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Characterisation of TAR 1 fisheries and age composition of landings in 2010/11 from Industry at-sea catch sampling

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EXECUTIVE SUMMARY

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Results from a 2010–11 Seafood NZ Ltd (formerly SeaFIC) at-sea sampling programme in TAR 1 are presented and discussed. Sampling on Sanford NZ Ltd and Aotearoa Fisheries Ltd trawl vessels and in processing sheds was largely undertaken by vessel crews and factory staff in accordance with a sampling design developed by SeaFood NZ scientists.

Spatial and temporal coverage of sampling in the Bay of Plenty and Statistical Area 004 was "reasonably" representative of the tarakihi trawl fishery in these areas and allowed catch-at-age analyses for this subarea. Sampling coverage in the West Coast North Island, East Northland and Hauraki Gulf regions of TAR 1 was found to be unrepresentative of the 2010–11 trawl fishery spatial and temporal patterns, and so catch-at-age analyses were not carried out for these regions.

Analysis of the Bay of Plenty at-sea data showed that Statistical Areas 004 and 008 had a similar broad range of age classes, distinct from Statistical Areas 009 and 010 which had fewer older tarakihi. These results provide evidence of stock separation in TAR 1 and point to the possible location of the north/south boundary. The degree of spatial resolution achieved may not have been possible with a land-based sampling programme.

In undertaking this programme both Sanford NZ Ltd and Aotearoa Fisheries Ltd have demonstrated that they are capable of collecting potentially useful data that would be difficult and costly to collect without their direct involvement. A key recommendation for future industry sampling programmes is for greater emphasis to be placed on data validation and quality assurance, and independent review.

1. INTRODUCTION

Ministry for Primary Industries project TAR201002 included an objective to sample the TAR 1 (Figure 1) bottom trawl fishery in the 2010–11 fishing-year. The design of the programme required TAR 1 to be stratified into three spatial areas: west coast North Island (WCNI); east Northland/ Hauraki Gulf (ENHG); Bay of Plenty (BPLE) (Figure 1) and originally called for land-based sampling methodologies.

In early 2011 two northern fishing companies, Sanford NZ Ltd and Aotearoa Fisheries Ltd (AFL), in conjunction with Seafood New Zealand (formerly SeaFIC) scientists developed methods for sampling inshore trawl catches at-sea. The Ministry for Primary Industries (formerly the Ministry of Fisheries) agreed to drop the TAR 1 land-based sampling objective from the TAR201002 project pursuant to an agreement from Sanford NZ Ltd and Aotearoa Fisheries Ltd to sample tarakihi catches on their own vessels at-sea.

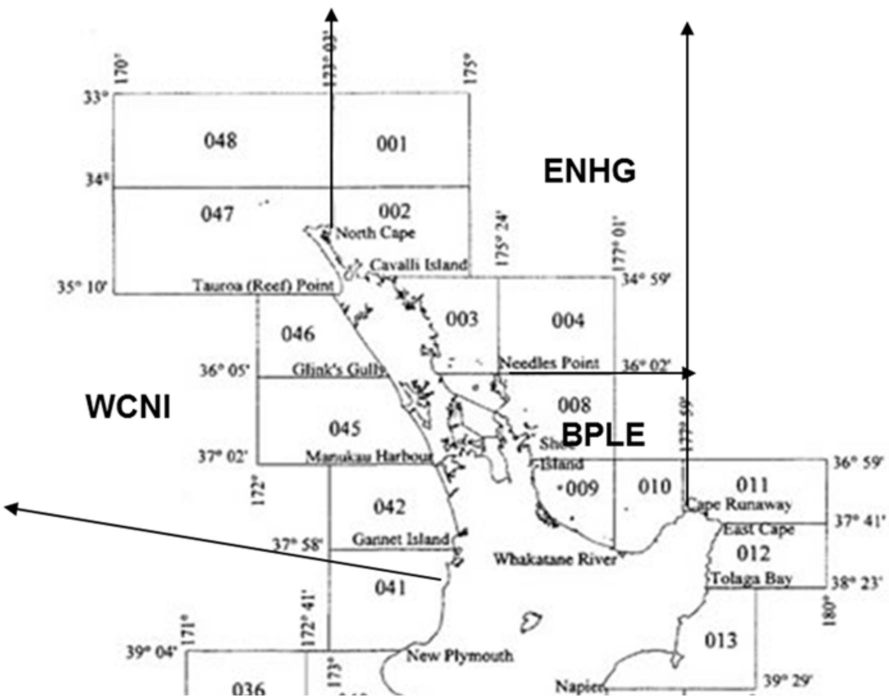


Figure 1: TAR 1 sub-region and statistical reporting area boundaries.

From January to September 2011 trawl catches of tarakihi (*Nemadactylus macropterus*) from the three TAR 1 sub-areas (Figure 1) were sampled for length and age. The objective of the programme was to describe the age and length composition of the TAR 1 single trawl fishery in 2010–11 and it was funded, designed and run by the TAR 1 quota holders with scientific input from SeaFIC scientists.

This report provides an analysis of the age and length data collected, reviews the efficacy of the Industry at-sea sampling programme, and includes a characterisation of the TAR 1 fishery for the 2000–01 to 2010–11 fishing years. This work was contracted to NIWA by MPI as additional objective (Objective 6) to TAR201002 and included the following tasks:

1. To characterise the TAR 1 fishery
2. To analysis TAR 1 catch-at-age data collected under a quota holder at-sea sampling programme in the 2010–11 fishing year.

2. METHODS

2.1 TAR 1 recent (2001–02 to 2010–11) fishery profile data

A characterisation of patterns in the TAR 1 fishery over the period October 2001 to September 2011 was undertaken using data extracted from the Ministry for Primary Industries (MPI) commercial catch, effort and landings reporting system. The dataset extracted included all effort details and associated catch weights (all species including tarakihi) from all trips landing tarakihi in TAR 1.

The MPI data were groomed and checked for typical reporting errors (see Appendix 1). Information to perform the characterisation was compiled into two tables:

1. Landed catch weight: A file containing the verified green (unprocessed) landed weight of all TAR 1 trips.
2. Trip effort data: A file containing details of individual fishing events (location, method, target species etc.).

Although the Trip effort data table has information on catch, these are only fisher estimates. The process followed was to prorate the actual trip landed weight totals across the effort information (i.e. individual sets, tows or days) on the basis of the estimated catch ratios. The link between the two data tables was the common trip number field (trip_key).

2.2 At-sea catch sampling

The purpose of the catch sampling programme was to measure length and sex, and to determine the age distribution of the TAR 1 single bottom trawl catch in 2010–11. In the 2010–11 fishing year Sanford Ltd and AFL Ltd accounted for over 80% of the TAR 1 annual catch. Therefore a catch sampling programme focussed on these two companies described the majority of the TAR 1 commercial fishery.

In 2010 Adam Langley undertook a comparison of shed-based and at-sea based sampling programmes using recent TAR 1 Sanford and AFL catch data (Appendix 2). He concluded that, while both programmes would be capable of providing adequate coverage of the TAR 1 single trawl fishery, an at-sea programme had the added advantage of providing fine-scale data that may also enable a more thorough analysis of the spatial variation in the commercial catch.

Although it was not feasible to implement an at-sea sampling on all Sanford and AFL trawl vessels, this analysis concluded that by restricting sampling to the four top Sanford and AFL TAR 1 catching vessels, a high degree of fishery coverage in each of the three TAR 1 sub-areas could still be achieved; the scope of the programme was to include at least these four vessels (Appendix 2).

In at-sea sampling, the basic sampling unit is the individual tow (as opposed to an individual landing in land-based sampling). The selection of samples is critical to ensure that sampling is representative. A sampling simulation analysis indicated that a high level of fishery representation could be achieved by sampling from all tarakihi tows catching more than 200 kg on each of the four candidate vessels (Appendix 2). The original design required collecting one bin of tarakihi (unsorted) from all candidate weight tows with sampled bins suitably labelled to identify the sample at unloading time and to link the sample to tow information on MPI catch effort reporting forms. Once in the factory, SeaFIC trained staff would be required to measure and sex all sampled fish, and to remove otoliths from every third fish.

Details of the SeaFIC sampling protocols supplied to vessel and shore based samplers for this project are given in Appendix 3. Note that these instructions differ from the originally recommended approach (Appendix 2) in that crews were instructed to sample only the first tow after mid-day catching greater than 50 kg of tarakihi as opposed to sampling every tow on the trip catching more than 200 kg of tarakihi.

2.3 Age determination

2.3.1 Otolith Selection

The direct ageing method was used to estimate the age composition of the TAR 1 sub-strata fisheries. The requirement to collect otoliths from every third fish in every sample bin meant that the number of otoliths collected was independent of tow catch weight. Not all of the collected otoliths could be aged (because of a cost constraint), so it was necessary to extract a random sub-sample for ageing. The number of otoliths to be aged from an individual tow sample was weighted by the relative weight of the tow consistent with a requirement that at least one otolith pair came from every tow sampled.

2.3.2 Otolith preparation

Preparation and reading of otoliths collected in 2010–11 followed the procedure described in Walsh et al. (2014) 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 at 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.

2.3.3 Forced margin method

The forced margin method is described in Walsh et al. (2014) and also defined in the glossary of the Ministry of Fisheries guidelines for New Zealand fish ageing protocols (Ministry of Fisheries 2011).

> **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 the 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 (CV).

2.4 Age composition

For each fishery, estimated numbers-at-age were calculated using the NIWA program Catch-at-length-and-age (Francis & Bian 2011). Scaled age-frequency distributions were estimated by sex, and overall for all strata combined. Mean-weighted coefficients of variation (MWCV) were estimated by bootstrap resampling (1000 bootstraps).

3. RESULTS

3.1 TAR 1 fishery characterisation

3.1.1 Data grooming errors

The “true” landed catch weights derived after removing non-terminating catch records (landing codes “PQRT” Appendix 1) from the landed catch data table are given in Table 1. For most years the amount of annual catch that could be linked directly to (prorated across) effort varied between 98 and 99% (Table 1); we are therefore confident that the TAR 1 characterisation results presented below are highly representative of the TAR 1 fishery over the 2001–02 to 2010–11 fishing years.

Table 1: Breakdown of total TAR 1 reported landed catch (t) showing total duplicate (retained not landed), “true” landed weights, and the amount (t) of “true” catch that could be included in the characterisation (linked to effort). Monthly Harvest Return (MHR) totals are also shown for comparison.

Fishing year	MHR	Reported catch	Retained catch	% retained	"True" catch	Effort link	% effort link
2001–02	1 480	1 500	2	0.13%	1 498	1 471	98.17%
2002–03	1 517	1 508	3	0.17%	1 505	1 479	98.26%
2003–04	1 541	1 545	10	0.68%	1 535	1 509	98.33%
2004–05	1 527	1 545	6	0.36%	1 540	1 516	98.47%
2005–06	1 409	1 405	5	0.38%	1 400	1 380	98.62%
2006–07	1 193	1 196	2	0.17%	1 194	1 179	98.71%
2007–08	1 286	1 277	4	0.29%	1 273	1 258	98.78%
2008–09	1 398	1 407	11	0.75%	1 396	1 388	99.42%
2009–10	1 332	1 357	28	2.10%	1 329	1 312	98.71%
2010–11	1 349	1 392	31	2.23%	1 361	1 307	96.00%

3.1.2 Catch by sub-stock

A large proportion of the annual TAR 1 catch was taken from the Bay of Plenty sub-stock. A moderate amount of the catch was obtained from the West Coast, North Island sub-stock. Consistently less catch came out of the combined areas of East Northland and Hauraki Gulf (Figure 2; Appendix 4).

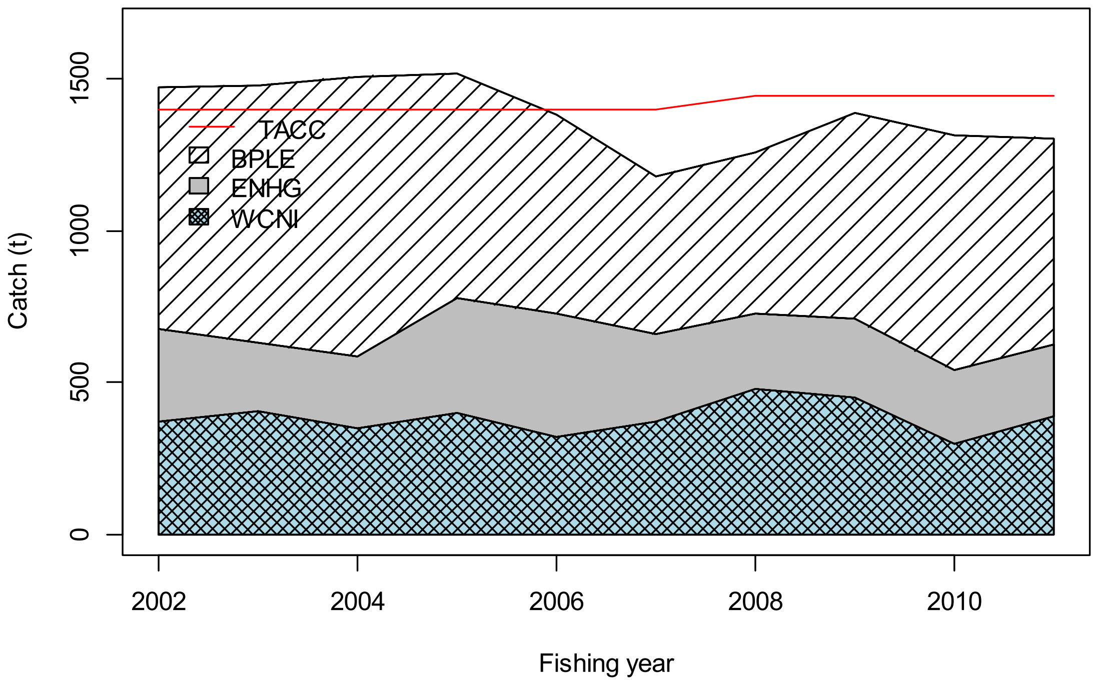


Figure 2: Annual TAR 1 catch by sub-stock 2001–02 to 2010–11 (BPLE= Bay of Plenty; ENHG = East Northland/Hauraki Gulf; WCNI = West Coast, North Island).

3.1.3 Main fishing methods

Bottom trawl was the dominant fishing method in all areas, with a low proportion of the catch taken by bottom longline in East Northland and Hauraki Gulf (ENHG), and bottom pair trawling on the west coast North Island (WCNI) (Figure 3; Appendix 5).

