Age composition of the commercial tarakihi (*Nemadactylus macropterus*) catch in quota management area TAR 2 in fishery year 2009–2010

S. Parker[1]
D. Fu[2]

[1]NIWA
PO Box 893
Nelson

[2]NIWA
Private Bag 14901
Wellington

New Zealand Fisheries Assessment Report 2011/59
December 2011

Published by Ministry of Fisheries
Wellington
2011

ISSN 1175-1584 (print)
ISSN 1179-5352 (online)

©
Ministry of Fisheries
2011

Parker, S.; Fu, D. (2011).
Age composition of the commercial tarakihi (*Nemadactylus macropterus*) catch in quota management area TAR 2 in fishery year 2009–2010.
New Zealand Fisheries Assessment Report 2011/59.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

EXECUTIVE SUMMARY

Parker, S.; Fu, D. (2011). Age composition of the commercial tarakihi (*Nemadactylus macropterus*) catch in quota management area TAR 2 in fishery year 2009–2010.

New Zealand Fisheries Assessment Report 2011/59.

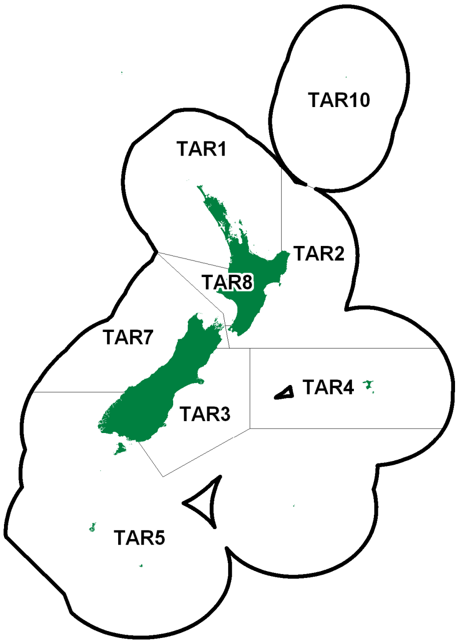
In preparation for an integrated stock assessment of east coast tarakihi, a catch sampling programme was carried out in the 2010 fishing year to generate an annual age composition for the TAR 2 catch from the single trawl fishery using market samples. A catch sampling programme was designed that included sampling in all twelve months in relation to the expected magnitude of catch. There was no formal temporal or spatial stratification, although post-stratification of samples to examine potential differences in age composition north and south of the Mahia Peninsula was conducted. Samples were collected from the processors landing the most fish in Napier and Gisborne, with some Napier-landed fish sampled after transport to Auckland. A total of 30 samples, each comprised of 60 fish was targeted.

Thirty-six samples were collected, with a total of more than 2000 fish sampled for biological information and otoliths. Given the variability in the timing and location of fishing in a given fishing year, sampling was roughly proportional to landed catch, statistical areas fished, and target species.

A total of 736 otoliths were aged following newly developed ageing protocols for tarakihi. Age composition was estimated for the entire catch, and for catch taken from north or south of Mahia Peninsula (39.264° S) based on spatial differences in population structure observed in other species. Fish south of Mahia Peninsula were typically younger than those to the north, ranging in age from 2–5 years old compared to 4–6 years old in the north. However, both areas lacked large or old fish. Although tarakihi can live to more than 40 years of age, the oldest fish sampled was 28, and only 4.4% of the fish in the catch were greater than 10 years old.

With a natural mortality estimate of 0.10, Chapman-Robson estimates of Z result in estimates of F ranging from 0.34–0.39 depending on the age of full selection chosen (4 or 5 years). Spawner per recruit analysis using growth data from this study and maturity data from the northeast South Island suggest that an equilibrium SPR of 45% would result from an F of 0.0695, and that current levels of F would result in an SPR of less than 10%.

These analyses assume that selectivity is maximum and constant for fish greater than 3 or 4 years old. If larger or older fish are not present in the areas sampled, their absence would be interpreted by these models as mortality due to fishing. However, the potential of an ontogenetic migration northward is supported by observations of a progressively older age composition north of Mahia Peninsula, and still older fish in the Bay of Plenty. Accurate interpretation of these data will require simultaneous analysis of samples from TAR 1, 2, and 3. Previous work has suggested that larvae from an East Cape spawning area and a Kaikoura spawning area are both transported by along shore currents to eastern Cook Strait, where mixing may occur, and a portion of the juveniles may then move towards the north. This life history would result in age composition of catches consistent with the data summarized here, and also consistent with the long history of stable catches in TAR 2.



1. INTRODUCTION

This report summarises a catch sampling programme conducted from October 2009 through to September 2010 to estimate the age composition of tarakihi captured in TAR 2.

The specific objectives were:

1) To characterise the TAR 2 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 ages).
3) To age tarakihi otoliths collected during the above sampling programme.

2. FISHERY SUMMARY

2.1 Commercial fisheries

Tarakihi (*Nemadactylus macropterus*) are caught commercially around both the North and South Islands mainly to depths of 250 m. 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 fishery was managed under the Adaptive Management Programme (AMP), based on a stable catch history and lack of trend in standardised CPUE analysis (Hanchet & Field 2001, Jiang & Bentley 2008, Ministry of Fisheries 2010, Bentley & Kendrick 2011). Fishing year is defined as the year in which the 12-month fishing year ends; the October 2009–September 2010 period is referred to as the 2010 fishing year.

2.2 Recreational fisheries

Recreation harvest of tarakihi in TAR 2 was last estimated in 1999–2000 at 191 t with a 27% CV (Boyd & Reilly 2005). No information on recreational harvest is available for the past decade.

3. DESCRIPTIVE ANALYSIS OF CATCH

3.1 Summary of catches

The total annual 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 2010), and was exceeded in 2006, 2009, and 2010 (Figure 1). Since 2001, TAR 2 catches have averaged 1 766 t but have ranged between 1 638 t and 1 986 t.

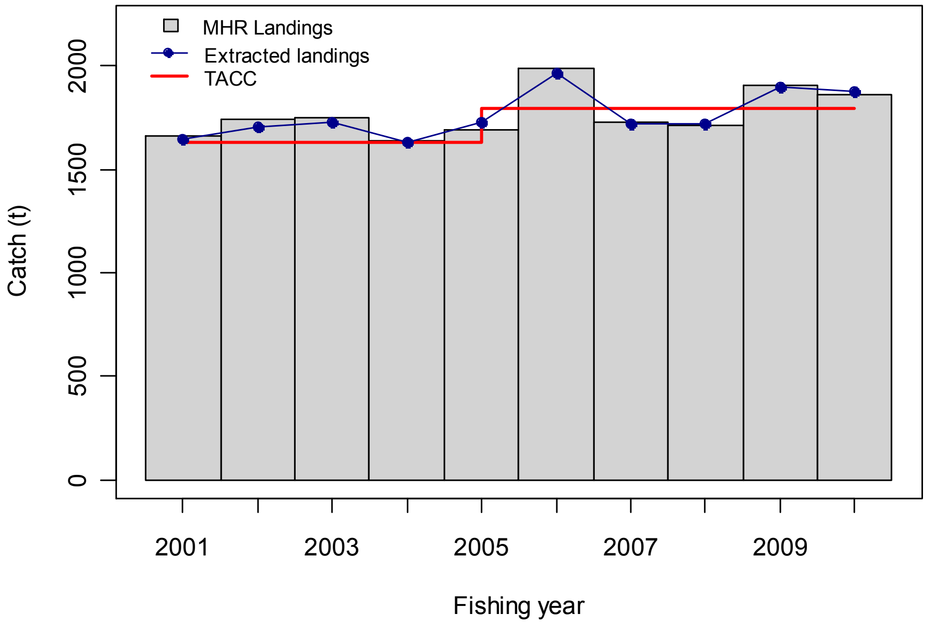


Figure 1: Total commercial catch (Quota Management Report (QMR)/Monthly Harvest Return (MHR)), total reported landings, and total allowable commercial catch (TACC) of TAR 2 (2001–2010).

3.2 Fishery characterisation

We characterised the TAR 2 fishery with the purpose of designing and assessing the design of a catch sampling programme for 2010, focusing on data from the past decade. Analyses were conducted using the statistical software R (R Development Core Team 2011).

The TAR 2 commercial catch in recent years has almost exclusively been taken (more than 99%) by bottom trawl (Table 1). Minor amounts of TAR 2 catch were landed using Danish seine, bottom longline, set net or mid-water trawl gears. The fishery characterisation is therefore based on the bottom trawl method.

The vast majority of tarakihi caught in FMA 2 are captured as the target species, with a minor proportion caught as bycatch while targeting red gurnard (*Chelidonichthys kumu*), warehou (*Seriolella brama*) or gemfish (*Rexea solandri*) (Figure 2). The proportion of the annual bottom trawl catch made whilst targeting tarakihi has increased by around 10% since 2005.

Table 1. Total landed catch (t) by fishing method from 2001 to 2010. BT, bottom trawl; DS, Danish seine; BLL, bottom longline; SN, set net; MW, mid-water trawl.

Fishing year	BT	DS	BLL	SN	MW	Other	Total
2001	1 550	30	1	3	1	6	1 591
2002	1 663	9	2	3	0	1	1 678
2003	1 688	4	2	3	2	0	1 699
2004	1 603	0	3	4	3	0	1 613
2005	1 669	3	5	6	1	0	1 684
2006	1 929	0	6	2	1	0	1 938
2007	1 663	3	6	1	0	0	1 673
2008	1 663	2	6	1	0	0	1 672
2009	1 815	0	10	1	1	0	1 827
2010	1 808	1	7	2	1	0	1 819
Total	17 051	52	48	26	10	7	17 194

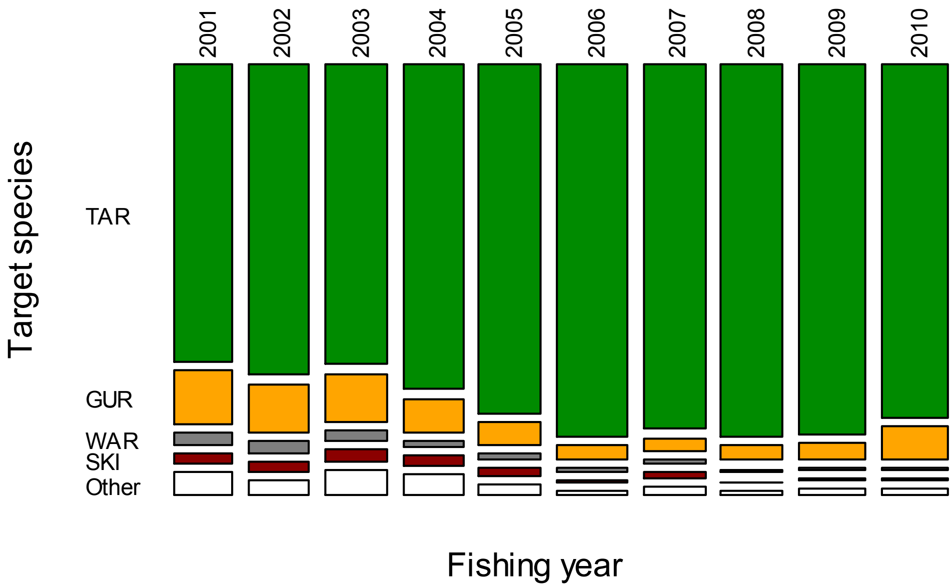
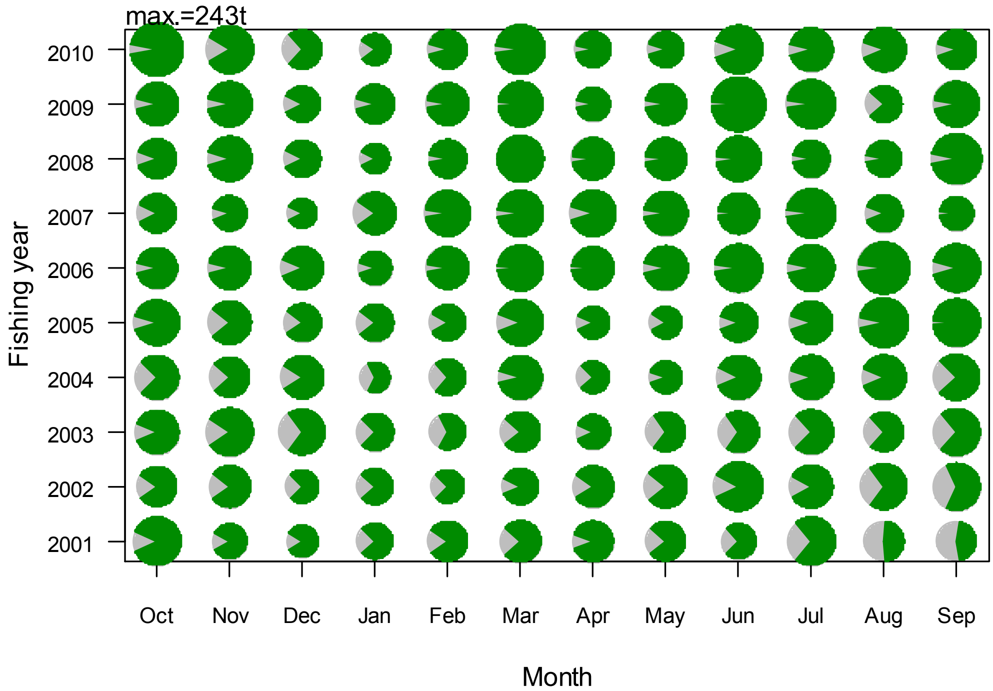


Figure 2: Annual proportion of TAR 2 reported by target species, 2001–2010.

Trawl catches are taken consistently throughout the year with no strong seasonal pattern. Most catch is from targeted tows in every month and in each statistical area (Figure 3a, b). There is no obvious seasonal pattern in the amount of catch, though some individual months tend to have higher landings than others (October/November and March). Statistical area 013 is the dominant area overall for TAR 2 catch, with the majority of TAR 2 catch typically occurring north of Hawkes Bay (See Figure 7 for statistical area locations).

