 m (if less than 6 m the CELR is still used). NCER forms were introduced on 1 October 2006 for set net vessels over 6 m (if less than 6 m the CELR is still used).

The extracted data were groomed and re-stratified to derive the datasets required for the characterisation using a variation of Starr's (Starr 2003) data processing method as implemented by Manning et al. (2004), with refinements by Blackwell et al. (2006), and Manning (2007), and further modified by Parker & Fu (2011b). The method allows catch-effort and landings data collected using different form types that record data with different spatial and temporal resolutions to be combined. It also overcomes the main limitation of the CELR and TCEPR reporting systems (frequent non-reporting of species that make up only a minor component of the catch). The major steps are as follows.

Step1: The fishing effort and landings data are first groomed separately. Outlier values in key variables that fail a range check are corrected using median imputation. This involves replacing missing or outlier values with a median value calculated over some subset of the data. Where grooming fails to find a replacement, all fishing and landing events associated with the trip are excluded.

Step 2: The fishing effort within each valid trip is then re-stratified by statistical area, method, and target species.

Step 3: The greenweight landings for each fish stock for each trip are then allocated to the effort strata. The greenweight landings are mapped to the effort strata using the relationship between the statistical area for each effort stratum and the statistical areas contained within each fish stock.

Step 4: The greenweight landings are then allocated to the effort strata using the total estimated catch in each effort stratum as a proportion of the total estimated catch for the trip. If estimated catches are not recorded for the trip although a landing was recorded for the trip, then the total fishing effort in each effort stratum as a proportion of the total fishing effort for the trip is used to allocate the greenweight landings.

Step 5: The original intent of the merging process was to allow trip level landings data to be mapped to CELR effort strata. However, many species are captured in fisheries reporting using a combination of form types, and some may use TCEPR forms almost exclusively. The grooming and merging process also allows an evaluation of the amount of catch and effort that is not captured using TCEPR forms at the fishing event level. If significant, the best characterisation dataset is likely to be the merged trip-level data. But if the amount of lost catch and effort is predictable, minor, and stable over time and area, the estimated catch at the level of the fishing event provides a much more detailed dataset for characterisation and CPUE analysis. With the implementation of TCER and NCER form reporting, more species are recorded at capture and estimated catches are much improved, minimizing the need for the rollup procedure.

Processed product weights in New Zealand fisheries are converted to greenweight catches using species and product-form specific conversion factors (multiplicative constants). Product form conversion factors for many New Zealand species have changed several times since the full implementation of the QMS. This means that different amounts of greenweight catch are associated with the same amount of processed catch for particular product forms throughout the database. We standardised these changes relative to the latest conversion factor defined for each product state by applying the catch-consistency checking algorithm designed by Blackwell et al. (2006). This algorithm systematically compares the different catch weights recorded for a particular fishing trip against one another and returns the single most consistent catch type for each trip and explicitly and rigorously accounts for conversion factor changes.

The landings data provide a verified green weight landed for a fish stock on a trip basis. However, landings data include all final landing events – where a vessel offloads catch to a Licensed Fish Receiver, and interim landing events, where catch is transferred or retained, and may therefore appear subsequently as a final landing event (Middleton 2007). Starr's procedure separates final and interim landings based on the landing destination code, and only landings with destination codes that indicate a final landing are retained (see Table 2 in Starr 2007).

2.1.1 Groomed and rolled up catch and effort data

2.1.1.1 TAR 2 fishery

The MHR and the reported raw landings are similar for all years with the exception of 2010 (Table 1, Figure 3). The data grooming and merging procedure resulted in the loss of 3– 8% per year and overall a loss of 3% of the reported landings records. This loss occurred as records were removed because of issues such as invalid target species, invalid fishing method code, double counted landing code, and the roll-up procedure such as straddling statistical areas and unmatched trips. The estimated catch after merging and grooming data are also shown. In our analyses we used merged landings data as they are closer to the MHR and were adequate for characterising the fisheries relative to a catch sampling programme.

Table 1: Annual MHR landings (t) of TAR 2 from 2002–2011 used in the characterisation, total reported landings (raw landings), merged and groomed landings (merged landings), estimated catch from merging landings (estimated catch).

Fishing year	MHR	Raw landings	Merged landings	Estimated catch
2002	1 742	1 708	1 689	1 511
2003	1 745	1 730	1 699	1 506
2004	1 638	1 632	1 613	1 445
2005	1 692	1 723	1 689	1 516
2006	1 986	1 962	1 941	1 789
2007	1 729	1 720	1 681	1 523
2008	1 715	1 718	1 676	1 513
2009	1 901	1 897	1 831	1 611
2010	1 858	1 880	1 838	1 675
2011	1 659	1 641	1 521	1 427

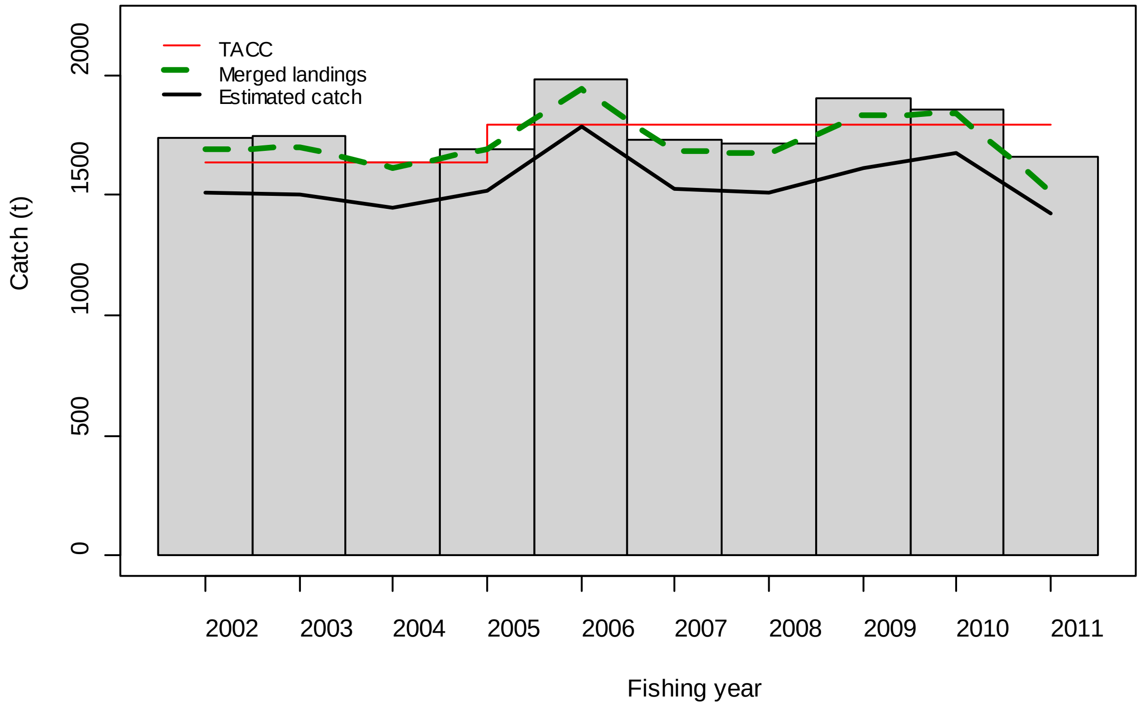


Figure 3: Total commercial catch in TAR 2 (2002–2011) from Monthly Harvest Return (MHR, grey bars), merged and groomed landings (merged landings, thick dashed line), estimated catch from merging landings (estimated catch, thick black line), and total allowable commercial catch (TACC, thin red line).

2.1.1.2 TAR 3 fishery

The MHR and the reported landings are similar for all years with the exception of 2010 (Table 2, Figure 4). The data grooming and merging procedure resulted in the loss of between 2 and 18% per year and overall a loss of 8% of the reported landings data. In our analyses we used merged landings data as they are closer to the MHR and were adequate for characterising the fisheries for the purposes of designing and assessing the representativeness of catch sampling programmes.

Table 2: Annual MHR landings (t) of TAR 3 from 2002–2011 used in the characterisation, total reported landings (raw landings), merged and groomed landings (merged landings), estimated catch from merging landings (estimated catch).

Fishing year	MHR	Raw landings	Merged landings	Estimated catch
2002	1 244	1 198	1 123	1 082
2003	1 156	1 170	1 146	1 063
2004	1 089	1 006	988	983
2005	905	877	863	852
2006	1 010	1 007	986	935
2007	1 080	1 087	1 014	992
2008	843	849	722	727
2009	1 017	1 076	891	895
2010	757	836	678	671
2011	1 207	1 223	1 056	1 040

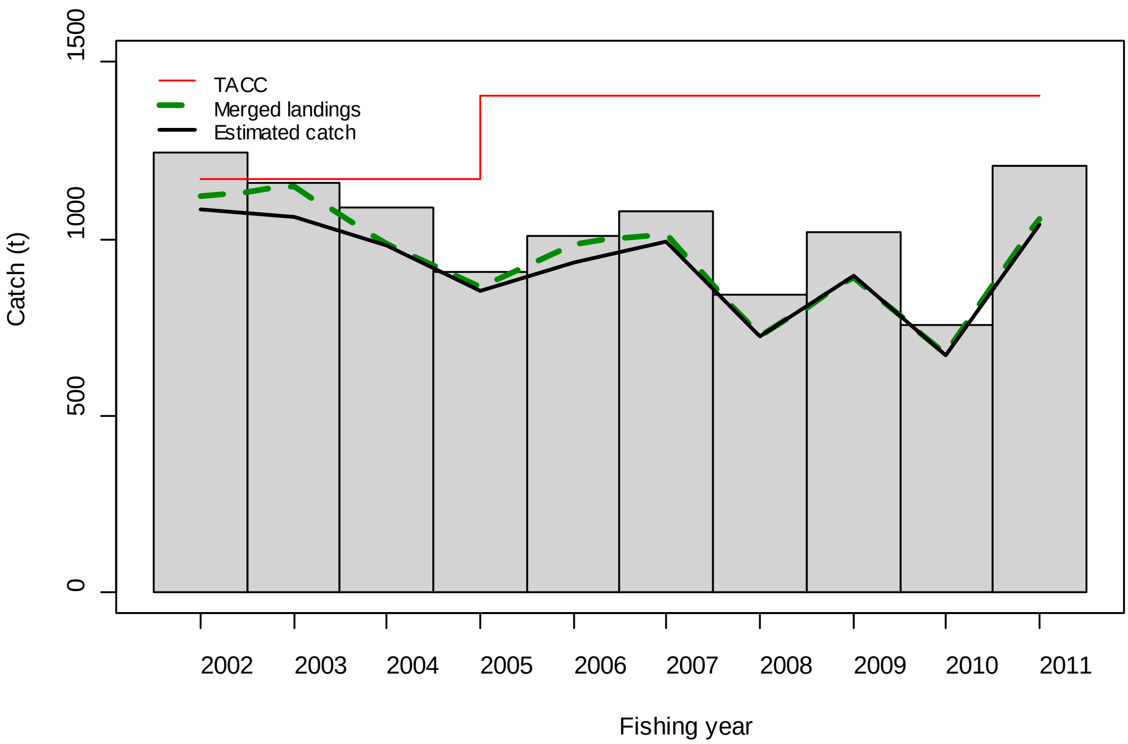


Figure 4: Total commercial catch in TAR 3 (2002–2011) from Monthly Harvest Return (MHR, grey bars), merged and groomed landings (merged landings, thick dashed line), estimated catch from merging landings (estimated catch, thick black line), and total allowable commercial catch (TACC, thin red line).

2.2 Catch sampling

The purpose of the catch sampling programme was to measure length and sex, and to determine the age distribution of the TAR 2 and TAR 3 catch landed in 2011 (See Parker & Fu 2011a, and Beentjes 2011 for a description of TAR sampling in 2010). Although samples obtained through an on-board observer programme would allow the actual location and fishing event associated with each sampled fish to be obtained, observer placement on small inshore vessels is not currently feasible, requiring catch sampling to occur on shore at landing from catch aggregated throughout the entire trip, assuming no discarding of tarakihi or location recording errors.

2.2.1 TAR 2 sampling design

All sampling was designed, conducted and analysed following recommended practices documented in "Guidelines to the design, implementation and reporting of catch sampling" (Ministry of Fisheries 2008b). Shore-based samplers ensured that fish in the landings sampled were caught using only one fishing method. Appropriate landings were identified through voluntary coordination between samplers and processor managers. In some cases, unsorted catch was trucked to secondary processing facilities, which made obtaining details of the landing difficult for samplers. But as long as no grading had occurred, catch was still sampled. The working group recommended that the TAR 2 sampling design for 2011 mirror the design implemented in the 2010 catch sampling programme (Northern Inshore Working Group, NINSWG 2010-59).

The sampling design comprised a single stratum, *i.e.*, no spatial or temporal divisions with different levels of sampling. Statistical area, target species, vessel size and gear type (bottom trawl only) were not used as strata to obtain discrete size or age compositions. Statistical areas 016, 017, 018, and 019 were excluded because of potential mixing of other stocks within those statistical areas and the low proportion of catches from those areas (see Figure 1). Sampling targeted two or three landings per month for 12 months. The samples were spread among five main processors in Gisborne and Napier as a proxy for statistical area, with about one-third of the samples taken from Napier and Gisborne processors that shipped unsorted catch to Auckland.

Sampling excluded trips where catch was from more than one quota management area. A few samples consisted of fish that were processed and frozen, and therefore length measurements were of filleted carcasses. The potential bias of measuring the length of filleted, frozen, and subsequently thawed carcasses is presumed to be small for tarakihi, but has not been investigated.

The NINSWG recommended a landing weight threshold of 750 kg for the 2011 sampling year to minimise the number of small landings while maximizing the proportion of the catch available for sampling. In 2011, 32% of the landings were greater than 750 kg, but these landings comprised 84% of the total landed weight (Figure 5).

Criteria for selecting landings to sample

1. Landing must be from a single vessel for a single trip using only bottom trawl gear in TAR 2.
2. Landing weight of TAR 2 must be over 750 kg.
3. Sample frequency in accordance with monthly sampling schedule, but more important to sample in relation to monthly landings.
4. The sample must not have been sorted or graded.
5. Each sample is comprised of 60 fish.

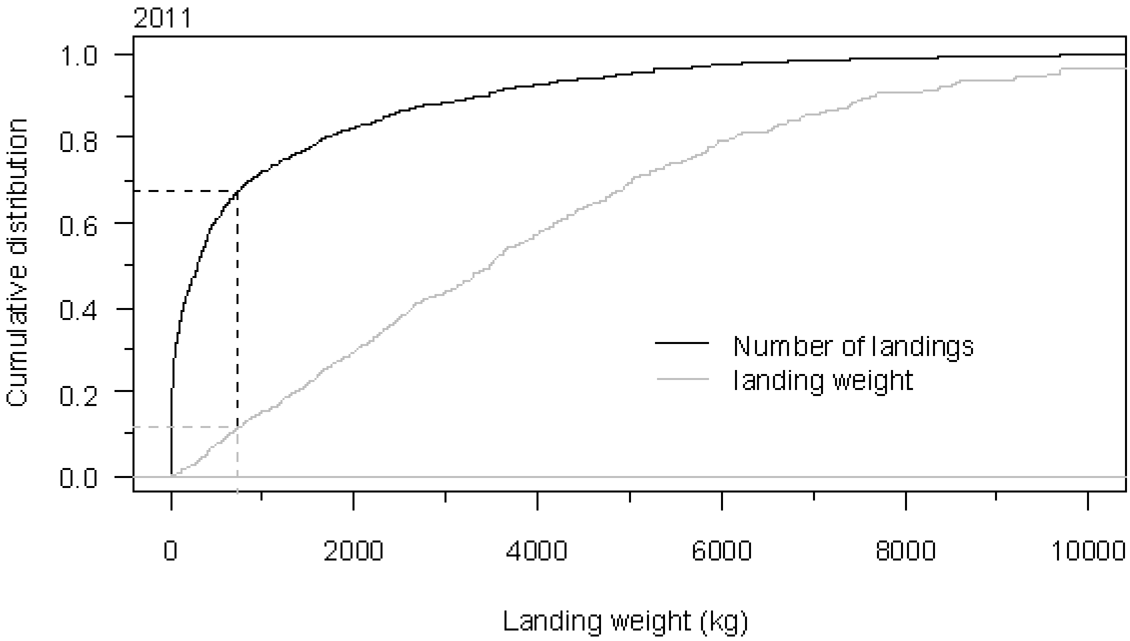


Figure 5. Cumulative distributions of TAR 2 landings by weight and numbers from 2011. Horizontal and vertical lines indicate the proportion of landings and cumulative weights below the 750 kg sampling threshold.

Sampling procedure

1. Details are obtained from each processor to complete the *Landing record*: i.e., vessel, landing weight (all fish), landed weight of TAR, landing date, statistical area fish caught.
2. Sample is assigned a Ministry of Fisheries *market* database landing number. This is typically the calendar year, the code for the sampling programme, and a two-digit sample sequence.
3. Approximately 10 bins of fish are chosen from which 60 individuals are selected by removing the six fish with their heads closest to the corner nearest to the sampler of each bin.
4. Length (FL), sex, and gonad stage (5 stage method, see Beentjes 2011) are recorded, and both otoliths are removed, cleaned of adhering tissue, dried, and placed in plastic Eppendorf vials, then inside otolith envelopes.
5. The full landing number (e.g., 2011 1101), species, fish number, date, length, sex and sampler initials are recorded on the otolith envelope.
6. Data are recorded on a waterproof *Otolith Inventory* form
7. A *Landing Record* form is completed at the end of the sampling.

All data collected were stored in the Ministry of Fisheries *market* database. Otoliths were stored at NIWA Greta Point in the otolith library collection and age results on the *age* database.

2.2.2 TAR 3 sampling design

The TAR 3 2011 catch sampling programme followed the recommendations of the NINSWG in December 2010 (NISWG 210/59). The design also follows the methods documented in “Guidelines to the design, implementation and reporting of catch sampling” (Ministry of Fisheries 2008b).

The sampling design in 2011 was the same as that used in 2010 with tarakihi landings stratified by method, statistical area, and season to allocate sampling effort in proportion to the catch from these strata (Beentjes 2011). This stratification was intended primarily to account for any spatial or temporal heterogeneity in the age composition.

Briefly, the two main fishing methods in TAR 3 are bottom trawl (about 75% of the catch), and set net (about 25% of the catch). Because both methods account for considerable catch they were sampled independently. Further, the set net fishery is likely to have a different selectivity to the trawl fishery, and also was thought to be more dependent on the seasonal spawning runs of mature tarakihi than the bottom trawl fishery in Pegasus Bay and Canterbury Bight. The targeted sample allocation included 40 bottom trawl and 16 set net landings in 2011 (Table 3).

Table 3: Bottom trawl (a) and set net (b) target sampled landings allocation and actual landings sampled for TAR 3 catch sampling in 2011. Samples were allocated to area and month combinations in proportion to catch from these strata using catch data from 2002–03 to 2007–08. Note that one BT landing in Apr-May from 024 was a set net landing sampled in error. BT, bottom trawl; SN, set net.

a)

		Allocated and sampled BT landings						
Stat area		Oct-Nov	Dec-Jan	Feb-Mar	Apr-May	Jun-Jul	Aug-Sept	Total
020	Target total	1	1	2	4	5	4	17
	Actual total	0	1	1	3	1	2	8
022	Target total	2	2	3	4	3	5	19
	Actual total	2	3	3	3	2	0	13
024	Target total	0	1	2	1	0	0	4
	Actual total	0	2	1	1	1	3	8
020, 022, 024	Target total	3	4	7	9	8	9	40
	Actual total	2	6	5	7	4	5	29

b)

		Allocated and sampled SN landings						Total
Stat area		Oct-Nov	Dec-Jan	Feb-Mar	Apr-May	Jun-Jul	Aug-Sep	
018	Target total	1	7	3	4	1	0	16
	Actual total	1	5	4	5	1	0	16

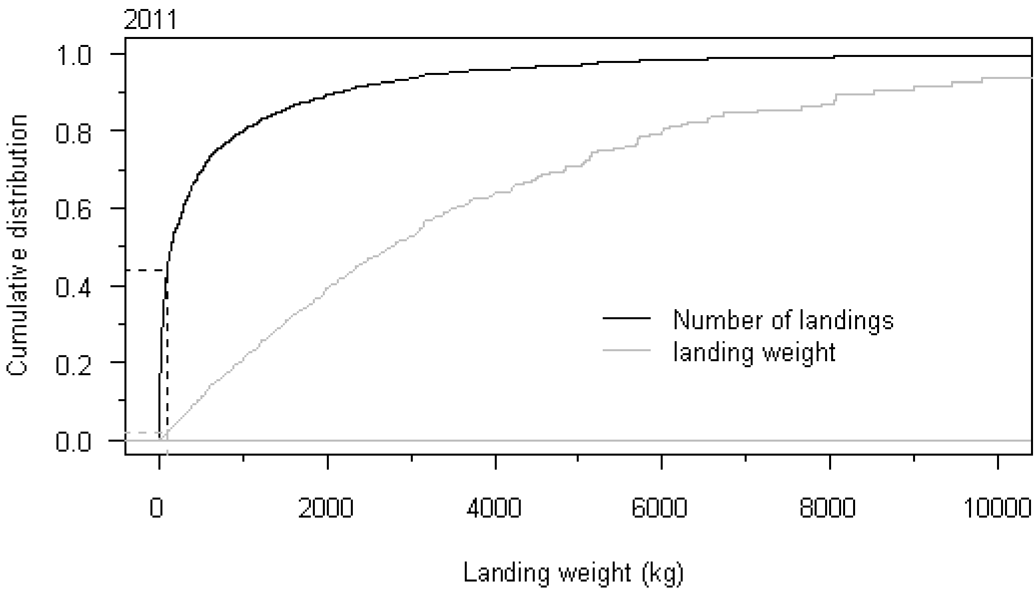
Processing sheds were contacted at least weekly or when samples were required to meet the sampling allocation target. The sheds sampled were:

> Set net fishery– Talley's Nelson, Talley's Motueka. Landings from Kaikoura were trucked to these processors in Nelson and Motueka.
>
> Bottom trawl fishery –United Fisheries Christchurch, Sanford Timaru, Talley's Timaru, Harbour Fish Dunedin.

For both the bottom trawl and set net fisheries the minimum landing weight to sample was set at 100 kg, which qualified 55% of bottom trawl landings and 43% of set net landings in 2011 (Figure 6).

All other sampling procedures were the same as described for TAR 2 above.

a)



b)

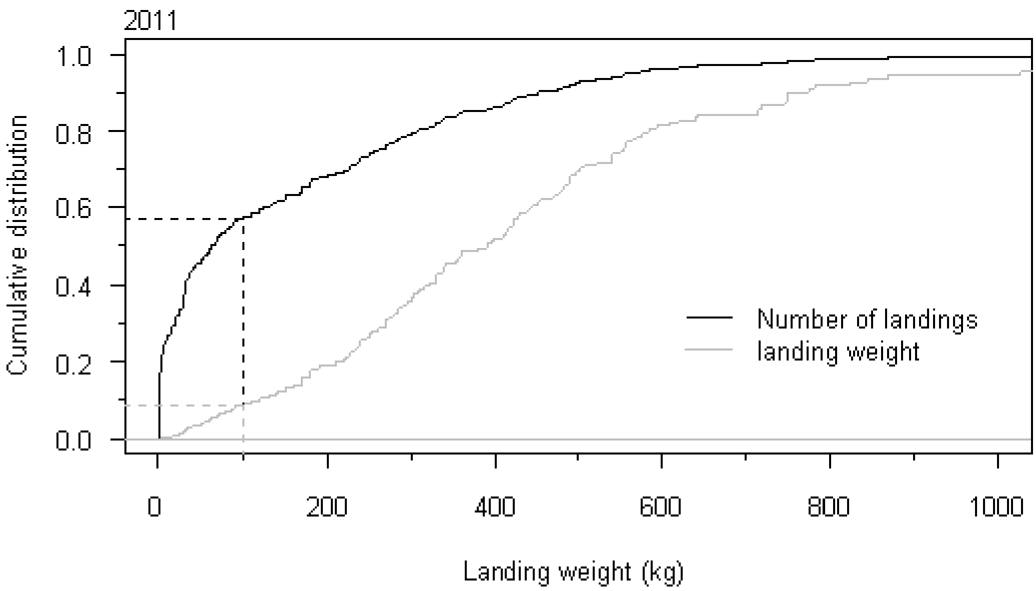


Figure 6: Cumulative landings of TAR 3 by number and weight for the bottom trawl fishery (a) and the set net fishery (b) for 2011. Horizontal and vertical lines indicate the proportion of landings and cumulative weights below the 100 kg sampling threshold.

2.3 Length composition

For TAR 2 and TAR 3, estimated scaled numbers-at-length were calculated using Catch-at-age software, developed by NIWA (Bull & Dunn 2002). Length data were scaled by landed weights of tarakihi from the sampled vessels, and by commercial catch from the sampling strata, *i.e.*, for TAR 3 bottom trawl this was the catch by two-month blocks in statistical areas 020, 022, and 024. For TAR 3 set net it was for commercial catch by two month blocks in statistical area 018. Scaled length-frequency distributions were estimated by sex, by season, and overall for all strata combined. The mean-weighted coefficients of variation (MWCV) were estimated using a bootstrapping routine (300 bootstraps).

2.4 Age determination

The direct ageing method was used to estimate the age composition of the fisheries in TAR 2 and TAR 3. This is also known as random age frequency sampling where otoliths are collected for all fish measured (60 fish per landing) and the age composition of the fishery is based on the age of a random selection of all sampled fish. In TAR 3 set net sampling the target was 16 landings so the expectation was that 960 individual lengths and otolith pairs would be collected (16 landings × 60 fish = 960). Similarly, for the bottom trawl fishery the expectation was that 2400 lengths and otolith pairs would be collected. For TAR 2 bottom trawl the target was 32 landings or 1920 otolith pairs.

The number of otoliths prepared and read for age was based on the requirement to meet a target MWCV of 30% or less, given available resources (Beentjes 2011, Parker & Fu 2011a). Given the results of the 2010 sampling (MWCVs near 20%), we selected a similar number of otoliths for each fishery. For TAR 3 this was about 350 set net and 600 bottom trawl otoliths, and for TAR 2 it was 750. These numbers are significantly less than the numbers of otoliths collected, so otoliths were randomly sub-sampled in proportion to landing weight, while ensuring that at least 10 otoliths from each sampled landing were included. The resulting sub-set comprised 345 otoliths from the set net fishery, 599 from the trawl fishery for TAR 3, and 783 from TAR 2.