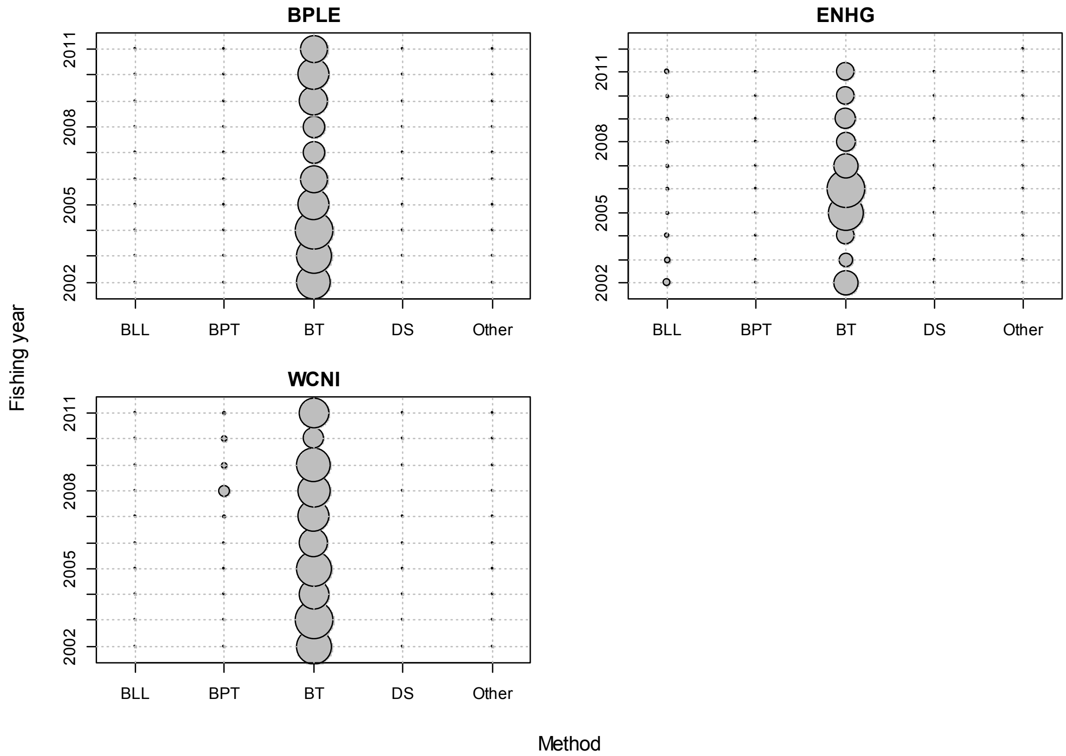


Figure 3: Relative annual TAR 1 catch by area and method (BLL = bottom longline; BPT = bottom pair trawl; BT = bottom trawl; DS = Danish seine); circle area proportional to landed weight within each area.

3.1.4 Single Bottom Trawl

The spatial distribution of TAR 1 trawl catches show strong emphasis being placed on Statistical Areas 009 and 010 of the Bay of Plenty; Statistical Areas 002 and 003 from a combined East Northland/Hauraki Gulf; and Statistical Area 047 of the West Coast, North Island (Figure 4; Appendix 6). These spatial patterns in trawl fishing activity have been relatively consistent through time (Figure 4; Appendix 6). Little fishing activity took place in the Hauraki Gulf (Statistical Areas 005, 006, 007) as the bottom trawl fishing method has been excluded from this area.

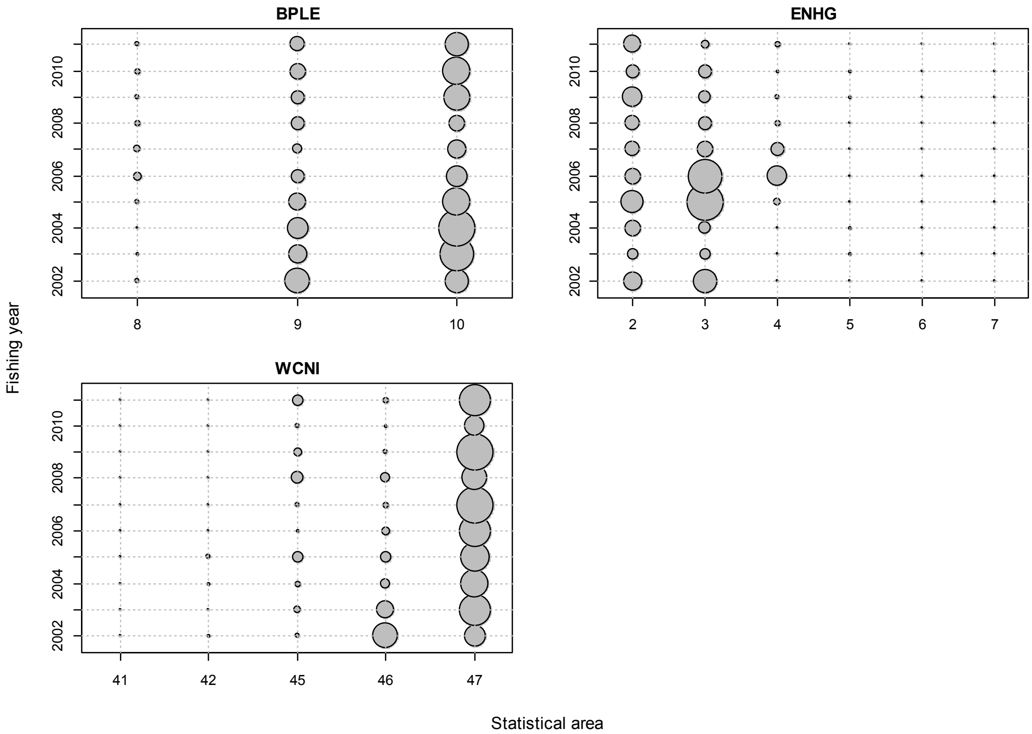


Figure 4: Relative annual TAR 1 bottom trawl catch by statistical reporting area; circle area proportional to landed weight within each area.

Very little tarakihi is taken while targeting other species in all three sub-stocks (Figure 5;Appendix 7).

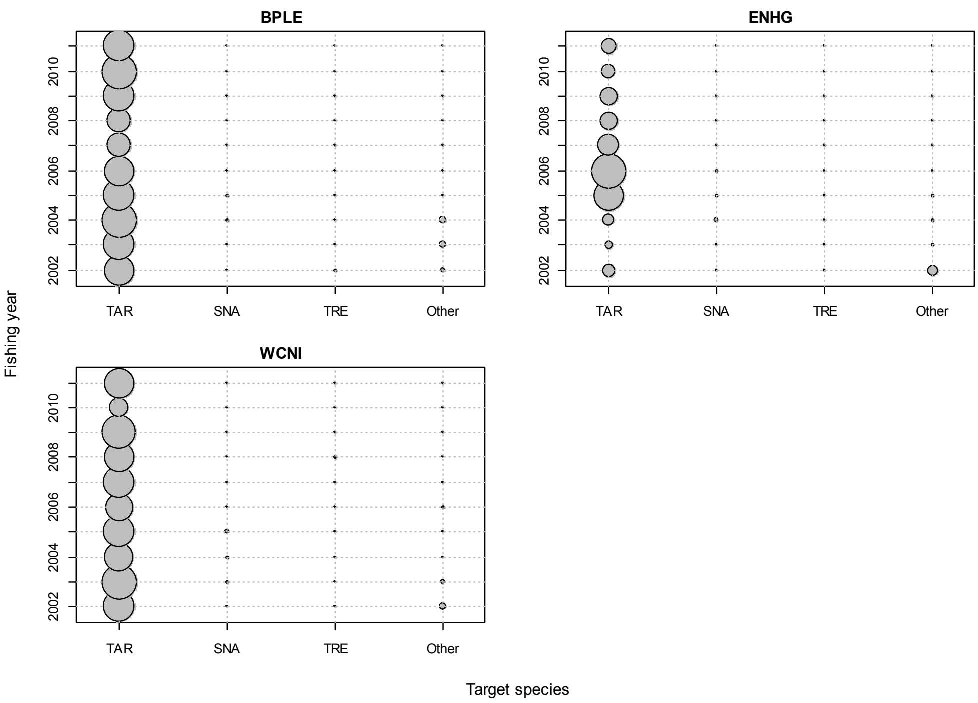


Figure 5: Relative annual TAR 1 bottom trawl catch by target species; circle area proportional to landed weight within each area.

There is evidence of late summer and autumn peaks in the Bay of Plenty and West Coast North Island single bottom trawl tarakihi catch series (Figure 6). The West Coast sub-stock shows a slight decrease in landed catch for summer and autumn in the early years of the time series, but catches increase from 2004–05 onwards. The East Northland/Hauraki Gulf trawl fishery is sporadic over the fishing year with little evidence of a seasonal trend.

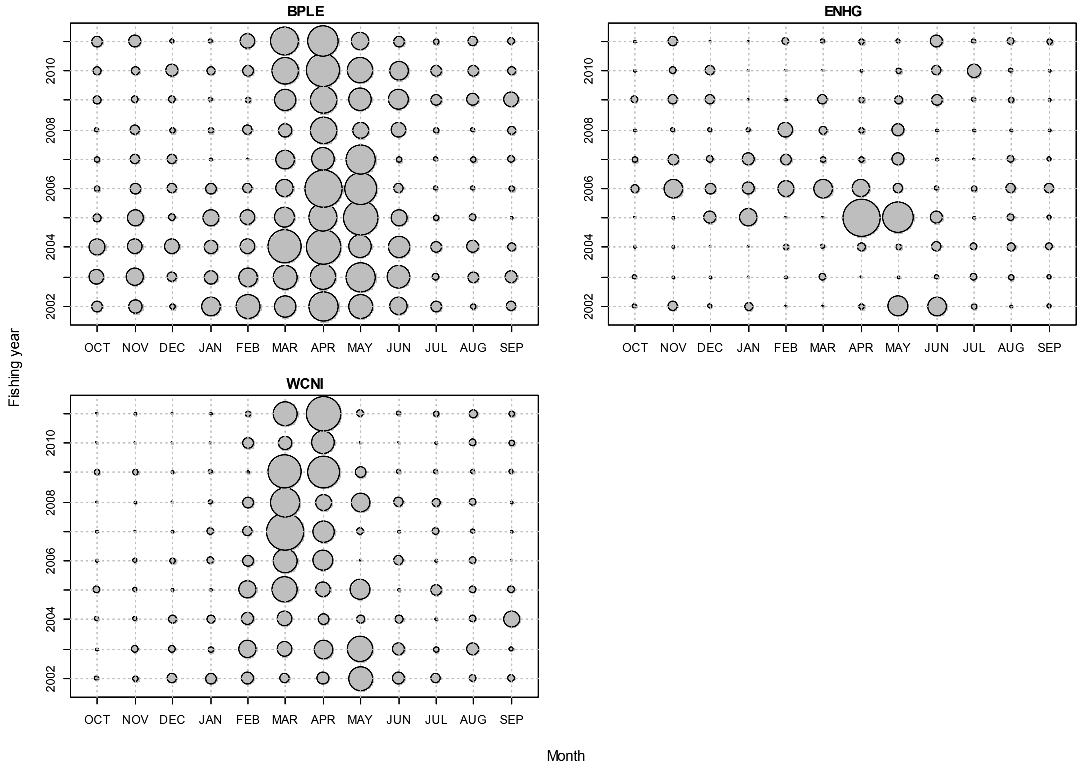


Figure 6: Relative annual TAR 1 bottom trawl catch by month; circle area proportional to landed weight within each area.

3.2 TAR 1 bottom trawl catch at-sea sampling results

3.2.1 Spatial coverage

With the exception of Statistical Area 004, the number of east Northland/Hauraki Gulf (ENHG) samples was limited and overall the spatial distribution relative to the operation of the fishery was poor (Figure 7). On the basis of poor spatial coverage the decision was made to exclude the ENHG spatial area from the TAR 1 catch at-age analysis but to retain the 004 spatial data for possible inclusion with a Bay of Plenty (BPLE) sub-area analysis.

Better spatial coverage was achieved over the west coast (WCNI); sub-area sampling matched the main catching areas of Ninety Mile Beach (047) in the north and the southern Kaipara region (045, 042) although no samples were obtained from southern most area (Figure 7). Sampling achieved an excellent spatial coverage of the Bay of Plenty sub-area with zones of high catch also well represented (Figure 7).

a. b.

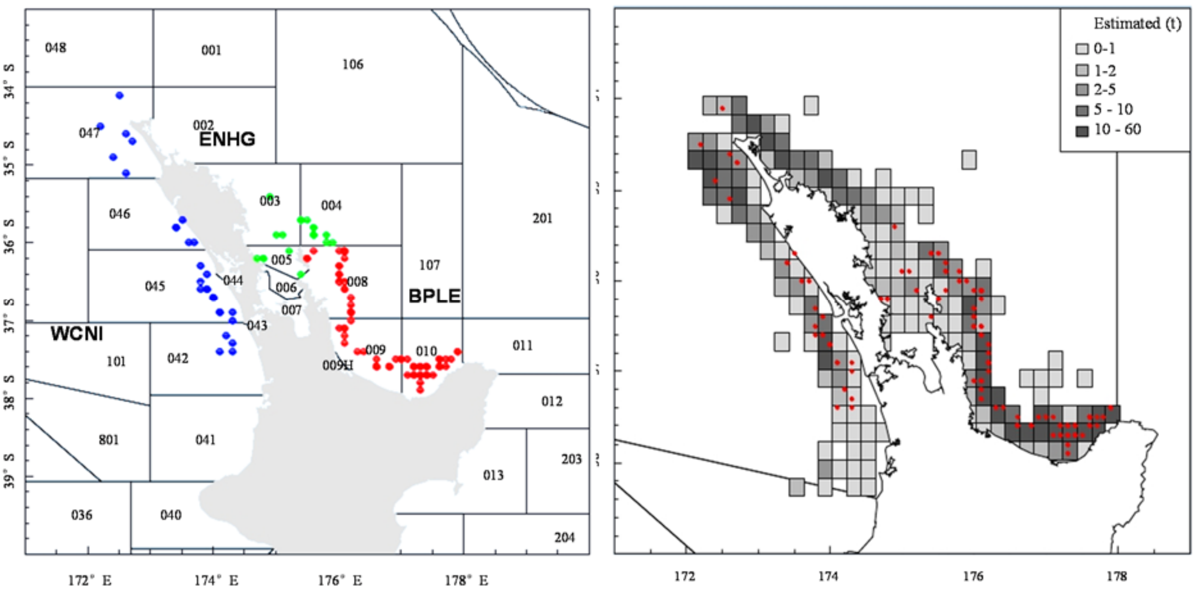


Figure 7: Distribution of TAR 1 trawl sample tows by statistical area (a) and relative to spatial trawl catch pattern (b) (figure courtesy of Adam Langley).