Different sized trawl vessels report fishing effort and catch using different forms with different levels of detail. Combining effort and catch for multiple form types requires aggregating catch and effort to the coarsest resolution, and is especially needed for non-target species as they are not typically listed as estimated catch (Starr 2007). However, tarakihi is often captured as the target species, and therefore usually listed in the estimated catch. Merging estimated catch data from Trawl Catch Effort Processing Return forms (TCEPR) used by vessels greater than 28 m in length, and Catch Effort Landing Return forms (CELR) used by smaller vessels, results in a good estimate of landed catch (Figure 4). Retained landings are typically higher than the estimated catch because not all catch is reported in the top five species (or eight species with the new TCER forms). Merging the two datasets results in an estimate of merged and retained landings that approximates the MHR value for each fishing year.

(a)



(b)

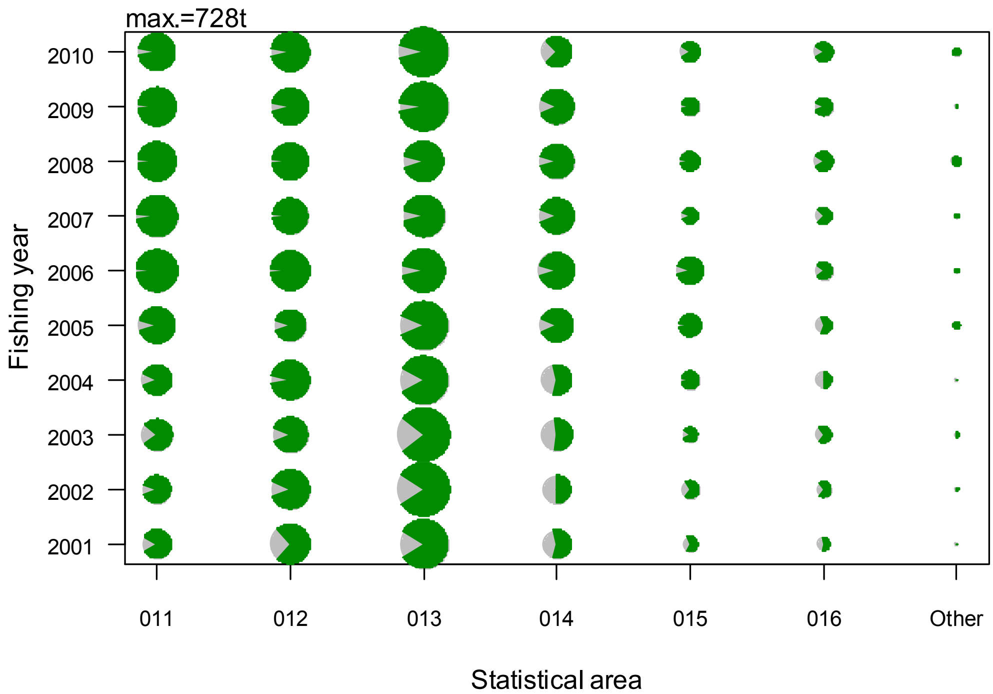


Figure 3. Pie charts of total TAR 2 landings by (a) month and year and (b) statistical area, 2001–2010. Pies show the proportion of catch in each cell landed as target (dark) or non-target (light).

Since 2008, 6–28 m vessels have been required to use Trawl Catch Effort Return forms (TCER), which in addition to requiring tow-level location and effort data, also require listing the top eight species caught by greenweight. Plotting the annual proportion of estimated catch by reporting form type shows the implementation of the TCER since 2008, which replaced the CELR form (Figure 5a). Landings grouped by form type also show the use of the CELR was discontinued in 2008, and was replaced by the CLR form to report almost all landings. The proportion of catch reported using TCEPR forms has been relatively stable through time, with a slight decline in the past few years.

The reporting rate, defined as the proportion of QMR catch reported by each form type has been consistently high, exceeding 90%, although CELR forms typically report less of the TAR 2 catch because only the top five species are listed (Figure 5b).

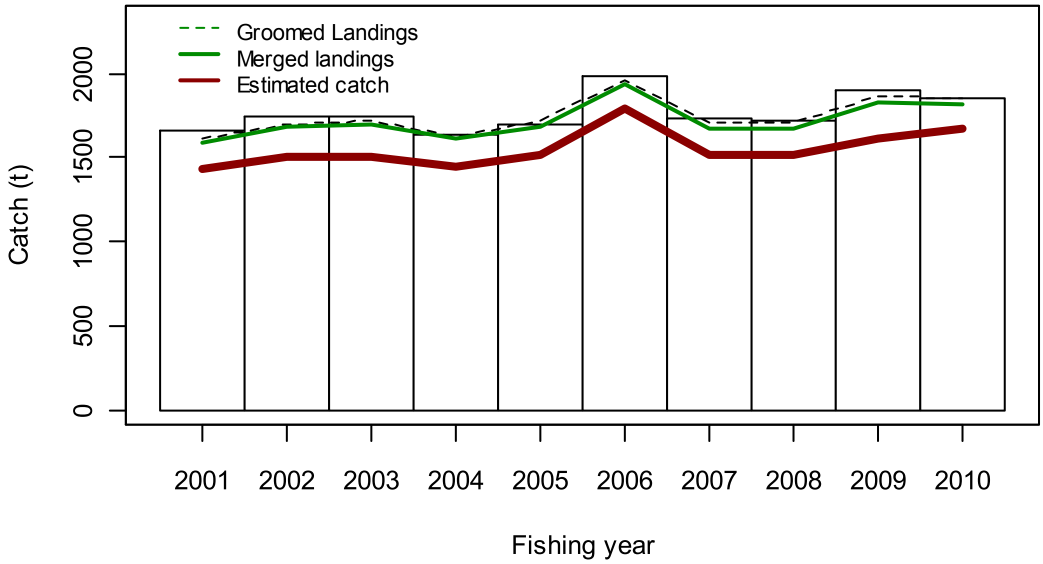


Figure 4. Total commercial catch (QMR/MHR, bars), estimated catch from fishing events (thick line), landings after grooming algorithm applied (dashed line), and merged landings from different form types (thin line) for TAR 2 (2001–2010).

Most of the TAR 2 catch is landed through one of four ports (Gisborne, Napier, Tauranga, and Wellington). Vessels landing in Gisborne and Napier tend to be non-TCEPR vessels (smaller vessels), while a significant portion of vessels landing in Tauranga and Wellington are TCEPR vessels (Figure 6a). The total amount landed each year varied by port with the dominant ports being Gisborne and Napier since 2001. During the past decade, the vessels landing TAR 2 in Tauranga were mostly TCEPR vessels, although in the past three years their landings have decreased.

There were no strong seasonal trends in landings in any of the major ports and ports did not show the same seasonal pattern, though there was a small tendency for the highest landings to occur during spring and winter months (Figure 6b).

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 6c). 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, and Tauranga landings were from fish caught in areas 011 and 012.

The spatial distribution of TAR 2 catches since 2008 can now be described more accurately than with statistical area alone. The distribution of tows reported on TCEPR forms is continuous along the entire east coast of the North Island at depths shallower than about 300 m (Figure 7a). Most of the catch comes from north of Hawkes Bay. Catch from any of the statistical areas in Cook Strait can be reported to TAR 2. Data from vessels using TCER forms show a similar distribution in general location of catch to TCEPR vessels, though with two hotspot areas off the Wairarapa and East Cape (Figure 7b). Interestingly, TCEPR vessels show high catches just outside Gisborne, while TCER data shows low catches in that area. Almost all catch occurs in the shoreward margin of each statistical area.

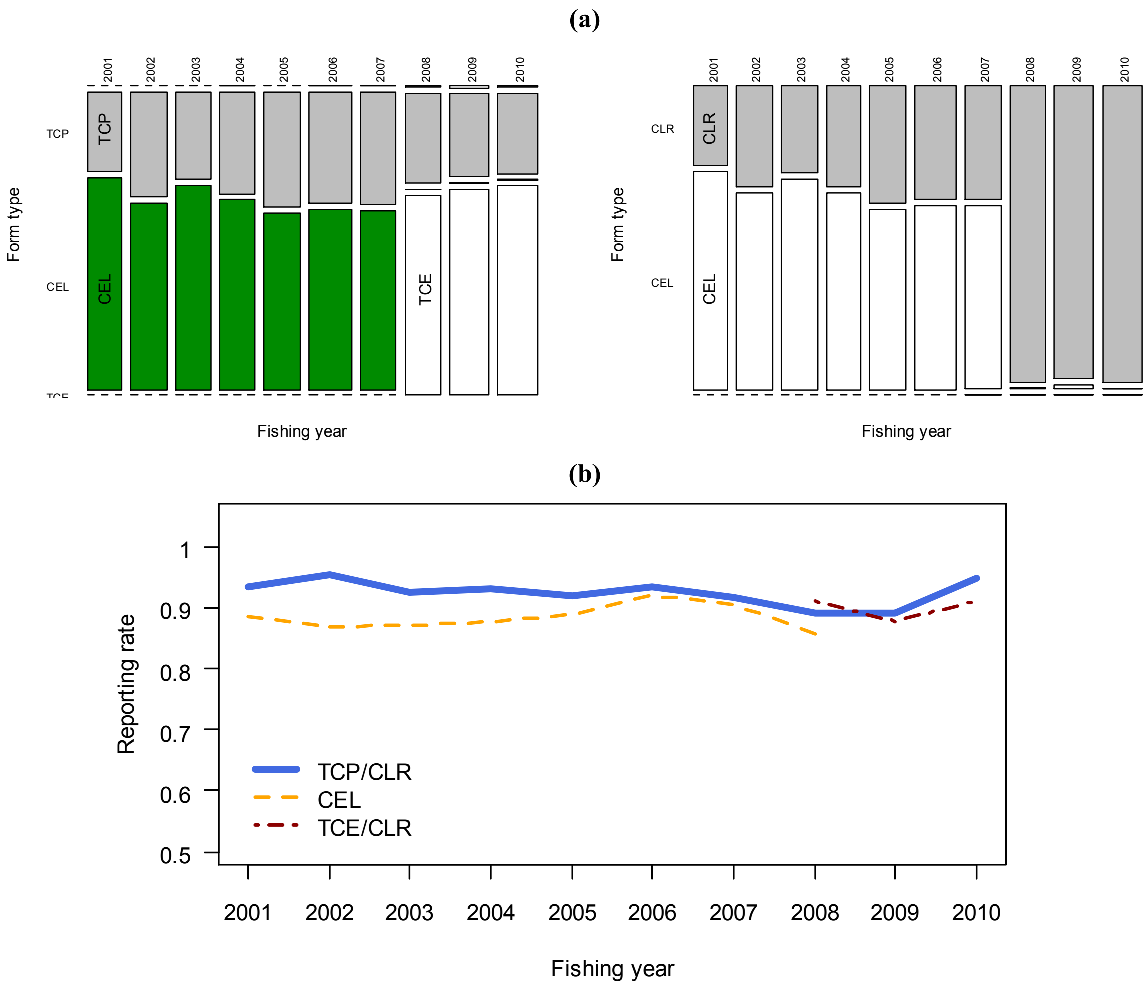
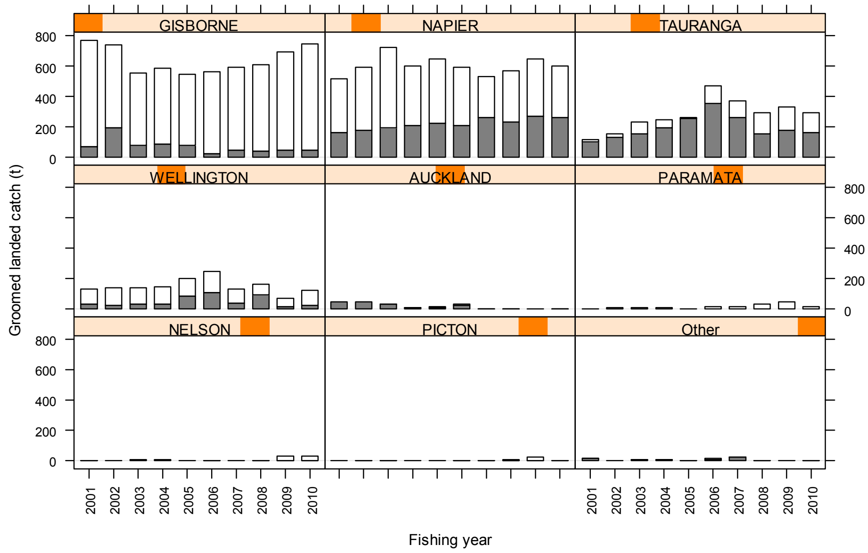


Figure 5. (a) Proportion of estimated catch (left) and landed catch (right) reported using each form type, 2001–2010. (b) The reporting rate (proportion of QMR catch) reported using each form type 2001–2010.

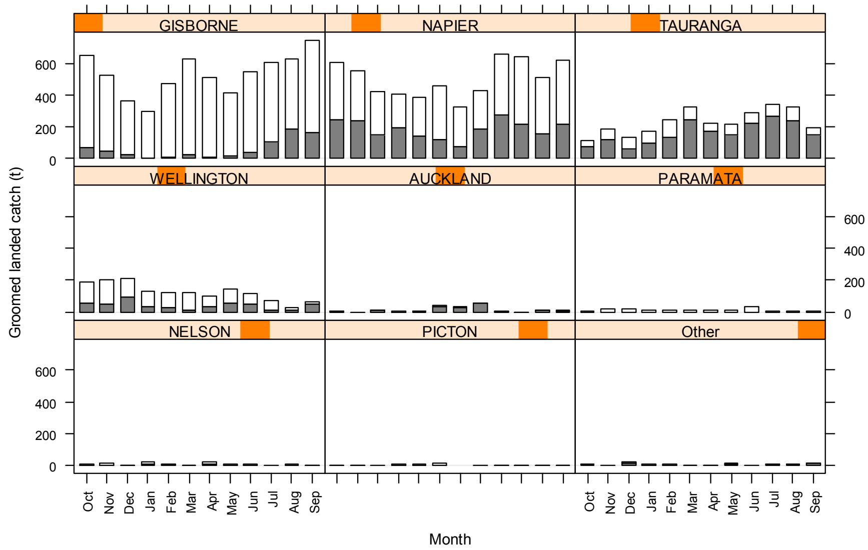
Plots of the distribution of fishing effort variables for TCEPR and TCER/CELR vessels show some significant differences between groups, and changes during the past decade, especially in 2008 (Figure 8). TCEPR vessels are consistently larger than CELR/TCER vessels, with mean lengths of 25 m while CELR/TCER vessels are usually 18–20 m in length. Fishing duration has changed the least, but even this has become less variable with time and is centred on 3.5 h tows for both large and small vessels.