Preparation and reading of otoliths collected in 2011 followed the same procedure and used the same age readers as in 2010. The methods are described in the tarakihi ageing standards and protocols document (NIWA 2011b) and were as follows:

1. Otoliths were rendered into thin-section preparations as follows: Tarakihi sagittal otoliths were individually marked on their distal faces with a fine sectioning line guide, under a stereomicroscope. The sectioning line followed the straightest dorso-ventral axis, orientated through the primordium. Otoliths were then embedded in an epoxy resin mould with standard curing @50 ºC. Thin sections were taken using a Struers Secotom-10 digital sectioning machine, with a section thickness of approximately 350 μm. Resulting thin section wafers were cleaned and embedded on microscope slides under a few drops of epoxy resin with a coverslip. Finally, these slides were oven cured at 50ºC.
2. Otoliths were read using transmitted light under a binocular microscope at a magnification of 100 times. Under transmitted light the wide opaque zone appears dark and the narrow translucent zone (hyaline) appears light.
3. Two elected core tarakihi “expert” readers (Mike Stevenson and Dane Buckthought) read all otoliths without reference to fish length.
4. Readers conformed to the documented protocols (above) when interpreting ring counts.
5. The forced margin method was used (see below).
6. A subsequent rereading of otoliths with discrepant age estimates was carried out by the two readers and a third adjudicating reader (Cameron Walsh) jointly with conferring.

Forced margin method

The forced margin method is described in the NIWA tarakihi ageing standards and protocols document (NIWA 2011b) and also defined in the glossary of the Ministry of Fisheries guidelines for New Zealand fish ageing protocols (Ministry of Fisheries 2011b).

> **Forced Margin /Fixed Margin** – Otolith margin description (Line, Narrow, Medium, Wide) is determined according to the margin type anticipated *a priori* for the season/month in which the fish was sampled. The otolith is then interpreted and age determined based on the forced margin. The forced margin method is usually used in situations where fish are sampled throughout the year and otolith readers have difficulty correctly interpreting otolith margins.

In this report age conforms to the “fishing year age-class” of tarakihi which is defined in Ministry of Fisheries guidelines for New Zealand fish ageing protocols as the age of an age group at the beginning of the New Zealand fishing year (1 October). It does not change if the fish have a birthday during the fishing season.

Fishing year age-class was assigned as follows: The wide margin (W) was assigned to otoliths collected in October–March. The resulting age of a fish recorded as 6W, for example, is 7 years. Otoliths collected from April–May were interpreted as L (Line), whilst those collected between June and September were interpreted as N (Narrow). Hence 7L and 7N were assigned ages of 7 years. The nominal birthday of tarakihi is taken as 1 May but has no bearing on the assignment of fishing year age-class.

Between-reader ageing precision was assessed by the application of the methods and graphical techniques documented in Campana et al. (1995) and Campana (2001); including APE (average percent error) and coefficient of variation (c.v.)..

2.5 Age composition

For each fishery (set net and bottom trawl for TAR 3, and bottom trawl for TAR 2), estimated scaled numbers-at-age were calculated using the NIWA program Catch-at-length-and-age (CALA, NIWA 2011a). 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 (see Section 2.3). 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).

3. RESULTS

3.1 TAR 2

3.1.1 TAR 2 fishery characterisation

The TAR 2 fishery was characterised for the purpose of designing and assessing the results of a catch sampling programme for 2011, focusing on data from the past decade. The reporting of catch effort data in the TAR 2 fishery has changed with the introduction of the TCER form in 2008 for vessels over 6 m. After 2007 CELRs are replaced by TCERs as the most commonly used form for reporting catch effort data. Similarly, few landings are reported on CELRs as CLRs are used (Parker & Fu 2011a).

The TAR 2 commercial catch in recent years has been taken almost exclusively (more than 99%) by bottom trawl (Table 4). Minor amounts of TAR 2 catch were landed using Danish seine, bottom longline, set net or mid-water trawl. The fishery characterisation is therefore based on the bottom trawl method.

The vast majority of tarakihi caught in TAR 2 are captured as the target species, with a minor proportion caught as bycatch while targeting red gurnard (*Chelidonichthys kumu*), blue warehou (*Seriolella brama*) or gemfish (*Rexea solandri*) (Figure 7). The proportion of the annual bottom trawl catch made whilst targeting tarakihi has increased from 2003 through 2006 to about 90%, but has been stable since then.

Table 4: TAR 2 total landed catch (t) and proportion of catch by fishing method from 2002 to 2011. BT, bottom trawl; DS, Danish seine; BLL, bottom longline; SN, set net; MW, mid-water trawl.

Fishing year	BT	BLL	DS	SN	Other	Total
2002	0.99	0	0.01	0	0	1 689
2003	0.99	0	0	0	0	1 699
2004	0.99	0	0	0	0	1 613
2005	0.99	0	0	0	0	1 689
2006	1.00	0	0	0	0	1 941
2007	0.99	0	0	0	0	1 681
2008	0.99	0	0	0	0	1 676
2009	0.99	0.01	0	0	0	1 831
2010	0.99	0	0	0	0	1 838
2011	0.99	0.01	0	0	0	1 521
Total	0.99	0	0	0	0	17 178

Trawl catches are taken consistently throughout the year with no strong seasonal pattern, though the largest catches were made in October and November during the past two years. Most catch is from targeted tows in every month and in each statistical area (Figure 8), that is, there is no spatial or temporal trend in the proportion of catch from targeted TAR fishing. Statistical area 013 was the dominant area overall for TAR 2 catch, with the majority of TAR 2 catch typically occurring north of Hawkes Bay (see Figure 1 for statistical area locations). Statistical areas 011, 012, and 014 showed similar catches each year.

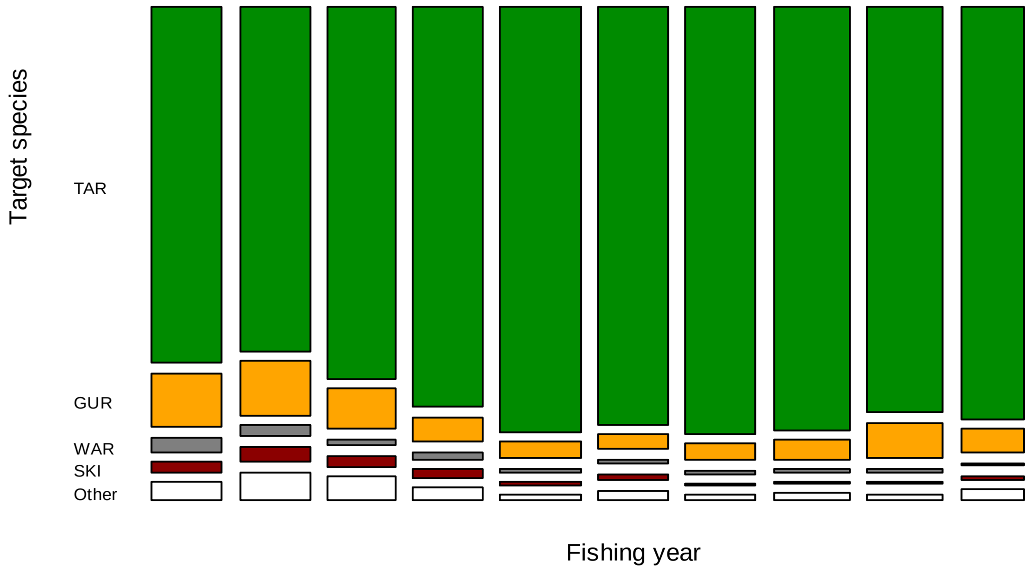
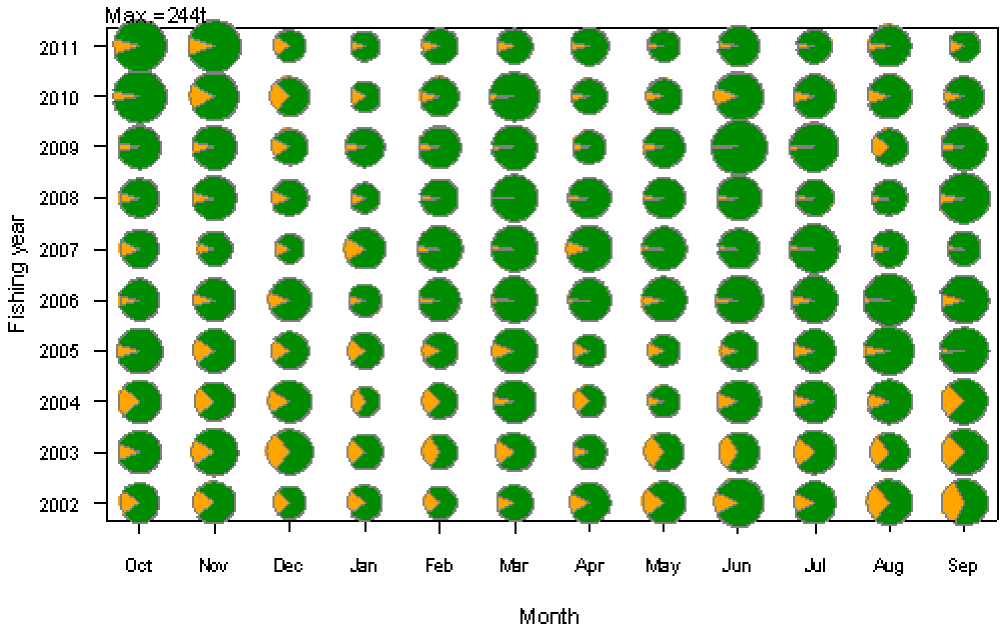


Figure 7: Annual proportion of TAR 2 reported by target species, 2002–2011.

Different sized trawl vessels historically reported fishing effort and catch using different forms with different levels of detail. However, since 2008, almost all catch has been reported using the Trawl Catch Effort Reporting (TCER) forms (Parker & Fu 2011a). TAR 2 is often captured as the target species, and therefore usually listed in the estimated catch. Almost all vessels now report tow-level catch data (Parker & Fu 2011a). Therefore, estimated catch data tracks the pattern in total landings using all forms fairly well and results in a good estimate of landed catch (see Figure 3).

(a)



(b)

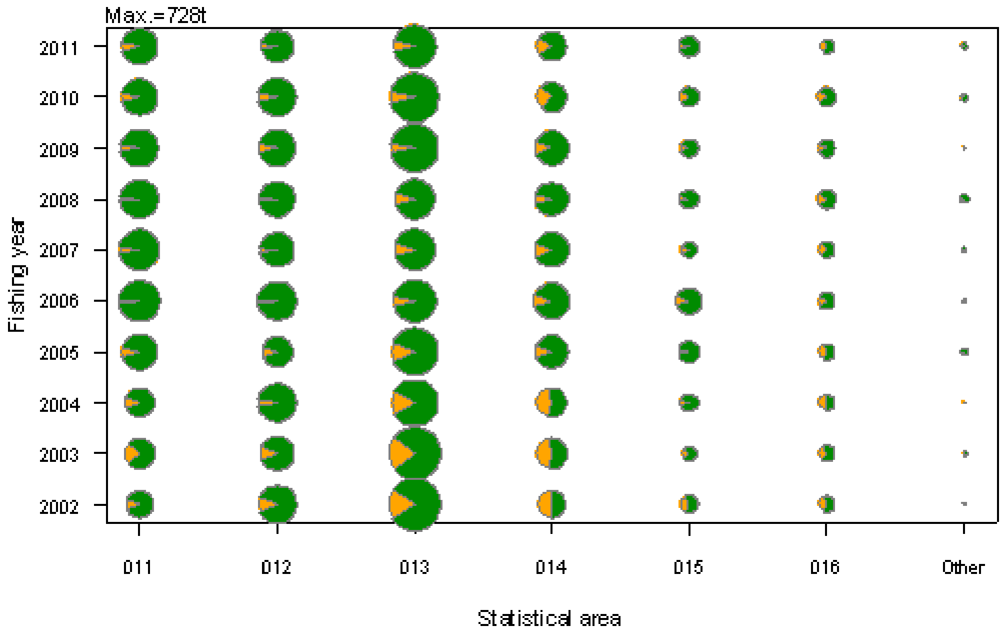


Figure 8: Pie charts of annual TAR 2 landings by (a) month and (b) statistical area, 2002–2011. Pies show the proportion of catch in each cell landed as target (dark) or non-target (light).

Most of the TAR 2 catch is landed through one of four ports (Gisborne, Napier, Tauranga, and Wellington). The amount of catch in each port has been relatively consistent over the past decade, though the amount landed into Wellington has varied since 2008 (Figure 9a).

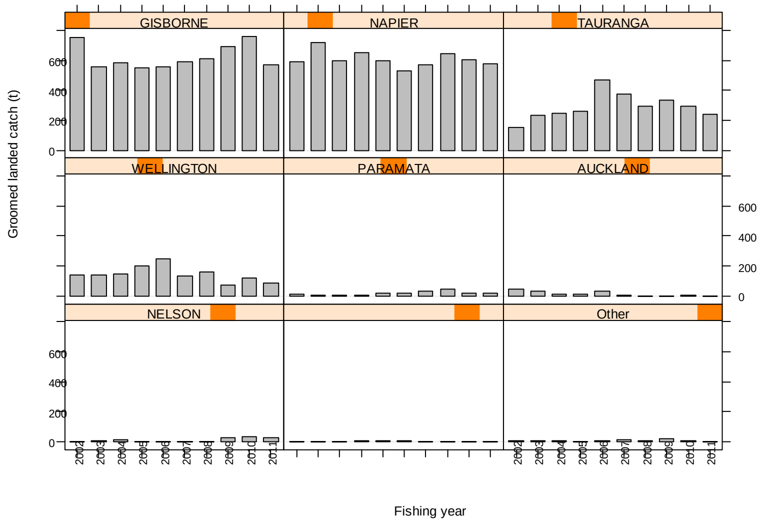
Although there has been some seasonal fluctuation in landed catch within Gisborne and Napier, there was no consistent pattern among ports. There has been some tendency for higher landings in Gisborne and Napier in the winter and spring months, that was not observed in Tauranga or Wellington (Figure 9b).

Although only six statistical areas in TAR 2 are routinely fished for tarakihi, and there was overlap in the port of landing, there were distinct patterns in location of the catch for each port (Figure 9c). Gisborne landings were primarily from fish caught in statistical areas 011, 012, and 013. Napier landings were primarily from fish caught in areas 012, 013 and 014, Tauranga landings were from fish caught in areas 011 and 012, and Wellington landings were from areas 014, 015, and 016.

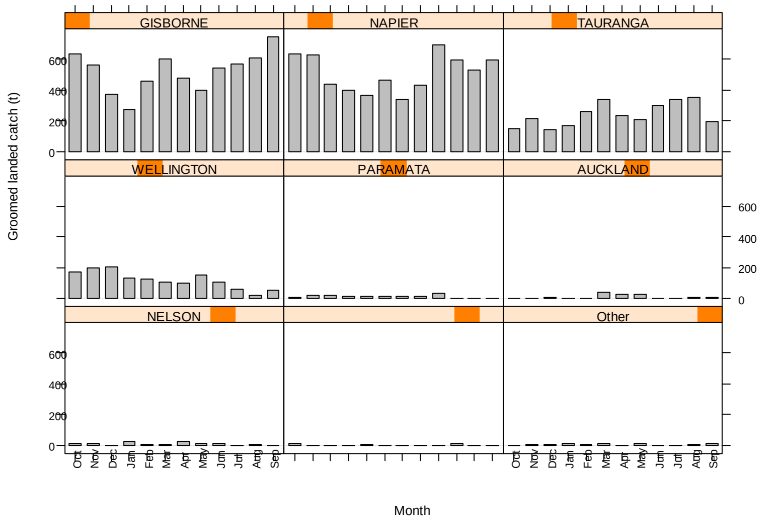
With the increased use of TCERs the spatial distribution of TAR 2 catches over the past five years can now be described more accurately than with statistical area alone. Tow position data showed a continuous band of reported catch following the entire coastline from Wellington to around East Cape (Figure 10). Therefore, almost all catch occurred in the shoreward margin of each statistical area. Some scattered catch was reported in very deep water east of Hawkes Bay. This was likely to be due to recording errors in tow position data.

Plots of the distribution of fishing effort variables showed some significant changes during the past decade (Figure 11). Fishing duration changed the least, but even this became less variable with time and is centred on 3.5 h tows. Tow speeds were mainly over 3 knots before 2008, but reduced to less than 3 knots since then. Trawl headline height has typically been about 4 m, and became less variable in recent years. Trawl width was variable over the past decade with no trend. Vessels landing TAR 2 generally fished waters in 100–200 m, though the median depth declined during the past decade. The median size of vessels was constant, but there was reduction in the number of larger vessels after 2008.

(a)



(b)



(c)

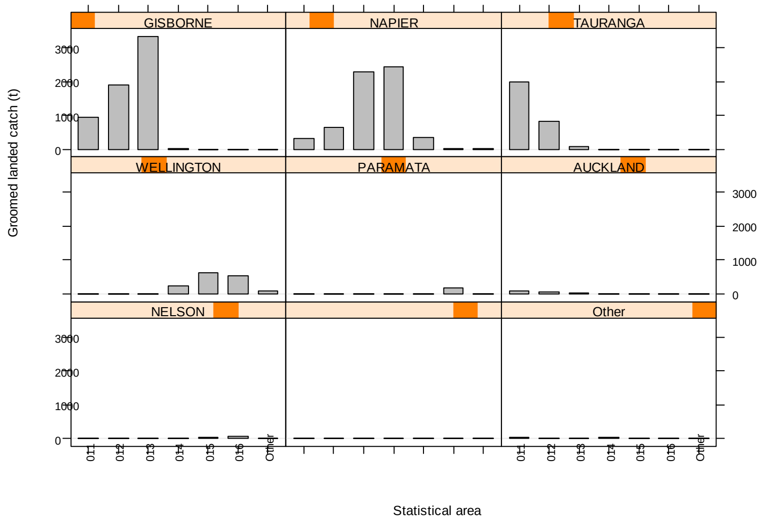


Figure 9: Distribution of landed catch of TAR 2 by major port and (a) year, (b) month, and (c) statistical area, 2002–2011.

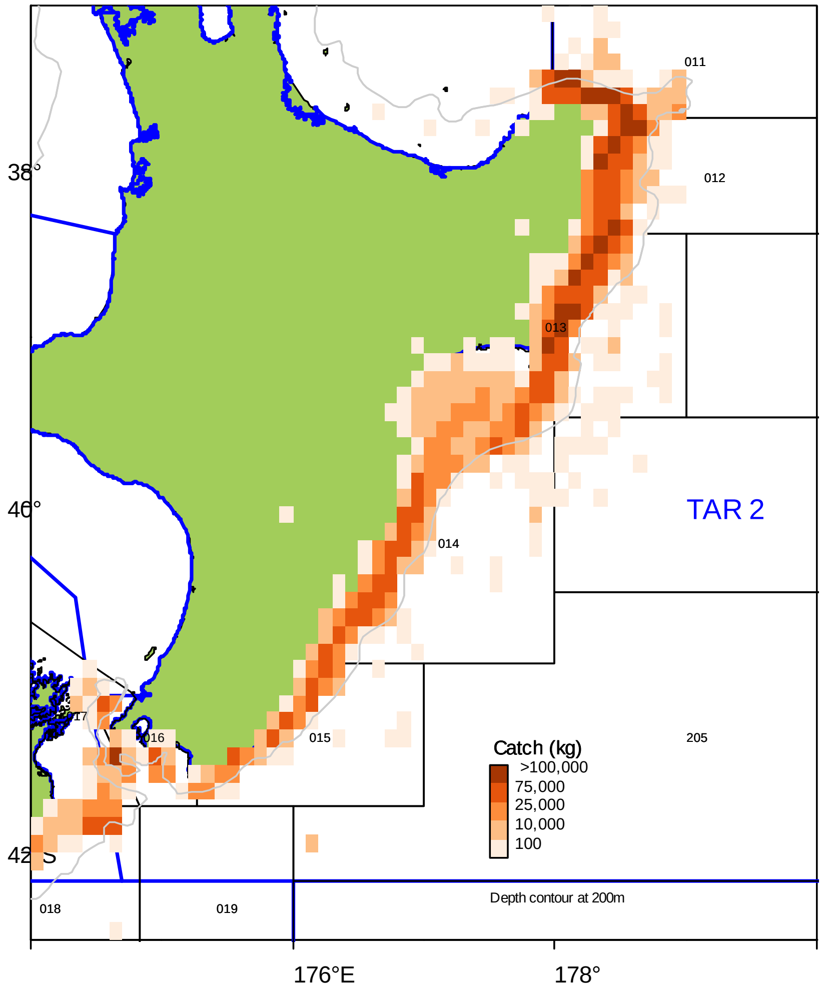


Figure 10: Total fine scale spatial distribution of TAR 2 catch (0.1 degree blocks) within each statistical area, 2008–2011 for all vessels landing TAR 2. The 200 m depth contour is shown as a light grey line.

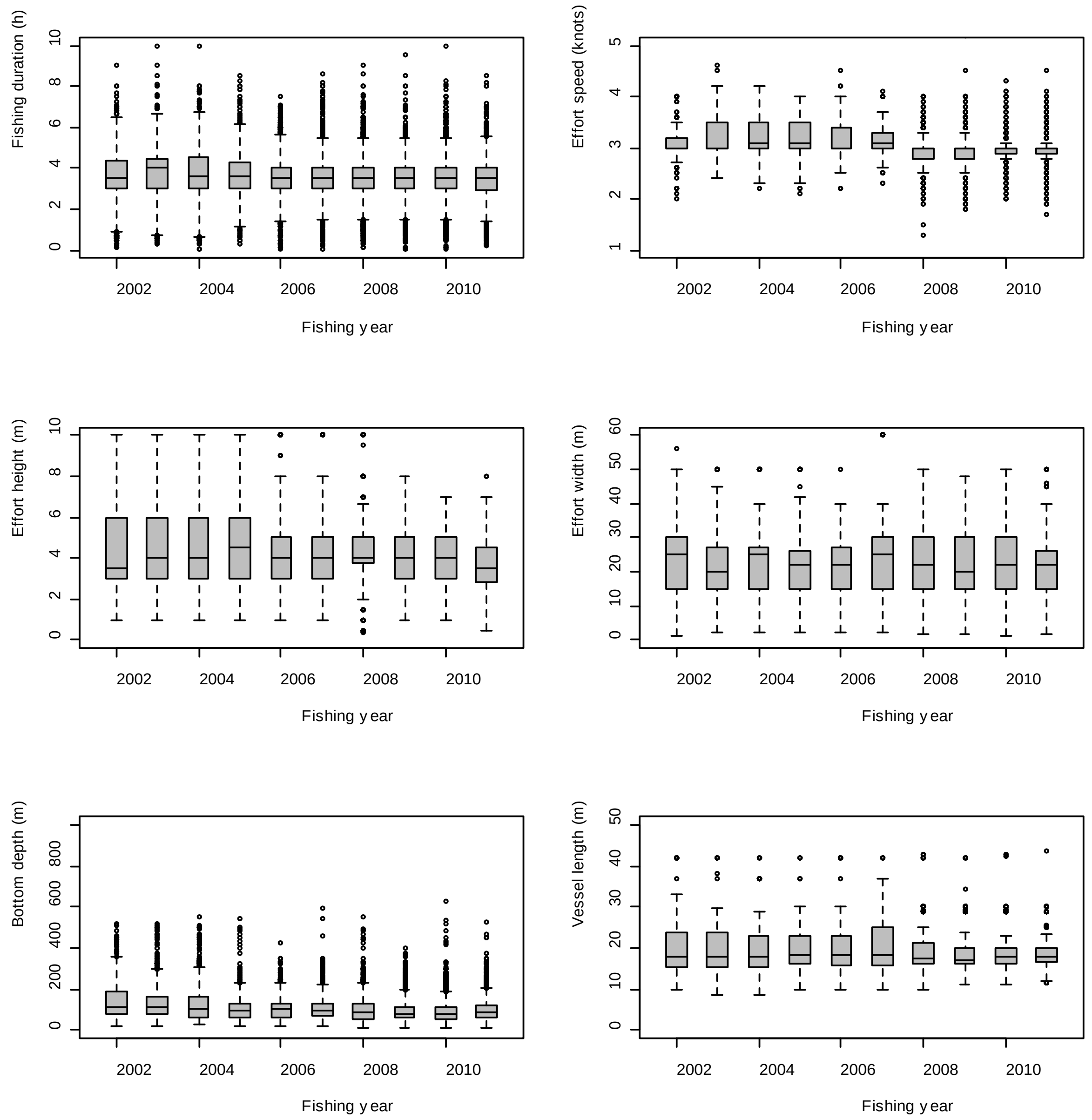


Figure 11: Characterisation of fishing effort for vessels landing TAR 2, 2002–2011. For each bar, the horizontal line indicates the median, top and bottom of the bar indicate the interquartile range, error bars indicate 1.5 times the interquartile range, and values outside this range (outliers) are indicated with circles.

3.1.2 TAR 2 bottom trawl catch sampling

Thirty samples were obtained, slightly below the target of 32 samples, though most of this was due to the late start of the project contract and coordination with remote processors (Table 5). Processors were very cooperative in providing access to landed catch and providing details of landings for record keeping. Because sampling was conducted in a remote port and catch was weather dependent, predicting the availability of landings was a logistical challenge. In some cases, a processor selected, weighed, and then processed and froze fish carcasses for sampling to occur at a later date. This enabled staff to minimize the number of trips to Napier and Gisborne but also resulted in some mismatch with the monthly pattern of fishery landings.

Table 5: Number of TAR 2 samples targeted in 2011 by month and the number of samples obtained. Each sample consisted of 60 fish.