3.2.2 Temporal coverage

Although spatial coverage was adequate on the west coast (WCNI), sampling was poorly representative of the monthly proportional catches in the fishery, with only three months sampled (Figure 8). On this basis, the decision was made to exclude the WCNI spatial area from the TAR 1 catch at-age analysis.

Sampling in the Bay of Plenty (BPLE) occurred throughout the 2010–11 fishing-year and was proportionally representative of the monthly catch pattern (Figure 9).

The rejection of the WCNI and ENHG components of TAR 1 left only the Bay of Plenty in the age analysis; however, an analysis of the Statistical Area 004 samples was also retained.

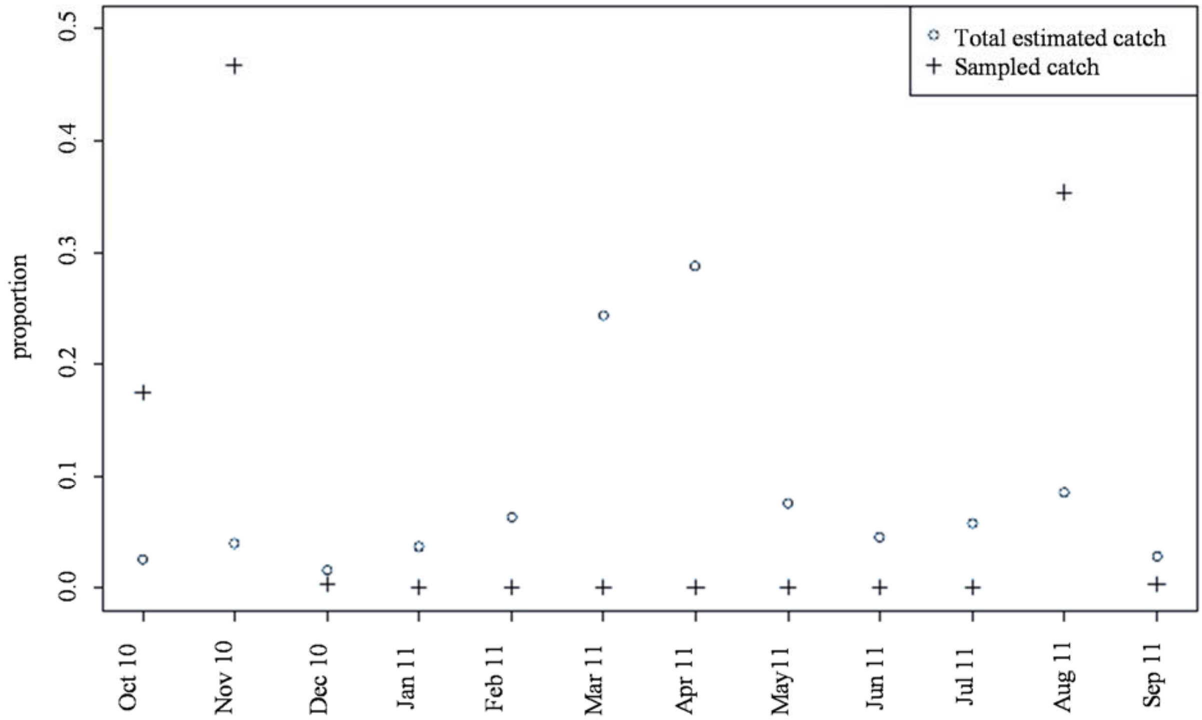


Figure 8: **Proportion of total WCNI estimated catch (circles) and the proportion of WCNI sampled catch (crosses) WCNI that occurred in each month in the 2010–2011 fishing year (graph courtesy of Adam Langley).**

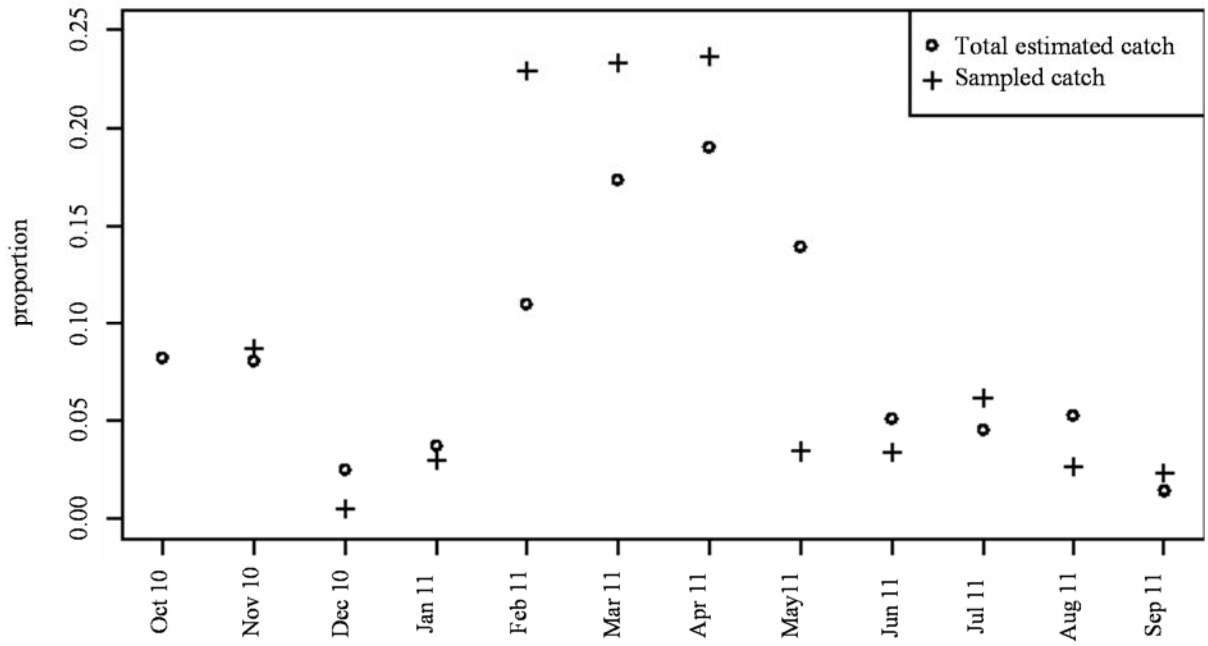


Figure 9: **Proportion of total BPLE estimated catch (circles) and the proportion of BPLE sampled catch (crosses) WCNI that occurred in each month in the 2010–2011 fishing year (figure courtesy of Adam Langley).**

3.2.3 BPLE fishery representativeness

Although the Langley sampling design (Appendix 2) called for 1 bin of tarakihi to be randomly sampled from **every** tow greater than 200 kg, the sampling instructions supplied to processing personnel and vessels skippers followed an earlier design which required only 1 bin of tarakihi to be sampled each day from the first tarakihi catch processed after mid-day greater than 50 kg (Appendix 3). The effect of following the old design was to bias sampling toward the mid-day period (Figure 10).

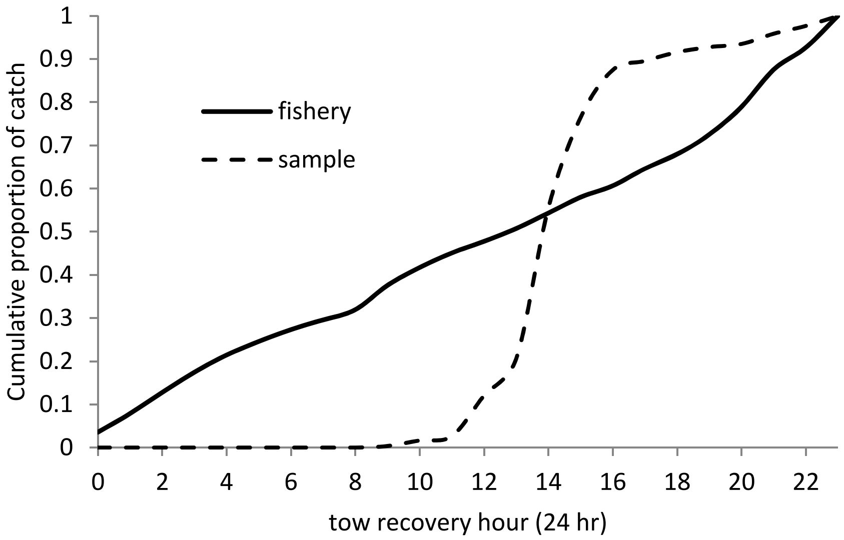


Figure 10: Cumulative BPLE bottom trawl tarakihi 2010–11 catch over 24 hours and cumulative weight of tows sampled.

Of the ten initial participant vessels in the 2010–11 TAR 1 catch sampling programme, only four delivered usable data (Appendix 8). Data from the BPLE and Statistical Area 004 came from only two vessels. Of the 21 trawl vessels landing BPLE tarakihi in 2010–11 the two sampled vessels were the top and fourth highest catching vessels and accounted for 30% of the total BPLE catch. Although the total weight of all BPLE sampled tows sampled represented only 5% of the 2010–11 total catch, these were “reasonably” representative of the fishery monthly catch pattern (Figure 9 and Figure 11).

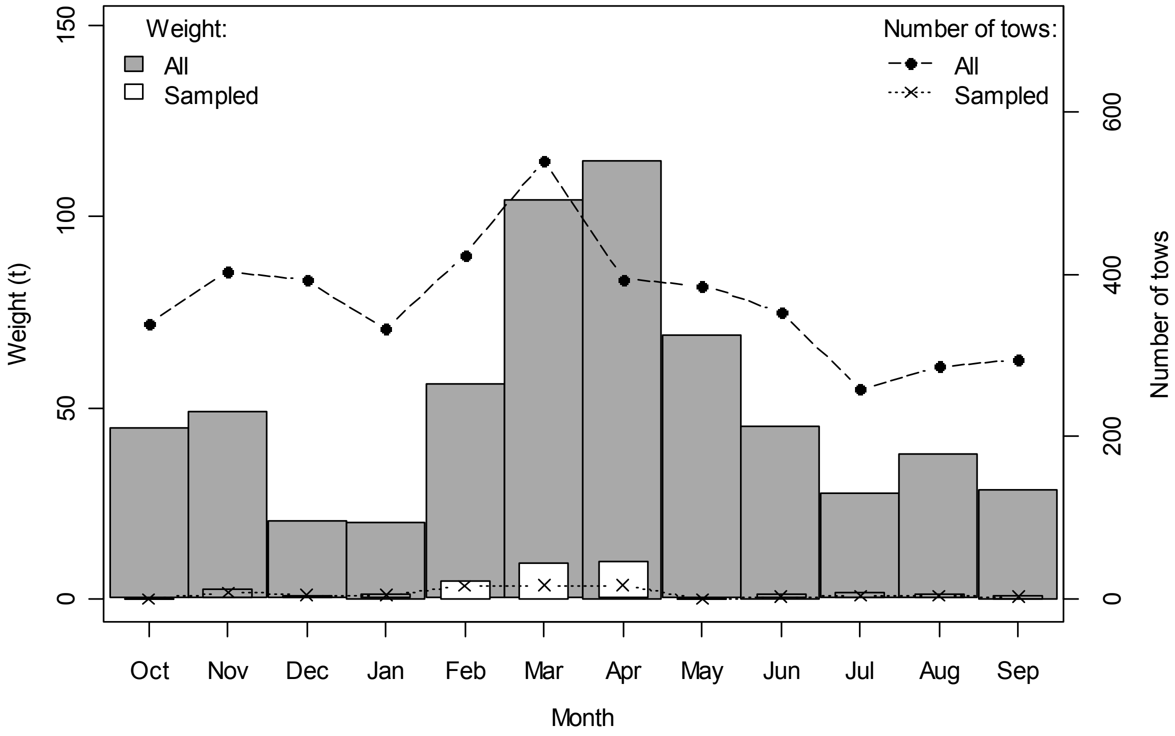


Figure 11: A comparison of the monthly catches and number of landings in the BPLE tarakihi bottom trawl fishery to those sampled in 2010–11.

Sampling was also "reasonably" representative of the relative frequency of individual tarakihi tow weights (Figure 12); the average weight of a BPLE tarakihi tow in 2010–11 was 790 kg, and the average weight of the sampled tows was 780 kg.

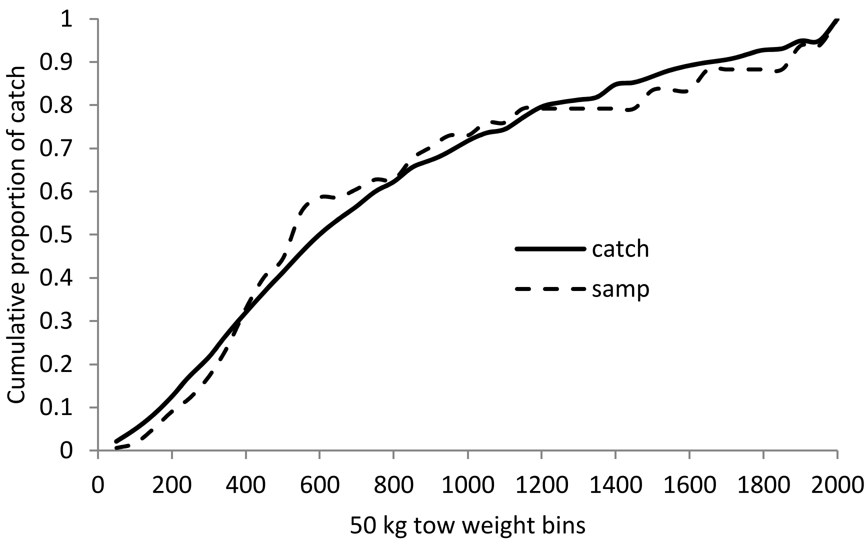
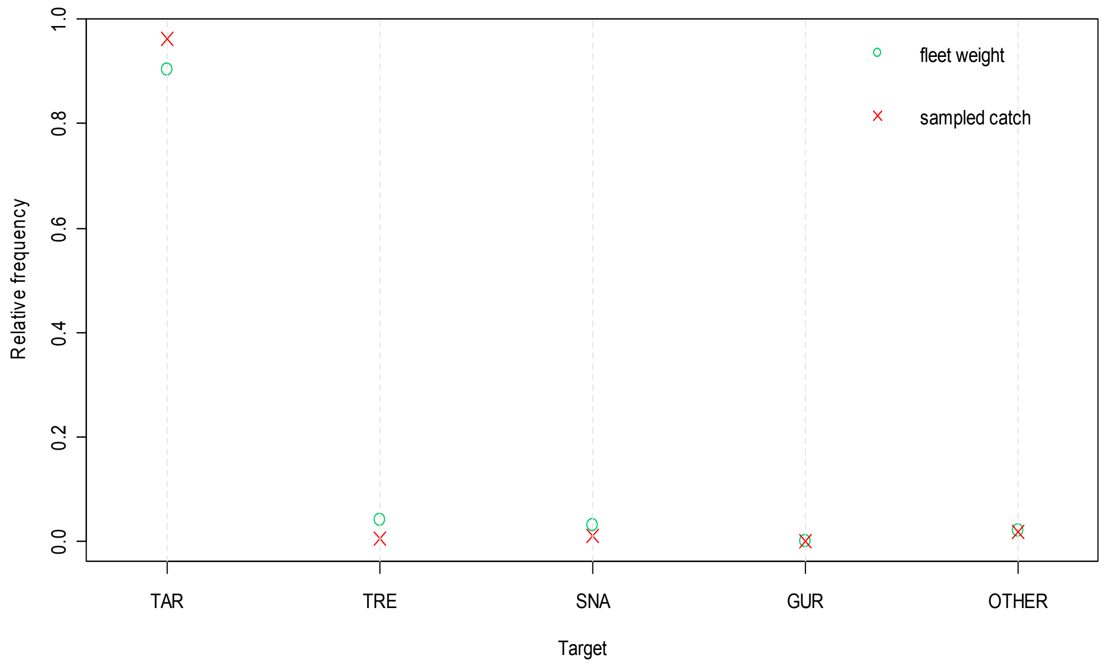


Figure 12: Cumulative proportion of 2010–11 BPLE trawl tarakihi catch (fishery and sampled) relative to 50 kg individual tow weight bins.