Tow speeds for TCEPR vessels have consistently been just over 3 knots. Data from TCER forms beginning in 2008 suggest that the smaller vessels' tows are slightly shorter in duration. Trawl height has become slightly higher for smaller vessels through time, but both groups of vessels are typically using trawls with about 4-m headline height. Trawl width has declined slightly for TCEPR vessels, with both groups using trawls with approximately 25 m spread. As expected, the smaller CELR/TCER vessels did not fish as deep as the larger vessels, but both groups generally targeted waters 100–200 m in depth.

(a)



(b)



(c)

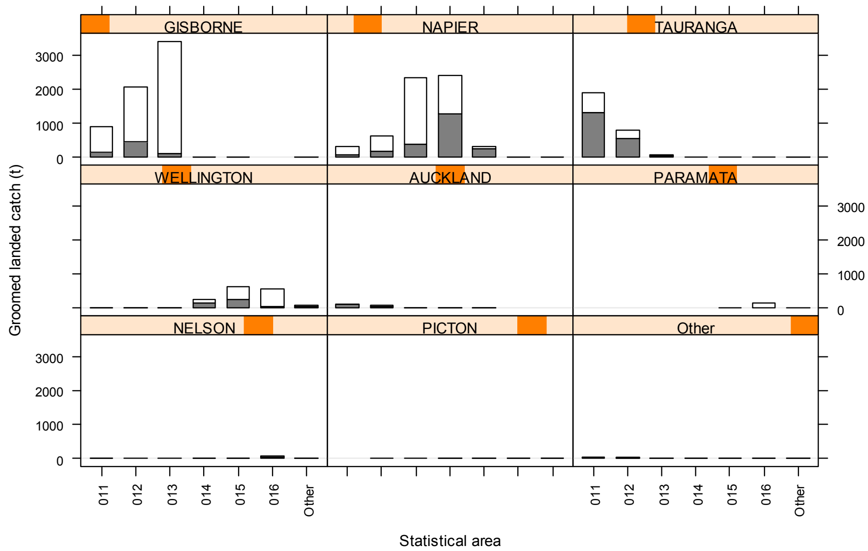


Figure 6. Distribution of landed catch of TAR 2 by major port and (a) year, (b) month, and (c) statistical area, 2001-2010. Total landed catch is split by reporting form type; either TCEPR (shaded) or other (CELR / TCER, white).

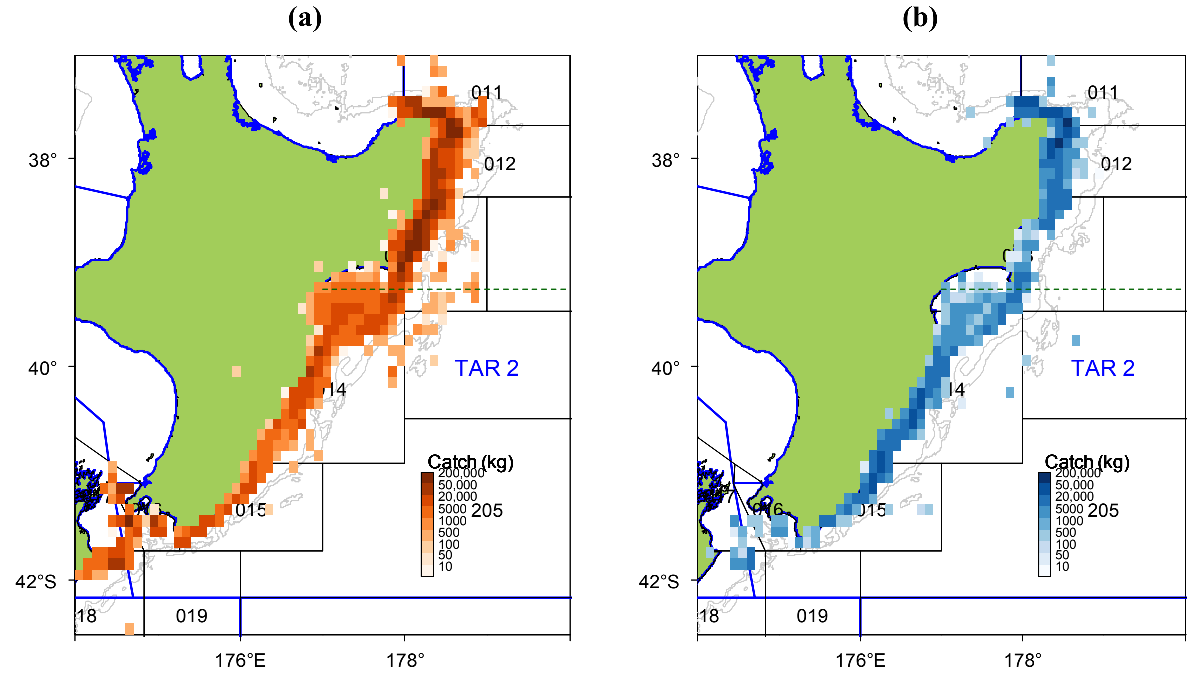


Figure 7. Total fine scale spatial distribution of TAR 2 catch (0.1 degree blocks) within each statistical area, 2008–2010 for vessels using (a) TCEPR forms or (b) TCER forms. 500 and 1000 m depth contours are shown as light gray lines.

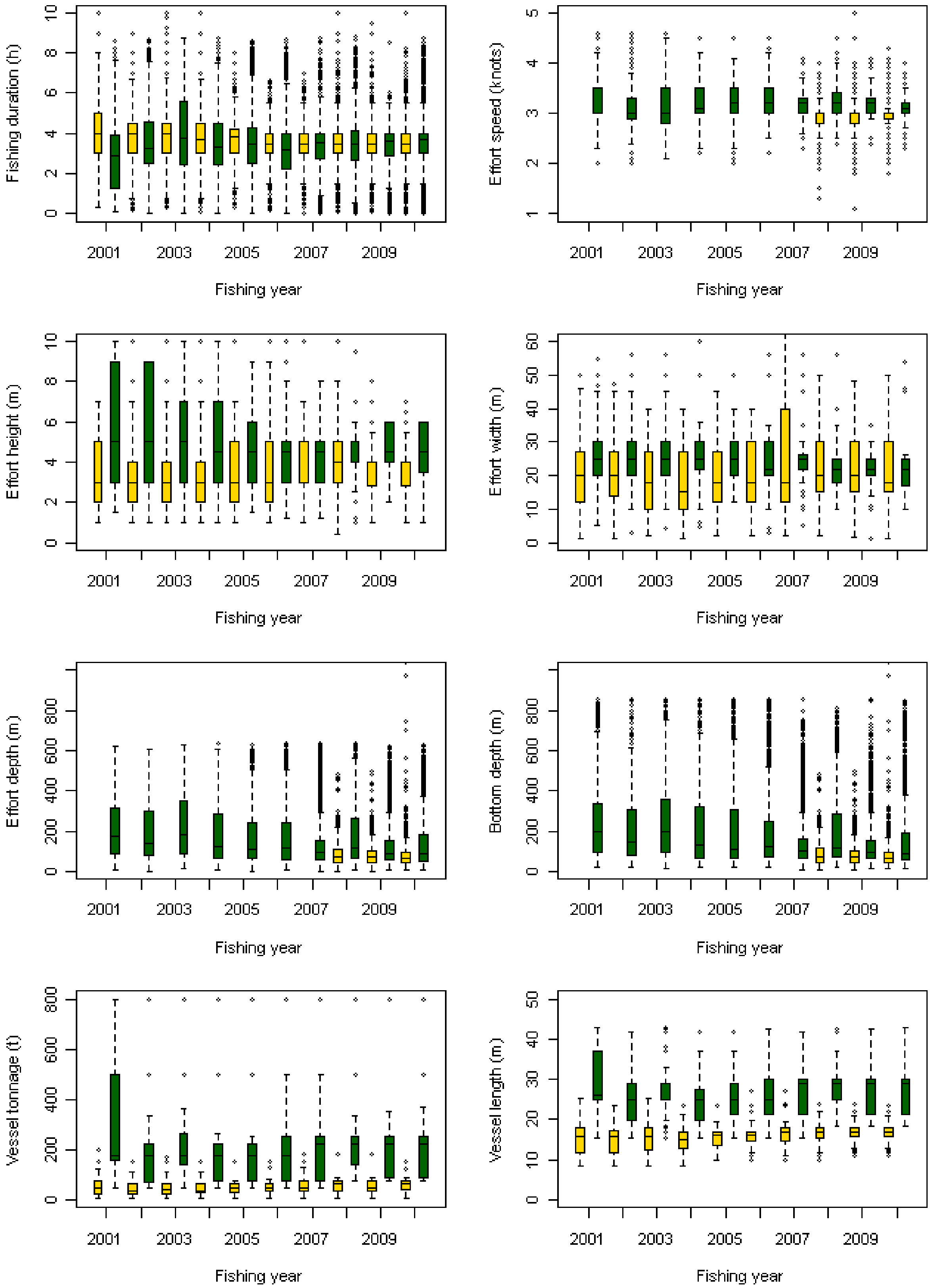


Figure 8. **Characterisation of fishing effort for vessels landing TAR 2, 2001–2010. Light bars indicate TCER/CELR vessels, dark bars indicate TCEPR vessels. For each bar, the horizontal line indicates the median, top and bottom of the bar indicate the interquartile range, error bars indicate the 95th percentile range, and circles indicate the values outside the range.**

4. Catch sampling

The purpose of the catch sampling programme was to describe the TAR 2 catch taken 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.

All sampling was designed, conducted and analysed following recommended practices codified by the Ministry of Fisheries (Science Group 2008). Shore-based samplers ensured that the landings sampled were caught using only one fishing method. Appropriate landings are identified through voluntary coordination between samplers and processor managers. In some cases, unsorted catch was trucked to secondary processing facilities, which sometimes made obtaining details of the landing difficult for samplers. But as long as no grading had occurred, it was possible to sample the catch.

The cumulative proportion of landings by weight and number indicated that restricting samples to landings greater than 1000 kg, would allow 88% of the landed weight to be available for sampling while reducing the number of potential trips by 33% (Figure 9a). The working group recommended a landing weight threshold of 750 kg for the 2010 sampling year. In 2010, 68% of the landings were less than 750 kg, so 32% of landings contained 92% of the total weight landed (Figure 9b).

4.1 Sampling design

The working group discussed several options to sample TAR 2 effectively (Northern Inshore Working Group, unpublished documents, October 2009). The sampling plan implemented 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. Statistical areas 016, 017, 018, and 019 were excluded because of potential mixing of stocks within those statistical areas and the low proportion of catches from those areas (see Figure 3). Sampling targeted two or three landings per month for 12 months. The samples were spread among five main processors in Gisborne and Napier, with about one-third of the samples taken from Napier and Gisborne processors that shipped unsorted catch to Auckland.

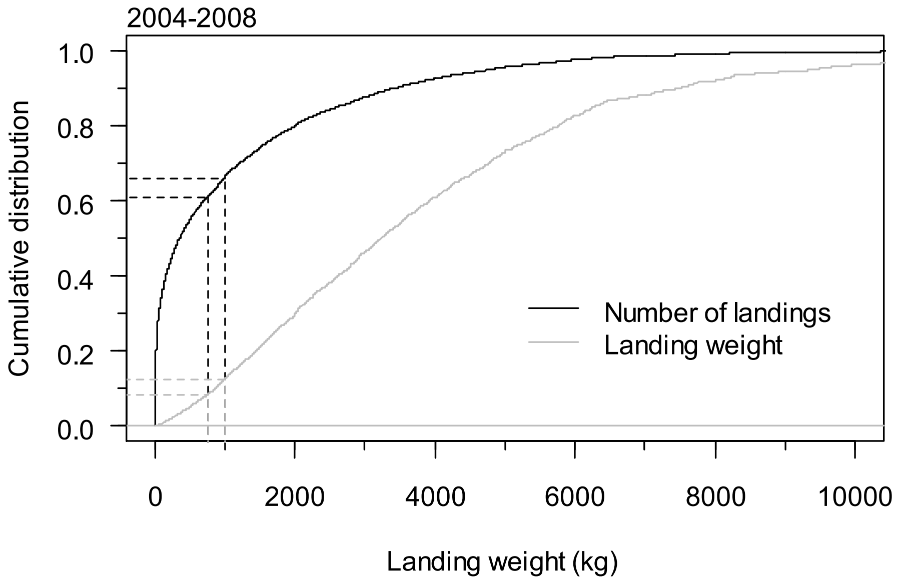
A sampling threshold of the landing weight of 750 kg was expected to minimize the numbers of landings qualifying for sampling, while maximizing the proportion of the total catch that would comprise sampled trips. Sampling excluded trips where catch was from more than one quota management area. Sixty fish were processed for each sample using a random age frequency strategy (otoliths collected from all fish) and a total of 1000 otoliths was planned to be aged. 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.