Month	Samples targeted	Samples obtained
October	NA	NA
November	2	1
December	3	3
January	3	2
February	3	5
March	3	2
April	3	2
May	3	4
June	3	3
July	3	4
August	3	2
September	3	2
Total	32	30

3.1.2.1 TAR 2 representativeness

Samples were obtained from fish landed in Napier and Gisborne. Vessels sampled were termed the "core" fleet. The characteristics of the core fleet were similar to the fleet as a whole, although precise comparisons are not useful because the number of core fleet vessels was small. A comparison of recorded fishing effort variables showed that the core fleet had similar fishing duration and speed to the entire fleet for the recent past, but tended to have lower (but a wide range of) headline heights (Figure 12). The core fleet vessels were among the smaller vessels in the fleet targeting TAR 2 historically, but became more similar in size during the past few years.

The depths fished during the sampled trips were generally similar to the distribution of depths fished for the entire fleet in 2011, though the median depth of the latter was somewhat lower (Figure 13). Both distributions show that almost all the effort was less than 150 m depth. The depth distributions for all trips landing TAR 2 generally increased from north to south and were shallowest in areas 012 and 013. They also varied by target species, being slightly shallower for GUR and deeper for SKI, but still spanning the depth range for TAR target tows (Figure 14).

The core fleet landed 43% of the total TAR 2 catch (38% in Napier and 72% in Gisborne). This resulted in 11.5% and 3.7% of the total catch being sampled in Gisborne and Napier respectively, or 5.5% overall.

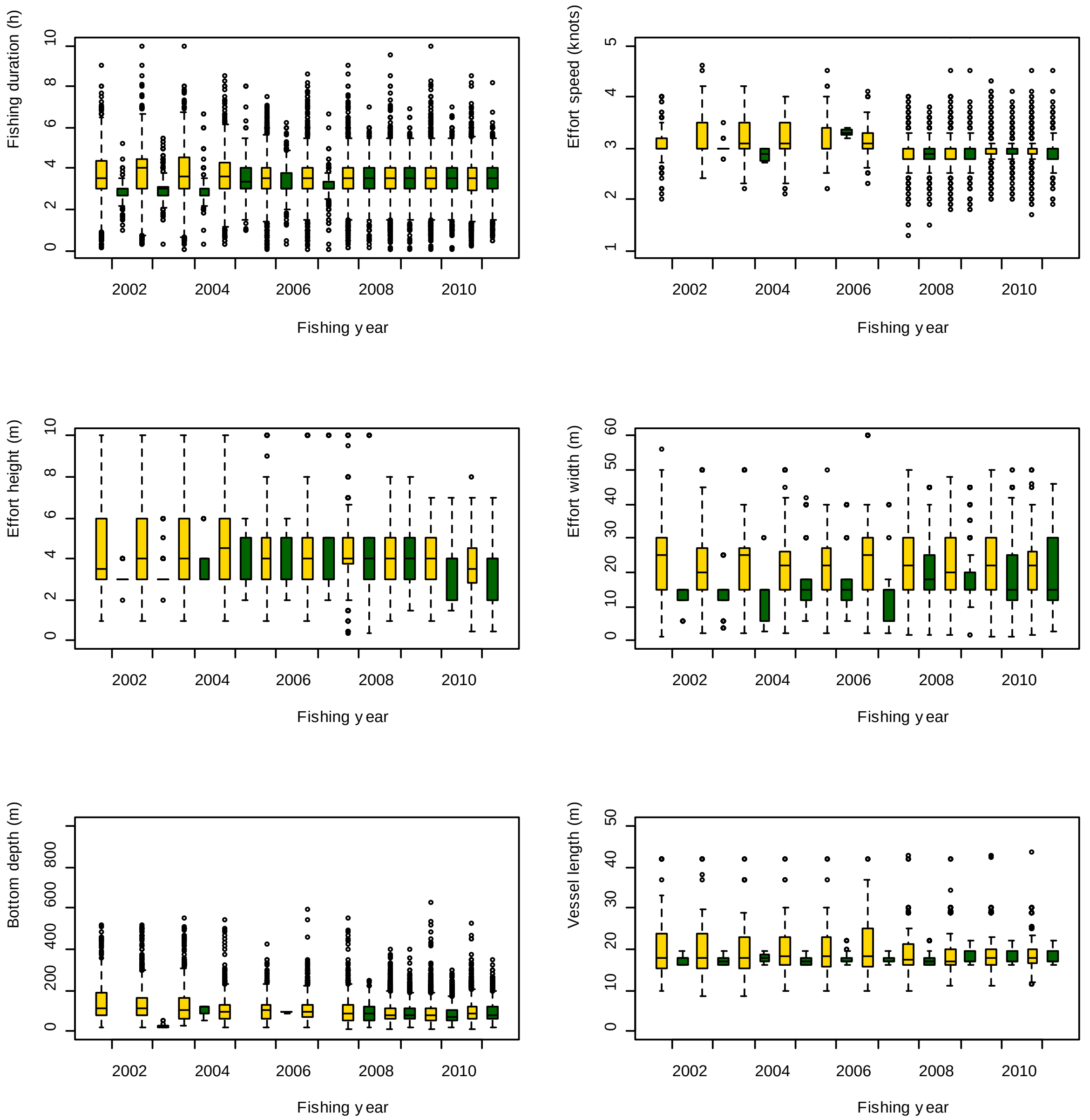


Figure 12: Characterisation of fishing effort for vessels landing TAR 2, 2002–2011. Light bars indicate the distribution of values for all vessels, dark bars indicate the distribution of all values for sampled vessels only (core fleet). For each bar, the horizontal line indicates the median, top and bottom of the bar indicate the interquartile range, error bars indicate 1.5 times the interquartile range, and values outside this range (outliers) are indicated with circles.

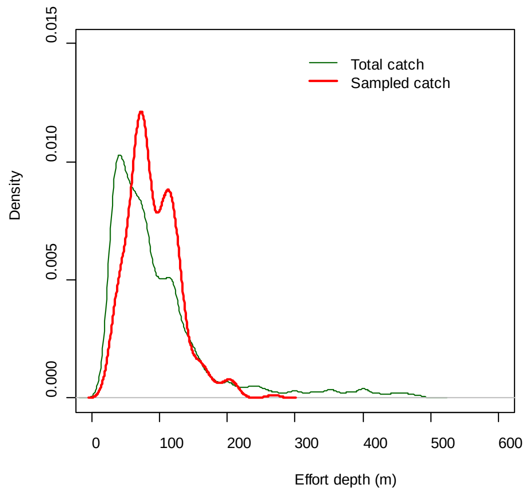
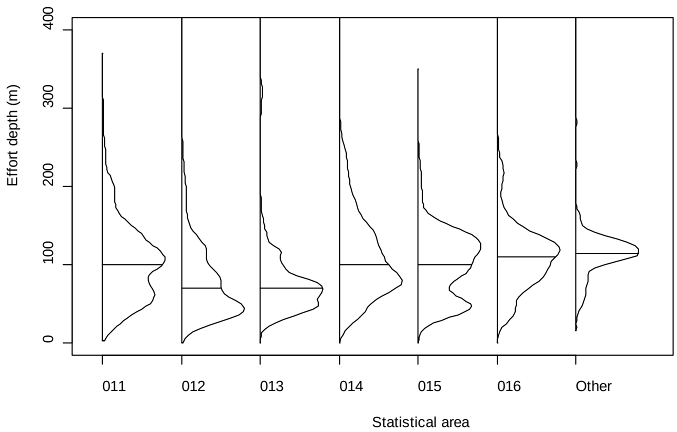


Figure 13: Depth distribution of TAR 2 target fishing in 2011 for all tows and for tows where catch was sampled for length and age distribution.

(a)



(b)

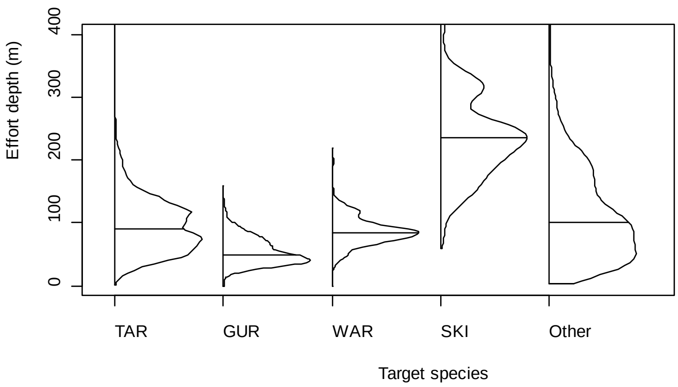


Figure 14: Depth distribution of tows from trips landing TAR 2 by (a) statistical area and (b) target species. Horizontal line indicates median of the distribution.

Although the sampling design prescribed the numbers of samples to be taken each month, the actual landings in each month were expected to be variable in any given year. Figure 15a shows the actual proportion of total annual catch landed by month and statistical area, and the corresponding proportion of the total catch landed and sampled in that same division. Because of the late programme start, October was not sampled, and only one sample could be sampled in November. Additional samples were obtained in December in recognition that October and November typically showed the largest landings. Otherwise, the relative proportions in the landings versus sampled catch were variable due to coordination issues with sampling in a remote port, as occurred in 2010.

Statistical areas were fairly well sampled, except that area 011 was oversampled and area 014 was under sampled (Figure 15b). These two areas do not contribute a great deal to the catch compared to statistical area 013. Note that statistical areas 015 and 016 were excluded from the sampling programme by design. As most of TAR 2 catch resulted from targeted tows, the proportion sampled by target species matched the distribution of landings well (Figure 15c). One strength of the random age frequency sampling method is that typically more samples are taken than are needed from each stratum so that otoliths can be selected in proportion to the actual total landing weights for the entire season to approximate the representative sample size for each landing. The representativeness of sampling among temporal or spatial strata is achieved in the scaling procedures.

3.1.3 TAR 2 length and age composition of the catch

Length composition of the catch

The length distributions were uni-modal. Males showed a length mode that was 3 cm smaller than for females, and the maximum size was somewhat larger for females, but otherwise the two distributions had a similar range of lengths and overall shape. Size distributions separated by season showed similar characteristics, different only in the sample sizes contributing to each season and sex (Figure 16). The sex ratio was 50% female and the overall MWCV was 18.8%.

Ageing precision

Age readings were very consistent between readers, with an average percent error (APE) of 1.6 and a c.v. of 2.27% (Figure 17). Only 16 of 783 readings (2%) disagreed by more than one year (Figure 17a, b), and there were no trends in discrepancies across the age range (Figure 17b, c). The range of final agreed age estimates was 2–26 years. Note that a reference set for TAR 2 has not yet been developed, so no reader agreement with previous TAR 2 ages was conducted.

Age composition of the catch

There were no strong differences in age composition between males and females (Figure 18). The overall mean weighted c.v. for the age composition of TAR 2 catch in 2011 was 11.7%, well below the target of 30%. These values are also influenced by the number of age classes present and the variability in the proportions at age among landings. Therefore, these sample sizes and associated c.v.s should be used with caution if used to predict c.v.s in other areas with different expected age compositions. The actual values plotted in Figure 18 are given in Appendix 1.

The proportion of three year old fish increased throughout the year, as occurred in 2010, and became dominant by winter. However, on an annual basis the most common age was 3 for males, but 5 for females, with an overall modal age of 5. The vast majority of the catch was 3–6 years old with fewer than 5% greater than 9, and fewer than 1% greater than 15 years.

The sex ratio was close to 1:1 in each season, and aside from the seasonal increase in 2 and 3 year olds, the remainder of the age composition did not change seasonally. This indicates that there was no migration of older, mature fish (male or female) into or out of the fishery during the year.

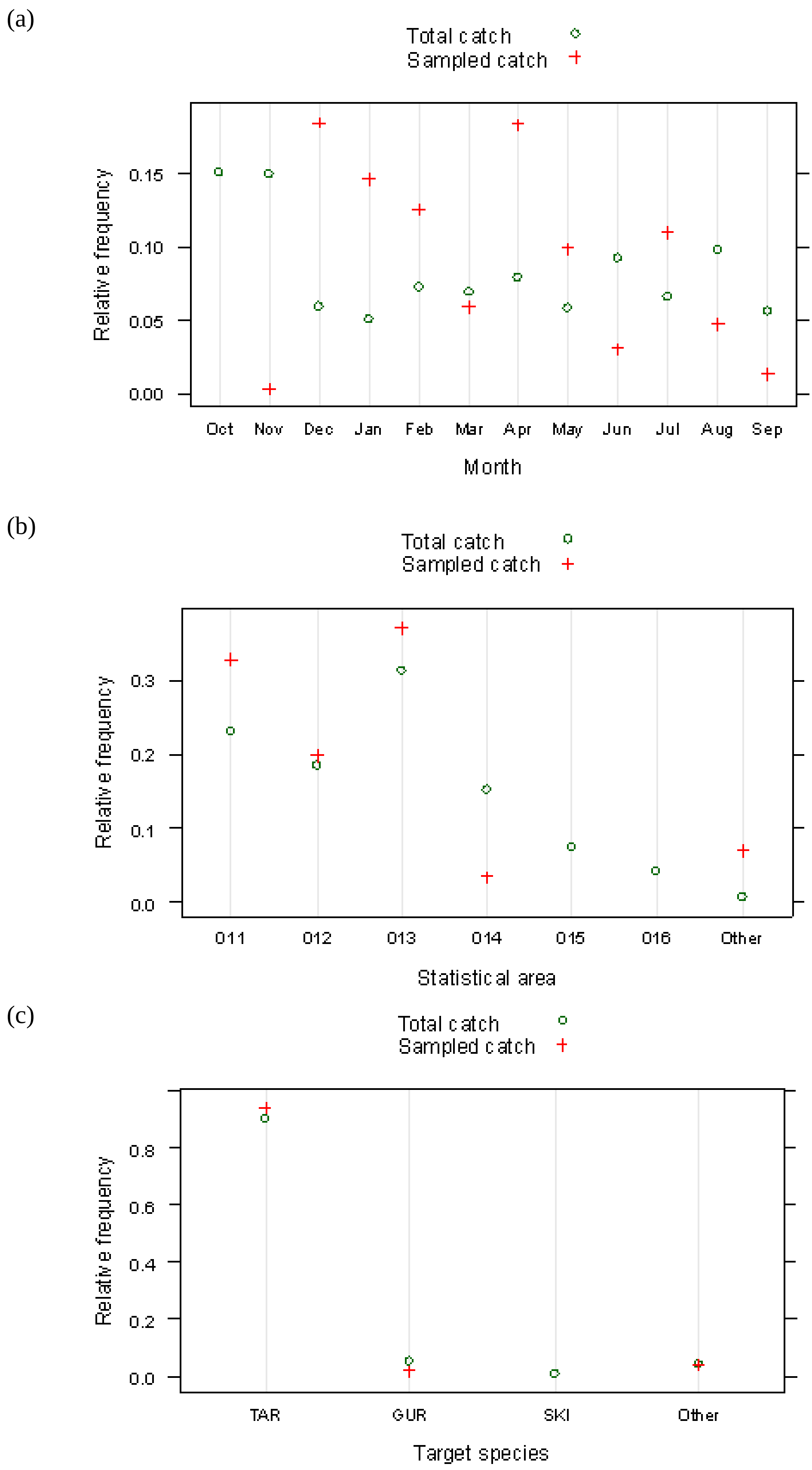


Figure 15: Proportion of total landed catch (circles) and the proportion of sampled catch (crosses) of TAR 2 that occurred in each (a) month, (b) statistical area, and (c) target species in the 2011 fishing year.

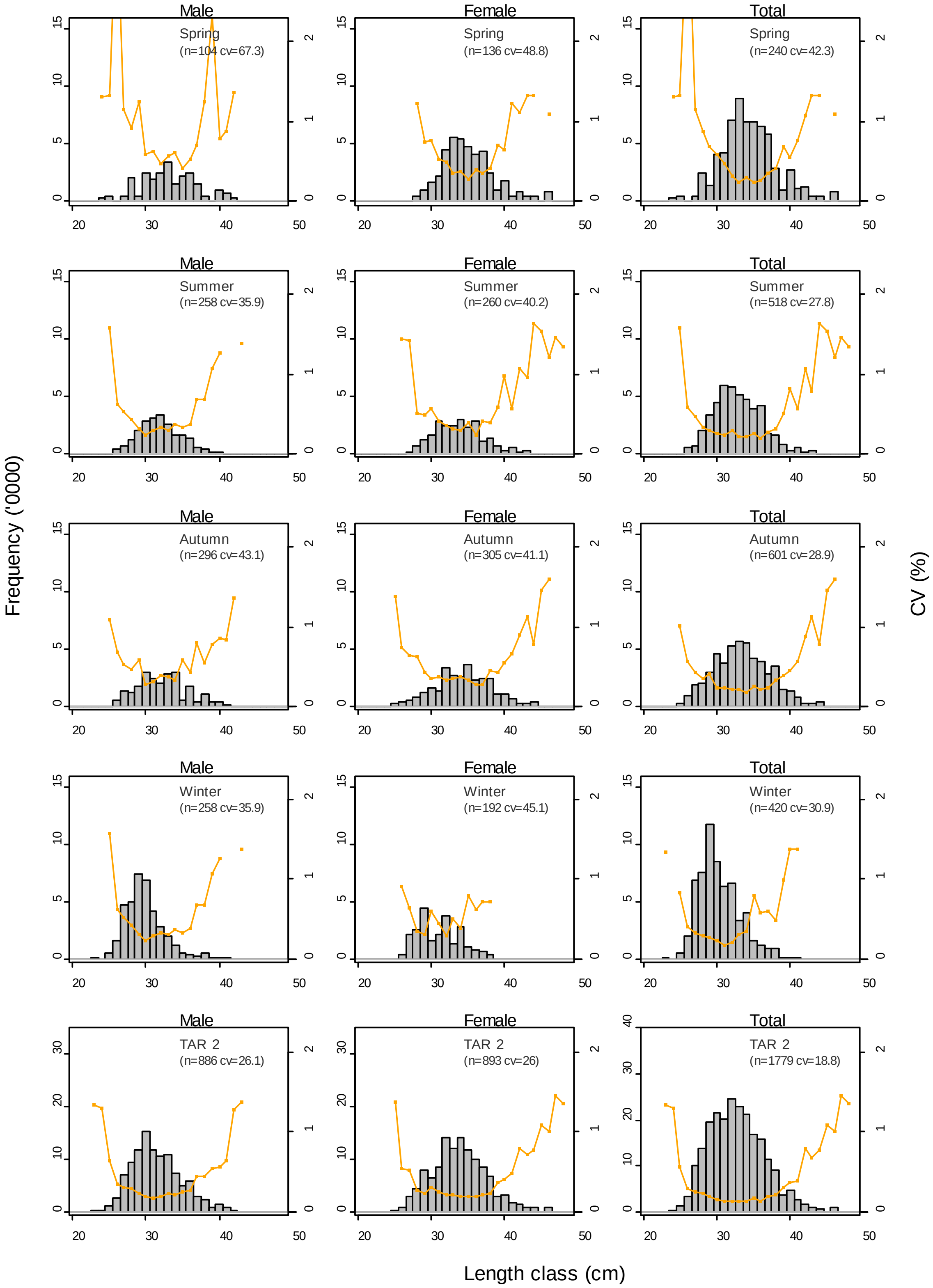


Figure 16: Scaled length frequency distributions for TAR 2 landings in the 2011 fishing year, segregated by sex, and stratified by season sampled. Line indicates the c.v. for each length class. n, number of fished measured; cv, MWCV for the entire distribution.

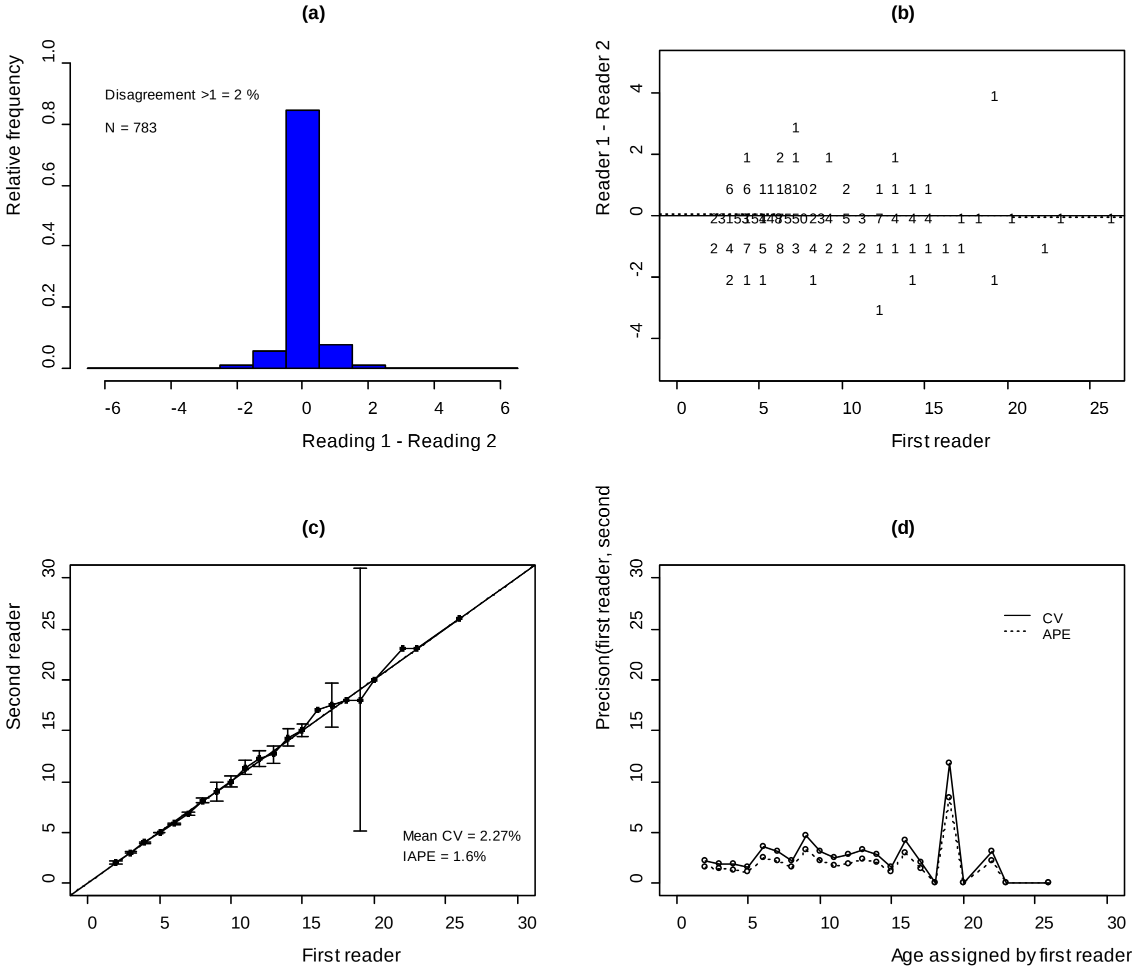


Figure 17: Age reader comparison plots for TAR 2 BT 2011: (a) histogram of age differences between two readers; (b) Difference between reader 1 and reader 2 as a function of the age assigned by reader 1. The number of fish in each bin is plotted as the plot symbol; (c) Age bias plot, showing the correspondence of ages between reader 1 and reader 2 for all ages. Error bars indicate the c.v. of the ages for each age by reader 1; (d) Plot of the c.v. and the average percent error (APE) for each age as assigned by the first reader. In panels b and c, solid lines show perfect agreement, dashed lines show the trend of a linear regression of the actual data.

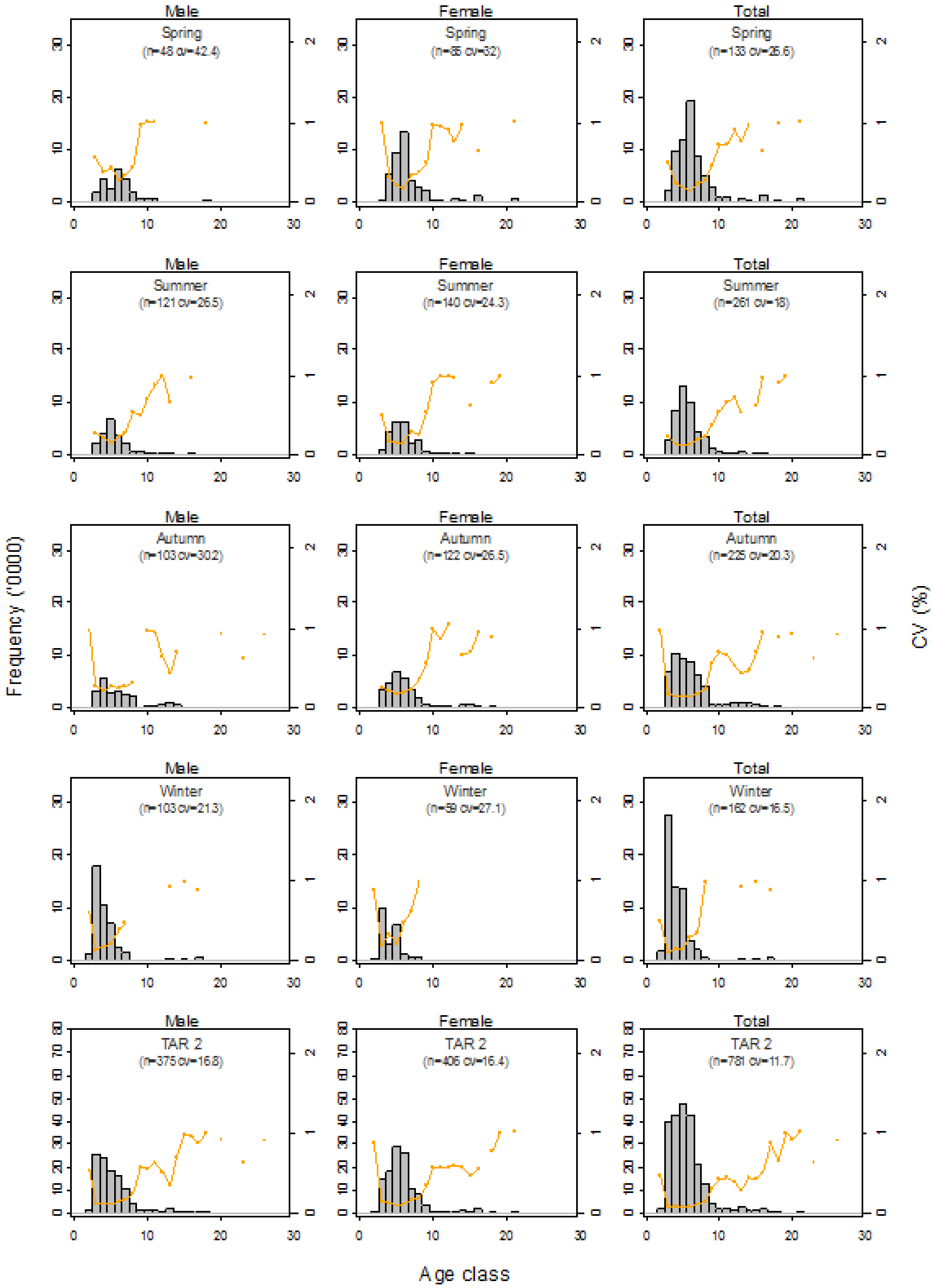


Figure 18: **Scaled age frequency distributions for TAR 2 landings in the 2011 fishing year, segregated by sex, and stratified by season sampled. Line indicates the c.v. for each age class. n, number.**

3.2 TAR 3

3.2.1 TAR 3 fishery characterisation (1990 –2010)

Starr et al. (2007) carried out a detailed characterisation of the TAR 3 fishery for the 17-year period from 1990 to 2006 as part of the AMP reporting requirements. This was subsequently updated with 2007 and 2008 data (Starr et al. 2009), and again with 2009 and 2010 data (Beentjes 2011). A brief summary of the key aspects of the TAR 3 fishery based on data up to 2010 is provided below:

Fishing method–about 69% of the landed catch was from bottom trawl, 29% from set netting, and 2% from Danish seine. Danish seining was a relatively new method in TAR 3.
Statistical area–The bulk (92%) of the landings were from three statistical areas: 018 (Kaikoura, 33%), 020, (Pegasus Bay, 26%) and 022 (Canterbury Bight, 33%).
Statistical area/method–Landings of tarakihi from set netting were virtually all from statistical area 018 (99%), whereas landings from bottom trawling were predominantly from statistical areas 020 (36%) and 022 (46%), and to a lesser extent from 024 (9%) and 018 (6%).
Target– Tarakihi was declared the target species in 93% of the landed set net catch of tarakihi in TAR 3. For bottom trawling, 91% of all landed tarakihi was taken with one of the following species declared as the target: TAR (36%), RCO (34%), BAR (12%), and FLA (9%).
Season– There was no strong seasonal pattern in landings from the trawl fishery, although landings were greatest from February to June, and also in September. The set-net fishery displayed a strong seasonal pattern with virtually all landings from December to June, but with peak landings between December and February, and again in May.