The catch sampling achieved good proportional coverage of the targeting pattern in the fishery and the relative catch from the BPLE statistical areas and the adjacent ENLD 004 statistical area (Figure 13).

a.



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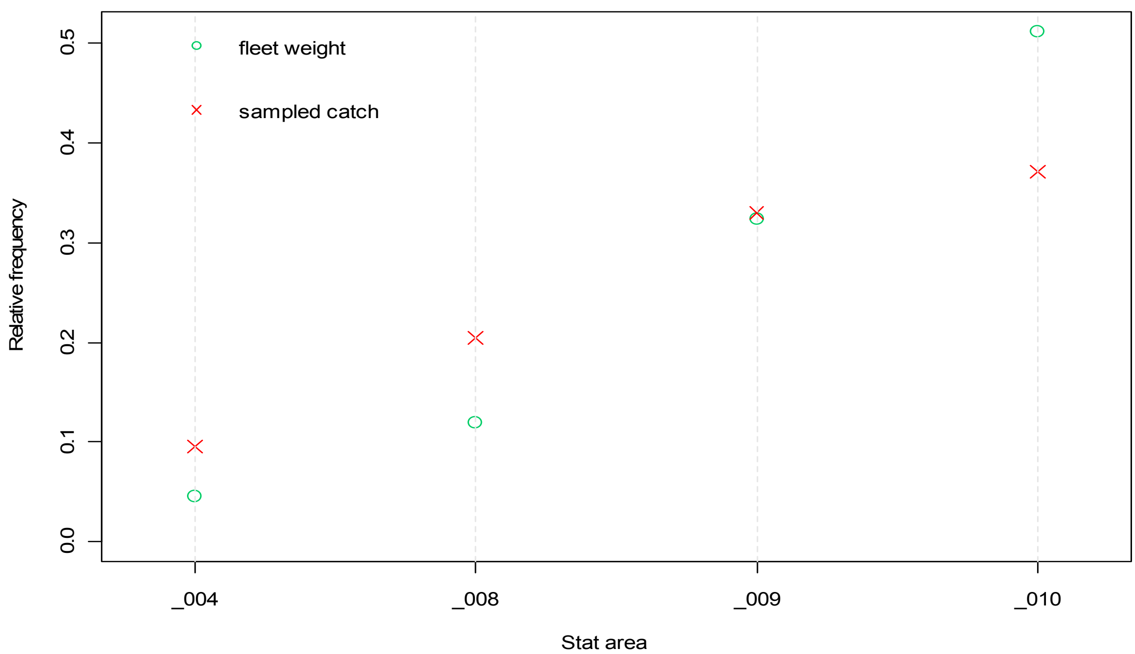

Figure 13: Proportion of BPLE total trawl catch (circles) and sampled catch (crosses) (a) by target species and (b) by statistical area (includes ENLD 004) in the 2010–11 fishing year.

Sampling of the BPLE fishery relative to capture depth was less than ideal; deeper tows being over-represented in the sampling (Figure 14).

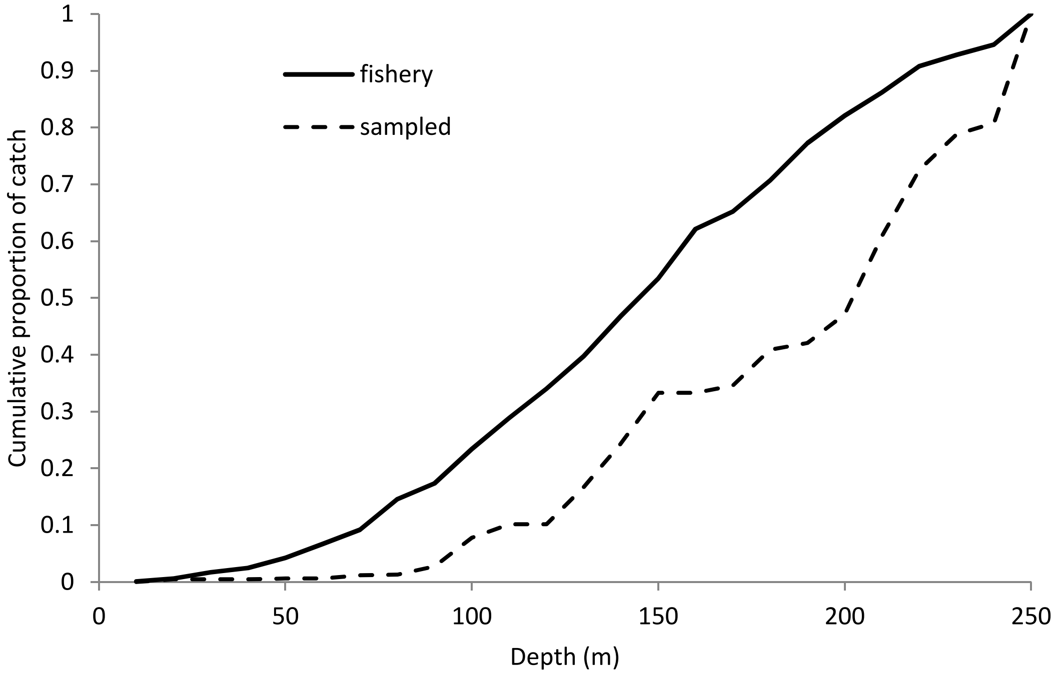

Figure 14: Cumulative proportion of 2010–11 BPLE trawl tarakihi catch (fishery and sampled) relative to tow depth.

Despite sampling only two vessels of the fleet of 21 vessels fishing tarakihi in the Bay of Plenty, sampling achieved a reasonable spatial and temporal representation of the 2010–11 tarakihi trawl catch. Sampling was biased toward noon-day and deeper water catches, but it is not known if this affected the age patterns seen in the catches.

Given these caveats; it was deemed that the level of sampling achieved by the industry TAR 1 sampling programme was possibly representative of the Bay of Plenty and Statistical Area 004 single trawl catches in 2010–11.

3.2.4 Ageing

A sub-sample of 500 otolith pairs from the BPLE area and 100 pairs from Statistical Area 004 was selected for ageing. Two otoliths were selected at random from each tow where the estimated catch of tarakihi was greater than 50 kg. All otoliths were included from sampled tows where the tarakihi catch exceeded 1000 kg. The remainder of the sample was selected at random from the available otoliths with selection probability weighted by the estimated catch weight in the sampled tows.

Age readings were reasonably consistent between readers, with an average percent error (APE) of 3.06 and a CV of 4.33% (Figure 15c). Less than 5% of the readings disagreed by more than one year (Figure 15a, b), and there were no trends in discrepancies across the age range (Figure 15b, c).

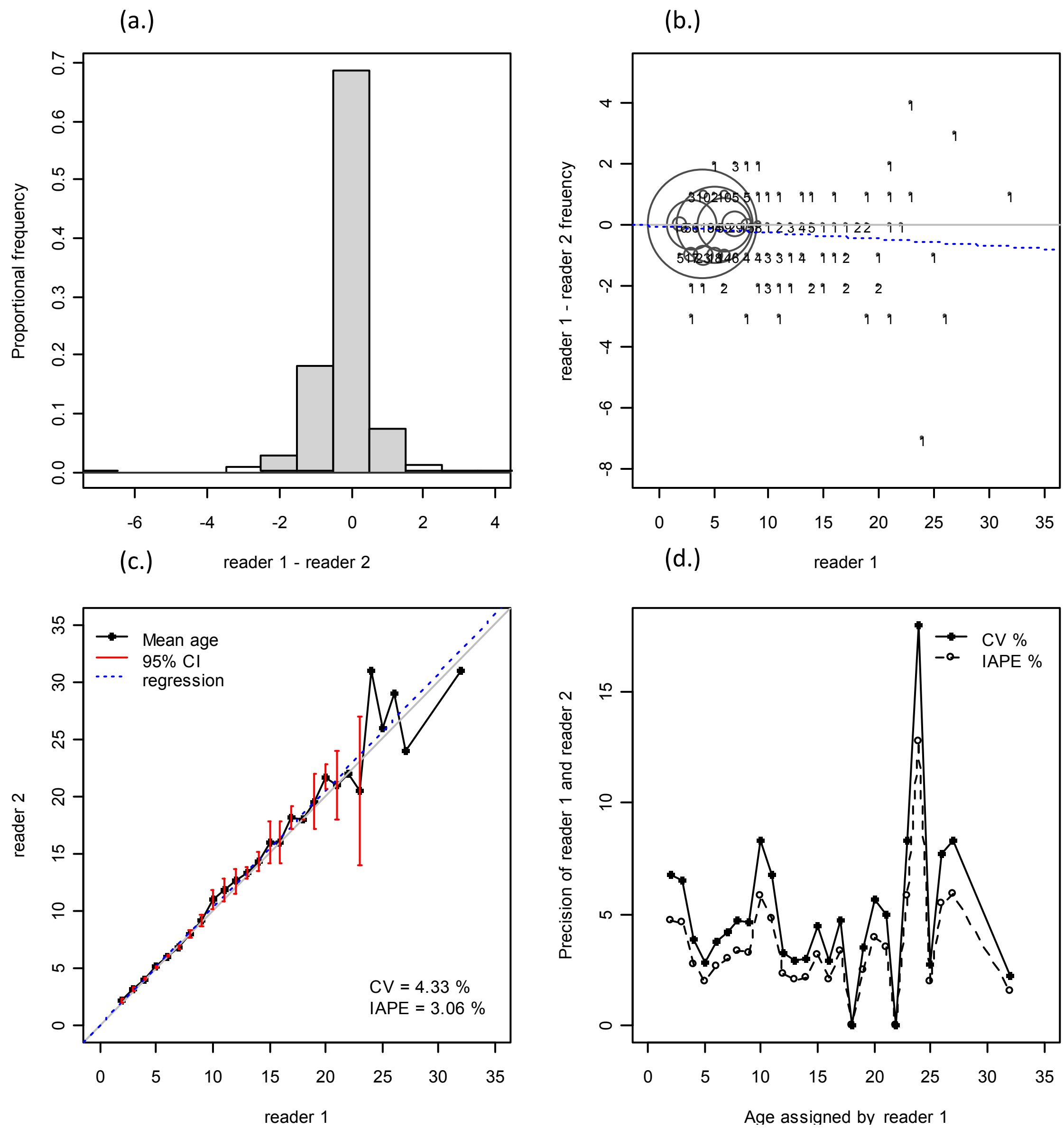

Figure 15: Age reader comparison plots for BPLE BT 2011: (a) histogram of age differences between two readers; (b) Difference between reader 1 and reader 2 as a function of the age assigned by reader 1. The number of fish in each bin is plotted as the plot symbol; (c) Age bias plot, showing the correspondence of ages between reader 1 and reader 2 for all ages. Error bars indicate the CV of the ages for each age by reader 1; (d) Plot of the CV 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.

3.2.5 Bay of Plenty and 004 catch-at-age composition

The proportions of male and female tarakihi in the Bay of Plenty (BPLE) sampled tows were similar (53% male) as was the age composition (Figure 16; Appendix 9).

The BPLE tows were comprised predominately of fish aged between 2 and 8 years; year classes older than 8 years are evident in the samples with approximately 2% of the sampled fish (numbers) being older than 20 years (Figure 16; Appendix 9). The overall precision on the age estimates was reasonable (MWCV 0.23; Figure 16; Appendix 9).

Figure 16: Scaled proportional tarakihi age frequencies and coefficients of variation (CV) of the 2010-11 BPLE (Statistical Areas: 008, 009, 010) commercial bottom trawl catch. Line indicates the CV for each age class. n, = number otoliths, mwcv = mean weighted CV.

3.2.6 Analysis of Bay of Plenty and 004 catch at-age composition

The northern Statistical Areas (004 and 008) had a greater proportion of fish older than 16 years than the south-western BPLE Statistical Areas (009 and 010) (Figure 17; Appendix 10; Appendix 11; Appendix 12; Appendix 13). Statistical Areas 004 and 008 had very similar sample age distributions (Figure 18) that were not statistically different (Table 2). Differences between the 009 and 010 sample age distributions (Figure 17 and Figure 18) were also not statistically significant (Table 2), whereas the sample age distributions from northern and southern statistical areas were significantly different (Table 2).

Table 2: Probability that the two age samples did not came from the same age-frequency distribution; i.e. rejection probability on the observed KS d-statistic (refer Appendix 14).