4.2 Sampling methodology

4.2.1 Criteria for selecting landing 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.

(a)



(b)

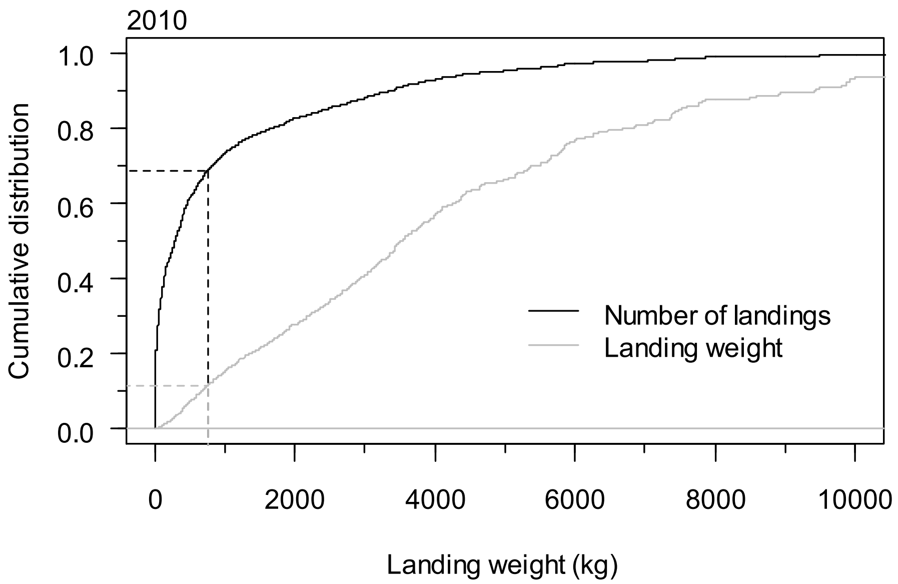


Figure 9. Cumulative distributions of TAR 2 landings by weight and number (a) from 2004–2008 used to plan catch sampling in 2010 and (b) the actual distribution of landings from 2010. Horizontal and vertical lines indicate the proportion of landings and cumulative weights below the 1000 kg or 750 kg sampling threshold.

4.2.2 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 NIWA 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, gonad stage (5 stage method, see description below) 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., 20101101), 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.

4.2.3 Gonad staging

Gonad staging used a standard NIWA method with the following five stages for males and females: 1, immature or resting; 2, maturing (oocytes visible in females, thickening gonad but no milt expressible in males); 3, mature (hyaline oocytes in females, milt expressible in males); 4, running ripe (eggs and milt free flowing); 5, spent (gonads flaccid and bloodshot). Typically stages 1 and 2 are considered immature because of errors in distinguishing resting fish from fish developing to spawn for the first time during much of the year. To aid in developing a maturity relationship to use in SPR analysis, we used survey data from a discrete period during the spawning season and scored stage 1 as immature, but ages 2–5 as mature (see below).

4.3 Catch sampling summary

Thirty-six samples were obtained, exceeding the target of 30 samples (Table 2). Processors were very cooperative in providing access to landed catch and to 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, and to attain more samples than prescribed.

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

Month	Samples targeted	Samples obtained
October	3	3
November	3	4
December	2	3
January	2	2
February	2	3
March	3	4
April	3	3
May	3	3
June	2	3
July	2	3
August	2	1
September	3	4
Total	30	36

4.3.1 Representativeness

Samples were obtained from fish landed in Napier and Gisborne, including those sampled in Auckland. In Gisborne, the 27 samples taken were from landings making up 11.46% of the total TAR 2 landed there. In Napier, the 9 landings made up 5.13% of the TAR 2 landings. Gisborne and Napier landings made up more than 73% of the total TAR 2 landings, more than double the landings of all other ports combined (Figure 10, Table 3). The vessels sampled as part of the catch sampling programme (termed the "core fleet") comprised most of the landings in Gisborne and 38% of the landings in Napier.

The 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. A comparison of recorded fishing effort variables shows that the core fleet was similar to the entire fleet for fishing duration and speed, and had similar size trawl gear, though they tended to have higher opening nets (Figure 11). In the past, the core fleet vessels had fished shallower, but the depth of fishing has converged to shallow depths in recent years. The core fleet vessels were among the smaller vessels in the fleet targeting TAR 2.

However, the depths fished during the sampled trips were generally similar to the distribution of depths fished for the entire fleet in 2010 (Figure 12). The depth distribution for trips landing TAR 2 were somewhat different depending on statistical area fished or target species; deeper towards the south, and slightly different by target species, being slightly shallower for GUR and deeper for SKI, but still covering the depth range for TAR target tows (Figure 13 a, b).

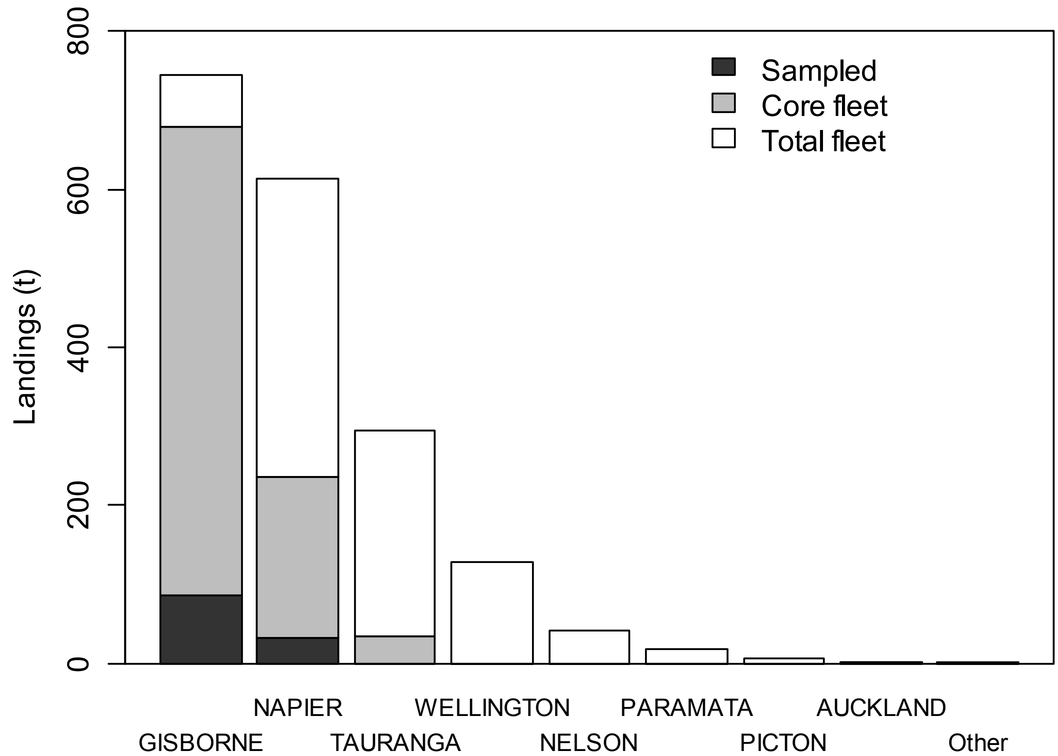


Figure 10. Total landed weight of TAR 2 by port partitioned into sampled landings, core fleet landings, and total fleet landings for the 2010 fishing year.

Table 3. Total greenweight and number of landings by port, divided by landings sampled, landings of the core fleet vessels, and total fleet landings.

Landings	Gisborne	Napier	Tauranga	Wellington	Nelson	Paremata	Picton	Auckland	Other
Tonnes									
Sampled	85.29	31.52	NA	NA	NA	NA	NA	NA	NA
Core fleet	592.90	204.44	35.00	NA	NA	NA	NA	0.85	NA
Total fleet	744.38	614.24	293.85	129	42.26	18.92	6.75	2.55	1.21
% sampled	11.46	5.13							
Number									
Sampled	27	9	NA	NA	NA	NA	NA	NA	NA
Core fleet	281	153	16	NA	NA	NA	NA	1	NA
Total fleet	371	506	139	168	34	75	6	6	81

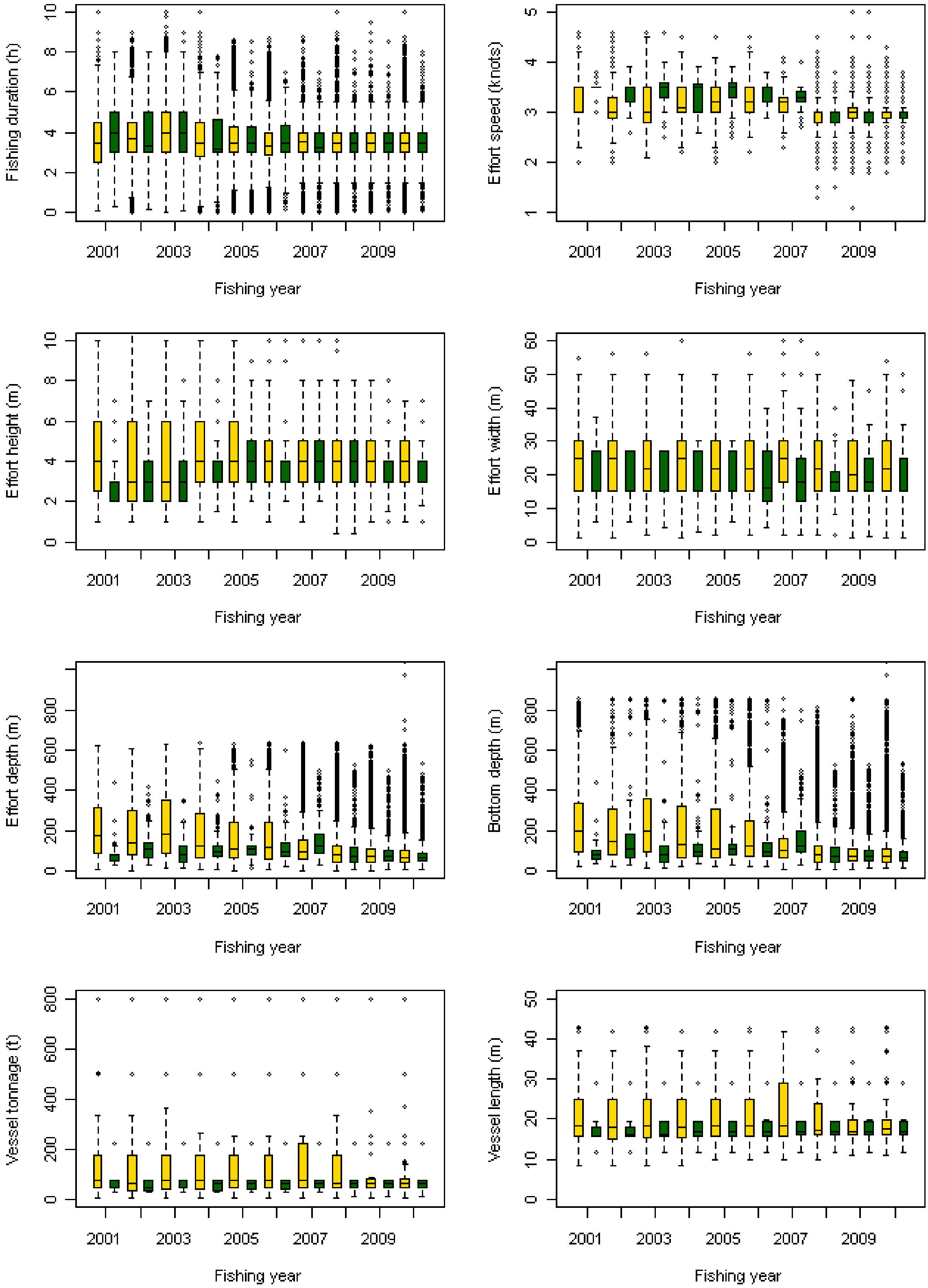


Figure 11. Characterisation of fishing effort for vessels landing TAR 2, 2001–2010. Light bars indicate the distribution of values for all vessels, dark bars indicate the distribution of values for sampled vessels only (core fleet). For each bar, the horizontal line indicates the median, top and bottom of the bar indicate the interquartile range, error bars indicate the 95th percentile range, and circles indicate the values outside the range.

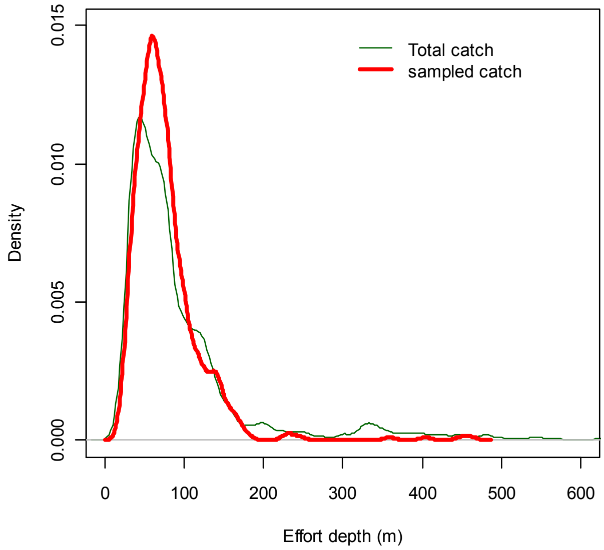


Figure 12. Depth distribution of TAR 2 target fishing in 2010 for all tows and for tows where catch was sampled for length and age distribution.