3.2.2 TAR 3 fishery characterisation (2002–2011)

The characterisation of the TAR 3 fishery based on catch effort data from 2002 to 2011, showed that bottom trawl and set net were still the dominant fishing methods used for TAR 3, and in 2011 bottom trawl accounted for 73%, set net 22% and Danish seine 5% of the catch (Figure 19). Set net proportion of annual TAR 3 landings has declined over time, and was only 8% in 2011. The characterisation of bottom trawl and set net fisheries are presented separately below and unless otherwise stated are based on the 2002 to 2011 extracted data.

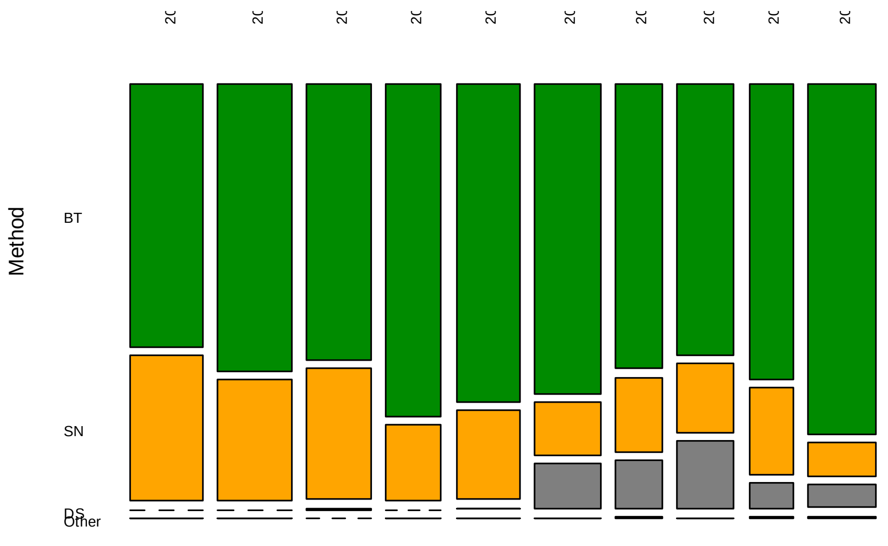


Figure 19: Total landed catch (t) by fishing method from 2002–2011 in TAR 3. BT, bottom trawl; DS, Danish seine; SN, set net.

The reporting of catch effort data in the TAR 3 fishery has changed over time with the introduction of the NCER form in 2007 and the TCER form in 2008 (Figure 20). CELRs were replaced by TCERs after

2007 as the most commonly used form for reporting catch effort data. Similarly little landing data is reported on CELRs after 2007 as CLRs or NCEs are used.

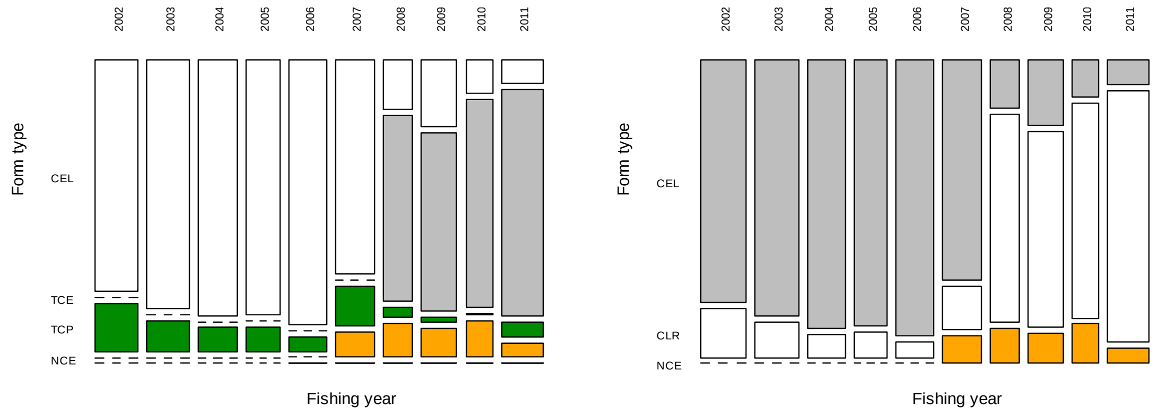


Figure 20: Relative proportions of form types used in TAR 3 from 2002–2011. Catch efforts data forms (left panel) and catch landing forms (right panel).

3.2.2.1 TAR 3 bottom trawl characterisation

The majority (55%) of tarakihi caught by bottom trawl in TAR 3 are captured by vessels reporting tarakihi as the target species from 2002 to 2011. This proportion increased from 2002 (14%) through to 2009 (77%), but has been stable since then (Figure 21). Red cod and barracouta are also important target species but the proportions of tarakihi catch recorded with red cod as target species has declined as tarakihi target has increased.

Bottom trawl catch comes mainly from statistical areas 020 and 022, with lesser amounts from 024 and 018 (Figure 22a).There is no strong seasonal pattern in TAR 3 BT landings, although landings have tended to be greatest from February to June and September, and less from October to December (Figure 22b).

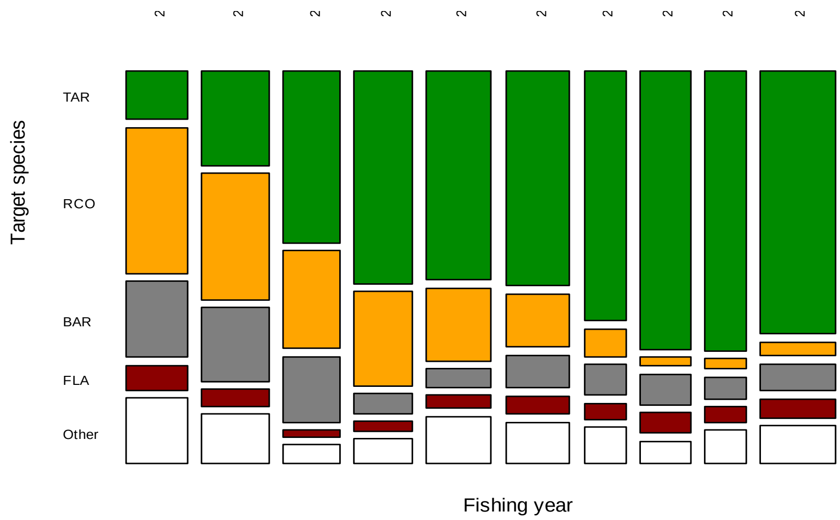
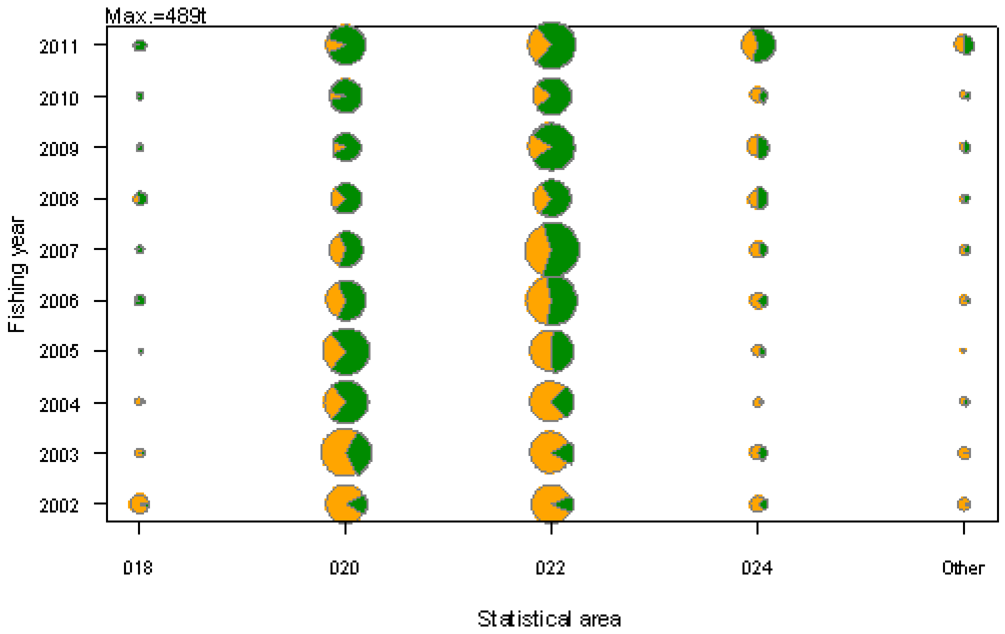


Figure 21: Annual proportion of TAR 3 bottom trawl reported by target species, 2002–2011.

(a)



(b)

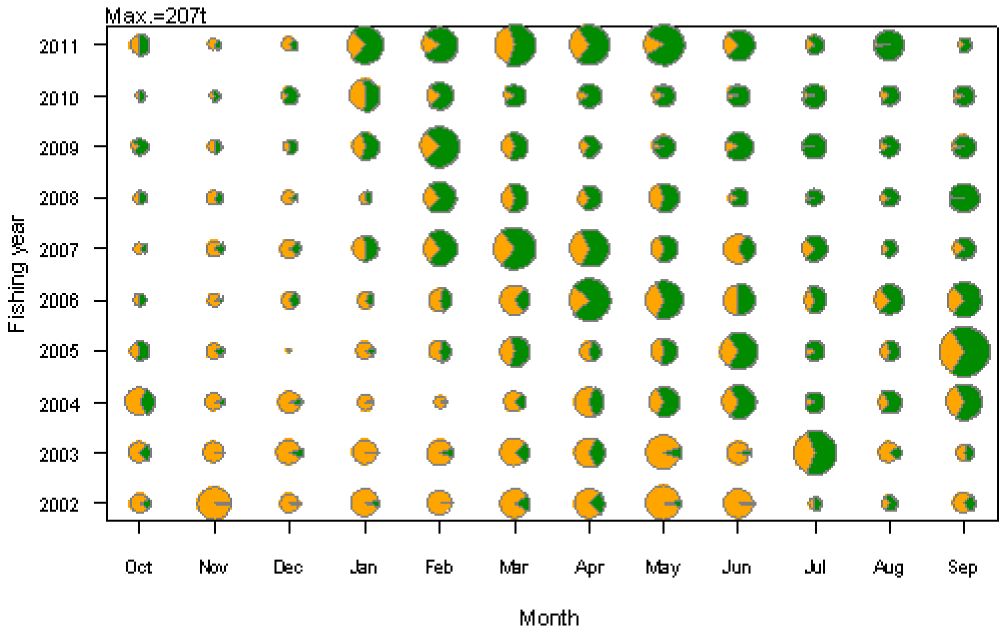


Figure 22: Bottom trawl catch of tarakihi in TAR 3 by statistical area (a) and month (b) for 2002–2011. Pies show the proportion of catch in each cell landed as target (dark) or non-target (light).

The distribution of TAR 3 bottom trawl catch by port of landings is shown by fishing year (2002 to 2011), month, and statistical area in Figure 23. The bulk of the catch was landed into Lyttelton and Timaru, with smaller landings into Port Chalmers, Akaroa, Moeraki, Oamaru, or other ports. The proportions landed in these ports varied little among the 10 years. Highest catches in Port Lyttelton were in autumn-winter, while for Timaru and Port Chalmers catches were generally highest in summer-autumn. For Lyttelton the bulk of the catch came from statistical areas 020 and 022, and for Timaru it was predominantly from statistical area 022. Port Chalmers tended to receive catch from area 024 and others (probably 025 and 026).

With the introduction of TCER forms in 2008, the spatial distribution of TAR 3 catches can now be described more accurately than with statistical area alone, which is all that is available on CELR forms. The distribution of tows was continuous along the entire east coast of the South Island at depths shallower than about 200 m, but most of the catch was taken from Canterbury Bight and Pegasus Bay (Figure 24). The outliers well offshore were likely to be errors in reporting locations.

Vessel and effort specifications of vessel landing tarakihi in TAR 3 from 2002 to 2011 are shown in Figure 25. Tow speeds before 2008 were above 3 knots and this declined to about 2.8 knots from 2008 onward, coinciding with the introduction of the TCER form. All other vessel and effort variables were largely constant over time (*i.e.*, fishing duration, headline height, depth, trawl net width, and vessel length).

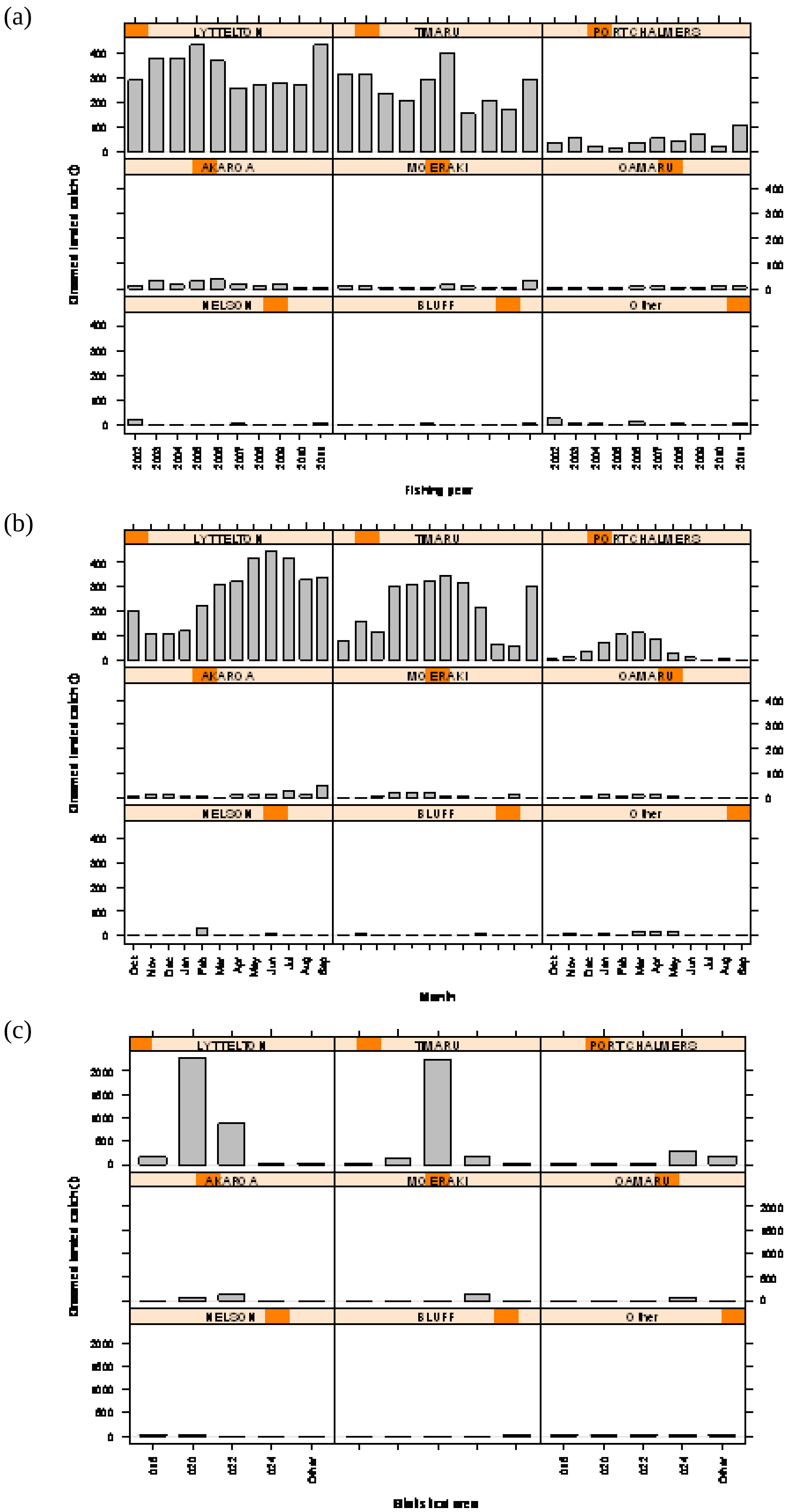


Figure 23: Distribution of landed bottom trawl catch of TAR 3 by major port and (a) year, (b) month, and (c) statistical area, 2002–2011.

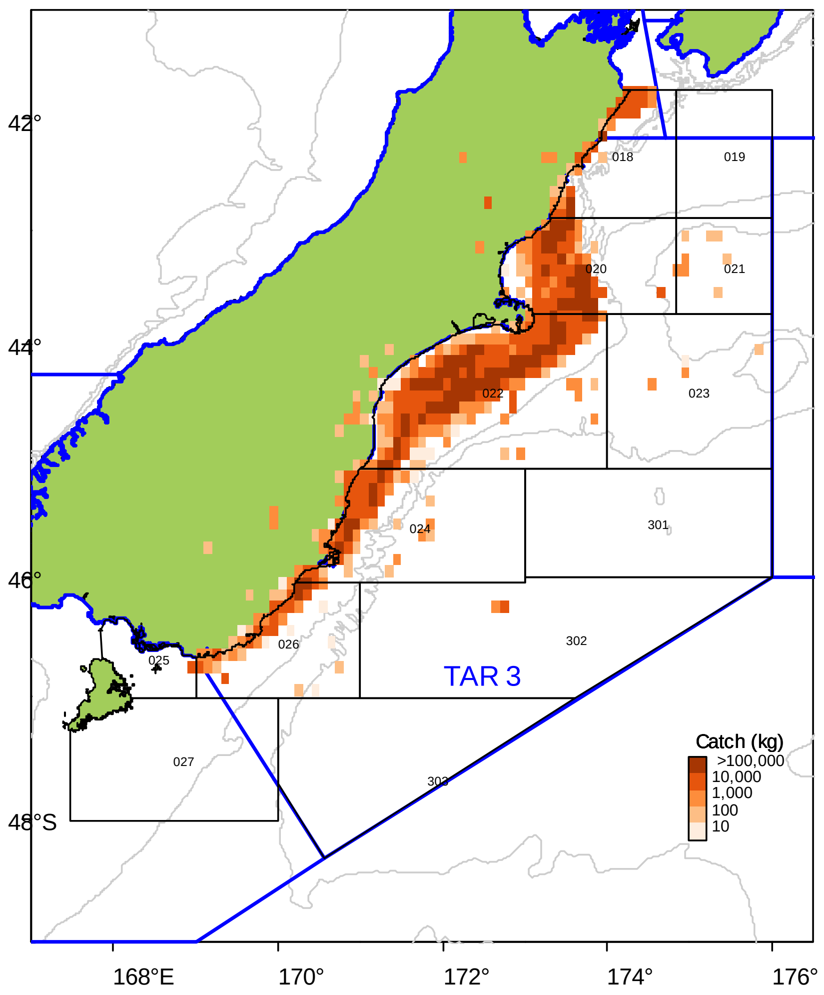


Figure 24: Total fine scale spatial distribution of TAR 3 bottom trawl catch (0.1 degree blocks) within each statistical area, 2008–2011 (TCER and TCEPR forms). 500 and 1000 m depth contours are shown as light grey lines.

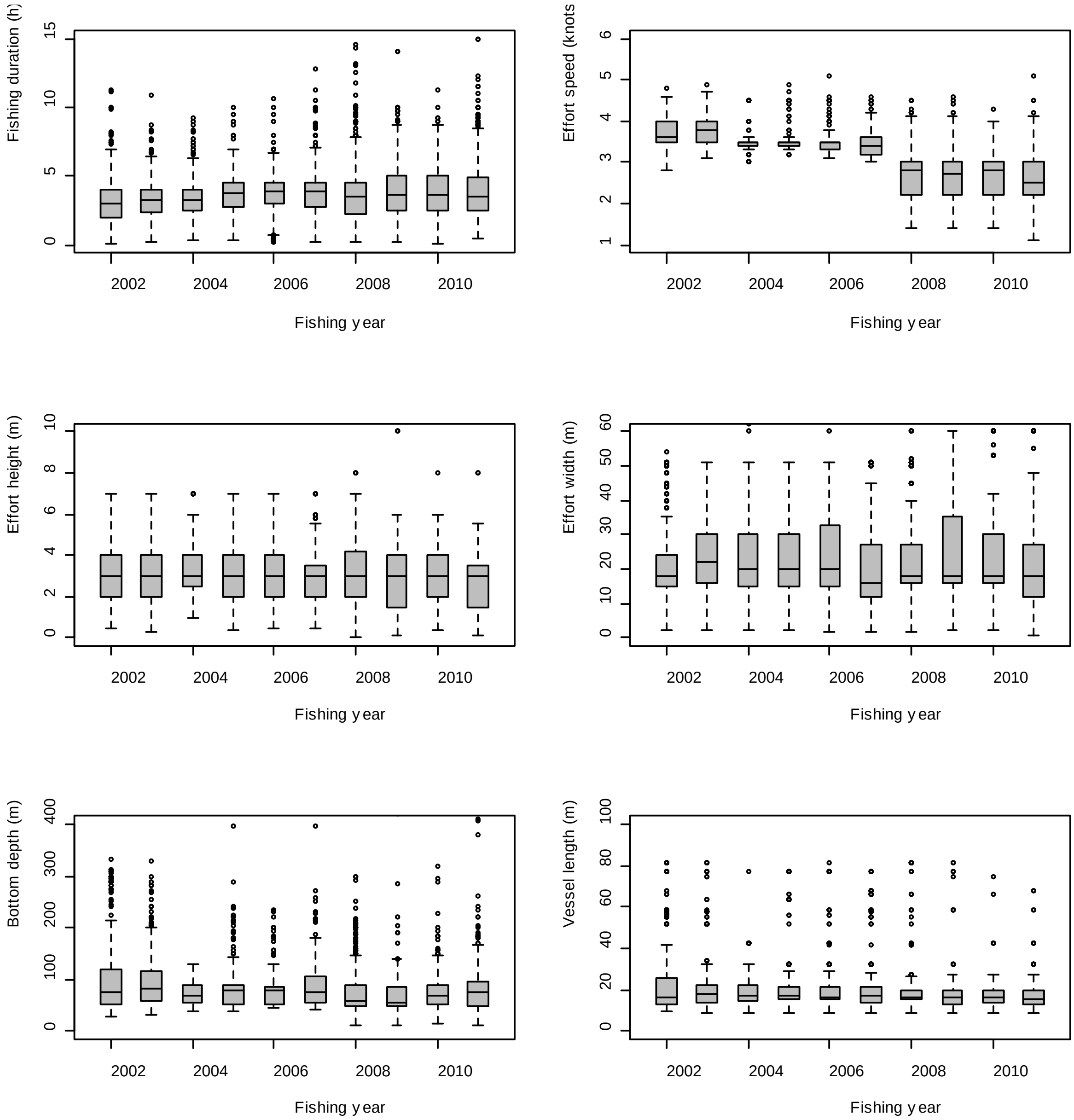


Figure 25: Characterisation of bottom trawl fishing effort for vessels landing TAR 3, 2002–2011. For each bar, the horizontal line indicates the median, top and bottom of the bar indicate the interquartile range, error bars indicate 1.5 times the interquartile range, and values outside this range (outliers) are indicated with circles.

3.2.2.2 TAR 3 set net characterisation

The vast majority (97%) of tarakihi caught by set net in TAR 3 from 2002 to 2011 are captured by vessels reporting tarakihi as the target species (Figure 26), with the proportion increasing slightly over time from 94% in 2002 to 98% in 2011. Other minor target species include rig, ling, and blue warehou, which are targeted in deeper water off Kaikoura.

Set netting occurred predominantly in statistical area 018, with minor catch in 024 (Figure 27a). There was a strong seasonal pattern in TAR 3 set net landings, with catches taken between November and June, particularly December-February and May (Figure 27b). The set net catch showed a decline through time with the 2011 catch only 8% of total TAR 3 catch compared with the ten-year average proportion of 22%.