	Statistical Area		
	008	009	010
004	0.482	0.002	0.000
008		0.000	0.000
009			0.900

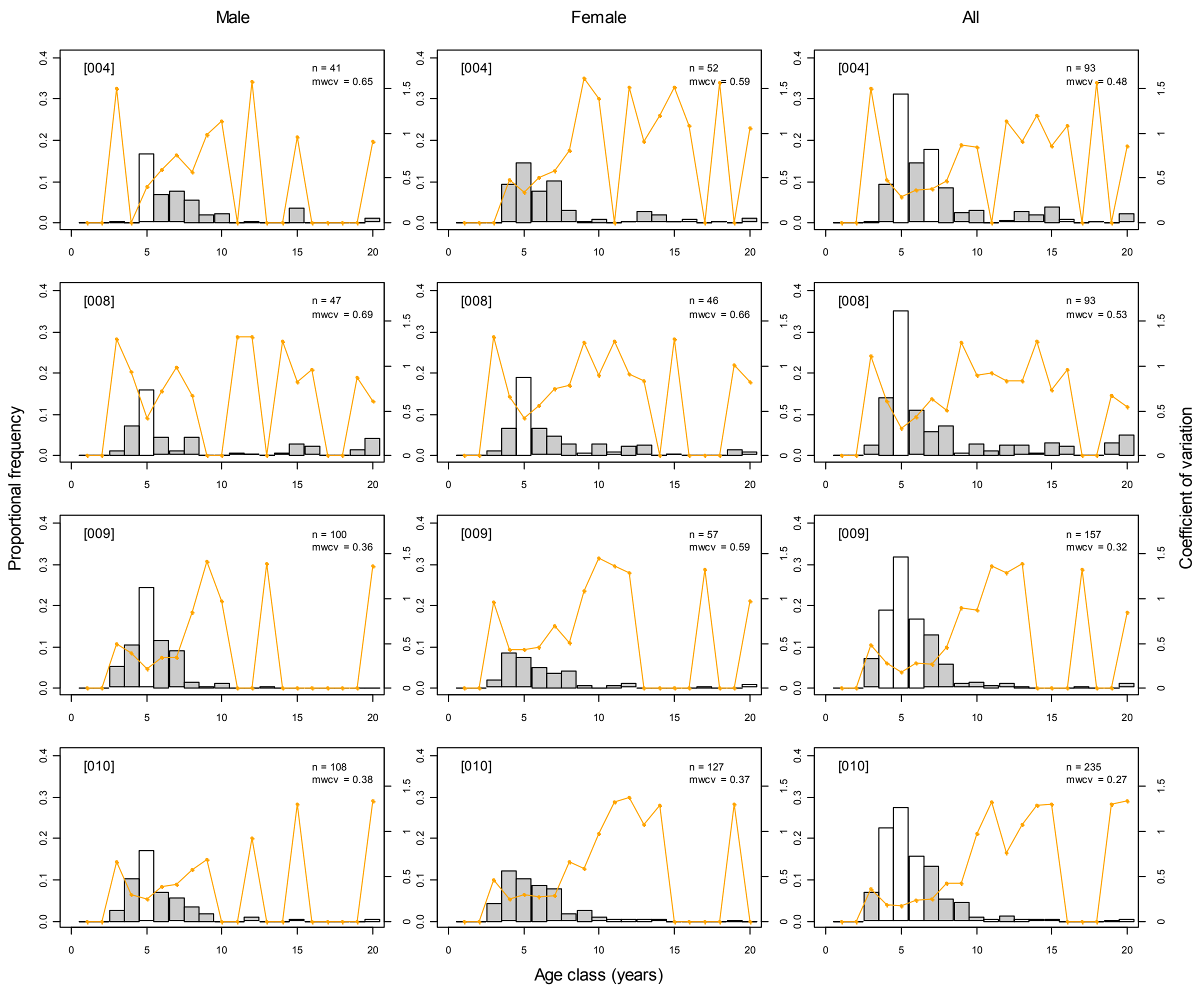

Figure 17: Scaled proportional tarakihi age frequencies and coefficients of variation (CV) of the 2010-11 tarakihi bottom trawl catch from Statistical Areas 004, 080, 090, 010. Line indicates the CV for each age class. n, = number otoliths, mwcv = mean weighted CV.

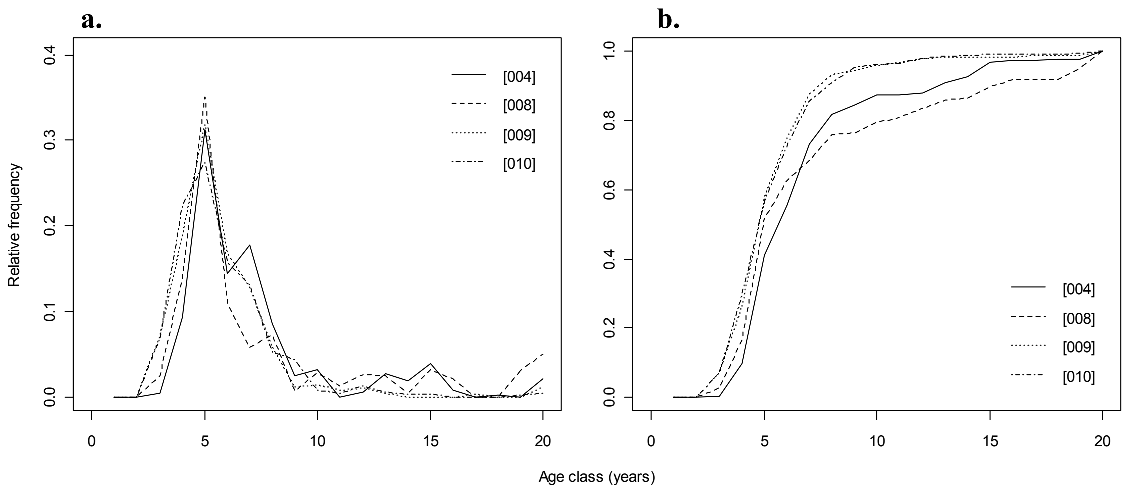

Figure 18: a. Scaled proportional tarakihi age frequencies and b. cumulative proportional age frequencies by statistical area.

4. DISCUSSION

For the purposes of understanding spatial stock structure, representative catch at-sea sampling is preferable to landed-catch sampling in that it allows age data to be collected at tow-level resolution. The disadvantage of at-sea sampling programmes is that they are typically more logistically complex and challenging than land-based programmes and hence more costly. It would have been preferable to use trained observers or technicians to sample the TAR 1 trawl fishery at sea in 2010–11 rather than largely inexperienced vessel crews and factory staff, but given the high associated cost this was not a feasible option.

The degree of potential bias/non-randomness due to the use of non-scientifically trained vessel and factory staff is unknown but potentially significant. The SeaFIC training procedures were largely undocumented and there was no independent observation or validation of the data collection process at-sea or in the sheds. Instructions such as “collect one random bin of fish from the tow”, and "collect otoliths from every third fish in the bin” (see Appendix 3) may seem straightforward, but non-statistically trained people often struggle with the concept of “random” such that it is very difficult for most lay people to select objects in a quasi-random way. It would be possible to compare the length composition from the at-sea bin sample to that of the otolith sub-sample to test that the otolith sample was unbiased, e.g. rank sums test (Ballara & O’Driscoll 2014); this was not done because NIWA was not provided with the sample bin length frequency data from SeaFIC.

Sampling coverage in the West Coast North Island, East Northland and Hauraki Gulf regions of TAR 1 was not representative of the 2010–11 trawl fishery spatial and temporal patterns. However, although biased toward tows from deeper water and midday, spatial and temporal sampling coverage in the Bay of Plenty and Statistical Area 004 was “reasonably” representative of the tarakihi trawl fishery in these areas.

Analysis of the Bay of Plenty and 004 at-sea data showed Statistical Areas 004 and 008 to have similar broad range of age classes as distinct from Statistical Areas 009 and 010 which had fewer older tarakihi. These results provide evidence of stock separation in TAR 1 and point to the possible location of the north/south boundary. It is likely that the degree of spatial resolution in the at-sea results would not have been achievable with a land-based sampling programme because vessels typically fish over broad spatial areas and the spatial location of the catch cannot usually be determined upon landing.

In undertaking this programme both Sanford NZ Ltd and Aotearoa Fisheries Ltd have demonstrated that they are capable of collecting potentially useful data that would be difficult and costly to collect without their direct involvement, and this should be both commended and encouraged. In order to maximise both the utility of the data and chances of success we believe future industry catch sampling programmes will need to place greater emphasis on data validation, quality assurance and independent review. In line with this we make the following recommendations:

1. At-sea sampling programmes should have clearly defined goals and objectives.
2. Programme designs should be subject to stringent peer review prior to implementation.
3. Sampling staff should receive scientifically accredited training and be required to achieve a minimum level of competency.
4. All sampling methodologies, training programmes, and sample collection systems (hard copy/electronic) should be fully documented.
5. Frequent sampling audits should be carried out by MPI observers or an accredited research provider.

5. ACKNOWLEDGEMENTS

We thank David Middleton and Adam Langley for providing the data and preliminary analytical results and for the material given in Appendix 2 and Appendix 3; Sanford NZ Ltd and Aotearoa Fisheries Ltd for collecting the data and agreeing to make it available; Dane Buckthought, Michael Stevenson and Caoimhghin Ó Maolagáin for otolith preparation and reading; and Mike Beentjes for reviewing the final report.

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7. APPENDICES

Appendix 1: Ministry for Primary Industries Catch Effort data generic errors and ambiguities.

The Ministry for Primary Industries catch effort data as a generality can be categorised into:

1. Landed catch information;
2. At-sea or effort information.

For analytical purposes there is usually a requirement to link the two data sources together, but because these data are often collected on more than one type of form the information is often “decoupled” and difficult to link; as a result a large number of errors and ambiguities inherent in the Ministry catch-effort data are a result of “orphaned” landing and effort data.

The quality of fisheries data varies greatly between fisheries and those undertaking analysis need to be aware of the specific data quality issues for each respective fishery. It is often the case that data errors cannot be corrected or inferred and the analyst must make a judgement call (often subjective) on what to exclude from the analysis. Analyses using fisheries catch effort information should ideally include a summary of the data errors and a description on how they were dealt with.

The following are some of the more common causes of erroneous catch and effort data:

Double recording of landed catch weights

Double recording of landed catch can come about as a result of fish being transferred to a location whereby it becomes part of the “Catch” of another trip. Double recording of landed weights is usually not as a result of erroneous recording, but typically comes about as a legitimate artefact of the catch reporting process. A typical instance where catch totals are reported twice is when a catch from one vessel is transferred to another, say at sea. The transference at sea by the first vessel constitutes as legitimate landing event for which the first vessel must complete a landing form. When the second vessel lands, say to shore, it is required to report both its own catch and the catch from the other vessel. Unfortunately there is no requirement for the second vessel to report the two catch totals separately.

Fishers are required to record the destination of all landed catch using a range of single letter codes thus it is possible to rationalise some of this double counting at least in the landed catch information. There are four codes indicating that a catch has been transferred to a non-terminating destination, i.e. the catch will have to be recorded again in a subsequent landing event. These codes are:
P - transferred to a holding receptacle in water (e.g. a lobster holding pot);
Q - transferred to a holding receptacle on land (e.g. a wharf chiller);
R - retained on board;
T - transferred to another vessel.

When summarising landed catch information it is reasonable to ignore any catch associated with these four landing codes as it will appear again as part of another landing (i.e. trip). The problem comes if there is a need to link effort to landed catch. In the above example the effort recorded by the second vessel for the “trip” will not represent all the catch it records as landed on that trip.

There are legitimate instances where fishers land catch in relation to a trip for which there has been no fishing effort; an example of this being where a vessel has received catch from another vessel at sea but has not undertaken any fishing of its own.

The difficultly for the Ministry, and for those analysing Ministry data, is determining whether the absence of corresponding landing (trip) and effort data is legitimate, or that the fisher has failed to provide the effort data. This is an example where an understanding of the fishery is required to determine if the ratio of missing effort to landed data is reasonable.

Missing or misaligned effort information resulting from trip date misspecification

Because the effort and landed catch data from a specific fishing trip are often recorded on separate forms, there is often no formal link between these two sets of information at the time of landing. The formal link, in the form of a trip key, is assigned by the Ministry data collating process at a later time on the basis on the fisher's reported trip start and end dates and the landing date. Effort and landed catch data can therefore become decoupled if a fisher makes an error in recording the trip dates.

Discrepancies between estimated and landed catch weights

For most trips a fisher is required to report catch information twice: first as an estimated catch on the effort reporting forms; second as a landed green weight. The estimated weights are the fisher's best guess at the weight; there is no legally binding requirement that these values are accurate. In contrast there are strong legal requirements for the declared landed weights to be accurate. Consequently, estimated catch totals often disagree with the landed catch weights. However, the catch estimates are usually believed to be reasonable in a relative sense, e.g. twice as much of species A was caught in the first tow than the second. The usual practice in most analytical situations is to prorate the effort estimated catches by the actual landed greenweight totals (assuming there are no reporting errors when linking the effort with the landed catch and that the landed catch is reasonable). However, under scenarios where the landed catch is non-terminating the effort and landed catch information will be matched to the effort such that incorrect scaling will result.

"Top five/eight" missing catch effort issue

Prior to 2006 most Ministry effort reporting forms only required estimated weights for the top five species caught in a tow or set. This meant, although all species caught should appear in the landed catch reporting forms, the catch of some species may go unrecorded in effort forms if they were not in the top five species. Reporting forms introduced after 2006 allow reporting of up to eight species making it more likely that effort will be recorded for most species of significance. Inaccurate prorating of the landed catch weights will occur if the "top five/eight" issue is common for the species of interest. In the worst cases the estimated catches will be a very small proportion of the landed catch weight total, making it invalid to simply prorate on the basis of estimated catch alone. In these instances the solution is to use some form of lumping or assigning criteria other than estimated catch (e.g. total amount of fishing effort or total catch of all species in a tow or set). The use of lumping criteria (sometimes referred to as "rolling up") can have a major influence on the interpretation of the results and if inappropriate may significantly bias the resultant analysis. It is very important that criteria for rolling up effort data is clearly described and justified.

Misreporting and general data quality issues

Inaccurate or incomplete reporting is a generic issue. Missing data or data outside a normal range are often easy to identify and allow for. Typically missing data are either imputed from the other data provided or the record is simply deleted. The problem comes when the data are plausible but inaccurate. In most instances these types of errors remain unidentified in the dataset.

Appendix 2: SeaFIC Report: Consideration of alternative designs for sampling the catch from the TAR 1 trawl fishery.

November 2010

Author: Adam Langley

Background

Sanford Ltd and Aotearoa Fisheries Limited (AFL) have proposed to conduct sampling of the TAR 1 catch. It is proposed to select the samples from the tarakihi catch taken from individual trawls during the fishing operations of the main vessels operating in the fishery. Individual samples would be linked to the respective trawl, thereby recording the location, time, date and total catch of the sampled trawl. The samples would be processed following the unloading of the vessel; the length and sex of the individual fish would be determined and otoliths collected from sub-sample of the fish measured.

The sampling approach would enable the determination of the length and age composition of the tarakihi catch at a range of spatial scales. A Ministry for Primary Industries research project has the stated objective of determining the age composition of the tarakihi catch from each of the main fishing areas within TAR 1 (Bay of Plenty, east Northland, and west coast North Island). Traditional **landing based** catch sampling programmes often struggle to achieve the collection of spatially distinct samples from the fishery due to the operation of the fleet. Fishing vessels frequently operate over relative large areas and the resultant landing may have been taken from several distinct regions. In contrast, the proposed at-sea sampling programme would facilitate the collection of samples at the required spatial resolution while also yielding data at a much finer spatial scale which would enable a detailed analysis of the length and age composition of the overall catch.