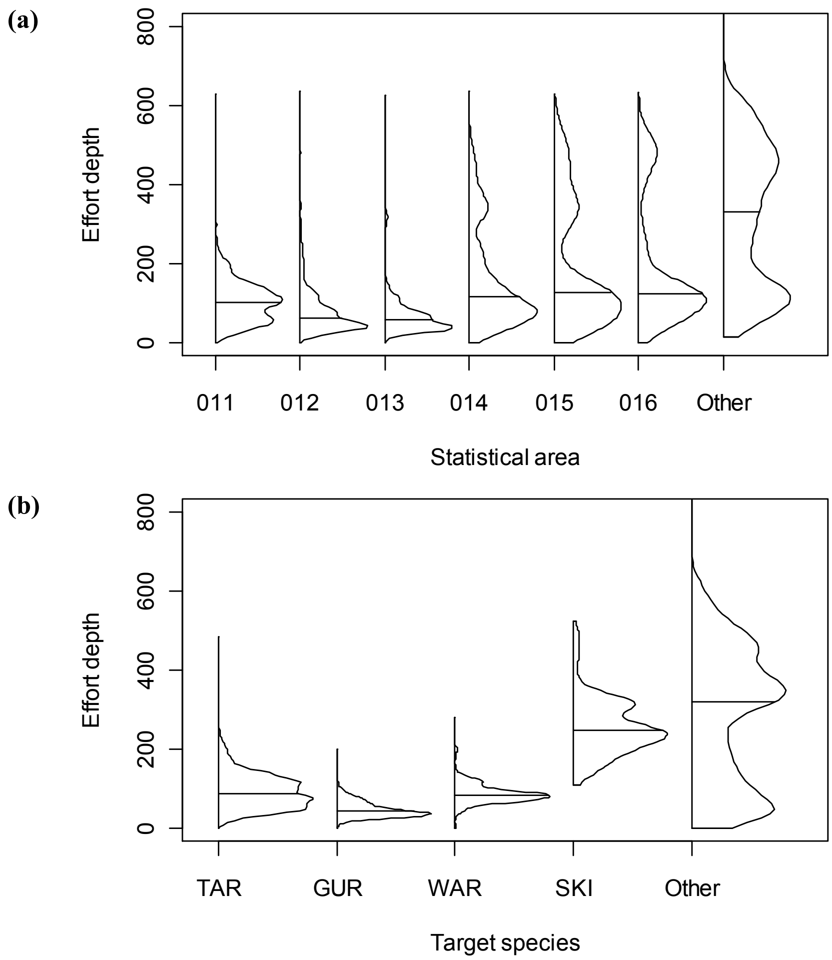


Figure 13. Depth distribution of tows from trips landing TAR 2 by (a) statistical area and (b) target species. Horizontal line indicates median of the distribution.

Although the sampling design prescribed the numbers of samples to be taken each month, the actual landing amounts in each month were quite variable in the historic data used to plan the sampling programme, and some mismatch was expected. Figure 14a shows the actual proportion of total annual catch landed by month and statistical area, and the corresponding proportion of the total sampled catch landed in that same stratum. Overall spring months (October and November) were over-sampled, winter months were under-sampled and sample representativeness for summer and autumn months was good, despite meeting or exceeding the target number of samples for all months except August (See Table 2).

Statistical areas were fairly well sampled, except that area 013 was oversampled and areas 011 and 012 were somewhat under sampled (Figure 14b). Note that statistical area 016 was excluded from the sampling programme by design. As most of TAR 2 catch is from targeted tows, the proportion sampled by target species matched the distribution of landings well (Figure 14c). One strength of the random age frequency sampling method is that more samples are taken from each stratum than needed so that after the season is over, otoliths can be selected in proportion to the total landing weight for the entire season to approximate the representative sample size for each stratum.

The processors sampled were active through much of the previous decade. The top two processors were sampled heavily as part of this sampling programme. Other, smaller processors were also sampled, but all sampled processors were in the top 11 for overall landings (Figure 15).

4.4 Length composition of the catch

There were no formal catch sampling stratifications within the sampling design specified by the working group. However, post-hoc stratification of either north or south of the southern tip of Mahia Peninsula (39.264° S) was attempted to address hypothesized differences in population size and age structure in these two areas (also hypothesised for SNA 2). Trips were stratified based on where tows within each trip were made. Most trips did not straddle the Mahia Peninsula line. However, three trips did. Plots of where the tows were made (and how much catch resulted from those tows) showed that minor amounts of catch came from one of the two areas. Therefore, catch was allocated to the area where the majority of the catch was recorded for the trip (Figure 16).

Length distributions were scaled from sampled catch to total catch for each area by sex. Sample sizes for the southern area were small, and corresponding c.v.s were almost double those for the northern area, though this was a result of the lack of formal stratification in sampling. Some evidence of different length distributions can be observed in the composite male plus female plots for northern versus southern fish, with the mode of southern fish at 29 cm and the mode of northern fish at 31–33 cm. (Figure 17). The maximum size observed was also larger in the northern area, but this may be an artefact of the larger sample size there. The size mode for all males was 2 cm larger than for females, and the maximum size was somewhat larger for males, but otherwise the two distributions had a similar range and shape.

(a)

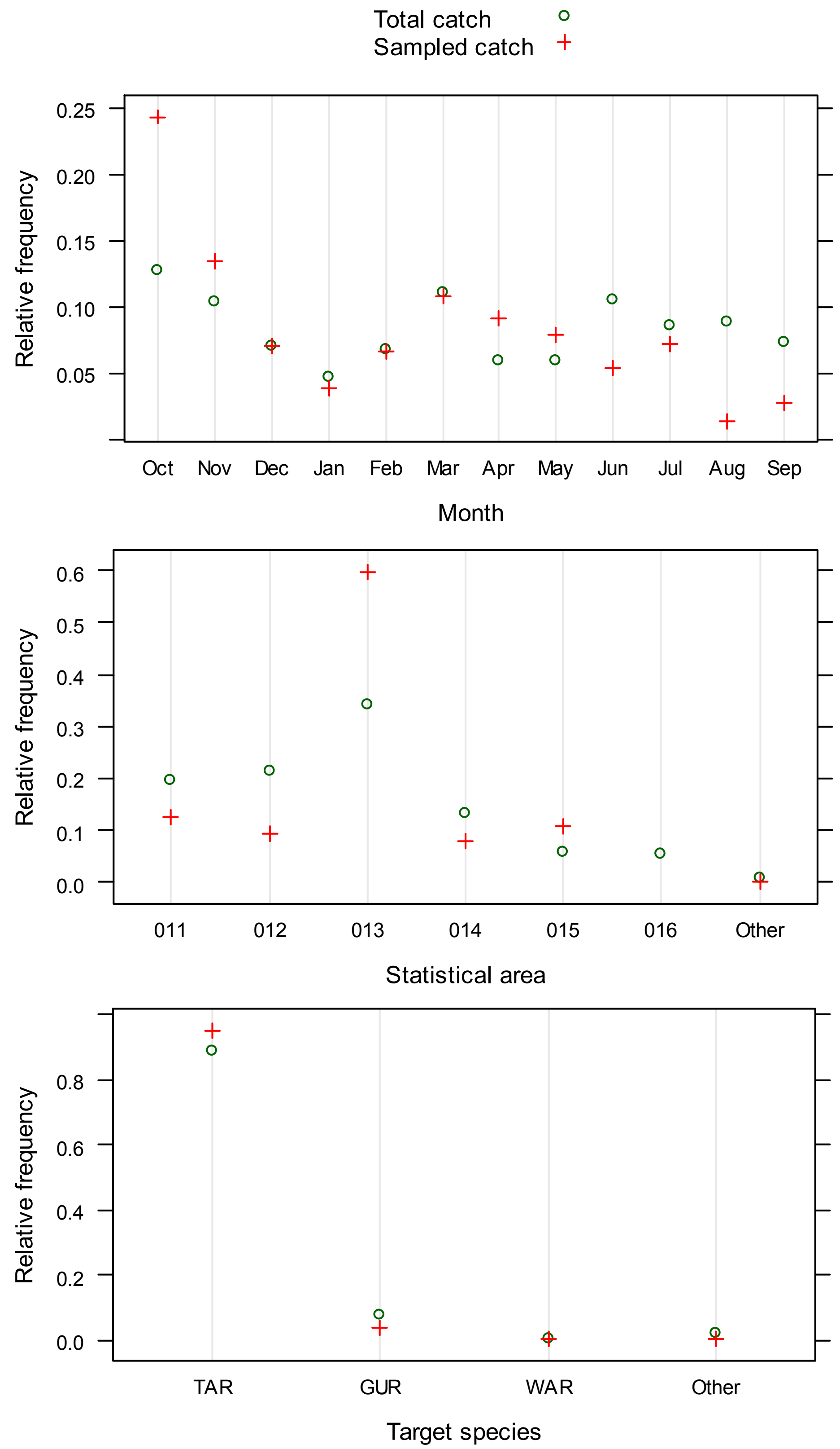


Figure 14. Proportion of total landed catch (circles) and the proportion of sampled catch (crosses) of TAR 2 that occurred in each (a) month, (b) statistical area, and (c) target species in the 2010 fishing year.

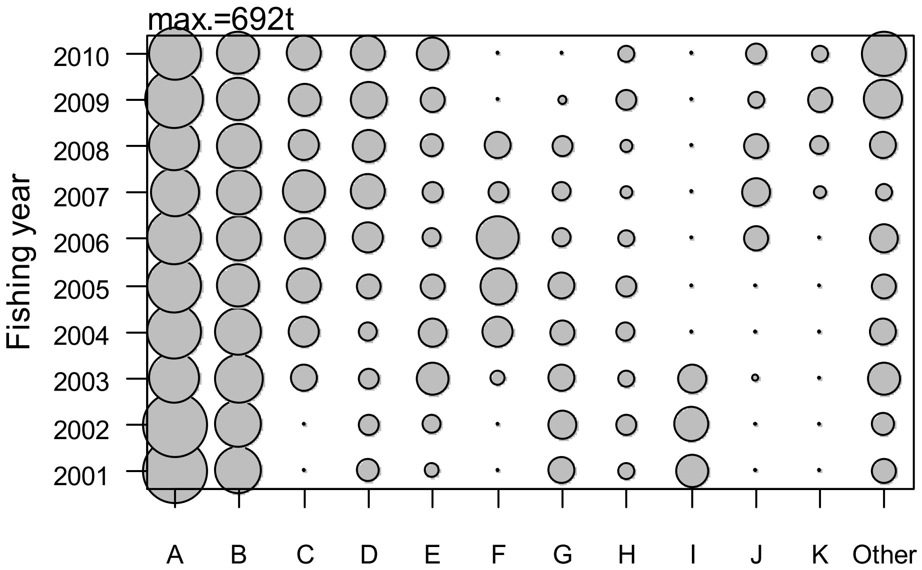


Figure 15. **Proportion of landings by the top 11 licensed fish receivers from 2001–2010. Landings were sampled in 2010 from LFRs A, B, F, H and K.**

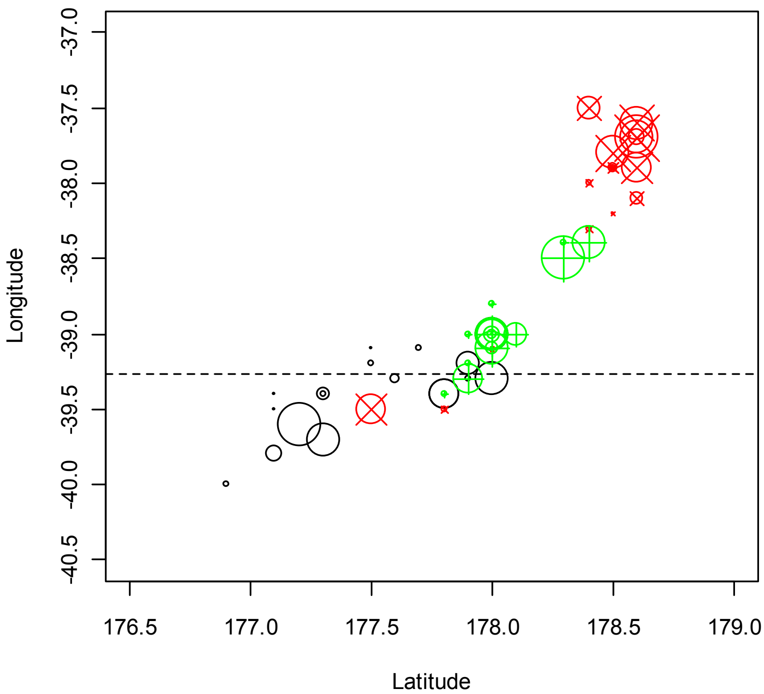


Figure 16. **Locations and relative amount of catch per tow for three trips (three symbols/colours) that straddle the 39.264 degree line of latitude (southern tip of Mahia Peninsula) used as a post-hoc stratification of landings.**

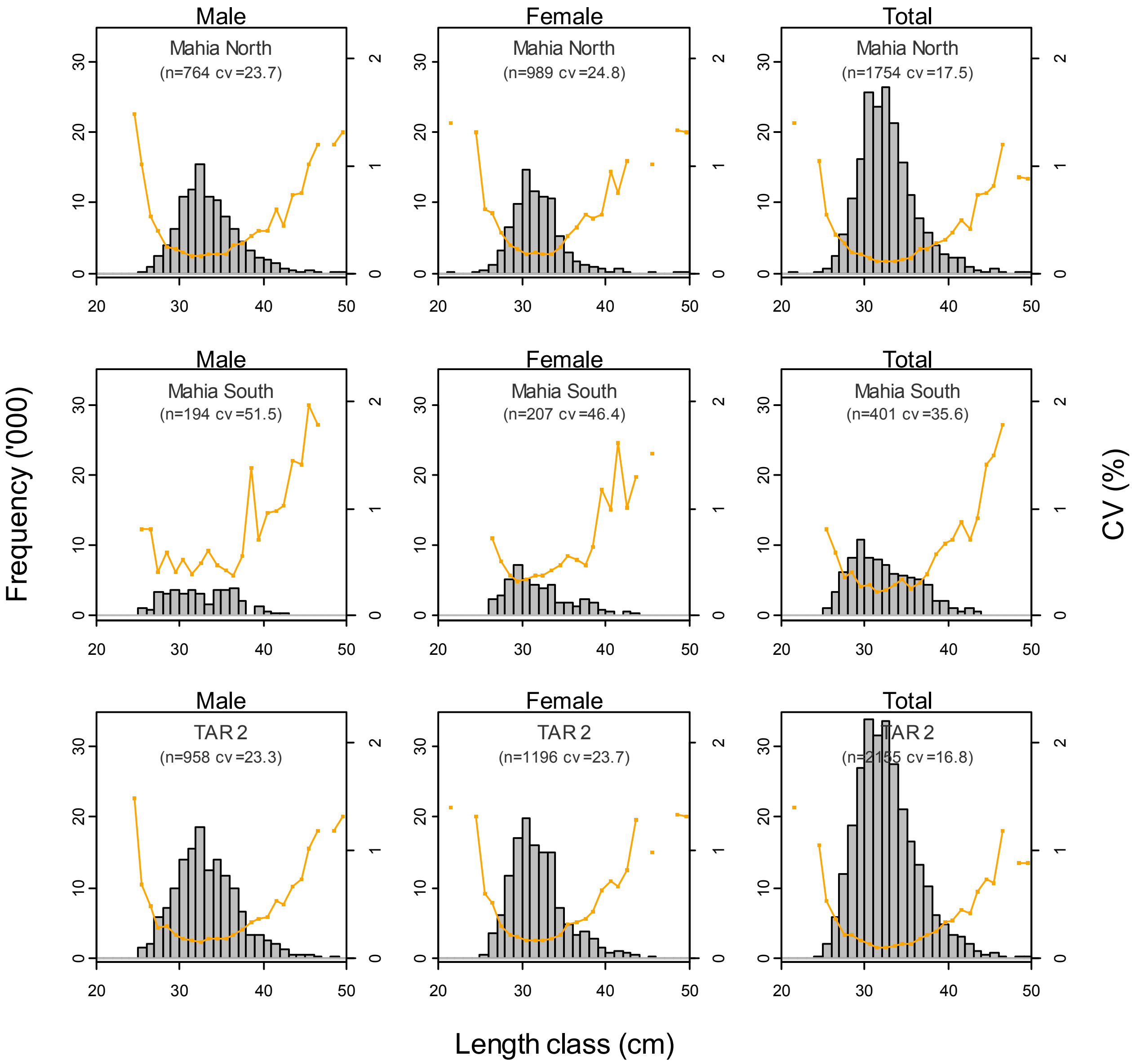


Figure 17. Scaled length frequency distributions for TAR 2 landings in the 2010 fishing year, segregated by sex, and stratified for fish north and south of Mahia Peninsula. Line indicates the c.v. for each length class.