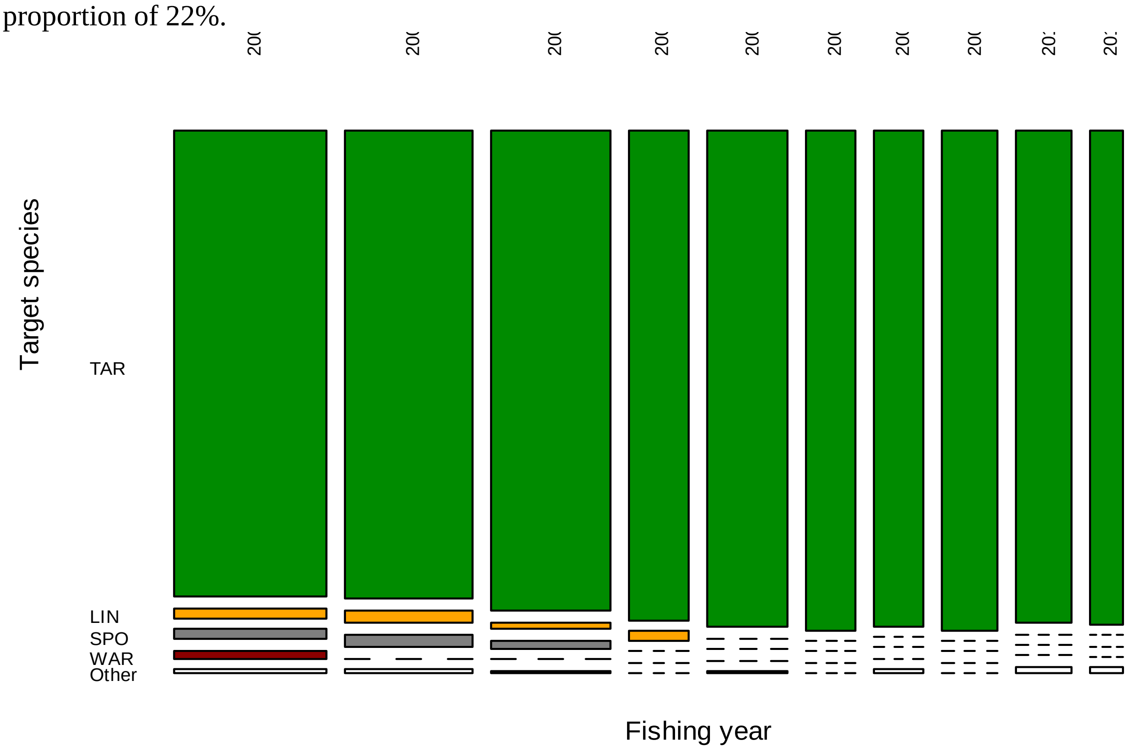


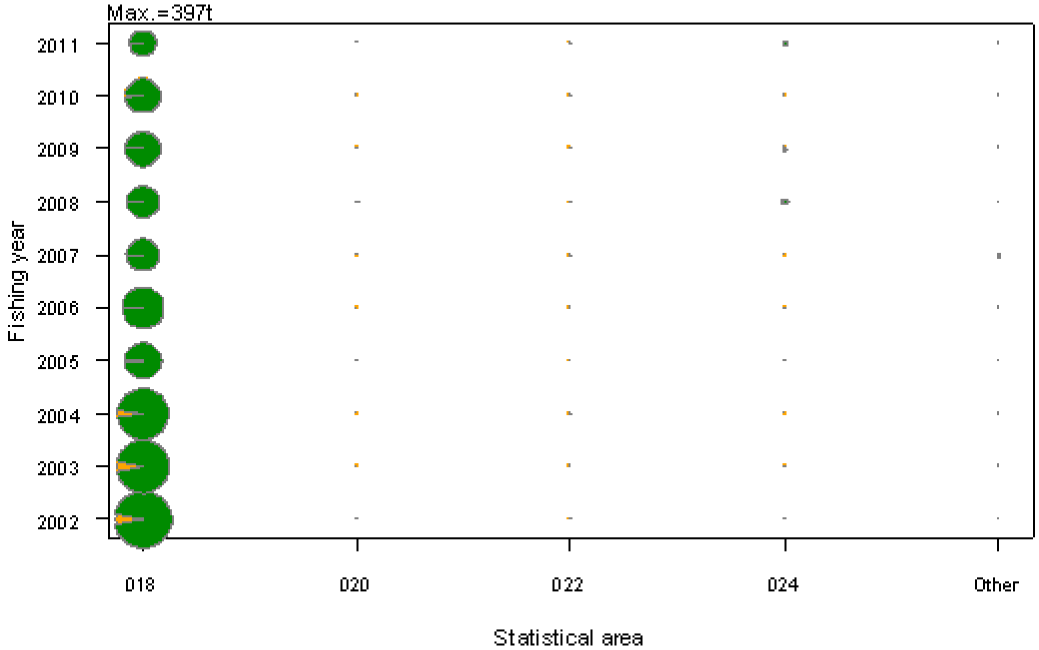
Figure 26: Annual proportion of TAR 3 set net reported by target species, 2002–2011.

The distribution of TAR 3 set net catch by port of landing is shown by fishing year (2002 to 2011), month, and statistical area (Figure 28). Virtually all the catch was landed into Kaikoura with a small amount into Oamaru and Karitane. Kaikoura landings indicated a steady decline from 2002 to 2011 (Figure 28a). Highest catches in Kaikoura were from December to February and in May, and for Oamaru catches were landed in April/May and September (Figure 28b). Virtually all Kaikoura catch came from statistical area 018, whereas catches landed into Oamaru and Karitane came from 024 (Figure 28c).

With the introduction of NCER forms in 2007 the spatial distribution of TAR 3 catches can now be described more accurately than with statistical area alone (Figure 29). The distribution of sets was clustered off Kaikoura and Oamaru, with the largest catches in the former area. Outliers from these clusters in deep waters were probably reporting errors.

Vessel and effort specifications of vessels landing tarakihi in TAR 3 from 2002 to 2010 by method set net are shown in Figure 30. Fishing duration increased after 2005, while the length of net set declined from 2003 to 2007, after which it has been stable. Vessel length has remained constant and number of sets has only been recorded since 2007.

(a)



(b)

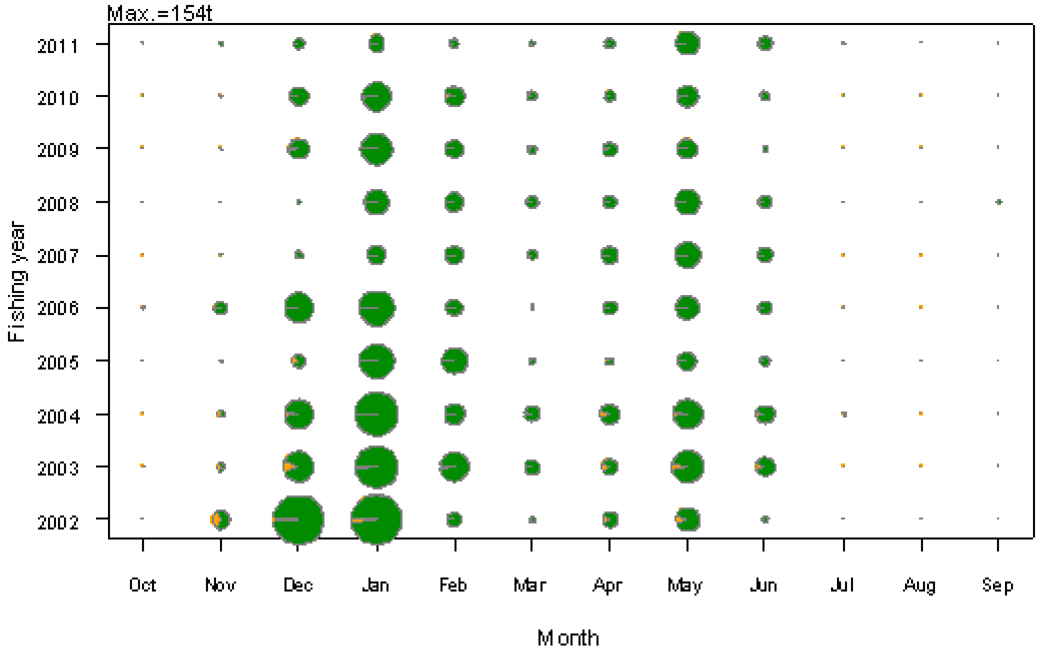
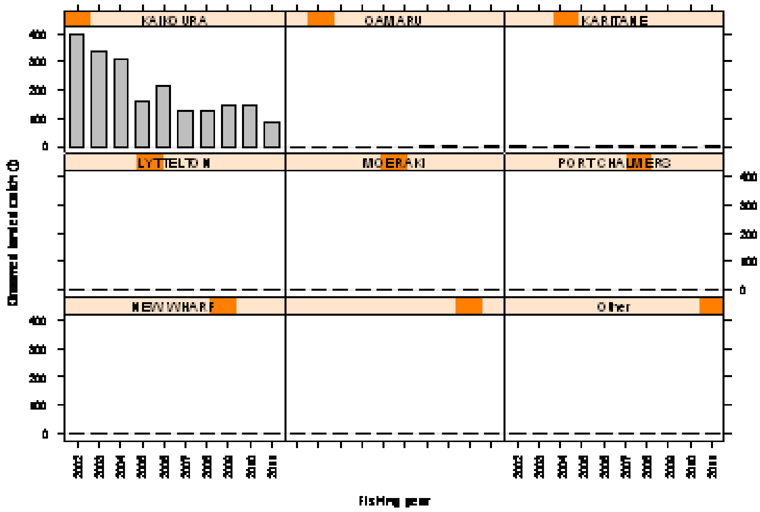
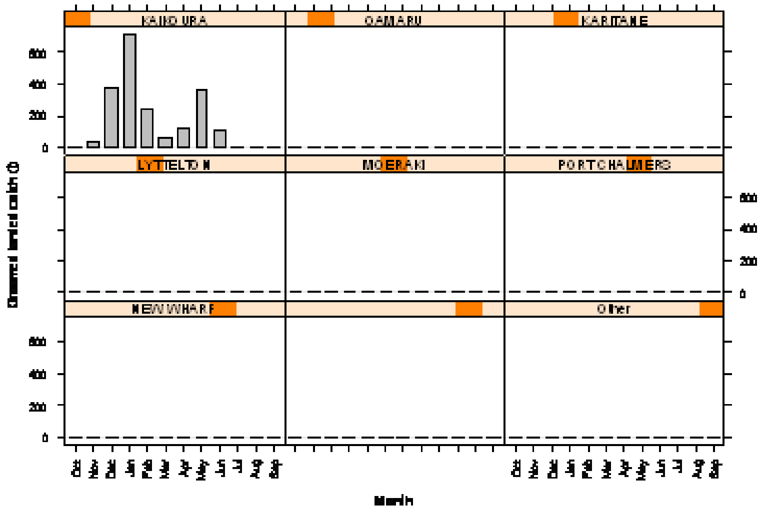


Figure 27: Set net catch of tarakihi in TAR 3 by statistical area (a) and month (b) for 2002–2011. Green represents target catch and the brown is bycatch.

(a)



(b)



(c)

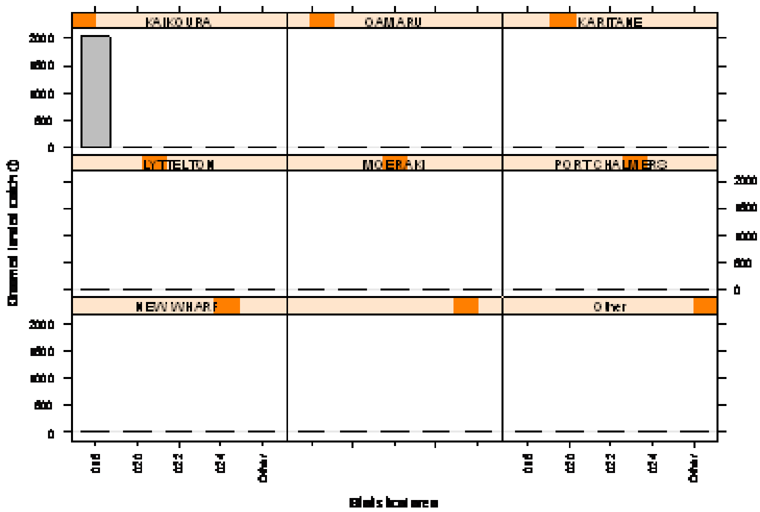


Figure 28: Distribution of landed set net catch of TAR 3 by major port and (a) year, (b) month, and (c) statistical area, 2002-2011.

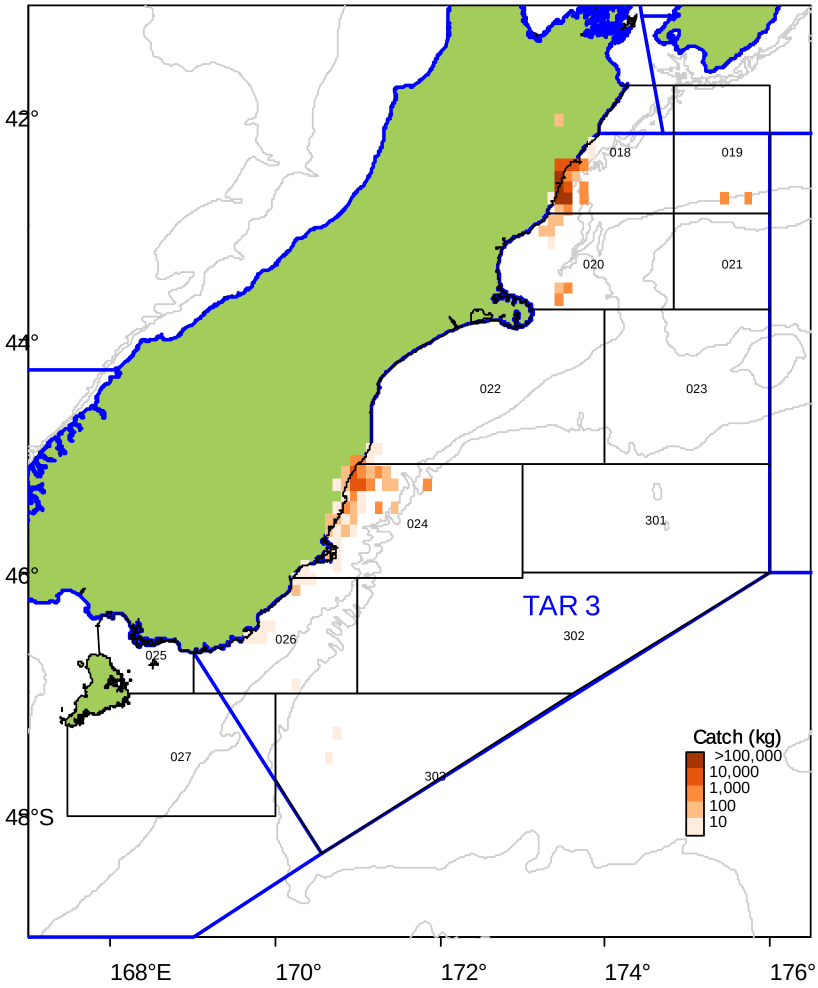


Figure 29: Total fine scale spatial distribution of TAR 3 set net catch (0.1 degree blocks) within each statistical area, 2007–2011 (NCER forms). The 500 and 1000 m depth contours are shown as light grey lines.

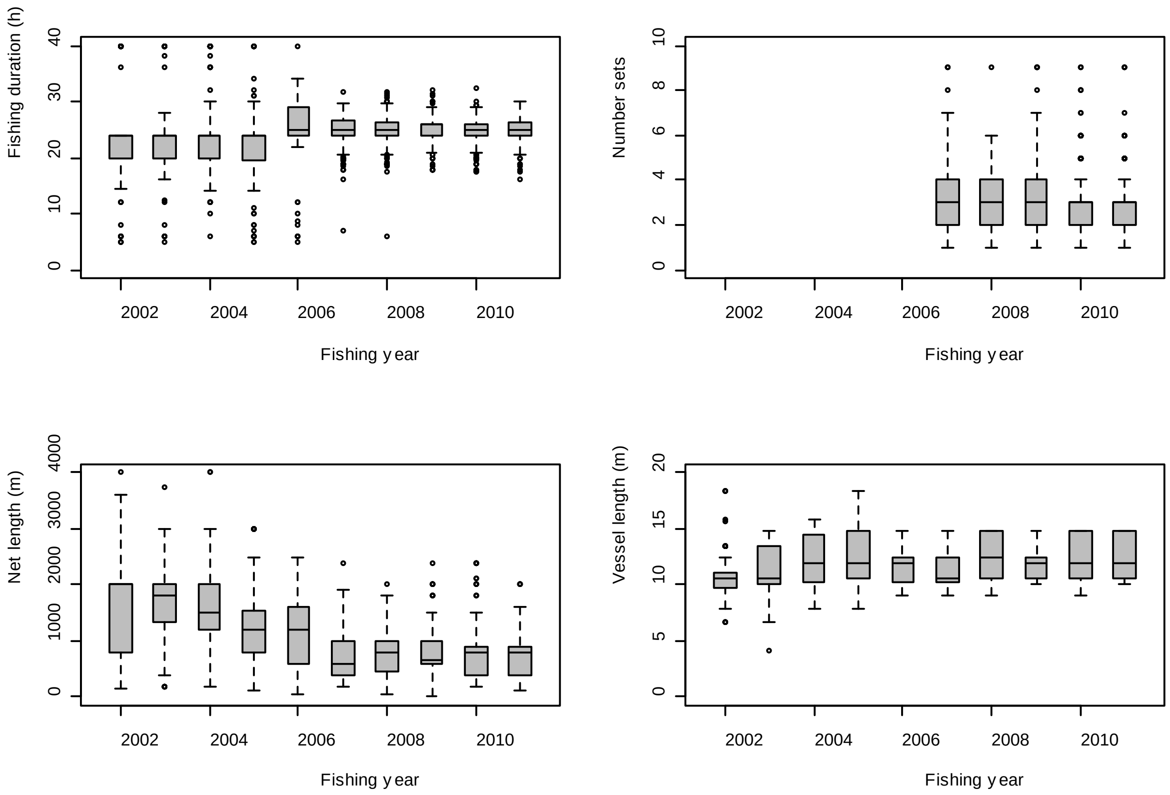


Figure 30: Characterisation of set net fishing effort for vessels landing TAR 3, 2002–2011. For each bar, the horizontal line indicates the median, top and bottom of the bar indicate the interquartile range, error bars indicate 1.5 times the interquartile range, and values outside this range (outliers) are indicated with circles.

3.2.3 TAR 3 bottom trawl catch sampling

For the bottom trawl fishery, 29 of 40 targeted landings were sampled, representing all six two-month blocks (see Table 3) and sampled in proportion to the temporal allocations, although the later part of the year was not as well sampled as planned. Because one landing was actually a set net landing it was dropped from the analyses, reducing the sampled landings to 28. The least well-sampled stratum was statistical area 020 (Pegasus Bay) in which only 8 of 17 planned landings were sampled, whereas statistical area 024 (Oamaru to Taieri Mouth) exceeded sampling targets (8 sampled from target of 4). Frequent contact was made with all processors and all landings that were made available were sampled, however, the target number for the bottom trawl fishery was not achieved because there were insufficient qualifying landings to sample or made available to the field samplers. Overall, 1670 fish were measured in the 28 valid landings sampled.

3.2.3.1 TAR 3 bottom trawl representativeness

Vessels sampled were termed the "core" fleet. The core fleet landed 68% of the TAR 3 bottom trawl catch (summarizing all their landings), and 10% of all bottom trawl landed weight was included in the sampled landings.

The TAR 3 bottom trawl vessel and gear characteristics of the core fleet were similar to the fleet as a whole, although precise comparisons cannot be made because the overall number of core fleet vessels was small (N = 13 vessels). However, headline height, net width, and vessel length appear to be overall slightly greater for the core vessels than those of the fleet which may be a result of targeting larger catches to sample (Figure 31).

The distribution of tow depths by sampled vessels in 2011 was very similar to that of all vessels, with modes at about 50 m and 90 m (Figure 32). Plotting the depth distribution for trips landing TAR 3 by target species, shows that the same overall bimodal depth distribution is evident for target species TAR, but the shallower peak is more a feature of targeting red cod, barracouta and flatfish (Figure 33a). Analysis of the depths of trawls landing TAR 3 by statistical area, revealed distinct area specific depth distribution profiles with the median depth getting shallower from north to south (greatest in statistical area 018 and shallowest in 024) (Figure 33b).

The sampled fish from the bottom trawl fishery were reasonably representative of the 2011 catch by month, statistical area, and target species (Figure 34).

In summary, the overall characteristics of the bottom trawl sampled vessels and their fishing patterns were similar to all vessels indicating that sampling was representative of the fishery.

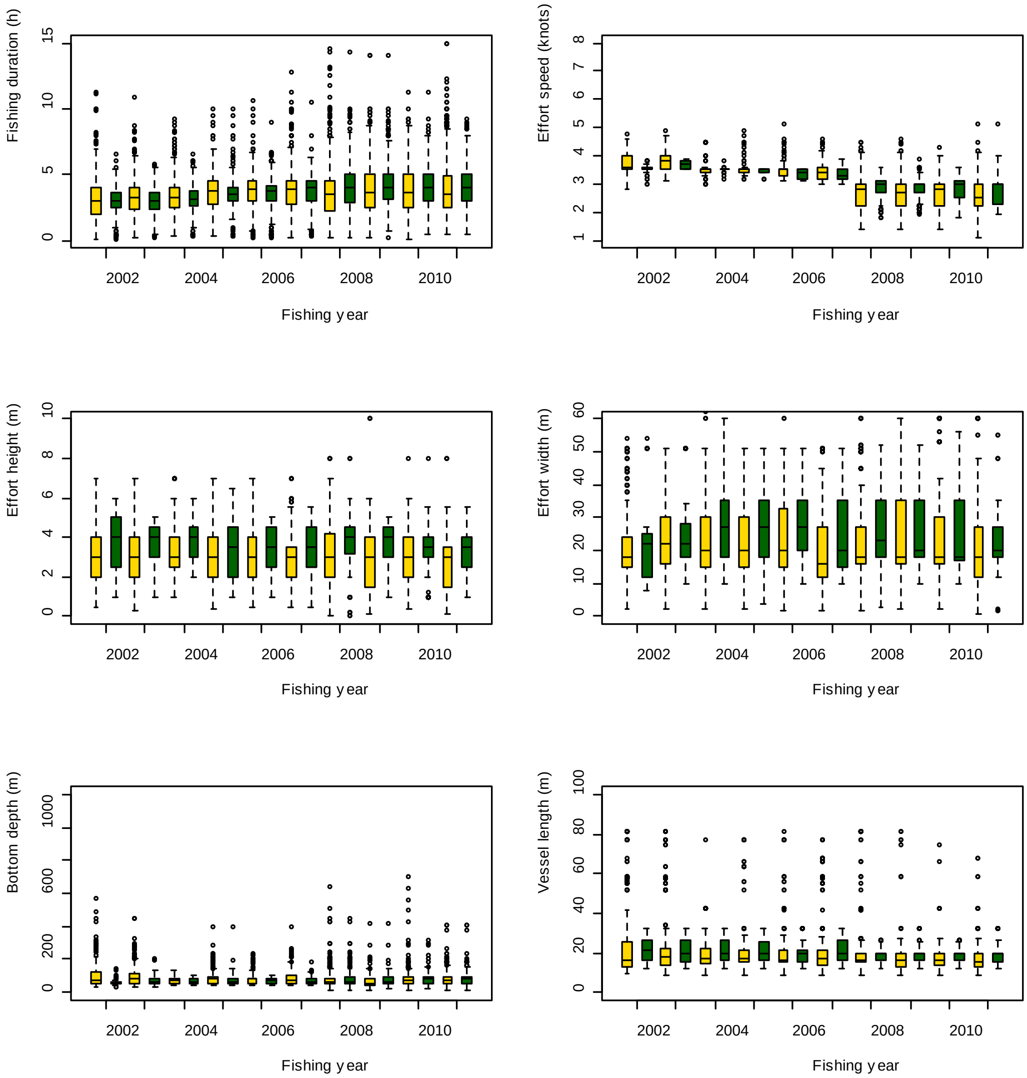


Figure 31: Characterisation of fishing effort for vessels landing TAR 3 bottom trawl, 2002–2011. Light bars indicate the distribution of values for all vessels, dark bars indicate the distribution of all values for sampled vessels only (core fleet). For each bar , the horizontal line indicates the median, top and bottom of the bar indicate the interquartile range, error bars indicate 1.5 times the interquartile range, and values outside this range (outliers) are indicated with circles.

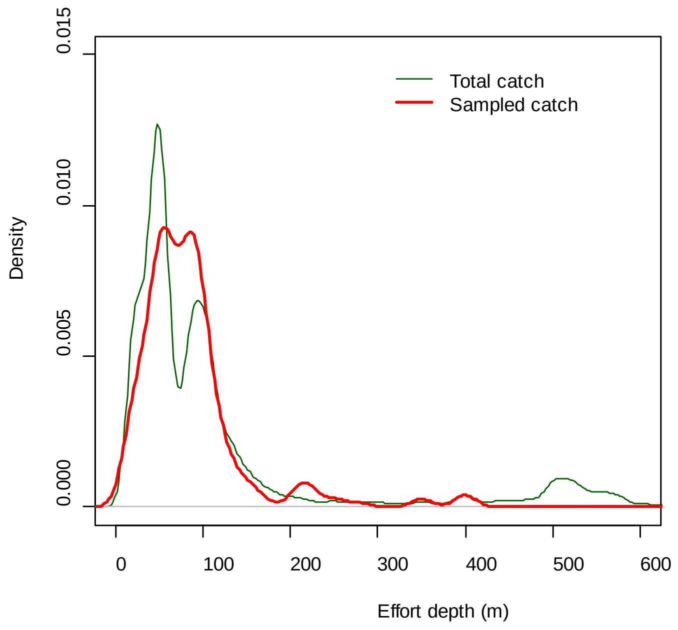


Figure 32: Depth distribution of TAR 3 target fishing in 2011 for all tows and for tows where catch was sampled.