This paper analyses recent trawl catch and effort data from the TAR 1 fishery to assess the feasibility of the two alternative sampling strategies, specifically:

1. To investigate the feasibility of applying a landing based catch sampling programme to determine the length and age composition of the tarakihi catch from each of the three main fishery areas; and
2. To determine an appropriate sampling approach for the proposed at sea sampling programme.

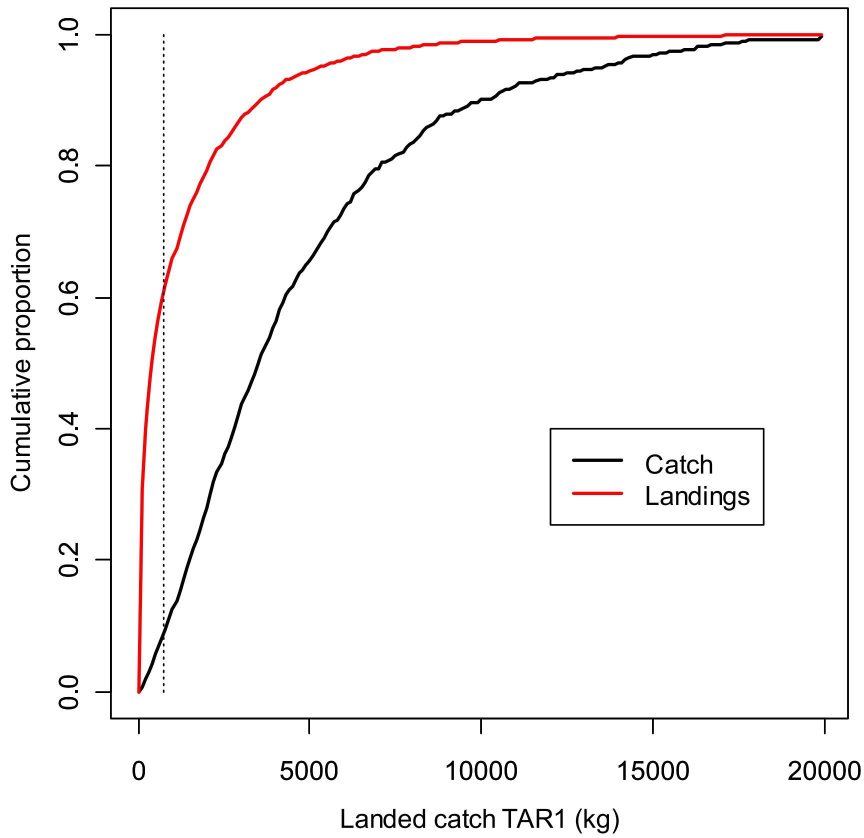
Sanford Ltd and AFL have nominated four vessels for participation in the at-sea programme: *VslA*, *VslB*, *VslC* and *VslD*. These vessels account for a significant component of the total TAR 1 catch. The sampling approach should ensure that the collection of the individual trawl samples is representative of the tarakihi catch of the four vessels in the three main fishing areas. Further, the sampled catch should be representative of the catch from the entire fishery in each area. This is beyond the direct control of the proposed at-sea sampling programme; however, given that the four sampled vessels account for a substantial proportion of the total catch it is envisaged that the catch sampled from these vessels will be representative of the entire fleet.

1.0 Landings based sampling

Detailed catch and effort data were available for the TAR 1 fishery from five recent fishing years (2004/05 to 2008/09). The data set included the fishing activity from all bottom trawl fishing trips that either recorded a trawl catch of tarakihi within TAR 1 or landed TAR 1. These data were applied to characterise the landed catch from the fishery and, thereby, determine the feasibility of collecting spatially discrete samples (landings) from the fishery.

There are a large number of bottom trawl fishing trips that catch tarakihi as a minor bycatch of other fishing activities; for example, 61% of bottom trawl fishing trips that caught TAR 1 landed a total

TAR 1 catch of less than 750 kg and these fishing trips accounted for only 9% of the total TAR 1 trawl catch (
Appendix Figure **2.1**). This catch threshold was adopted as a minimum catch for landings to qualify for selection by the sampling programme inclusion in the sampling programme on the somewhat arbitrary basis that over 90% of the total catch would be available for sampling. These landings were deemed to be qualifying landings and included 39% of the initial bottom trawl fishing trips that caught TAR 1 in the five year period.



Appendix Figure 2.1: Cumulative TAR 1 catch and number of fishing trips by the total landed TAR 1 catch from the trip. The vertical dashed line represents the minimum catch threshold of 750 kg.

The resultant data set of qualifying landings represents a total sample of about 300–450 trips per annum and a total annual TAR 1 catch of 800–1,000 t (Appendix Table 2.1). Approximately 80–100 of these trips were conducted by the four nominated vessels, accounting for 37% and 49% of the total TAR 1 trawl catch in 2007/08 and 2008/09 respectively.

Appendix Table 2.1: The number of qualifying landings and associated landed catch of TAR 1 by fishing year.

	Fishing year				
	2004/05	2005/06	2006/07	2007/08	2008/09
Trips	450	444	312	297	313
Catch	1,081	1,053	822	806	977

The selection of fishing trips was further refined based on the distribution of the tarakihi catch within TAR 1. Fishing trips were deemed to be available for sampling if at least 90% of the total tarakihi catch (from TAR 1 or other TAR fishstocks) was taken within one of the three sub-areas of TAR 1 (Bay of Plenty, east Northland, and WCNI). Approximately 60% of the total qualifying fishing trips met the criterion (Appendix Table 2.2), representing a similar proportion of the catch from TAR 1 (Appendix Table 2.3). In most years, approximately 60–70% of the total TAR 1 catch from each sub-area was included within the fishing trips that could be assigned to the specific sub-area (Appendix Table 2.4).

Appendix Table 2.2: Proportion of the bottom trawl fishing trips (with a TAR 1 catch of at least 750 kg) that can be assigned to a sub-area of TAR 1.

Sub area	Fishing year				
	2004/05	2005/06	2006/07	2007/08	2008/09
WCNI	0.228	0.140	0.144	0.237	0.209
ENLD	0.088	0.149	0.129	0.107	0.083
BPLE	0.436	0.299	0.323	0.318	0.284
MIX	0.248	0.412	0.404	0.338	0.423

Appendix Table 2.3: Proportion of the catch from qualifying landings that can be assigned to a sub-area of TAR 1.

Sub area	Fishing year				
	2004/05	2005/06	2006/07	2007/08	2008/09
WCNI	0.185	0.148	0.215	0.276	0.263
ENLD	0.149	0.160	0.128	0.105	0.080
BPLE	0.365	0.276	0.291	0.346	0.279
MIX	0.301	0.416	0.365	0.273	0.378

Appendix Table 2.4: Proportion of the total TAR 1 catch from each sub-area (from qualifying landings) from landings that can be assigned to a sub-area of TAR 1.

Sub area	Fishing year				
	2004/05	2005/06	2006/07	2007/08	2008/09
WCNI	0.716	0.574	0.708	0.798	0.825
ENLD	0.658	0.579	0.614	0.613	0.512
BPLE	0.709	0.592	0.598	0.716	0.532

On that basis, it should be feasible to select a sufficient number of landings to obtain the requisite number of samples (15 samples per sub-area) from the fishery (in 2008/09 a total of 66, 25, and 87 landings were available from WCNI, EN, and BPLE respectively). However, there may be logistical difficulties in gaining access to the entire set of landings and gaining sufficient information to ensure that an individual landing met the prerequisite criteria prior to sampling.

Further, there is concern that the exclusion of fishing trips with catches from more than one area may introduce a bias in the sampling design. For example, the landed catch from the four nominated vessels in the fishery accounted for a considerable proportion of the total TAR 1 catch in recent years. However, the operational range of these vessels is typically larger than the other vessels in the fleet and a higher proportion of the fishing trips catch tarakihi in more than one sub-area or across QMA boundaries (especially Bay of Plenty and QMA 2, Bay of Plenty and East Northland, and East Northland and WCNI). Hence, a significant proportion of the catch from these vessels is likely to be excluded from a landing based sampling programme (Appendix Table 2.5).

Appendix Table 2.5: Proportion of the total TAR 1 catch from each sub-area (from qualifying landings) from landings that can be assigned to a sub-area of TAR 1 for the four nominated vessels.

Sub area	**Fishing year**				
	2004/05	2005/06	2006/07	2007/08	2008/09
WCNI	0.054	0.039	0.214	0.246	0.528
ENLD	0.155	0.092	0.087	0.041	0.263
BPLE	0.122	0.126	0.216	0.407	0.216

However, a comparison of the spatial, seasonal and depth distribution of the total TAR 1 catch from each sub-area with the catch from the individual trips that caught tarakihi exclusively within a sub-area did not indicate any marked difference in the distribution of the catch. On that basis, it is considered feasible to adequately sample the regional components of the TAR 1 fishery via a landings based sampling programme. However, this conclusion is only valid if the entire fleet is available for sampling; for example, the available landings from the four nominated vessels alone would not be sufficient to ensure representative sampling of the total fishery (at the sub regional level).

2.0 At-sea sampling

The feasibility of undertaking an at-sea based sampling programme was investigated using the detailed catch and effort data from the tarakihi trawl fishery. The initial data set was refined to include only fishing trips by four candidate vessels that landed at least 50 kg of TAR 1 (*qualifying fishing trips*). The total tarakihi catch included within the data set is presented in Appendix Table 2.6.

Appendix Table 2.6 : Total tarakihi catch from qualifying fishing trips by vessel and fishing year.

Vessel	2004/05	2005/06	2006/07	2007/08	2008/09
VslC	109.955	168.336	188.392	164.785	218.059
VslD	49.193	85.564	37.825	3.693	19.377
VslA	19.385	47.925	43.1	43.33	158.985
VslB	44.31	51.505	82.35	124.707	153.815

An analysis of the fishing activity of the qualifying fishing trips for the four candidate vessels revealed a high proportion of the individual trawls conducted during a fishing year caught no tarakihi (actually, recorded no estimated catch of tarakihi) (Appendix Table 2.7). Similarly, a high proportion of the individual fishing days also included no trawls with a catch of tarakihi exceeding 50 kg (Appendix Table 2.8). The level of fishing effort directed at tarakihi varied considerably among the four vessels (Appendix Table 2.7).

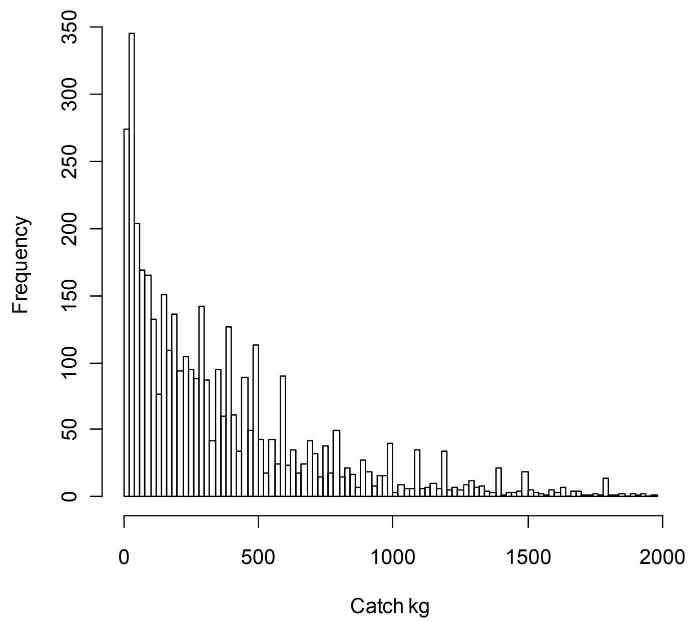
Appendix Table 2.7: Proportion of zero TAR trawl catches by vessel and year (for qualifying trips).

Vessel	2004/05	2005/06	2006/07	2007/08	2008/09
VslC	0.59	0.60	0.68	0.65	0.74
VslD	0.59	0.52	0.73	0.83	0.98
VslA	0.26	0.31	0.21	0.23	0.33
VslB	0.82	0.91	0.40	0.47	0.55

Appendix Table 2.8: Proportion of total days fished with no individual TAR trawl catch greater than 50 kg (for qualifying trips).

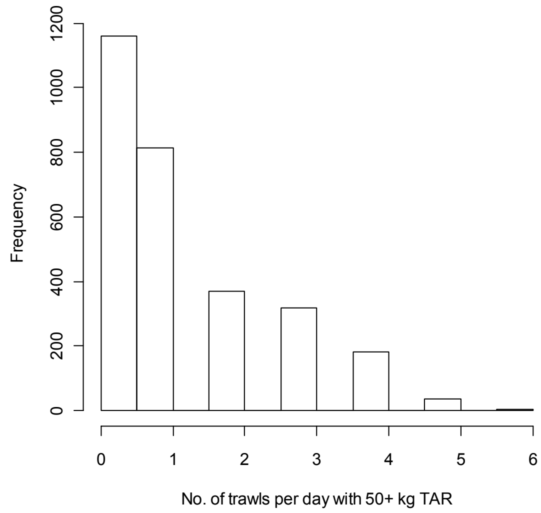
Vessel	Proportion of days
VslC	0.725
VslD	0.516
VslA	0.413
VslB	0.700

For the four candidate vessels, 16% of the non-zero tarakihi trawl catches were comprised of small catches of tarakihi (1-50 kg) (Appendix Figure 2.2). Overall, 76% of the tarakihi catch was taken from trawls that caught 200-1200 kg of tarakihi. A small number of larger catches were also taken.



Appendix Figure 2.2: Distribution of non-zero TAR catches for the four vessels.

A high proportion of the individual fishing days for the four vessels included no trawls with more than 50 kg of tarakihi. Many fishing days included a single trawl catch of tarakihi exceeding 50 kg with a similar number of days yielding multiple trawl catches (2-5 trawls) (Appendix Figure 2.3). This suggests a range of modes of fishing conducted during individual fishing trips: non tarakihi target fishing days, days when limited targeting of tarakihi occurs and days when tarakihi (or associated species) are the principal target species.



Appendix Figure 2.3: Distribution of days (unique vessel, date) by the number of trawls that had at least 50 kg TAR.

The proportion of days assigned to each of the three modes of fishing (1, non-target; 2, single target trawl; 3, multiple target trawls) varied considerably among the four vessels (Appendix Table 2.9). There is also likely to be considerable variability in the distribution of fishing effort among modes of fishing for individual fishing trips.

Appendix Table 2.9: Number of fishing days assigned to three modes of fishing by vessel for all qualifying trips (all years combined).