4.4.1 Otolith selection and processing

Otoliths were processed and ages estimated following the procedures detailed in the tarakihi ageing guidelines document (NIWA 2011a). Briefly, otolith thin sections were prepared for a random subset (weighted by landing weight) of the collected otoliths, and ages were determined independently by two otolith readers. Discrepancies were resolved by consensus with a third age reader. Reader diagnostics were calculated using the initial ages from each reader. Ages were estimated for a total of 736 otoliths, the number being limited by available budget. As no previous c.v.s for TAR 2 were available, sample sizes were loosely based on those from Manning et al. (2008) for TAR 7.

4.4.2 Age interpretation

Age interpretation and reader consistency were analysed following Campana et al. (1995) and Campana (2001). Age readings were very consistent between readers, with an average percent error (APE) of 2.68 and a c.v. of 3.79% (Figure 18). Only 12 of 736 readings (1.6%) disagreed by more than 1 year (Figure 18 a, b), and there were no trends in discrepancies across the age range (Figure 18 b, c). The range of final agreed age estimates was 2–28 years.

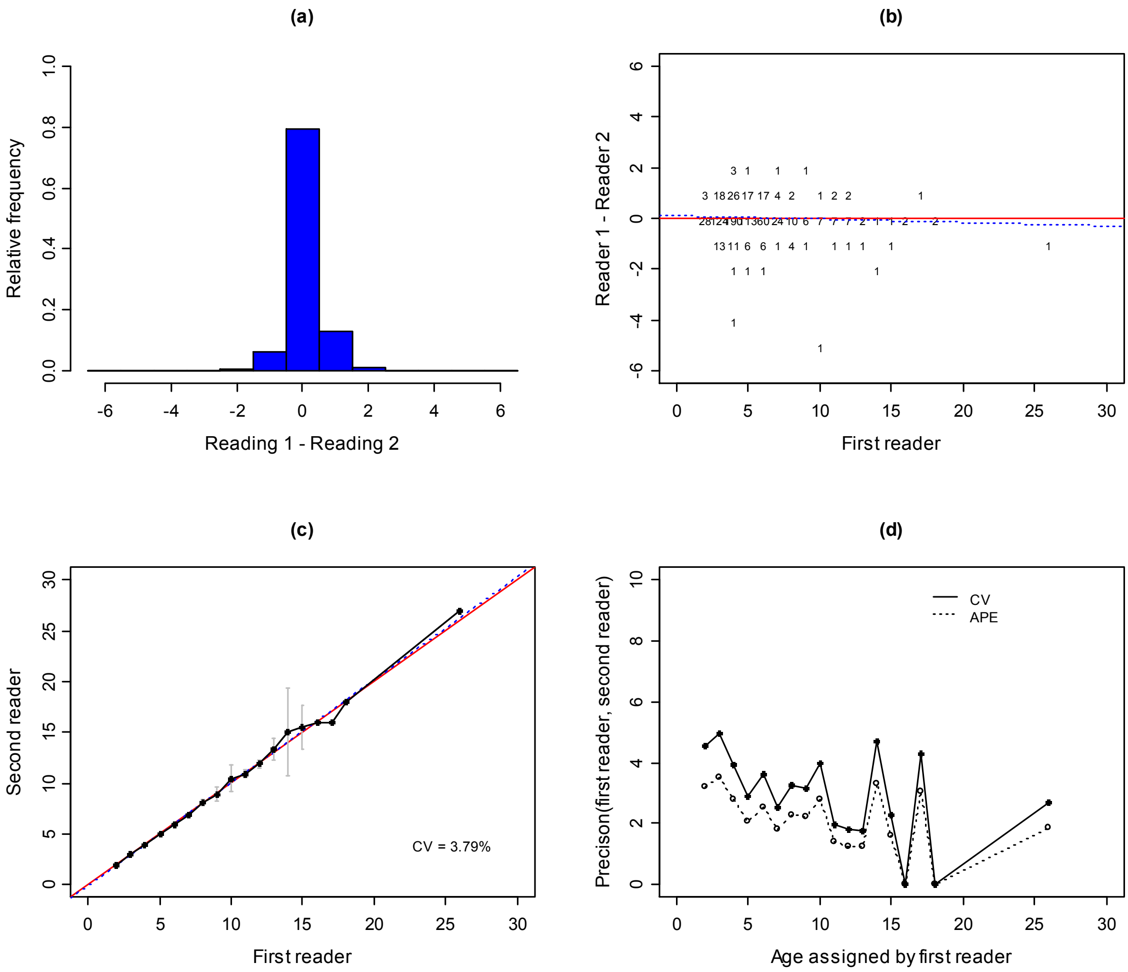


Figure 18. Age reader comparison plots: (a) histogram of age differences between two readers; (b) Difference between reader 1 and reader 2 as a function of the age assigned by reader 1. The number of fish in each bin is plotted as the plot symbol; (c) Age bias plot, showing the correspondence of ages 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, red solid lines show perfect agreement, dashed blue lines show the trend of a linear regression of the data points.

4.5 Age composition of the catch

The stratified, sexed age data were used to generate direct age frequencies for the total catch north and south of Mahia Peninsula using CALA (NIWA 2011b).

There were no strong differences in age composition between males and females (rows 1 and 2 of Figure 19). However, column 3 of Figure 19 indicated that fish from south of Mahia Peninsula were younger than fish north of the peninsula. Northern fish were primarily 4–6 years old, while southern fish were 2–5 years old. This could be an indication that juveniles move north as they age and the fishery is only sampling the juvenile portion of the stock, that gear selectivity is different in the two areas, or that the older fish are not in the southern area (either because of spatial heterogeneity or because they have been removed). The overall mean weighted c.v. for the age composition of TAR 2 catch in 2010 was 0.195, well below the target of 0.30. Therefore, fewer otoliths could be sampled and read if no spatial or temporal stratification is needed. However, sex-specific c.v.s from the southern area were greater than 0.30 because of the lower sample sizes there. 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 applied to other areas with different expected age composition. The actual values plotted in Figure 19 are given in Appendix 1.

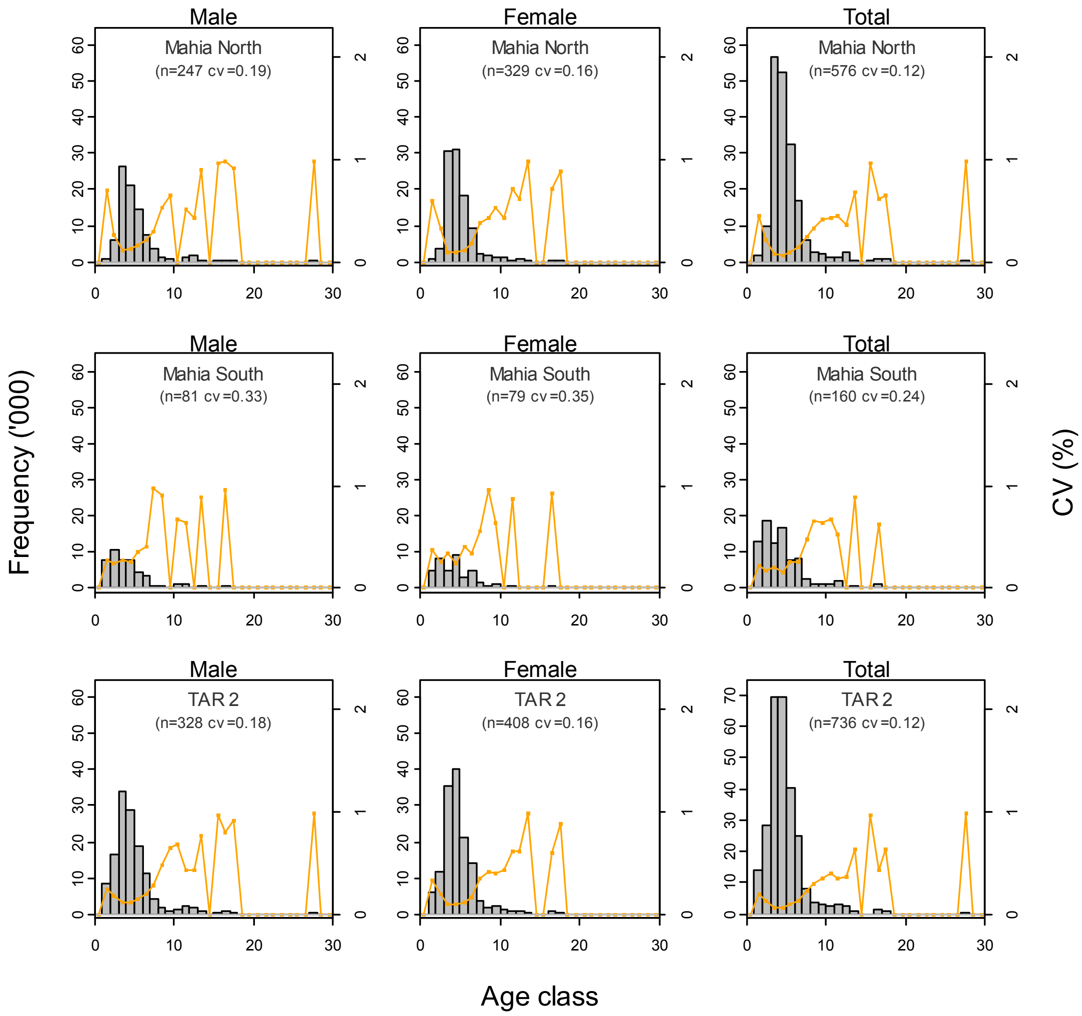


Figure 19. Scaled age frequency distributions for TAR 2 landings in the 2010 fishing year, segregated by sex, and stratified for fish north and south of Mahia Peninsula. Lines indicate the c.v. for each age.

As an aid for planning future sampling programmes, the age composition, stratified by season, was estimated to check for potential differences in seasonal fishing location and/or fish movements (Figure 20). Comparing the 4 year old age class among seasons, for example, the proportion of 4 year olds in the catch increases throughout the year. The same is true of younger fish, although the effect is not as pronounced. The young, fast growing fish are growing quickly (or move to where the fishery is occurring), and are then captured in higher proportions relative to the static abundance of older fish. This indicates that catch sampling programmes would yield different age compositions depending on when sampling occurs during the year. Therefore, it will be important in future catch sampling programmes that samples are spread throughout the year, or that the year is divided into several strata for proper weighting of the catch.

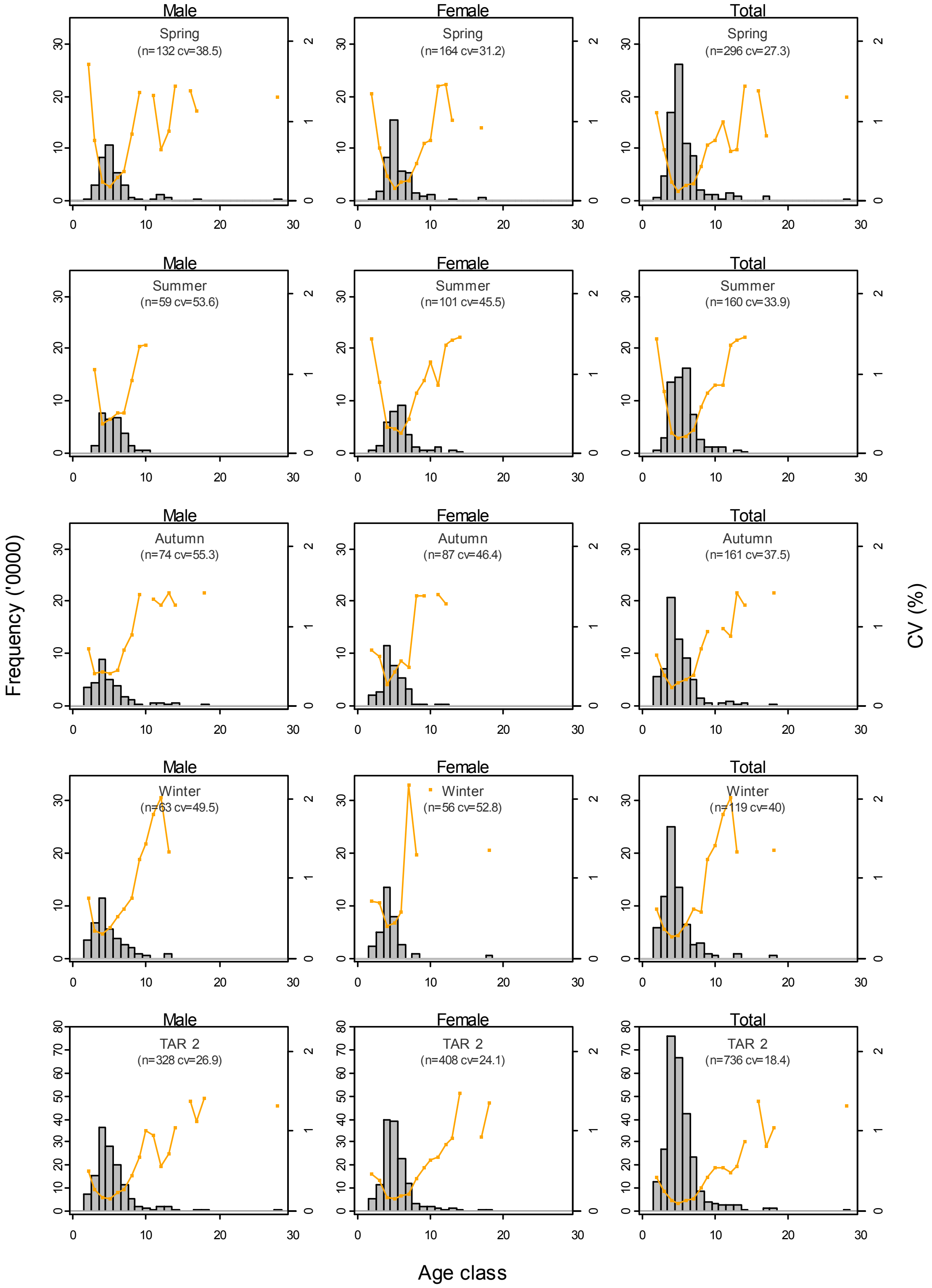


Figure 20. **Scaled age frequency distributions for TAR 2 landings in the 2010 fishing year, segregated by sex, and stratified by season. Lines indicate the c.v. for each age.**