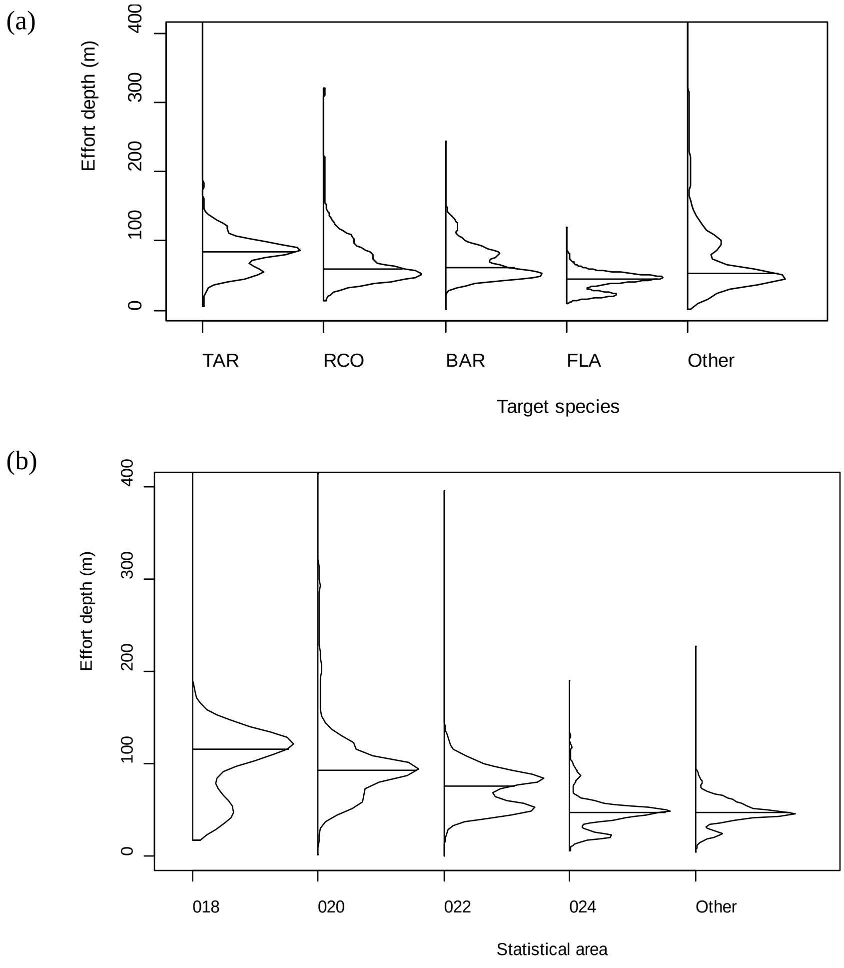
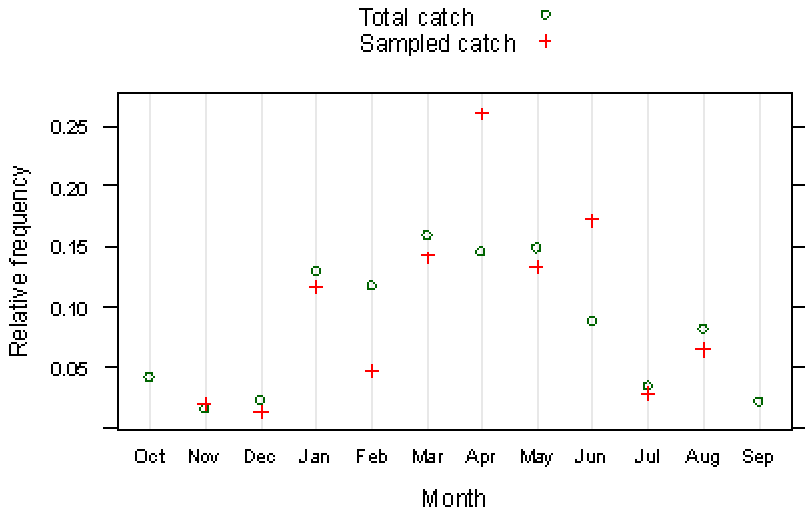
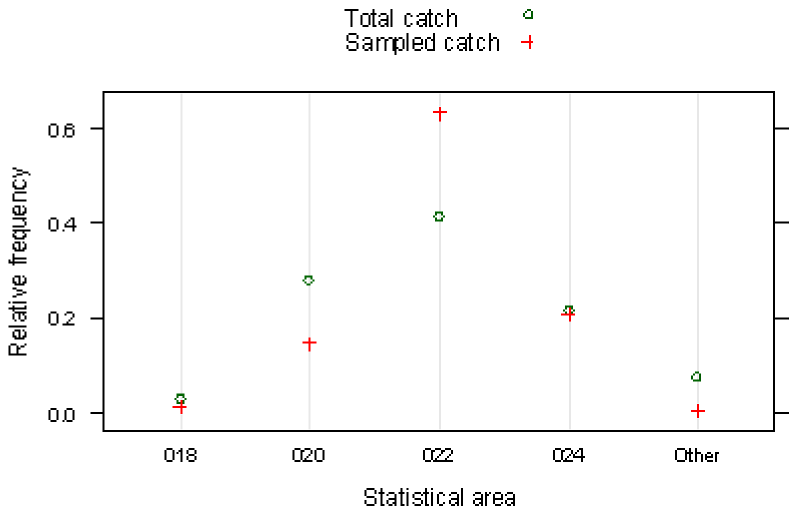


Figure 33: Depth distribution of tows from trips landing TAR 3 by (a) target species (b) statistical area Horizontal line indicates median of each distribution.

(a)



(b)



(c)

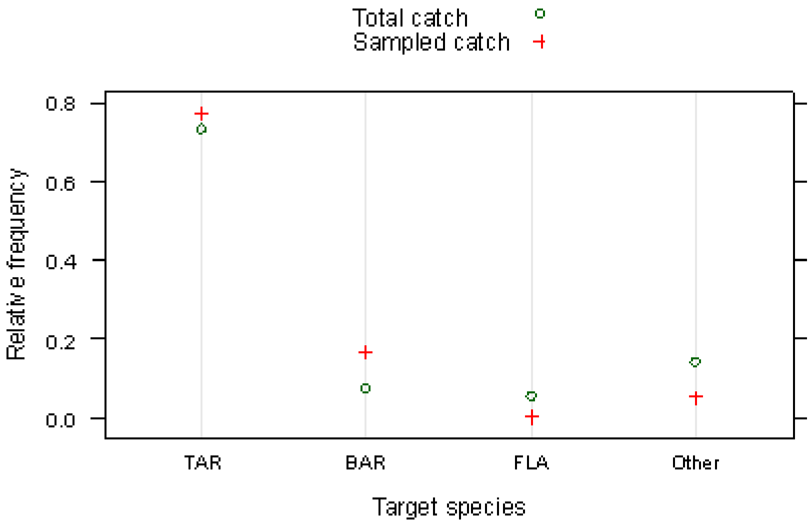


Figure 34: Proportion of bottom trawl total landed catch (circles) and the proportion of sampled catch (crosses) of TAR 3 that occurred in each (a) month, (b) statistical area, and (c) by target species in the 2011 fishing year.

3.2.4 TAR 3 bottom trawl length and age composition of the catch

Length composition of the catch

The scaled length frequency distributions from the TAR 3 bottom trawl fishery were unimodal for both males and females with peaks at 28 cm fork length, with most fish between 25 and 35 cm (Figure 35). The minimum and maximum lengths were 20 and 42 cm for males, and 18 and 43 cm for females. Mean lengths of scaled distributions were 28.4 cm for males, 28.8 cm for females, and 28.5 cm overall. The mean weighted c.v.s were 21.7% for males, 20.9% for females, and 16.3% overall. The sex ratio was 53% male. Modal progression is evident in the seasonal scaled length frequency distributions.

Ageing precision

Bottom trawl age readings were very consistent between the two readers, with an APE of 0.7 and a c.v. of 1.0% (Figure 36). Percent agreement was 94% and only 2 of 599 readings (0.3%) disagreed by more than 1 year. There was no age estimation bias across the age range. The range of final agreed age estimates was 2–31 years, although 96% of ages were less than 8 years old.

Age composition of the catch

The scaled age frequency distributions for TAR 3 bottom trawl were unimodal with peaks at 3 years for both males and females, with most fish (91% for males and 95% for females) from 3 to 5 years old (Figure 37). Minimum and maximum ages were 2 and 19 years for males, and 2 and 31 years for females. Mean ages of scaled distributions were 3.6 years for males, 3.6 years for females, and 3.6 years overall. The mean weighted c.v.s were 22.4% for males, 20.1% for females, and 16.9% overall. There was no clear seasonal change in the scaled age frequency distributions except that in spring the 4 year olds dominate but in the summer, autumn, winter, and overall 3 year olds are the dominant age class.

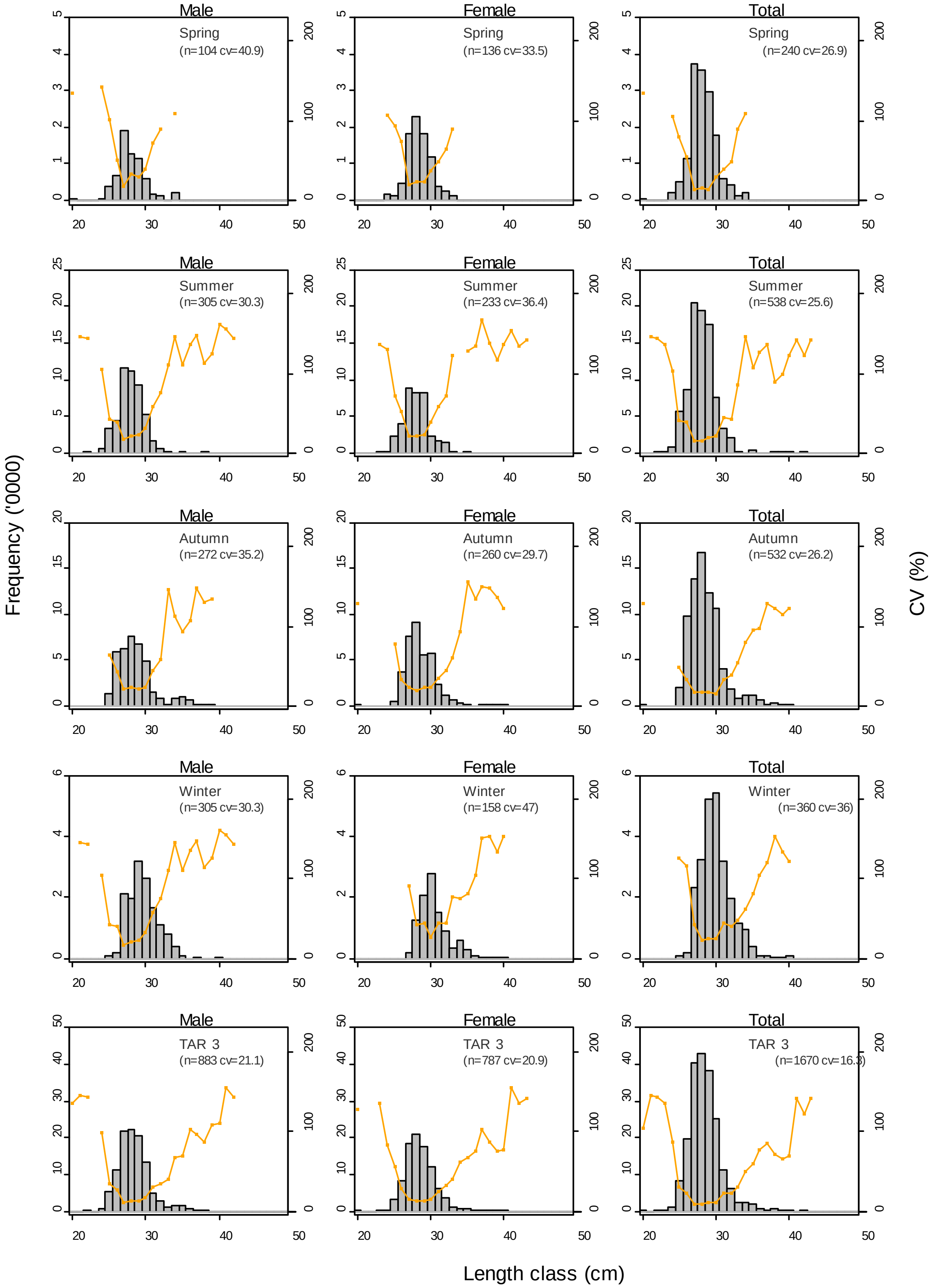


Figure 35: Scaled length frequency distributions for TAR 3 bottom trawl landings in the 2011 fishing year, segregated by sex, and stratified for fish by season sampled. Line indicates the c.v. for each length class. n, number of fished measured; cv, MWCV. 20 cm is set as the minus group.

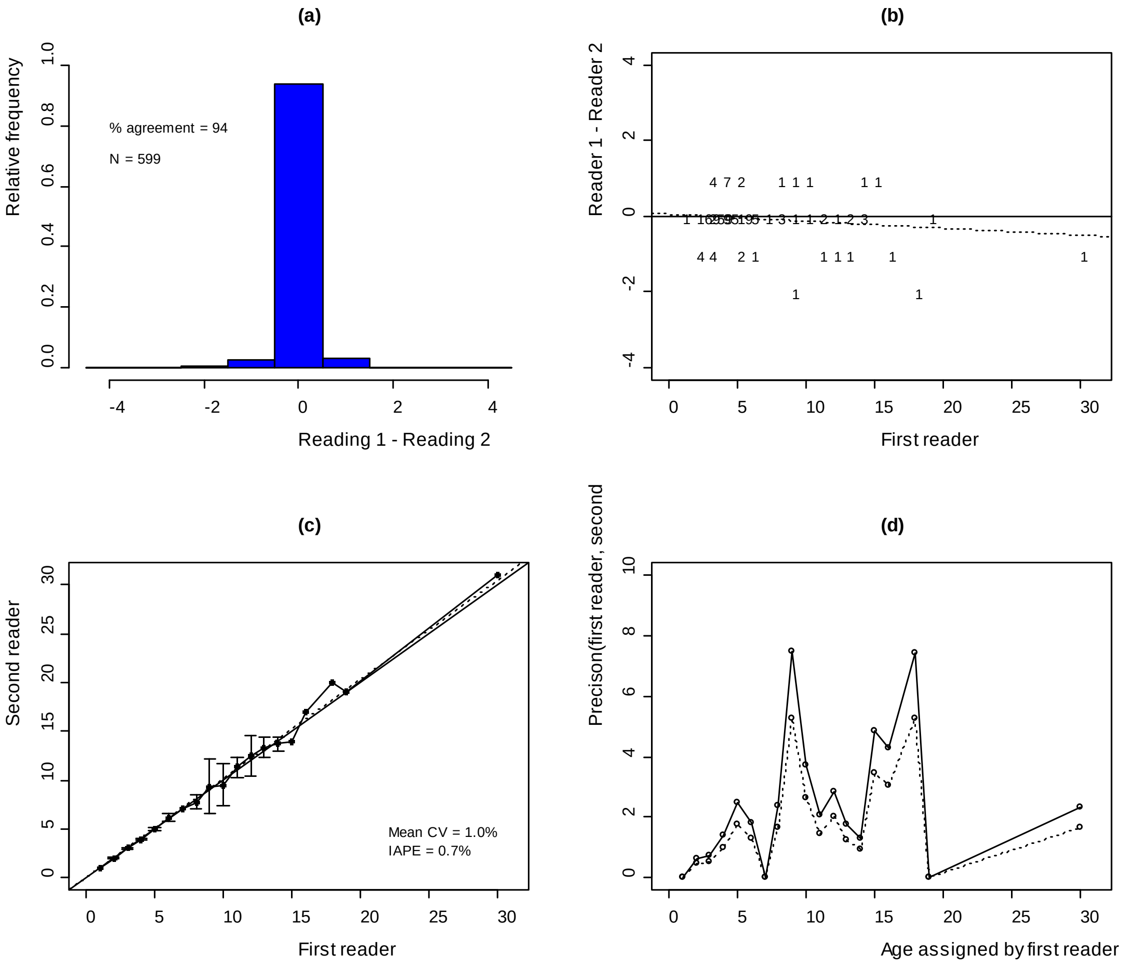


Figure 36: Age reader comparison plots for TAR 3 bottom trawl catch sampling in 2011: (a) histogram of age differences between two readers; (b) Difference between reader 1 and reader 2 as a function of the age assigned by reader 1. The number of fish in each bin is plotted as the plot symbol; (c) Age bias plot, showing the correspondence of ages between reader 1 and reader 2 for all ages. Error bars indicate the c.v. of the ages for each age by reader 1; (d) Plot of the c.v. and the average percent error (APE) for each age as assigned by the first reader. In panels b and c, solid lines show perfect agreement, dashed blue lines show the trend of a linear regression of the data.

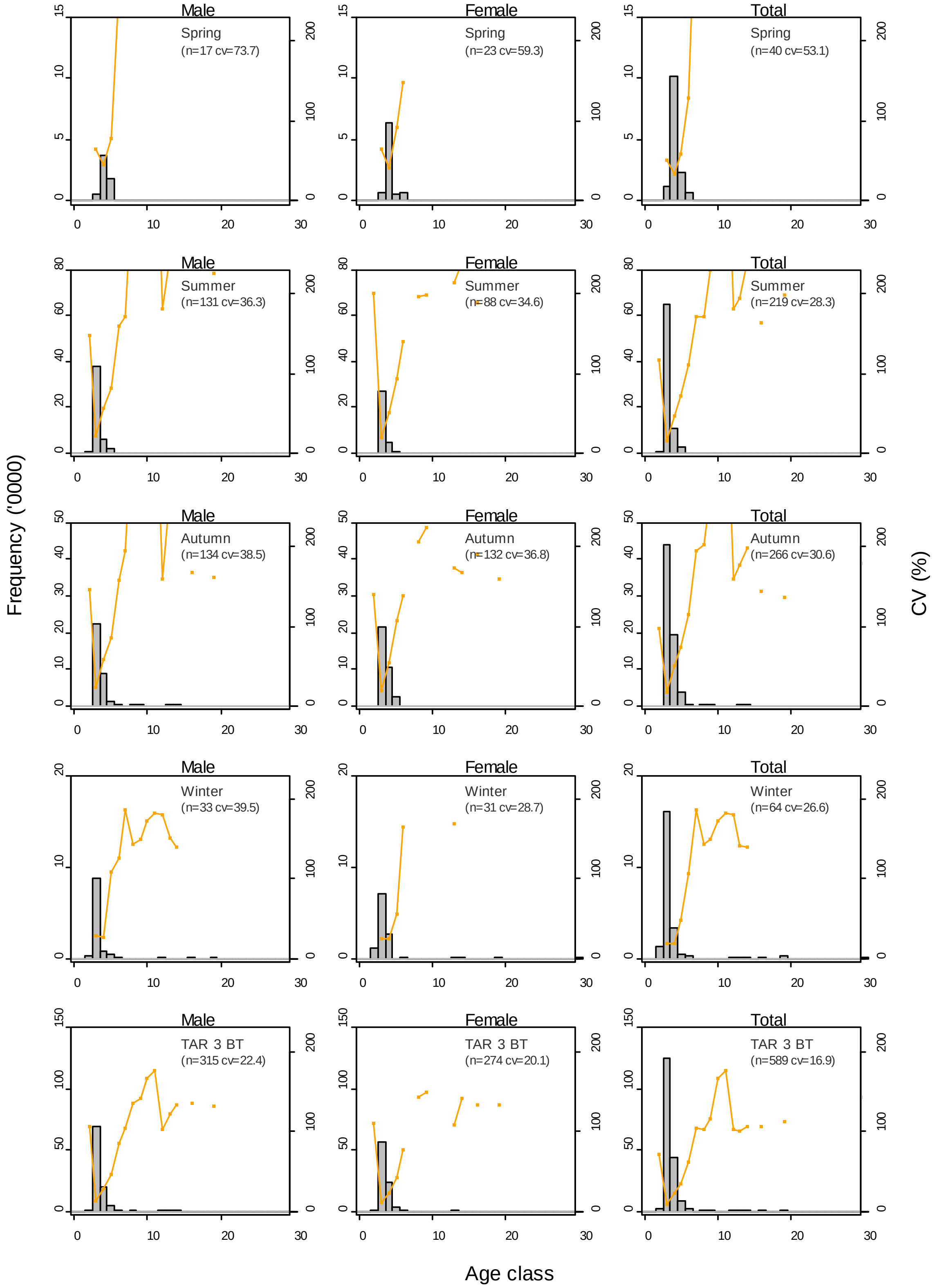


Figure 37: Scaled age frequency distributions for TAR 3 bottom trawl landings in the 2011 fishing year segregated by sex, and stratified for fish by season sampled. Lines indicate the c.v. for each age.

3.2.5 TAR 3 set net catch sampling

For the set net fishery, 16 landings were sampled, meeting the target of 16, and they were also collected roughly in proportion to the monthly targets (seeTable 3).

3.2.5.1 TAR 3 set net representativeness

The core fleet landed 65% of the TAR 3 set net catch in 2010–11(summarizing all their landings), and 6% of all set net landed weight was included in the sampled landings.

The TAR 3 set net vessel and gear characteristics of the core fleet were similar to the fleet as a whole, although precise comparisons cannot be made because the number of core fleet vessels was small (N = 3 vessels, Figure 38). Depth information is not recorded on either CELR or NCER forms.

The sampled fish from the set net fishery were reasonably representative of the 2011 catch by month, statistical area, and target species (Figure 39).

In summary, the overall characteristics of the sampled set net vessels and their fishing patterns were similar to all vessels indicating that sampling was representative of the fishery.

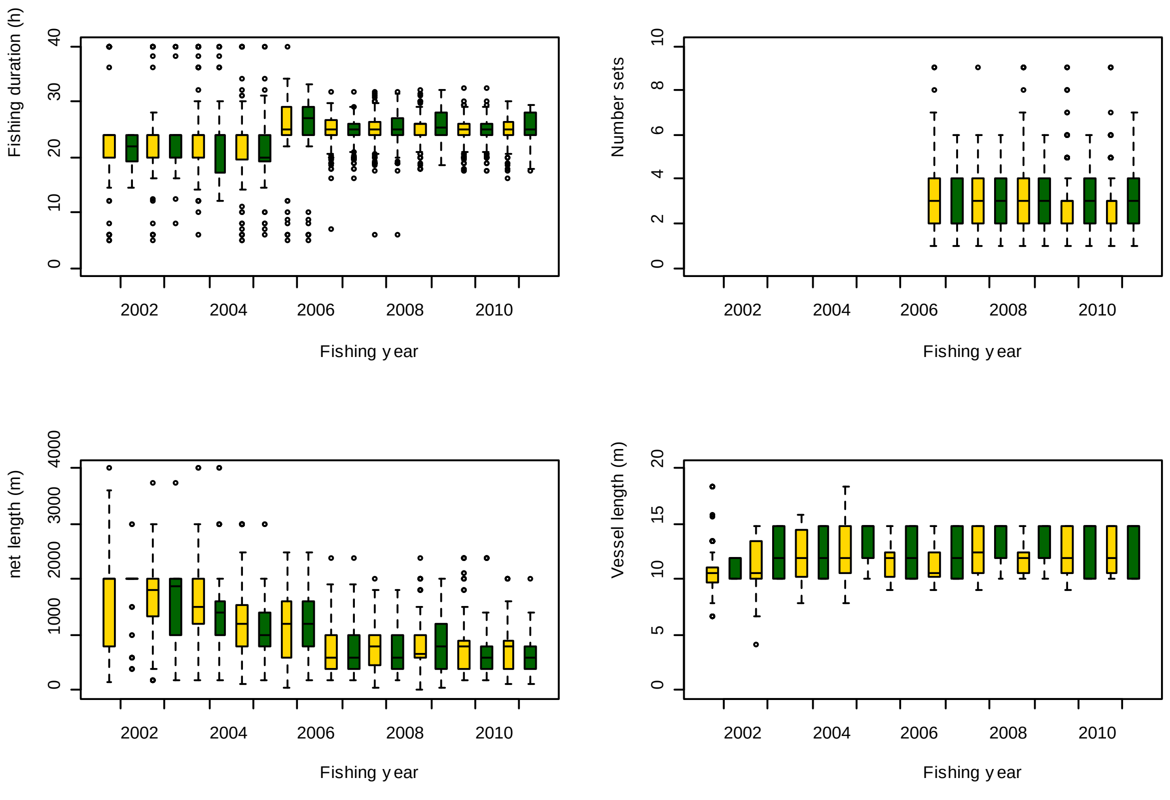


Figure 38: Characterisation of fishing effort for vessels landing TAR 3 set net, 2002–2011. Light bars indicate the distribution of values for all vessels, dark bars indicate the distribution of all values for sampled vessels only (core fleet). For each bar, the horizontal line indicates the median, top and bottom of the bar indicate the interquartile range, error bars indicate 1.5 times the interquartile range, and values outside this range (outliers) are indicated with circles.