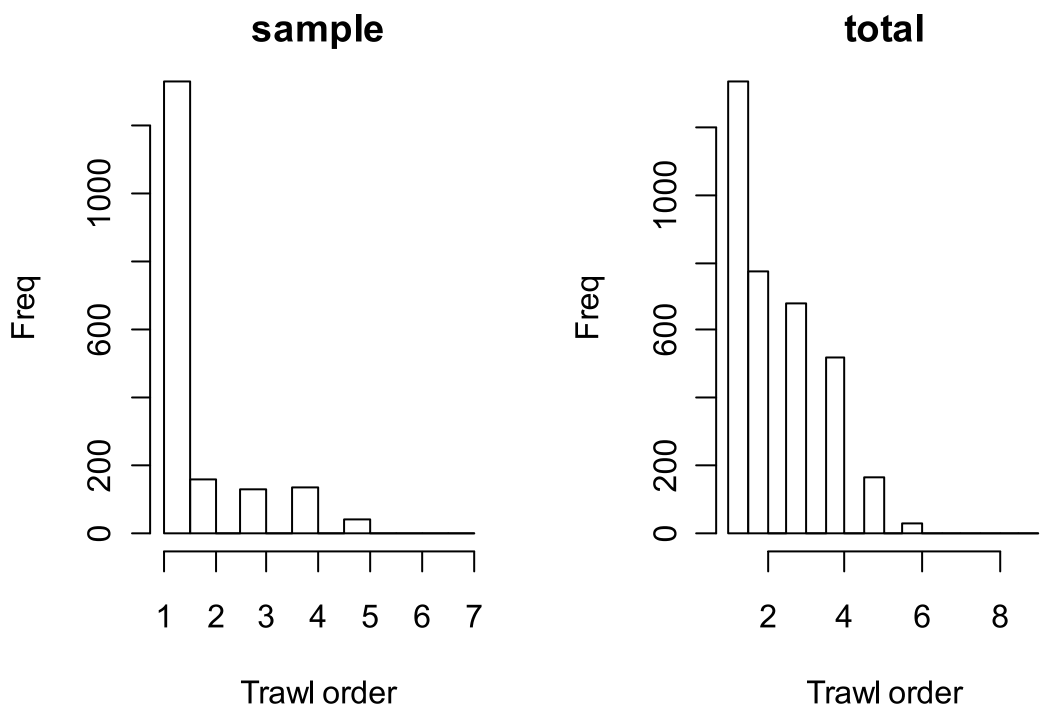
Vessel	Non-target	Single TAR	Multi TAR
VslC	259	172	510
VslD	207	193	28
VslA	492	191	155
VslB	203	257	217

A range of different strategies were investigated for selecting individual trawls to be sampled. One option would be to select the first trawl from each day that caught more than a minimum (50 kg) catch of tarakihi. A minimum of 50 kg was selected as it was deemed to represent a reasonable minimum sample size (approximately 50 fish). For some vessels, the retrospective application of these criteria would have resulted in the sampling of a large proportion of the total annual catch (Appendix Table 2.10). This is because some vessels will only conduct a single trawl directed at tarakihi during a day (e.g. *VslD* and *VslB*). Conversely, vessels that frequently conduct multiple target tarakihi trawls would have a lower level of sampling coverage (*VslC*).

Appendix Table 2.10: Proportion of the total annual tarakihi catch sampled based on the selection of the first trawl each day with a catch more than 50 kg.

Vessel	2004/05	2005/06	2006/07	2007/08	2008/09
VslC	0.429	0.393	0.373	0.374	0.346
VslD	0.979	0.971	0.971	0.597	0.460
VslA	0.668	0.540	0.697	0.683	0.576
VslB	0.904	1.000	0.586	0.629	0.576

Such a sampling protocol would typically result in the first trawl of the day being sampled (Appendix Figure 2.4). This is because either a vessel is targeting tarakihi throughout the day and there is a significant catch of tarakihi in the first trawl or vessels may have a single trawl directed at tarakihi early in the morning and then switch to target other species in subsequent trawls. Hence, the resulting distribution of sampled trawls is likely to be biased towards the first trawl of the day and subsequent trawls that catch tarakihi are poorly represented under the "first trawl" sampling approach (**Appendix Figure 2.4).**



Appendix Figure 2.4: A comparison of the distribution of trawls (order of trawl in the day, e.g. 3 represents the third trawl of the day) selected by a sampling protocol that selects the first trawl of the day with more than 50 kg of tarakihi (left) and the distribution of all trawls that catch at least 50 kg of tarakihi (right).

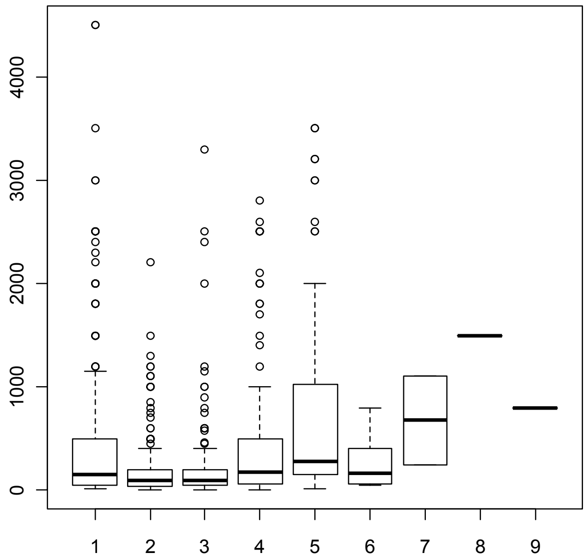
An alternative sampling approach is to randomly select an individual trawl each day. Typically, 2-5 trawls are conducted on each fishing day. Sampling was simulated by randomly selecting one trawl from the first, second, third or fourth trawl of the day. If the selected trawl caught less than 50 kg of tarakihi then no sample was collected on that day.

The random sampling approach ensures that the samples are collected in a manner that is representative of the daily distribution of tarakihi trawl catches. However, the approach substantially reduces the sampling coverage of the fishery (Appendix Table 2.11) as there are many days when a sample is not taken and the sampling effort on the first trawl of the day (often with higher catches) is reduced. An alternative approach would be to select the next available trawl if the randomly selected trawl had insufficient catch. However, this approach results in the distribution of sampling being biased towards the trawls later in the day.

Appendix Table 2.11: Proportion of the total annual tarakihi catch sampled based on the random selection of the 1-4 trawl of each day.

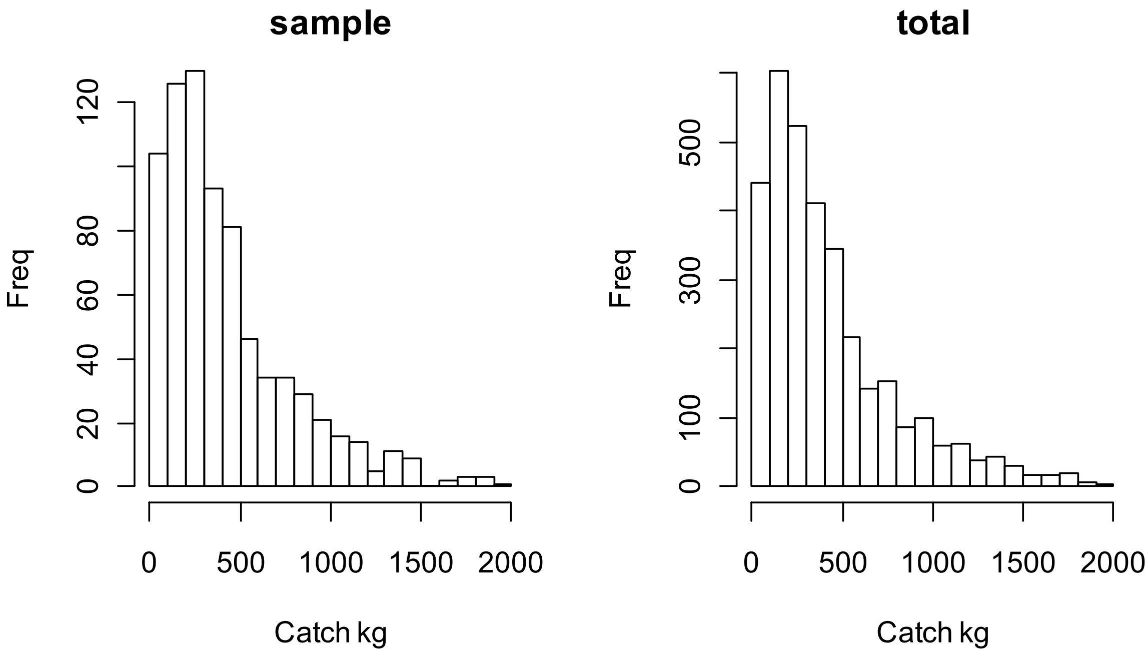
Vessel	2004/05	2005/06	2006/07	2007/08	2008/09
VslC	0.273	0.255	0.241	0.228	0.238
VslD	0.194	0.235	0.245	0.039	0.183
VslA	0.168	0.186	0.228	0.212	0.255
VslB	0.101	0.154	0.249	0.226	0.258

An examination of the trawl catches for individual vessels revealed different fishing strategies among the four candidate vessels. For *VslA*, the first and last trawls in a day tended to have considerably larger catches of tarakihi (Appendix Figure 2.5). This pattern was also evident in the daily distribution of trawls by the *VslB*. No daily trend in tarakihi catch was apparent for *VslC*, while *VslD* tended to have higher catches of tarakihi from the first trawl of the day.



Appendix Figure 2.5: Distribution of VslA non zero catches (kg) of tarakihi from successive trawls during a day.

Nonetheless, this variability in fishing operation of the individual vessels tended to be obscured when data from the four vessels were combined. As a result, the random sampling design tended to yield a relatively unbiased sample of the trawl catches with respect to catch size (Appendix Figure 2.6).



Appendix Figure 2.6: The distribution of the individual tarakihi catches random sampled (left) and the total trawl catches available for sampling from the four vessels (right).

Nevertheless, in terms of optimising sampling effort to achieve maximum coverage of the total catch, it is clearly more efficient to concentrate sampling effort on those trawls with the higher catch. Limiting sampling to trawls that exceed a minimum catch of 200 kg is likely to result in about 90% of the total catch from these four vessels being sampled (Appendix Table 2.12), although this would also require a considerable increase in the number of sampling events compared to the other sampling strategies (Appendix Table 2.13). For example, the random sampling protocol would have collected 217 samples in 2008/09 representing 100 t of catch, while sampling all trawls in excess of 200 kg would require the sampling of 750 trawls (Appendix Table 2.13) but would achieve coverage of 451 t of catch. The latter level of sampling would be necessary to achieve a moderate level of coverage (30-40%) of the total (entire fleet) for each of the three sub-areas of TAR 1 (Appendix Table 2.20).

(Arguably, this level of sampling is high although it is distributed over a large number of trips and I would prefer setting high targets recognising that the level of sampling will not be achieved each trip).

To investigate the representativeness of the proposed sampling programme, the distribution of the total TAR 1 bottom trawl catch from 2007/08 and 2008/09 was compared with the distribution of catch that would have been retrospectively sampled under the sampling regime that selects all trawl catches in excess of 200 kg from the candidate vessels. The spatial (statistical area), monthly and depth distribution of the two components of the catch were comparable in both years (Appendix Figure 2.7–2.9), although the sampling programme under-represented the proportion of the catch taken in the Bay of Plenty (statistical areas 009 and 010) in 2008/09 (Appendix Figure 2.7). On that basis, it is likely that catches sampled at-sea from the four candidate vessels would be representative of the entire fishery. The collection of fine scale catch, effort and size frequency data would also enable a more thorough analysis of the variation in the commercial catch and may enable improved precision in the estimates of the age composition across years.

Appendix Table 2.12: Proportion of the total TAR 1 catch sampled from the four candidate vessels if all trawls of catch greater than 50 kg are selected.

Vessel	2004/05	2005/06	2006/07	2007/08	2008/09
VslC	0.993	0.996	0.989	0.993	0.992
VslD	0.982	0.997	0.999	0.953	0.993
VslA	0.949	0.986	0.983	0.980	0.994
VslB	1.000	1.000	0.991	0.985	0.989

Appendix Table 2.13: Proportion of the total TAR 1 catch sampled from the four candidate vessels if all trawls of catch greater than 100 kg are selected.

Vessel	2004/05	2005/06	2006/07	2007/08	2008/09
VslC	0.978	0.988	0.979	0.981	0.975
VslD	0.961	0.992	0.990	0.827	0.986
VslA	0.807	0.931	0.935	0.947	0.981
VslB	0.998	1.000	0.982	0.971	0.973

Appendix Table 2.14: Proportion of the total TAR 1 catch sampled from the four candidate vessels if all trawls of catch greater than 200 kg are selected.

Vessel	2004/05	2005/06	2006/07	2007/08	2008/09
VslC	0.939	0.965	0.946	0.931	0.914
VslD	0.907	0.968	0.974	0.433	0.954
VslA	0.576	0.852	0.878	0.865	0.954
VslB	0.989	0.987	0.932	0.926	0.921

Appendix Table 2.15: Proportion of the total TAR 1 catch sampled from the four candidate vessels if all trawls of catch greater than 400 kg are selected.

Vessel	2004/05	2005/06	2006/07	2007/08	2008/09
VslC	0.772	0.811	0.767	0.689	0.674
VslD	0.788	0.937	0.916	0.311	0.888
VslA	0.314	0.669	0.838	0.754	0.902
VslB	0.947	0.950	0.806	0.781	0.794

Appendix Table 2.16: The number of trawls with catch of tarakihi exceeding 200 kg by the candidate vessels by fishing year.

Vessel	2004/05	2005/06	2006/07	2007/08	2008/09
VslC	154	245	305	315	372
VslD	48	70	33	4	25
VslA	28	72	36	52	122
VslB	30	49	123	202	231

Appendix Table 2.17: The number of days with at least one catch of tarakihi exceeding 200 kg by the candidate vessels by fishing year.

Vessel	2004/05	2005/06	2006/07	2007/08	2008/09
VslC	72	106	129	130	156
VslD	48	68	31	2	12
VslA	25	41	28	40	80
VslB	29	49	74	122	127

Appendix Table 2.18: The number of trips with at least one catch of tarakihi exceeding 200 kg by the candidate vessels by fishing year.

Vessel	2004/05	2005/06	2006/07	2007/08	2008/09
VslC	29	35	39	38	43
VslD	22	29	9	2	3
VslA	16	15	13	21	29
VslB	10	12	27	35	35

Appendix Table 2.19: The average number of trawls per trip with a catch of tarakihi exceeding 200 kg by the candidate vessels by fishing year.