No dominant age classes were observed. However, few age classes were present and a strong mode is not typically detectable with a single year of data unless it occurs in the older cohorts. More than 50% of the catch was 4 or 5 years old, and only 1% was greater than 15 years. Note that this includes samples from throughout the year. It is not possible (due to limited sample size in each month) to determine whether trends in age structure of the catch occur due to temporal aspects of fishing. The archived otolith samples from the four trawl surveys conducted in the 1990's would provide an interesting comparison to help interpret these data relative to spatial age structure.

4.6 Mortality estimates

A point estimate of natural mortality (M) was calculated following Hoenig (1983) as $-\ln(0.01)/A_{max}$, where A_{max} is the maximum observed age, representing the mortality rate that would leave 1% of the original population after A_{max} years. Although no fish in our samples were greater than 28 years old, TAR 3 samples contained fish up to 38 years old (M. Beentjes, unpublished data), and Stevenson & Horn (2004) reported fish up to 44 years old. Using the A_{max} from Stevenson & Horn (2004), which is consistent with A_{max} values from the Chatham Islands (Vooren 1977) and the east coast of the South Island (Annala 1987), a point estimate of M would be 0.105. The TAR plenary document (Ministry of Fisheries 2010) combined all studies of TAR age and growth, and recommended a best estimate of 0.10 for M, and we use that estimate in our analysis.

Chapman-Robson estimates of total mortality (Z) depend on the age of full recruitment to the fishery (Robson & Chapman 1961). This age is usually estimated from the scaled age composition as the age class with the peak abundance, or one year after that age. We estimated total mortality (Z) for ages 3–5 as 0.339, 0.444, and 0.496. Subtracting the estimate of natural mortality leaves an estimate of F as 0.24 if age at full selection is 3, or 0.34–0.39 depending on the age of full selection chosen. Vooren & Tong (1973) analysed the East Cape tarakihi fishery and reported F values in 1971 between 0.50 and 0.75. They recommended an annual TACC of between 1 000 and 1 500 t. In 1971, the proportion of fish greater than 10 years of age in the East Cape fishery was 7.8% (Annala 1987). The 2010 age composition of the catch is very similar, with slightly less (4.4%) of the catch greater than 10 years old. This lower value is consistent with the higher TACC of 1 611–1 796 t since the late 1980s.

4.7 Spawning biomass per recruit

Spawner per recuit analysis (%SPR) was conducted using CASAL (Bull et al. 2008). Growth functions are required for %SPR calculations, but little recent growth data from TAR 2 are available, especially spanning the full range of sizes. We fit von Bertalanffy growth curves to male and female age at length data collected in 2010 (Figure 20). The length range available (and corresponding age range) was minimal and therefore provided modest information to estimate sizes of young or old fish, resulting in poor fits. For comparison, curve fits were available from Vooren & Tong (1973) from the east coast of the North Island, but these were again from a restricted size range, as the same size range was present. In addition, Stevenson & Horn (2004) suggested that the Vooren & Tong (1973) age data may be poor because they used whole otoliths to determine ages. We conclude from these curve fits that suitable data do not exist for the east coast of the North Island. Therefore, to estimate growth parameters for this region as a sensitivity analysis, we used curve fits from the northeast South Island from Annala et al. (1990), which had a much larger range in size and age, and also reported a sample size of 599 fish (Figure 21).

Spawning biomass per recruit analysis also requires an estimate of the age at maturity ogive. Maturity stages were collected during sampling, but macroscopic stages are not reliable in all months, especially for adult resting fish and immature fish beginning to develop for the first time, both of which can be scored as stage 2. The use of macroscopic maturity codes should therefore be restricted to autumn months (Figure 22). No age-based transition was apparent when comparing maturity stages observed by age group (Figure 23).

Sample size during the spawning and pre-spawning period were minimal. We therefore used maturity staging data from the kah9304 ECNI trawl survey which was conducted in March 1993 and provided adequate sample sizes to characterise length at maturity (Figure 24). Three other mid-1990 trawl surveys were conducted in February, so were excluded as being too early. Otolith samples from these surveys have never been aged, so the length at maturity logistic function parameters ($L_{50\%}$ and $L_{95\%}$) were translated to $A_{50\%}$ and $A_{95\%}$ parameters for males and females using the Annala et al. (1990) northeast South Island von Bertalanffy curve fits (see Figure 21). These values were then used in the %SPR analysis.

Spawner per recruit analysis suggests that tarakihi populations are not very productive (Figure 25). Because robust life history parameters were not available from the samples generated from this study alone, a sensitivity analysis was conducted to determine whether different growth parameters would influence the relationship between the equilibrium %SPR and fishing mortality. However, the influence of the different von Bertalanffy curves was minimal (Figure 25), so a single result based on data from this study is presented. Following draft operational guidelines for a species with M = 0.10, productivity would be classified as "low" and a corresponding target SPR level of 45% would be appropriate (Ministry of Fisheries, Operational Guidelines). The fishing mortality associated with 45%SPR is 0.0695, approximately 70% of M (Figure 25). The current (2010) estimate of F (0.34–0.39) is associated with an equilibrium SPR of 8.67–7.29%. The SPR analysis assumes that the entire population is well characterised demographically, and therefore that growth, maturity and natural mortality are all correctly estimated. It also assumes that fishing mortality occurs on the entire population. Therefore, if fishing occurs on a subset of the population, or if the sampled fish do not represent the entire population in demographic parameters, SPR analysis will be biased.

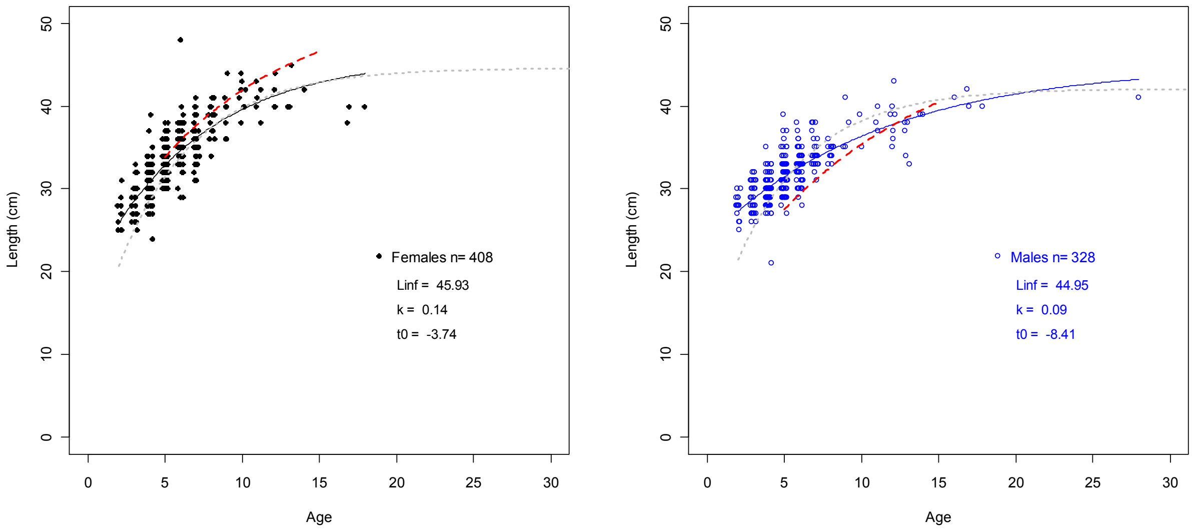


Figure 21. von Bertalanffy growth curve fits for female and male tarakihi sampled in TAR 2 in 2010. Curves are shown for females (black dots and line), males (blue circles and line), the male and female curves fits (red dashed lines) for East Coast North Island by Vooren & Tong (1973), and the male and female curve fits (gray dashed lines) from the north-east South Island from Annala et al. (1990). Age values for points are jittered to reduce overlap and show data density.

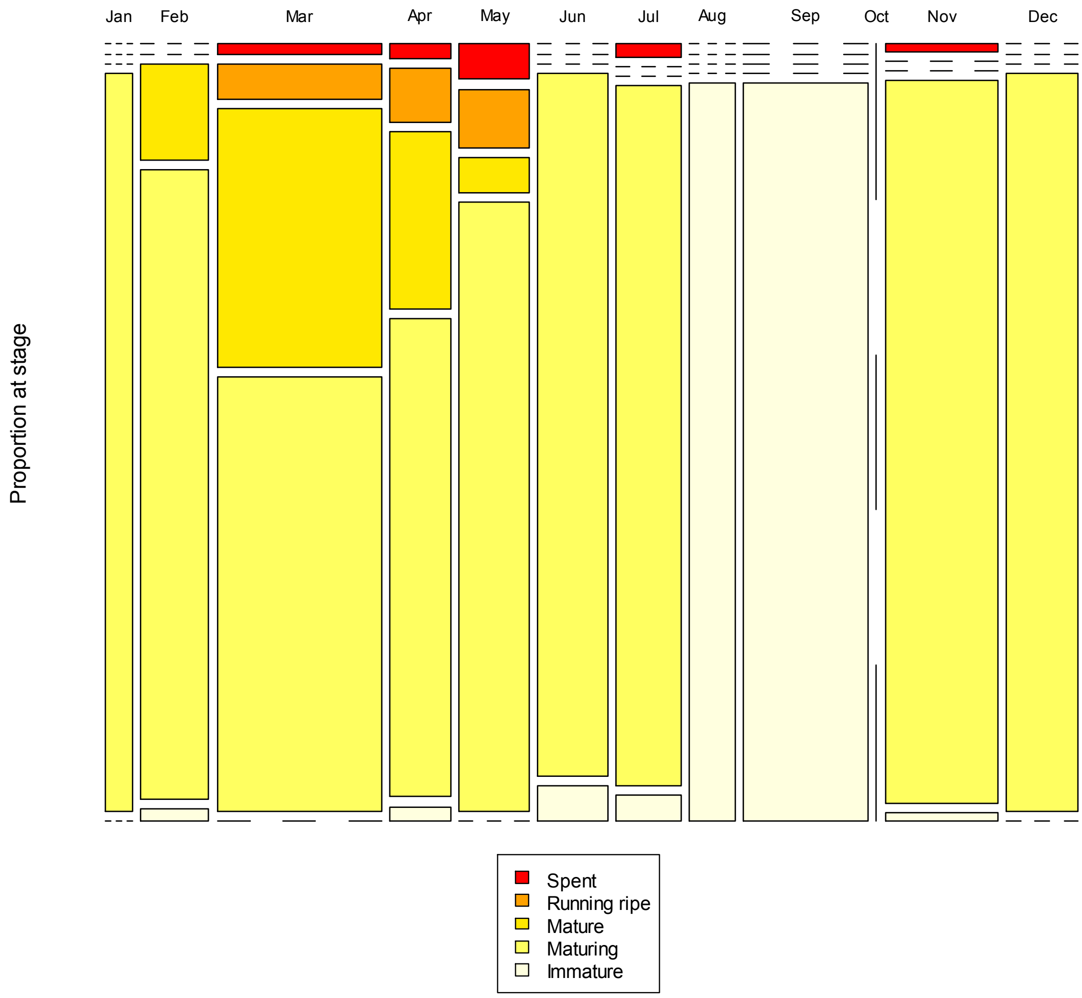


Figure 22. Proportion of female tarakihi by month in each reproductive stage from TAR 2 market samples in 2010. Bar width is proportional to sample size in that month. Dashes indicate no samples in that category.