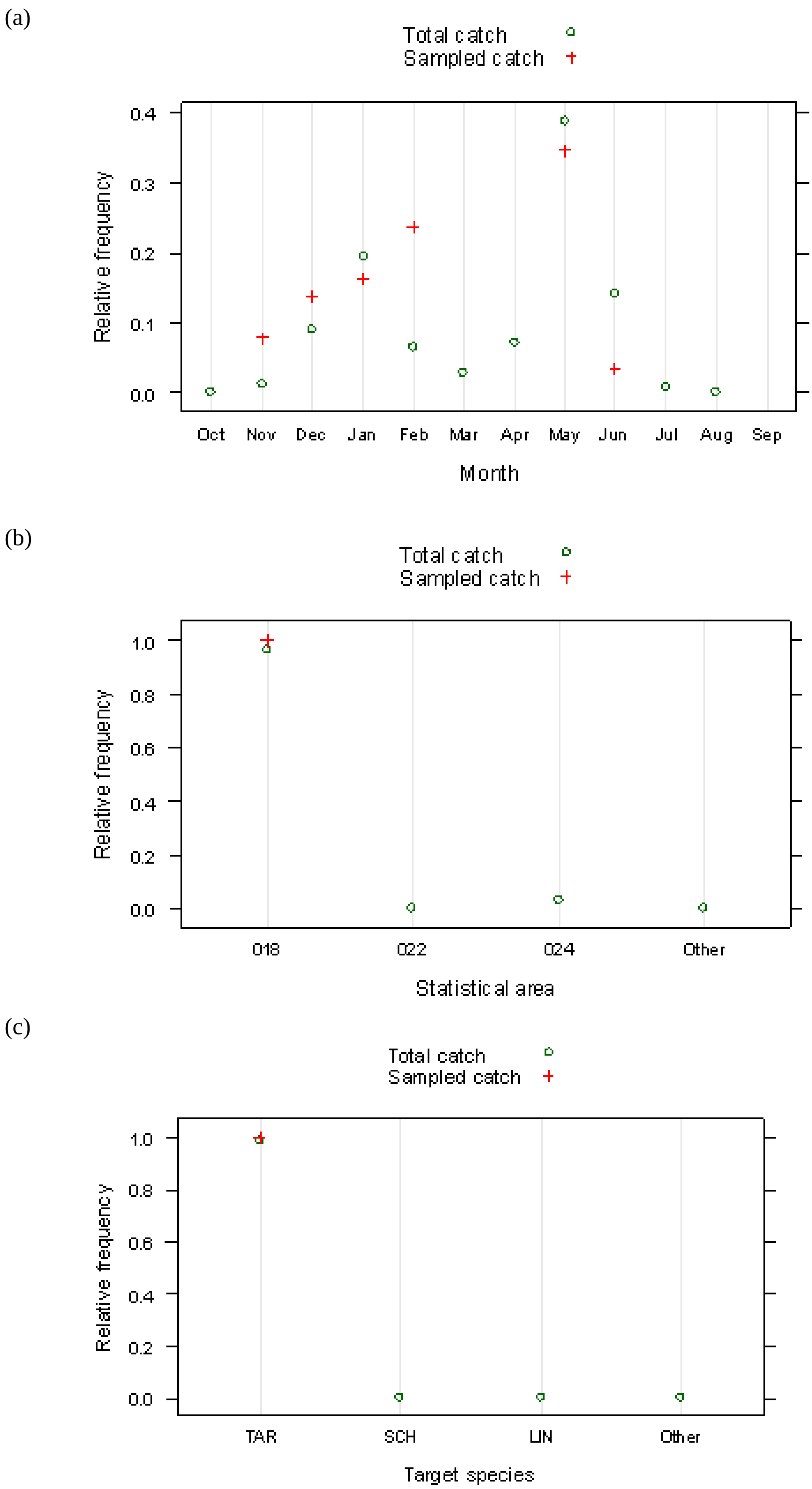


Figure 39: Proportion of set net total landed catch (circles) and the proportion of sampled catch (crosses) of TAR 3 that occurred in each (a) month, (b) statistical area, and (c) by target species in the 2011 fishing year.

3.2.6 TAR 3 set net length and age composition of the catch

Length composition of the catch

The scaled length frequency distributions from the TAR 3 set net fishery were unimodal for both males and females with peaks at about 33 cm and 35 cm fork length respectively, with most fish between 30 and 40 cm (Figure 40). The minimum and maximum lengths were 25 and 42 cm for males, and 25 and 49 cm for females. Mean lengths of scaled distributions were 32.7 cm for males, 34.0 cm for females, and 33.5 cm overall. The mean weighted c.v.s were 27.8% for males, 22.4% for females, and 18.2% overall. The sex ratio was 39% male. There was no clear seasonal change in the scaled length frequency distributions.

Ageing precision

Set net age readings were very consistent between the two readers, with an APE of 1.54 and a c.v. of 1.09% (Figure 41a,d). The percent agreement was 90% and only 2 of 253 readings (0.6%) disagreed by more than 1 year. There was no age estimation bias across the age range, (Figure 41b,c). The range of final agreed age estimates was 3–24 years, although 92% of ages were less than 8 years old.

Age composition of the catch

The scaled age frequency distributions for TAR 3 set net were unimodal with peaks at 5 years for both males and females, with most fish (87% for males and 90% for females) from 3 to 6 years old (Figure 42). Minimum and maximum ages were 3 and 17 years for males, and 3 and 24 years for females. Mean ages of scaled distributions were 4.7 years for males, 4.9 years for females, and 4.8 years overall. The mean weighted c.v.s were 34.3% for males, 22.3% for females, and 18.1% overall. The older fish (7 years and older) were landed in spring and summer whereas in the autumn/winter period the oldest fish was 6 years old.

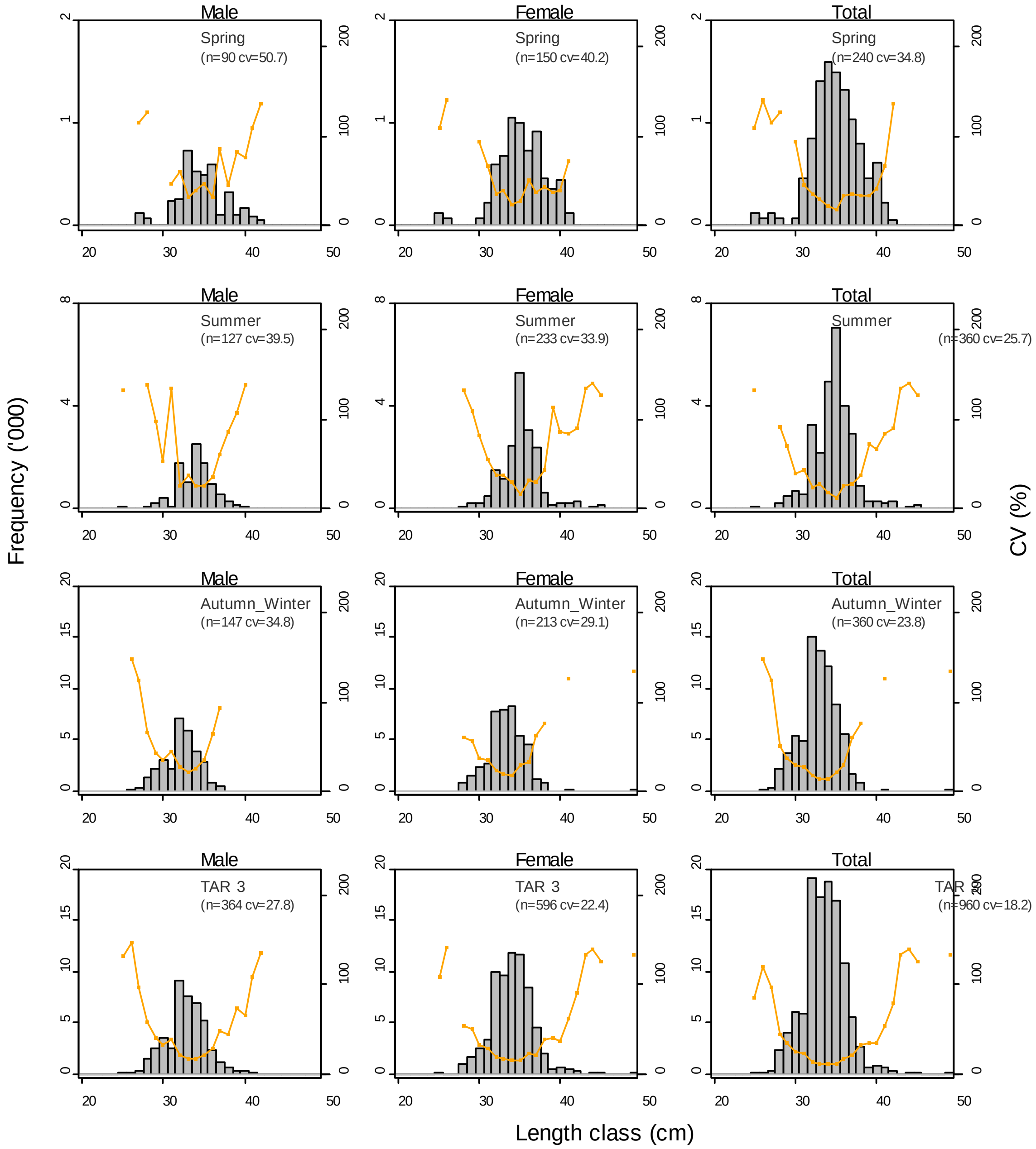


Figure 40: Scaled length frequency distributions for TAR 3 set net landings in the 2011 fishing year, segregated by sex, and stratified for fish by season sampled. Line indicates the c.v. for each length class. n, number of fished measured; cv, MWCV. 20 cm is set as the minus group.

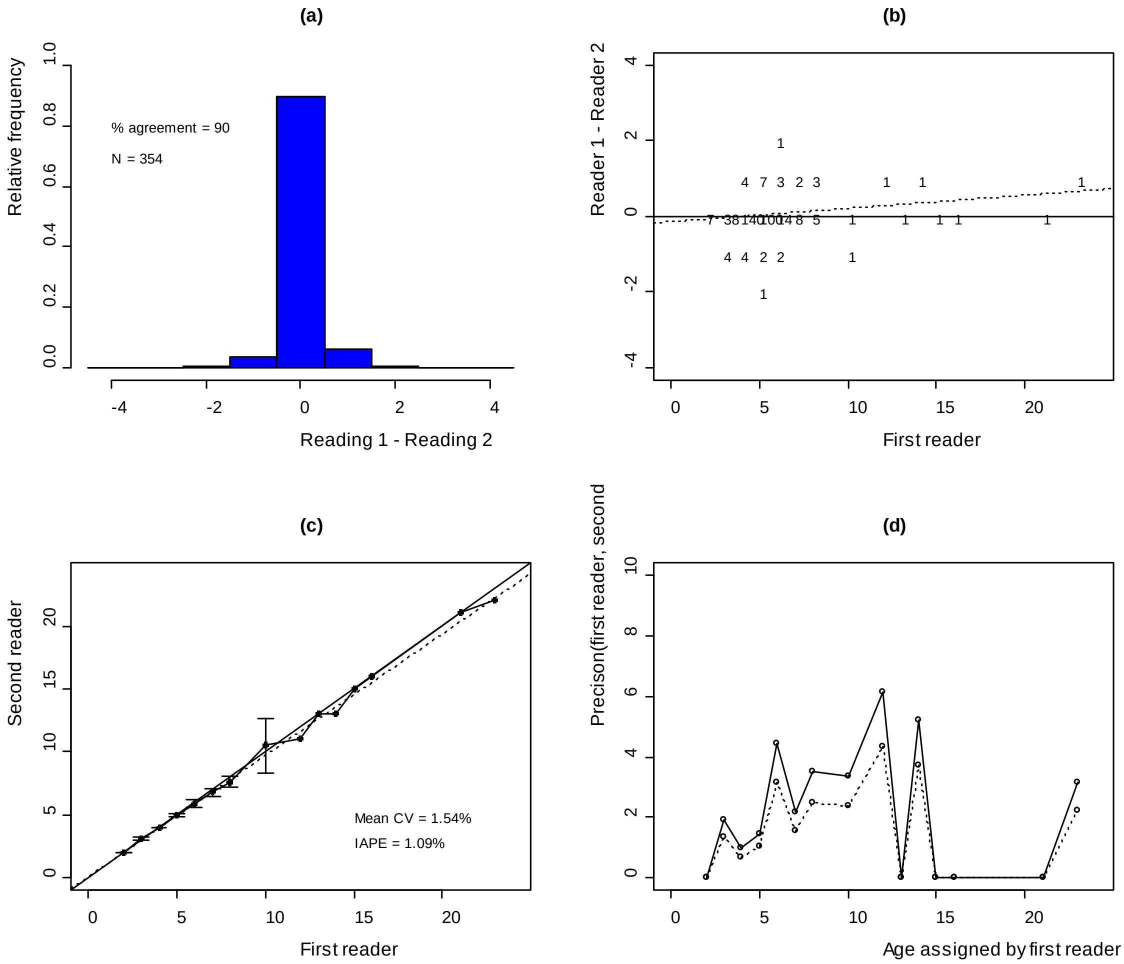


Figure 41: Age reader comparison plots for TAR 3 set net catch sampling in 2011: (a) histogram of age differences between two readers; (b) Difference between reader 1 and reader 2 as a function of the age assigned by reader 1. The number of fish in each bin is plotted as the plot symbol; (c) Age bias plot, showing the correspondence of ages between reader 1 and reader 2 for all ages. Error bars indicate the c.v. of the ages for each age by reader 1; (d) Plot of the c.v. and the average percent error (APE) for each age as assigned by the first reader. In panels b and c, solid lines show perfect agreement, dashed blue lines show the trend of a linear regression of the data.

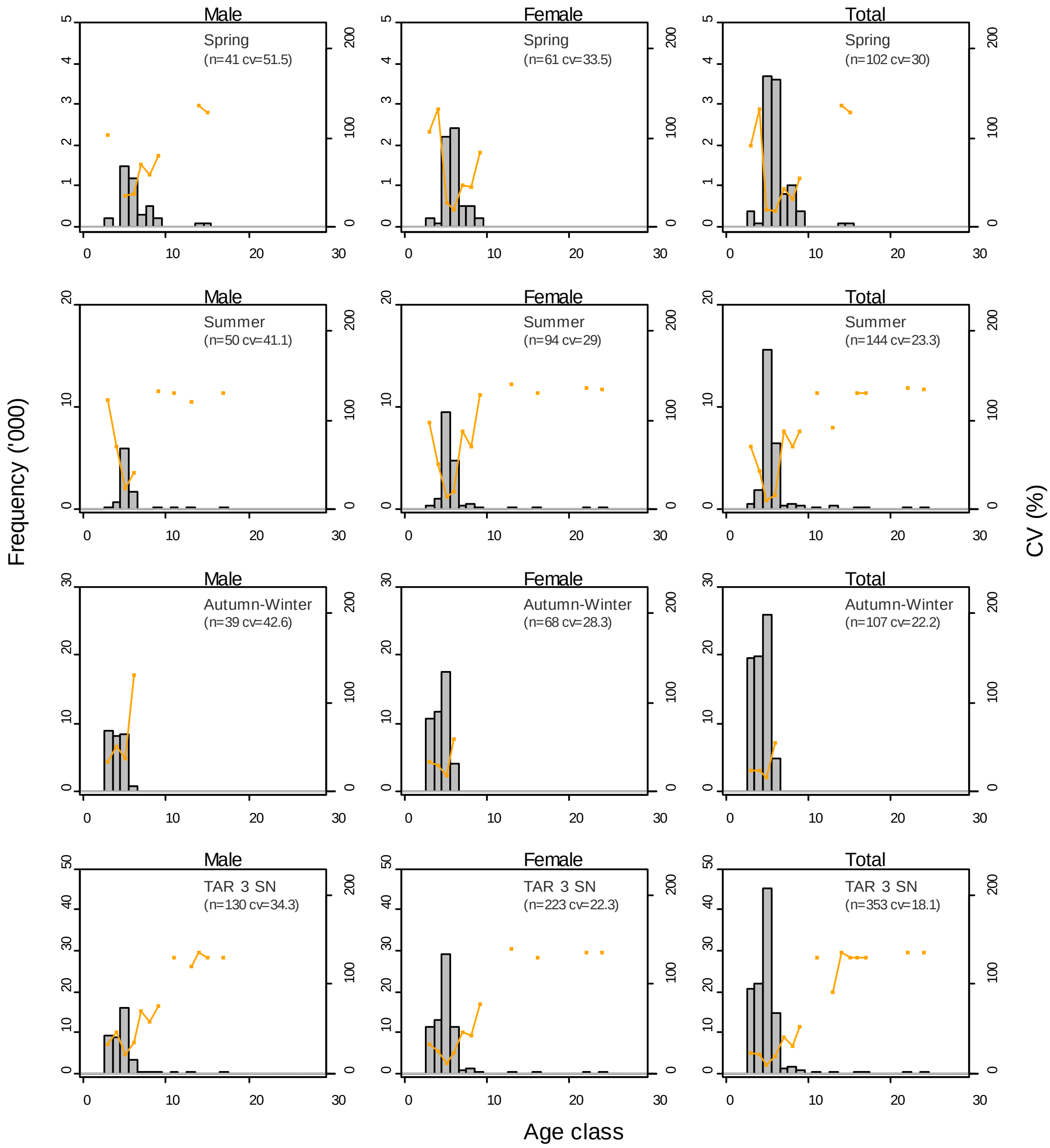


Figure 42: Scaled age frequency distributions for TAR 3 set net landings in the 2011 fishing year segregated by sex, and stratified for fish by season sampled. Lines indicate the c.v. for each age.

4. DISCUSSION

This report presents the results of the 2011 TAR 2 bottom trawl and the TAR 3 bottom trawl and set net fisheries catch sampling. This is the second year of a two year sampling programme (see TAR200901 described in Parker & Fu 2011a, and TAR200902 in Beentjes 2011).

4.1 Representativeness of sampling

Characterisations of TAR 2 and TAR 3 fisheries from Beentjes (2011) and Parker & Fu (2011a) were used to design the catch sampling programmes in 2010–11 with the aim of ensuring that the sampled landings were representative of the catch of the entire fleet for each fishery to minimize bias in the estimated length and age compositions. For example, if all landings were sampled at the beginning or at the end of the season and the fish or fishery moved seasonally, there would be a risk of a bias in the size and age of fish sampled compared to the actual catch.

A characterisation of the commercial fishery in each of TAR 2 and TAR 3 was updated for the period 2002 to 2011 to determine whether the sampling design was appropriate and if catch sampling was representative. Although temporal matches to the pattern in landed catch were not ideal, all three sampling programmes (TAR 2 bottom trawl, TAR 3 bottom trawl, and TAR 3 set net) matched the spatial patterns of the fisheries (by statistical area, and target species) and were likely to be adequate on a seasonal basis. The vessels sampled showed similar effort characteristics to the fleet as a whole for each fishery. In total, 6%, 10%, and 11% of the entire catch was actually made available for sampling from the TAR 3 set net, TAR 3 bottom trawl, and TAR 2 bottom trawl fisheries, respectively.

The MWCVs of the age compositions for the three fisheries were from 12–18%, considerably less than the target of 30%. Therefore, the sampling programmes were adequate in scope and the distributions are of adequate precision for use in stock assessment modelling.

4.2 Length and age composition of TAR 2 catch

The overall length and age composition of the TAR 2 catch was similar between 2010 and 2011, but with some age progression signal, especially in females (Figure 43). Both years showed a sex ratio of approximately 50%, and a young, uni-modal age distribution with most fish between 3 and 8 years old. Seasonal progression of increasing proportions of 2 and 3 year old fish from spring to winter occurred in 2011 as observed in 2010. This progression indicates smaller fish recruiting into the fishery, either through growth, migration, or spatial movement of fishing effort. It also indicates that catch sampling programmes would yield somewhat different age compositions depending on the temporal distribution of sampling and can be influenced by how the age compositions are stratified during the scaling process. Data provided in Appendix 2 are seasonally stratified values.

The most common age overall in 2010 was 4, but in 2011 was 5, showing modal progression (Figure 44). The relative strength of 3-4-5 year olds in 2010 was roughly similar to the relative strength of 4-5-6 year olds in 2011. In 2011, the presence of a strong 3 year old age class appearing in winter is suggested (mostly males), though this group was not fully selected by the fishery and may not fully recruit until 2012.

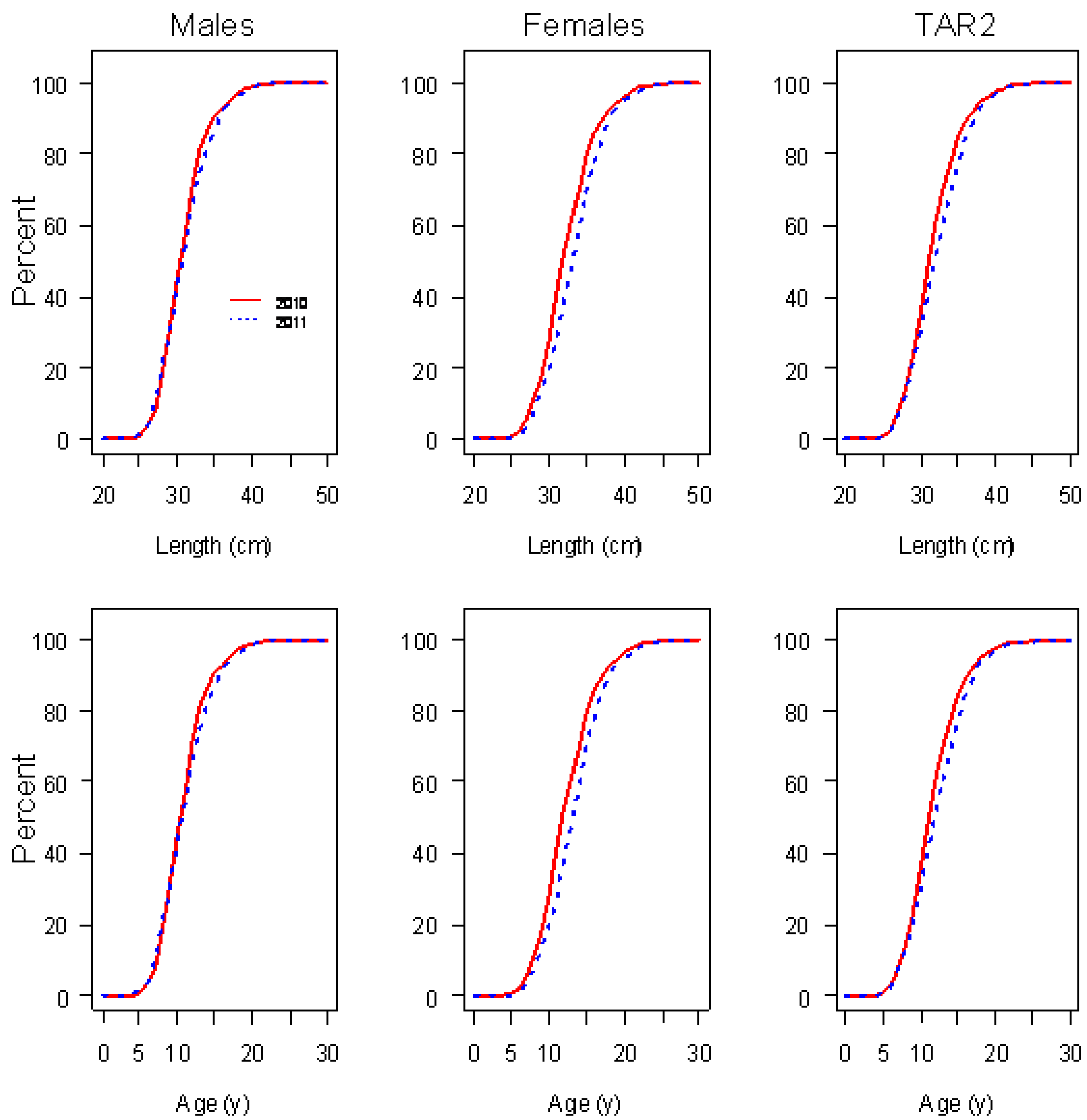


Figure 43: Scaled length and age cumulative frequency distributions for TAR 2 landings from 2010 (red solid line) and 2011 (blue dashed line) by sex and in total.

2010

2011

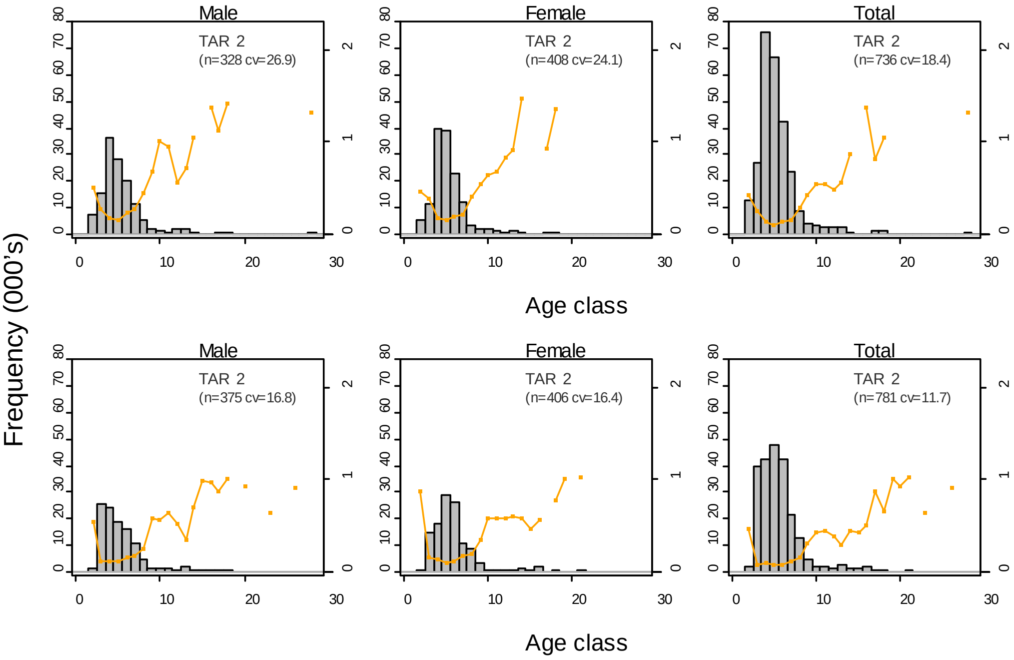


Figure 44: **Comparison of the 2010 and 2011 overall age compositions for TAR 2 bottom trawl.**

4.3 Length and age composition TAR 3 catch

2011 sampling

The TAR 3 bottom trawl catch in 2011 was characterised by single and narrow modes for both the length and age distributions for both sexes with most fish between 3 and 5 years old, and few older fish (see Figure 35 and Figure 37). There are indications of modal progression in the length distributions during the fishing year. The age distribution is characterised by the very high proportion of 3 year old fish compared to the other age classes, with the exception of spring when 4 years olds were dominant. This suggests progressive recruitment of age 3 fish into the fishery as observed in TAR 2.The MWCV of 17% for age indicates that adequate numbers of fish were measured and aged from the bottom trawl fishery.

Similarly, the TAR 3 set net catch in 2011 was characterised by single and narrow modes for both the length and age distributions for both sexes, with most fish between 4 and 7 years old, but dominated by the 5 and 6 year old fish (see Figure 40 and Figure 42). These fish were on average about 5 cm larger and 2 years older than those from the bottom trawl fishery. The MWCV of 18% for age indicates that adequate numbers of fish were measured and aged for the set net fishery.