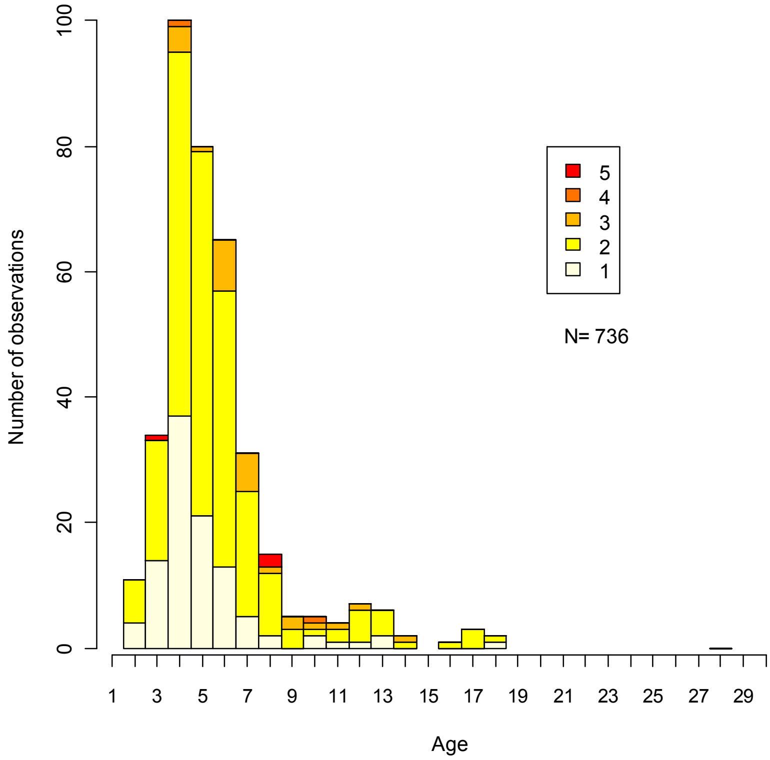


Figure 23. **Number of observations of tarakihi of each age, grouped by gonad stage (see text for description of stages).**

(a) (b)

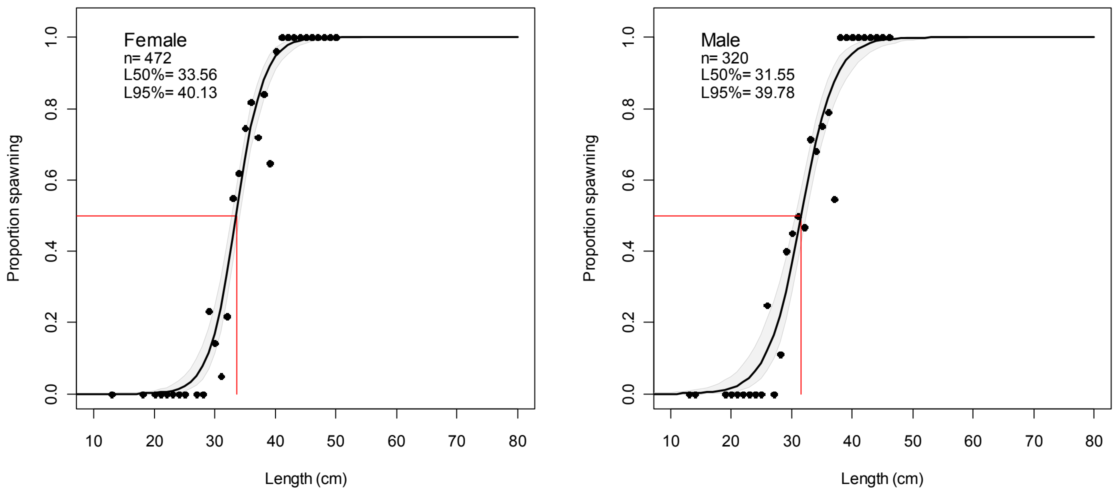


Figure 24. Length at maturity for (a) female and (b) male tarakihi from the east coast of the North Island trawl survey (kah9304) using stage 1 as immature and stages 2–5 as mature. Red lines indicate the $L_{50\%}$ maturity. Grey zones indicate the 95% confidence intervals for each ogive fit.

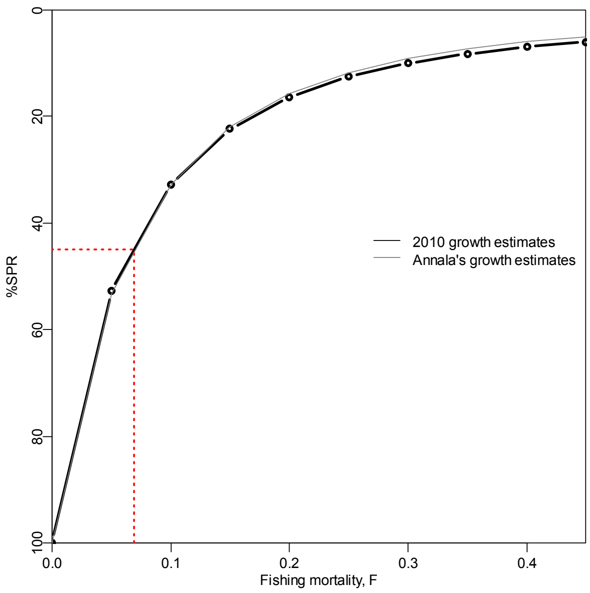


Figure 25. Spawning biomass per recruit relationships for two growth functions; data from this study (thick black line), and data from Annala et al. (1990) from the north-east South Island (thin gray line). Dashed lines indicate the fishing mortality associated with 45% SPR.

5. Recommendations

These analyses assume that selectivity is maximum and constant for fish greater than 3 or 4 years old. If larger or older fish are not present in the areas sampled, then their absence would be interpreted by these models as mortality due to fishing. The potential of an ontogenetic migration northward is supported by progressively older fish north of Mahia Peninsula, and still older fish in the Bay of

Plenty (NIWA, unpublished data). Accurate interpretation of these data requires integrated analysis of samples from TAR 1, 2, and 3. Annala (1987) suggested that larvae from an East Cape spawning area and a Kaikoura spawning area are both transported by along shore currents towards eastern Cook Strait, where mixing may occur, and some juveniles could then move towards the north. This life history would result in an age composition of catch consistent with the data summarized here, and also consistent with the long history of stable catches in TAR 2.

6. ACKNOWLEDGMENTS

We thank the processors in Napier, Gisborne, and Auckland, for coordinating sampling efforts. We also thank Ron Blackwell, Mike Stevenson, Dane Buckthought and Cameron Walsh for assistance with sampling and age determination. We thank Jeremy McKenzie and Mike Beentjes for helpful discussions about sampling design, ageing protocol development, and project oversight. This project was funded under contract TAR200901 by the Ministry of Fisheries.

7. REFERENCES

Annala J.H. (1987). The biology and fishery of tarakihi, *Nemadactylus macropterus*, in New Zealand waters. Fisheries Research Division Occasional Publication No. 51. 16 p.

Annala, J.H.; Wood, B.A.; Hadfield, J.D.; Banks, D.A. (1990). Age, growth, mortality and yield–per–recruit estimates of tarakihi from the east coast of the South Island during 1987. MAF Fisheries Greta Point Internal Report No. 138. 23 p. (Unpublished report held in NIWA Greta Point library, Wellington.)

Bentley, N.; Kendrick, T.H. (2011). CPUE for tarakihi (TAR 2) from bottom trawling targeting tarakihi (BT.TAR). Draft report to Northern Inshore Working Group, April 2011. Unpublished report held by the Ministry of Fisheries. 24p.

Boyd, R.O.; Reilly, J.L. (2005). 1999/2000 national marine recreational fishing survey: harvest estimates. Draft New Zealand Fisheries Assessment Report

Bull, B.; Francis, R.I.C.C.; Dunn, A.; McKenzie, A.; Gilbert, D.J.; Smith, M.H.; Bian, R. (2008). CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.20-2008/02/14. NIWA Technical Report 130. 275 p.

Campana, S.E. (2001). Accuracy, precision, and quality control in age determination, including a review of the use and abuse of age validation methods. *Journal of Fish Biology 59:* 197–242.

Campana, S.E.; Annand, M.C.; McMillan, J.I. (1995). Graphical and statistical methods for determining the consistency of age determinations. *Transactions of the American Fisheries Society 124*: 131–138.

Hanchet, S.M.; Field, K. (2001). Review of current and historical data for tarakihi (*Nemadactylus macropterus*) Fishstocks 1, 2, 3, and 7, and recommendations for future monitoring. *New Zealand Fisheries Assessment Report 2001/59*. 42 p.

Hoenig, J.M. (1983). Empirical use of longevity data to estimate mortality rates. *Fishery Bulletin 81*: 898–903.

Jiang, W.; Bentley, N. (2008). TAR 2 Adaptive management programme draft report: 2006/07 fishing year. Unpublished report held by the Ministry of Fisheries, Wellington. 57 p.

Manning, M.J.; Stevenson, M.L.; Horn, P.L. (2008). The composition of the commercial and research tarakihi (*Nemadactylus macropterus*) catch off the west coast of the South Island (TAR 7) during the 2004–05 fishing year. *New Zealand Fisheries Assessment Report 2008/17*. 65 p.

Ministry of Fisheries (2010) Report from the Fishery Assessment Plenary, May 2010: stock assessments and yield estimates. Ministry of Fisheries unpublished report held by NIWA Library, Wellington.

NIWA (2011a). Tarakihi ageing guidelines v3. Unpublished document held by NIWA, Wellington. 13 p.

NIWA (2011b). Catch and Length at Age (CALA).

R Development Core Team (2011). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. http://www.R-project.org.

Robson, D.S.; Chapman, D.G. (1961). Catch curves and mortality rates. *Transactions of the American Fisheries Society 90*:181-189.

Science Group (2008). Guidelines to the design, implementation and reporting of catch sampling programmes. Unpublished report, Science Group, Ministry of Fisheries. 18 p.

Starr, P.J. (2007). Procedure for merging MFish landing and effort data. Unpublished report, AMP Working Group 2007/04 (Version 2.0). 17 p.

Stevenson, M.L.; Horn, P. (2004). Growth and age structure of tarakihi (*Nemadactylus macropterus*) off the west coast of the South Island. *New Zealand Fisheries Assessment Report 2004/11*. 23 p.

Vooren, C.M. (1977). Growth and mortality of tarakihi (Pisces: Cheilodactylidae) in lightly exploited populations. *New Zealand journal of marine and freshwater research 11(1)*: 1–22.

Vooren, C.M.; Tong, L.J. (1973). A survey of the tarakihi *Cheilodactylus macropterus* (Bloch and Schneider), in the East Cape area, New Zealand, 26–30 March 1971. *Fisheries Research Bulletin 9.* 28 p.

Appendix I. Scaled age frequencies of the 2010 TAR 2 commercial bottom trawl catch, pooled, or split by catch in to the north (N) or south (S) of the Mahia Peninsula (see text).

age	male_pooled	female_pooled	total_pooled	male_cv_pooled	female_cv_pooled	total_cv_pooled
1	0.00	0.00	0.00	0.00	0.00	0.00
2	84622.60	58780.80	143403.00	0.25	0.33	0.20
3	165634.00	118146.00	283780.00	0.18	0.20	0.14
4	338887.00	355370.00	694258.00	0.11	0.10	0.07
5	288107.00	403055.00	691162.00	0.12	0.09	0.07
6	188121.00	212691.00	400812.00	0.15	0.12	0.09
7	110629.00	140744.00	251373.00	0.19	0.17	0.12
8	43522.80	38595.30	82118.00	0.28	0.34	0.22
9	17024.40	19894.40	36918.80	0.48	0.41	0.30
10	7314.35	22558.30	29872.70	0.65	0.40	0.34
11	12363.20	11746.40	24109.50	0.68	0.43	0.40
12	24078.10	9040.49	33118.50	0.42	0.62	0.35
13	15875.20	8912.91	24788.10	0.44	0.61	0.36
14	7591.87	2178.68	9770.55	0.76	0.98	0.63
15	0.00	0.00	0.00	0.00	0.00	0.00
16	1143.50	0.00	1143.50	0.97	0.00	0.97
17	5838.53	9674.33	15512.90	0.79	0.60	0.44
18	3160.09	3694.04	6854.13	0.91	0.88	0.64
19	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00
28	4501.82	0.00	4501.82	0.98	0.00	0.98
29	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00

Appendix I. Continued.

age	male_N	female_N	total_N	male_cv_N	female_cv_N	total_cv_N
1	0.00	0.00	0.00	0.00	0.00	0.00
2	7529.84	8439.16	15969.00	0.70	0.60	0.45
3	61489.10	35270.20	96759.30	0.26	0.33	0.20
4	262874.00	304917.00	567791.00	0.12	0.10	0.07
5	212701.00	313101.00	525802.00	0.13	0.09	0.07
6	145086.00	181340.00	326426.00	0.16	0.12	0.10
7	75565.70	94469.50	170035.00	0.22	0.19	0.14
8	37710.30	21529.70	59240.00	0.30	0.39	0.25
9	10466.30	15199.30	25665.70	0.53	0.44	0.33
10	7314.35	13065.90	20380.30	0.65	0.52	0.41
11	0.00	11746.40	11746.40	0.00	0.43	0.43
12	11714.90	3006.55	14721.40	0.52	0.71	0.44
13	15875.20	8912.91	24788.10	0.44	0.61	0.36
14	1143.50	2178.68	3322.18	0.90	0.98	0.69
15	0.00	0.00	0.00	0.00	0.00	0.00
16	1143.50	0.00	1143.50	0.97	0.00	0.97
17	1143.50	4979.30	6122.80	0.98	0.72	0.62
18	3160.09	3694.04	6854.13	0.91	0.88	0.64
19	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00
28	4501.82	0.00	4501.82	0.98	0.00	0.98
29	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00

Appendix I. Continued.

age	male_S	female_S	total_S	male_cv_S	female_cv_S	total_cv_S
1	0.00	0.00	0.00	0.00	0.00	0.00
2	77092.80	50341.60	127434.00	0.28	0.36	0.22
3	104145.00	82875.60	187021.00	0.24	0.26	0.17
4	76012.80	50453.40	126466.00	0.28	0.33	0.21
5	75406.20	89953.90	165360.00	0.26	0.24	0.16
6	43035.80	31350.80	74386.70	0.36	0.41	0.26
7	35063.30	46274.80	81338.20	0.41	0.34	0.26
8	5812.44	17065.60	22878.00	0.98	0.55	0.48
9	6558.09	4695.03	11253.10	0.90	0.96	0.66
10	0.00	9492.41	9492.41	0.00	0.64	0.64
11	12363.20	0.00	12363.20	0.68	0.00	0.68
12	12363.20	6033.95	18397.10	0.64	0.87	0.53
13	0.00	0.00	0.00	0.00	0.00	0.00
14	6448.36	0.00	6448.36	0.89	0.00	0.89
15	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00
17	4695.03	4695.03	9390.05	0.96	0.93	0.62
18	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00