Comparison of TAR 3 in 2010 and 2011

Fish in the bottom trawl fishery were smaller and younger in 2011 than 2010 (Figure 45). The 2011 bottom trawl fishery is dominated by 3 year old fish whereas in 2010, 4 and 5 year old fish were represented in higher proportions (Figure 46). There are more than twice the numbers of fish in the 2011 bottom trawl age composition, a result of the scaling by higher catches compared to 2010 (2010 catch = 418 t, 2011 catch = and 897 t). The higher catches are consistent with the TAR 3 bottom trawl CPUE which showed a marked increase in 2011 after the absence of any trend since 2004 (Starr & Kendrick 2012), consistent with a strong 3 year old age class entering the fishery. The numbers of 4 years olds in 2011 were greater than the number of 3 year olds in 2010 suggesting that tarakihi were not fully recruited until age 4 years. Sex ratios are close to parity for the bottom trawl fishery in both years (2010 = 44% male, 2011 = 53% male).

The length and age distributions for the set net catch are similar for 2010 and 2011 with a tendency for fish to be overall slightly younger in 2011 (Figure 47). In both years age distributions have a dominant 5 year old age class, but the 3 years olds are more prominent in 2011, particularly in the autumn-winter period, despite there being less than half the number of fish in the 2011 set net age composition (Figure 48). This is consistent with the bottom trawl results and also suggests good recruitment of 3 years olds to the set net fishery in 2011. Similarly, the numbers of 4 years olds in 2011 were greater than the number of 3 years olds in 2010 suggesting that tarakihi were not fully recruited until age 4 years. Sex ratios were skewed towards females in the set net fishery in both years (2010 = 33% male, 2011 = 39% male). The 5 year old fish dominate the age distributions for both 2010 and 2011 and suggest that either fish are not fully selected to the set net fishery when they are older than age 5, or that some 5 year old fish in 2010 moved out the fishery and did not appear in 2011 as 6 year olds.

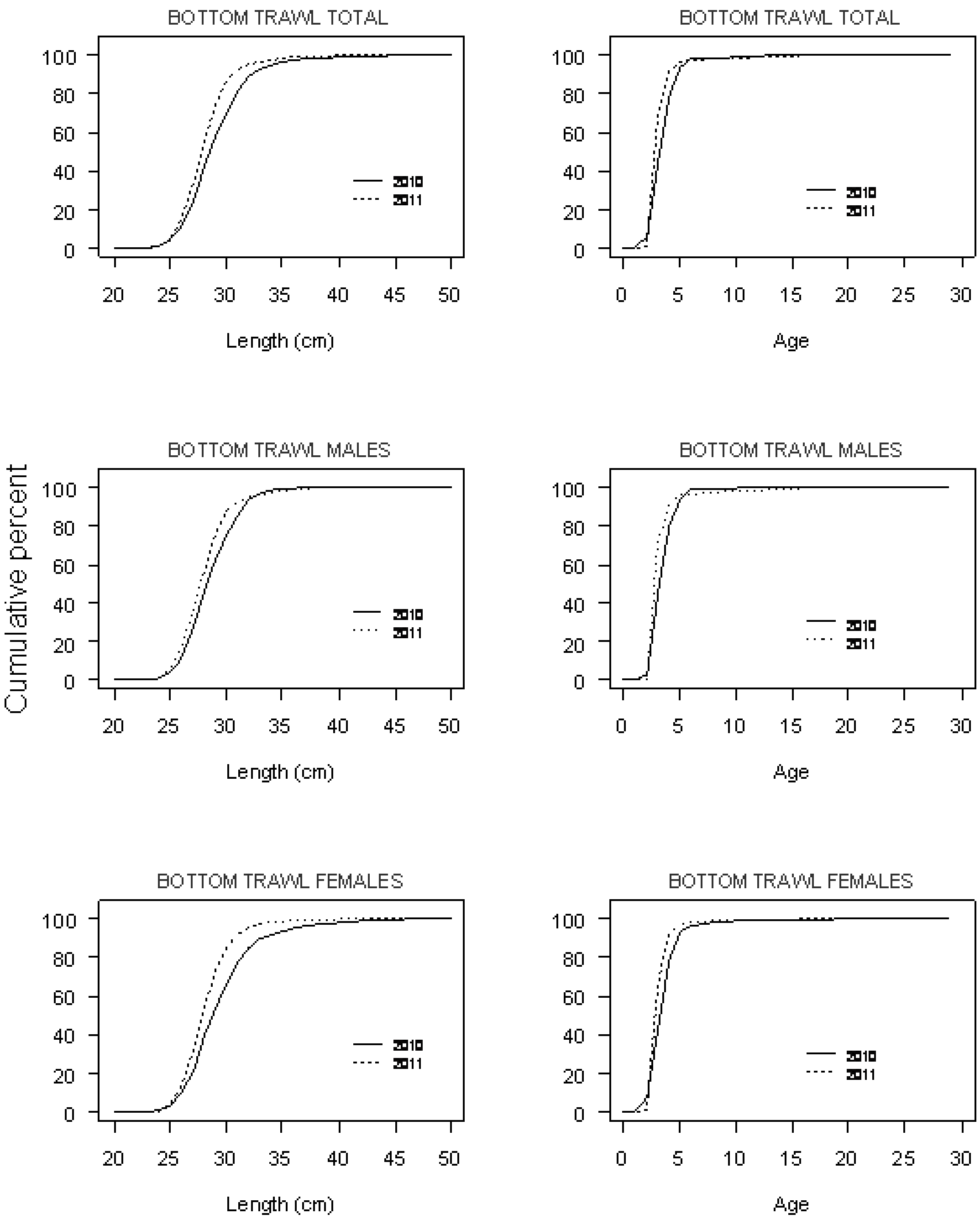


Figure 45: **Scaled length and age cumulative frequency distributions for TAR 3 bottom trawl landings from 2010 (solid line) and 2011 (dashed line) by sex and total.**

Comparison of TAR 3 bottom trawl and set net

The set net tarakihi catch off Kaikoura is thought to be based on a spawning migration, giving rise to the seasonal nature of the fishery. However, although gonad staging was not analysed in 2011, in the 2010 catch sampling, gonad staging indicated that only a small proportion of the set net fish were spawning and this was not substantially greater than the proportion spawning in the bottom trawl fishery in Pegasus Bay and the Canterbury Bight (Beentjes 2011). The larger and older tarakihi sampled from the set net fishery (on average about 4 cm larger and a year or two older) could be, to some extent, a result of gear selectivity – the target set net fishery uses 125 mm mesh size compared to a 100 mm codend in the bottom trawl fishery and deep water set netting (targeting ling, rig, school shark, dark ghost shark) uses 175 mm. Spawning fish observed in 2010, tended to be in the late summer-autumn period, consistent with the findings from earlier studies (Tong & Vooren 1972, Vooren & Tong 1973, Vooren 1975). It is noteworthy that the only fish with gonad condition recorded as ripe, were females. Size at 50% maturity for tarakihi is about 32 cm and 5 years of age (Parker & Fu 2011a) which indicates that the bulk of trawl caught fish, but less than half of the set net fish are immature.

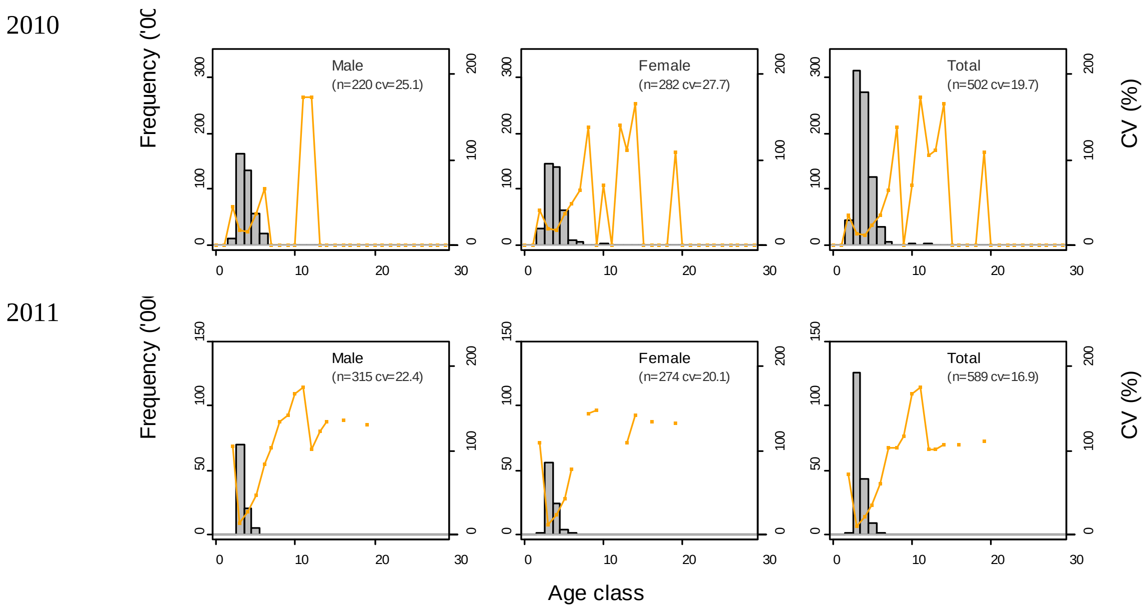


Figure 46: Comparison of the 2010 and 2011 overall age compositions for TAR 3 bottom trawl.

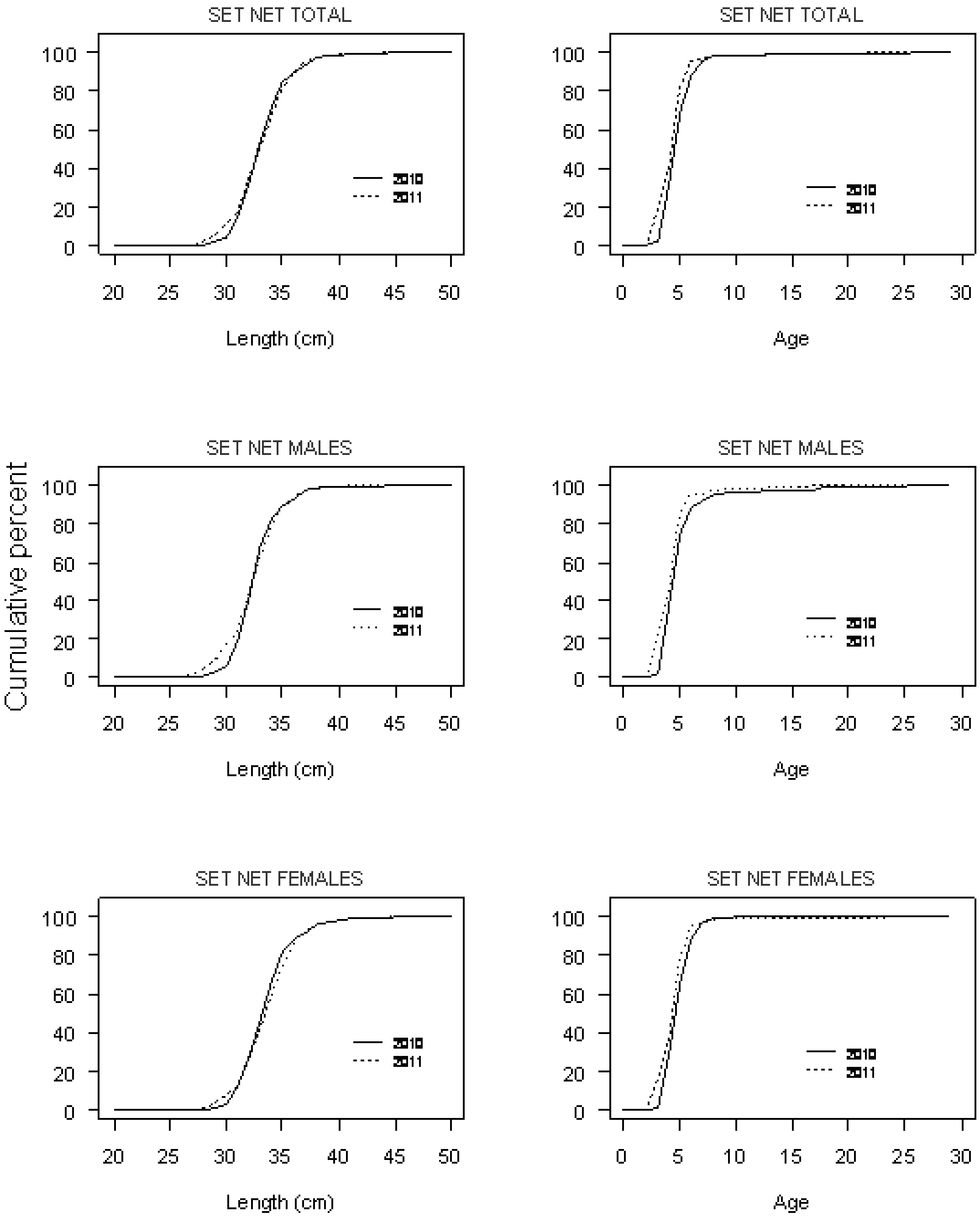


Figure 47: Scaled length and scaled age cumulative frequency distributions for the TAR 3 bottom trawl fishery in 2010 and 2011.

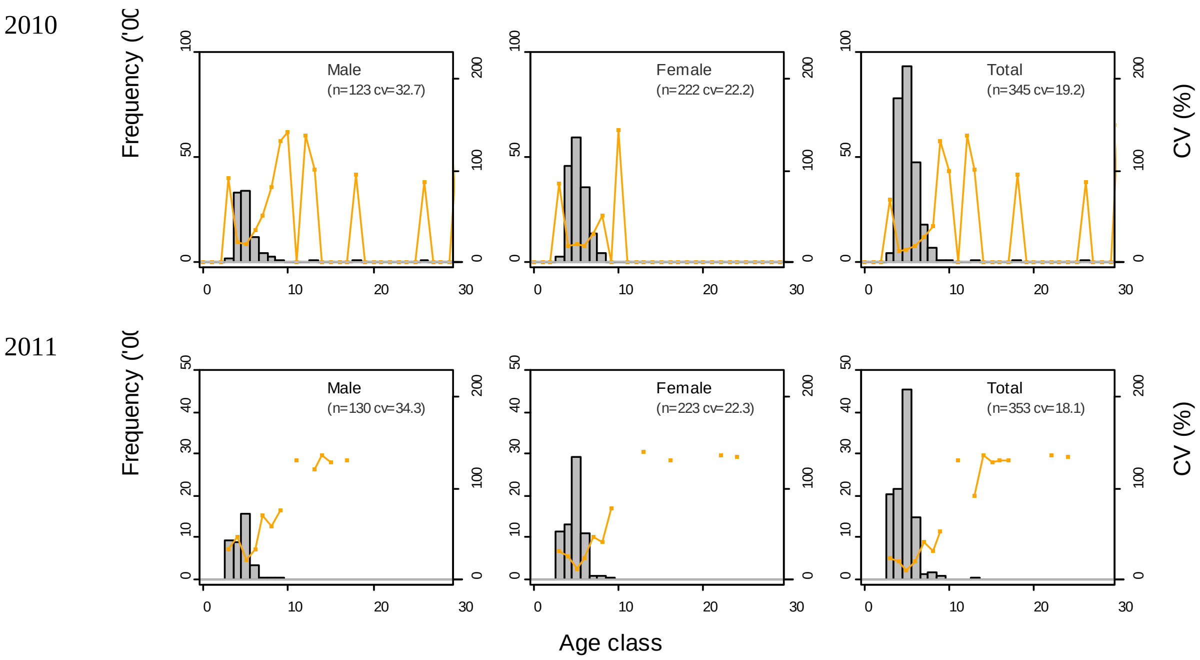


Figure 48: Comparison of the 2010 and 2011 overall age compositions for TAR 3 set net.

4.4 Comparison between QMAs and historic surveys

The 2010 and 2011 catch sampling programmes indicate that tarakihi from the ECSI (TAR 3) fisheries, and particularly those from the bottom trawl fishery, are smaller and younger than tarakihi caught from the east coast of the North Island (TAR 2). Catch in both areas are considerably smaller and younger than those captured in TAR 7 in 2004–05 (Manning et al. 2008). The main difference between the TAR 2 and TAR 3 age compositions is that TAR 3 is comprised of few fish older than about 6 years, particularly the trawl fishery. The length distributions from the ECSI *Kaharoa* trawl survey winter time series from 1991 (Beentjes & Wass 1994) through to the most recent survey in 2009 (Beentjes et al. 2010) have shown a consistent length distribution with few fish over 35 cm and the largest mode similar to that observed in the catch sampling in 2010, although no ageing has been carried out. These findings support the view that this area has been predominantly a juvenile area since at least the early 1990s.

In contrast, research trawl surveys of Pegasus Bay in 1970 and 1978 show a good representation of older fish with 20% of fish older than 10 years (Tong 1979). Similarly, research trawl surveys from Kaikoura to Cape Campbell in 1970 (Vooren 1973) and 1978 (Tong 1979) also showed tarakihi populations with more than 20% of fish older than 10 years. This age composition appears to have remained through to the late 1980s as the 1987 *James Cook* survey between Banks Peninsula and Cook Strait showed that length and ages of both sexes were reasonably well represented out to 45 cm and about 30 years of age or more (Annala et al. 1990). Further, a comprehensive *W.J. Scott* trawl survey of the ECSI between 1978 and 1980 (Fenaughty & Bagley 1981) showed variable length distributions spatially and temporally but, in the Canterbury Bight and Banks Peninsula to Kaikoura areas, tarakihi between 40 and 50 cm were caught, comprising reasonably high proportions of the catch in the latter area. This is stark contrast to the 2010 and 2011 length distributions where few fish over 40 cm were observed (see Figure 47).

These findings suggest that there has been a marked change in the age composition of the TAR 3 fishery between the 1970s and what was observed in 2010–11, with the loss of virtually all fish above 10 years of age. The change is most evident for the area north of Banks Peninsula, and also casts doubt on the commonly held view that the ECSI, south of Pegasus Bay, was always exclusively a nursery ground for juvenile tarakihi. Note that some of the early research surveys mentioned above targeted tarakihi and fished on known tarakihi grounds where they were likely to catch larger fish, whereas the commercial bottom trawl fishery is not a target fishery, and hence may not be landing the largest fish in the population. This does not, however, explain the absence of large fish in the set net target fishery.

Comparison of the age composition of TAR 2 over time suggests a relatively stable young population, typically lacking large numbers of adults. Vooren & Tong (1973) showed similar age and size distributions to Parker and Fu (2011a) and the present study, though the whole otolith ageing methodology of Vooren & Tong (1973) tended to underestimate age, and the most common ages reported were 6–7 years old, versus 4–5 years old in 2010–11. Still, their survey (Vooren & Tong 1973) matched the distribution of the fishery and occurred during the spawning season, documenting spawning fish from Gisborne to East Cape. This matches observations of spawning locations from egg surveys conducted in the same area over relatively shallow waters (Robertson 1978).

A similar size composition (though slightly larger), was observed in the series of east coast North Island trawl surveys (1993–96, Stevenson & Hanchet 2000a). Therefore data from around 1970, the mid-1990s, and in 2010–11, along with a long history of stable catches at the TACC (set near to what was recommended by Vooren (1973) all suggest a stable, but mainly juvenile age composition with a minor proportion of the population more than 10 years old.

Tong & Vooren (1972) sampled the Bay of Plenty and described an age structure that was similar to the age composition at East Cape (Vooren & Tong (1973), though the mode here was 7–8 years old. Parker & Fu (2011a) suggested that tarakihi south of Mahia Penninsula were younger than those to the north. These studies all suggest a cline in age from the Wairarapa coast through to the northern Bay of Plenty, with adult fish mainly in the Bay of Plenty region. In all of these studies, relatively small proportions of fish older than 10 years were observed. Given that fish sampled from the bottom trawl fishery in Canterbury Bight were younger than those sampled by Parker & Fu in TAR 2, this cline may extend from east coast South Island to the Bay of Plenty.

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Appendix I: Scaled age frequencies and coefficients of variation (c.v.) of the 2011 TAR 2 commercial bottom trawl catch. Results are shown by age and sex for the 2011 fishing year, and c.v.s are also shown for combined ages by season and for the fishing year.

	Numbers			Coefficient of variation (c.v.)		
Age class	Males	Females	Total	Males	Females	Total
0	0	0	0	NA	NA	NA
1	0	0	0	NA	NA	NA
2	13 694	3 923	17 617	0.55	0.88	0.46
3	252 299	147 938	400 238	0.11	0.14	0.08
4	244 884	180 992	425 876	0.11	0.14	0.09
5	188 951	291 139	480 090	0.12	0.10	0.07
6	160 517	263 821	424 338	0.14	0.11	0.08
7	108 407	104 446	212 853	0.18	0.17	0.11
8	46 227	83 918	130 145	0.25	0.20	0.14
9	12 546	35 191	47 737	0.58	0.35	0.31
10	11 454	8 064	19 518	0.56	0.59	0.42
11	9 858	7 805	17 663	0.64	0.57	0.44
12	6 577	5 382	11 959	0.52	0.59	0.38
13	16 079	7 079	23 158	0.34	0.60	0.29
14	4 443	8 643	13 087	0.69	0.58	0.44
15	2 944	8 202	11 146	0.98	0.46	0.41
16	2 006	15 681	17 687	0.97	0.56	0.51
17	4 385	0	4 385	0.87	NA	0.87
18	3 828	2 659	6 487	1.00	0.78	0.67
19	0	291	291	NA	1.00	1.00
20	458	0	458	0.94	NA	0.94
21	0	5 552	5 552	NA	1.02	1.02
22	0	0	0	NA	NA	NA
23	916	0	916	0.63	NA	0.63
24	0	0	0	NA	NA	NA
25	0	0	0	NA	NA	NA
26	458	0	458	0.92	NA	0.92
27	0	0	0	NA	NA	NA
28	0	0	0	NA	NA	NA
29	0	0	0	NA	NA	NA
30	0	0	0	NA	NA	NA

	Mean weighted c.v.		
Stratum	Males	Females	Total
Fishing year	0.168	0.164	0.117

Stratum	Mean weighted c.v.		
Spring	0.424	0.32	0.266
Summer	0.265	0.243	0.180
Autumn	0.302	0.265	0.203
Winter	0.213	0.271	0.165

Appendix II: Scaled age frequencies and coefficients of variation (c.v.) of the 2011 TAR 3 commercial bottom trawl catch. Results are shown by age and sex for the 2011 fishing year, and c.v.s are also shown for combined ages by season and for the fishing year.

	Numbers			Coefficient of variation (c.v.)		
Age class	Males	Females	Total	Males	Females	Total
0	0	0	0	NA	NA	NA
1	0	0	0	NA	NA	NA
2	7 204	11 039	18 243	1.062	1.101	0.718
3	695 295	562 841	1258140	0.139	0.119	0.096
4	198 886	240 492	439 378	0.281	0.238	0.226
5	52 929	35 395	88 324	0.467	0.433	0.353
6	6 685	12 137	18 822	0.842	0.777	0.614
7	2 699	0	2 699	1.037	NA	1.037
8	5 064	2 441	7 505	1.353	1.443	1.025
9	3 376	506	3 882	1.424	1.488	1.166
10	1 688	0	1 688	1.672	NA	1.672
11	1 688	0	1 688	1.761	NA	1.761
12	4 005	0	4 005	1.022	NA	1.022
13	3 882	3 499	7 381	1.230	1.094	1.005
14	5 064	1 811	6 876	1.341	1.419	1.067
15	0	0	0	NA	NA	NA
16	1 811	2 441	4 252	1.357	1.341	1.068
17	0	0	0	NA	NA	NA
18	0	0	0	NA	NA	NA
19	1 811	1 811	3 623	1.311	1.330	1.120
20	0	0	0	NA	NA	NA
21	0	0	0	NA	NA	NA
22	0	0	0	NA	NA	NA
23	0	0	0	NA	NA	NA
24	0	0	0	NA	NA	NA
25	0	0	0	NA	NA	NA
26	0	0	0	NA	NA	NA
27	0	0	0	NA	NA	NA
28	0	0	0	NA	NA	NA
29	0	0	0	NA	NA	NA
30	0	1 811	1 811	0	1.4251	1.4251

	Mean weighted c.v.		
Stratum	Males	Females	Total
Fishing year	0.224	0.201	0.169

Stratum	Mean weighted c.v.		
Spring	0.737	0.593	0.531
Summer	0.363	0.346	0.283
Autumn	0.385	0.368	0.306
Winter	0.395	0.287	0.266

Appendix III: Scaled age frequencies and coefficients of variation (c.v.) of the 2011 TAR 3 commercial set net trawl catch. Results are shown by age and sex for the 2011 fishing year, and c.v.s are also shown for combined ages by season and for the fishing year.

	Numbers			Coefficient of variation (c.v.)		
Age class	Males	Females	Total	Males	Females	Total
0	0	0	0	NA	NA	NA
1	0	0	0	NA	NA	NA
2	0	0	0	NA	NA	NA
3	9 217	11 306	20 522	0.325	0.322	0.232
4	8 834	12 961	21 794	0.465	0.256	0.205
5	15 838	29 259	45 097	0.210	0.119	0.091
6	3 528	11 198	14 726	0.342	0.230	0.189
7	308	879	1 187	0.706	0.463	0.403
8	509	1 060	1 569	0.584	0.417	0.308
9	389	387	775	0.758	0.775	0.521
10	0	0	0	0.000	NA	NA
11	185	0	185	1.308	NA	1.308
12	0	0	0	NA	NA	NA
13	185	189	374	1.205	1.396	0.912
14	95	0	95	1.365	NA	1.365
15	95	0	95	1.295	NA	1.295
16	0	181	181	NA	1.306	1.306
17	185	0	185	1.306	NA	1.306
18	0	0	0	NA	NA	NA
19	0	0	0	NA	NA	NA
20	0	0	0	NA	NA	NA
21	0	0	0	NA	NA	NA
22	0	192	192	NA	1.364	1.364
23	0	0	0	NA	NA	NA
24	0	181	181	NA	1.351	1.351
25	0	0	0	NA	NA	NA
26	0	0	0	NA	NA	NA
27	0	0	0	NA	NA	NA
28	0	0	0	NA	NA	NA
29	0	0	0	NA	NA	NA
30	0	0	0	NA	NA	NA

	Mean weighted c.v.		
Stratum	Males	Females	Total
Fishing year	0.343	0.223	0.181

Stratum	Mean weighted c.v.		
Spring	0.515	0.335	0.300
Summer	0.411	0.290	0.233
Autumn-winter	0.426	0.283	0.222