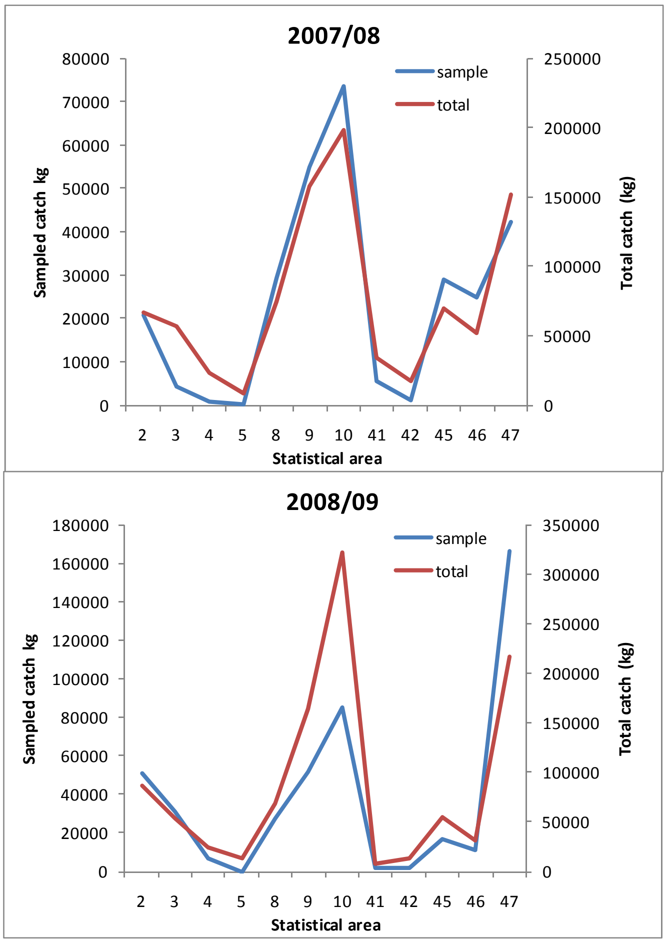
Vessel	2004/05	2005/06	2006/07	2007/08	2008/09
VslC	5.3	7.0	7.8	8.3	8.7
VslD	2.2	2.4	3.7	2.0	8.3
VslA	1.8	4.8	2.8	2.5	4.2
VslB	3.0	4.1	4.6	5.8	6.6

Appendix Table 2.20: The total tarakihi catch from trawls with a catch of tarakihi exceeding 200 kg by the candidate vessels by fishing year for the three sub-areas of TAR 1.

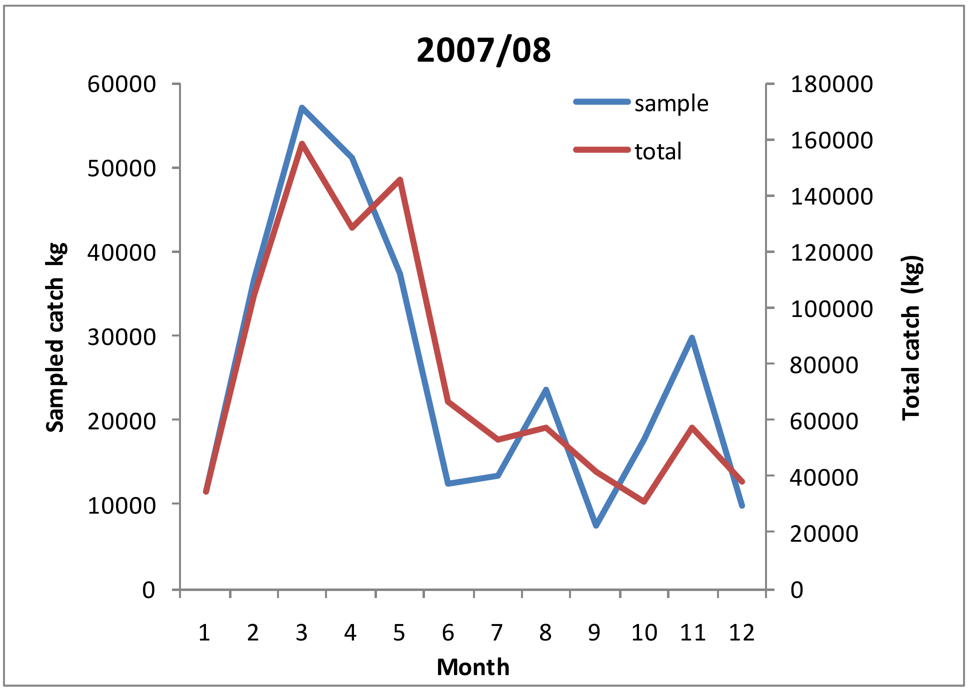
	2004/05	2005/06	2006/07	2007/08	2008/09
BPLE	124.8	149.8	152.3	157.8	164.9
ENLD	39.3	42.0	30.2	25.8	88.8
WC	11.6	16.9	76.4	103.1	197.4

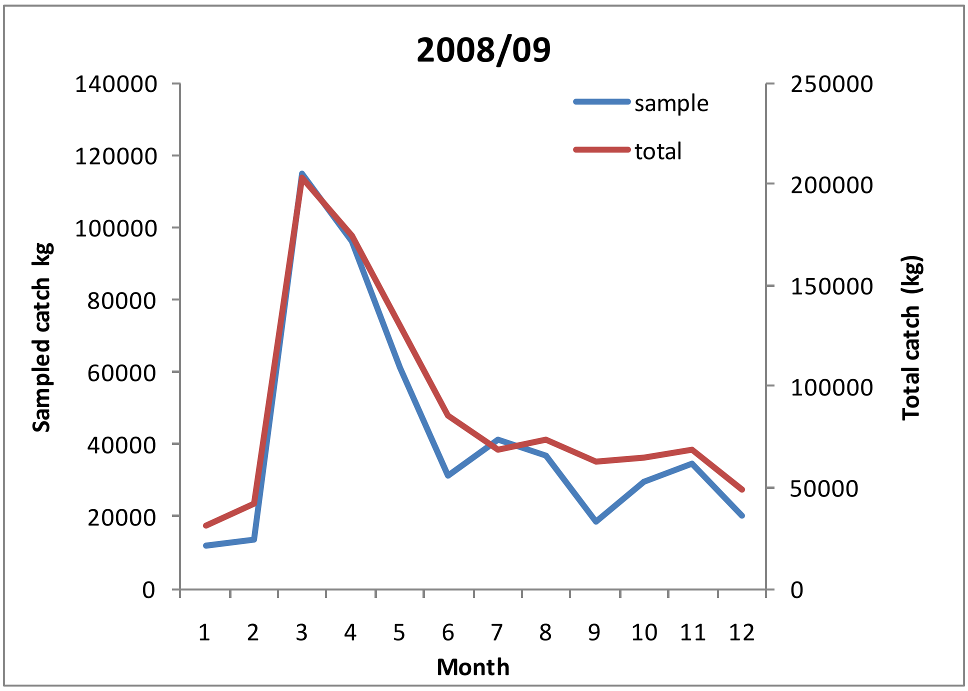
Appendix Table 2.21: The proportion of the total from each sub-area of TAR 1 that would be covered by the sampling of all trawls by the candidate vessels with a tarakihi catch exceeding 200 kg.

	2004/05	2005/06	2006/07	2007/08	2008/09
BPLE	0.203	0.276	0.346	0.367	0.298
ENLD	0.141	0.132	0.161	0.167	0.502
WC	0.038	0.056	0.293	0.317	0.612

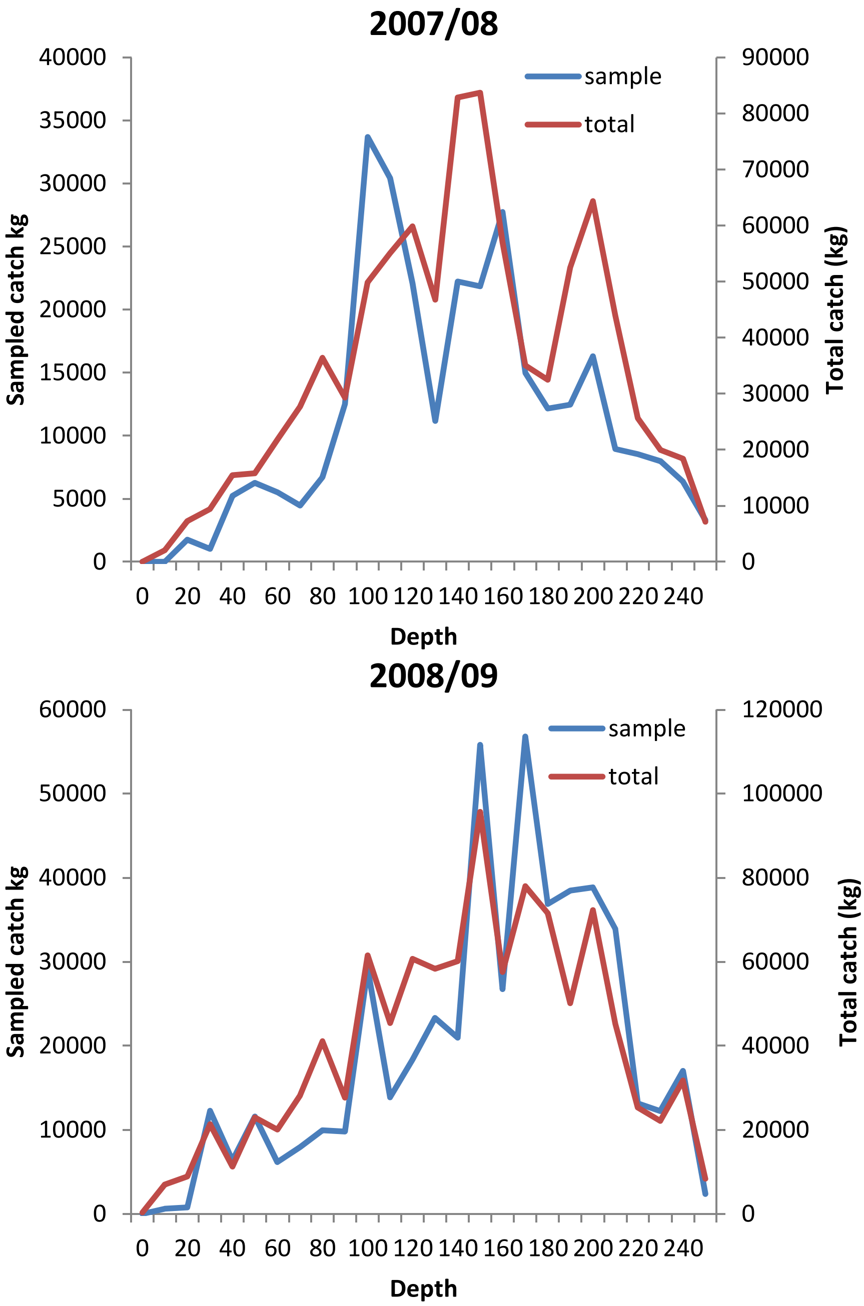


Appendix Figure 2.7: Comparison of the tarakihi catch distribution by statistical area for the total catch and the hypothetical sampled component of the catch from the proposed at-sea sampling programme (samples collected from the catches exceeding 200 kg by candidate vessels) for 2007/08 and 2008/09.





Appendix Figure 2.8: **Comparison of the tarakihi catch distribution by month (1 = January) for the total catch and the hypothetical sampled component of the catch from the proposed at-sea sampling programme (samples collected from the catches exceeding 200 kg by candidate vessels) for 2007/08 and 2008/09.**



Appendix Figure 2.9: **Comparison of the tarakihi catch distribution by depth (m) for the total catch and the hypothetical sampled component of the catch from the proposed at-sea sampling programme (samples collected from the catches exceeding 200 kg by candidate vessels) for 2007/08 and 2008/09.**

Appendix 3: SeaFIC at-sea sampling instructions as supplied to Sanford and AFL Ltd sampling staff.

Background

1. Biological data will be collected from TAR 1 and TAR 2 trawl fisheries during September 2010 to September 2011.
2. Sampling will take place on **nominated vessels** at the level of **individual tows**.
3. The sampled catch will be processed ashore after landing.

Sample selection

1. One trawl will be sampled on each day of fishing by every participating vessel.
2. The first trawl hauled after midday should be sampled.
3. One bin of TAR should be sampled at random from the catch of the sampled trawl.
4. Fish must be sampled from the catch at random (i.e. not graded).
5. Sample sizes are specified in terms of a number of bins. Because a variety of bin sizes are in use, select the appropriate number of bins to sample from the table below.
6. To avoid any unintentional size selection, there is no need to count the number of fish sampled. Simply fill the required number of bins with fish of the required species.

Sampling at sea: instructions for vessel crew	
Daily	✓ Sample the first trawl hauled after midday on each day of fishing ✓ Sample tarakihi (TAR) from this trawl according to the instructions below ✓ If tarakihi is not present in this trawl then sample tarakihi the next time it is caught

Sampling	✓ Collect the required sample size (see table below). ✓ Fill the required number of bins with fish selected from the catch at random. Do not sort the fish by size before sampling, other than to remove fish below the MLS. ✓ If the catch is relatively clean, scoop fish into the sampling bin. If the catch is mixed, fill the sample bins as the catch is sorted by species. Fill the sample bins with the required species first, then store the remainder of the catch as normal ✓ Securely attach a uniquely numbered tag to each bin of sampled fish. If the tags are not pre-labelled with a unique code, write the vessel name, date and time on the label. The time given must be the time at which the sampled tow began. ✓ Record samples taken on the Inshore Vessel Biological Sampling cover sheet to ensure that each bin can be matched to the correct catch effort data
When landing the catch	✓ Ensure tagged sampling bins are clearly identified at landing and separated from the main catch

Sample size

Company	Bin type	Nominal fish weight (kg)	Bin volume (l)	External dimensions (mm)	Number of bins to sample per species
Sanford	660 PUR "dolav"		631	1225 x 1025 x 748	1*
Sanford	FC16 Hoki Crate	25 kg	45	800 x 445 x 223	1
Sanford	#7 Staka Nesta		32	645 x 415 x 215	1
Moana	Orange #12	35 kg		710 x 440 x 315	1
Moana	Drummond #16	25 kg		795 x 425 x 225	1

*Use of large bins will require sub-sampling ashore. Use of smaller bins for sampling is therefore preferred, if these are available.

Sample processing

1. Fish to be processed are selected at sea and sampled into tagged bins (separate bins for each species and trawl sampled). Sub-sampling ashore is only required if the tagged bins are large "dolavs". In this case scoop a sub-sample of fish into a regular fish bin, and transfer the bin tag to the sub-sample.

2. A new sampling form must be used for each bin of fish processed. Record bin origin and sampler identification in the header of the form.

3. **Fork length** and **sex** are to be determined for **every fish** in the selected bins. **Otoliths** must be extracted from **every third fish.**

4. To avoid bias, the next fish to be measured should always be the fish closest to the bottom right hand corner of the bin.

5. Each fish must be **sexed** and measured to the **nearest centimetre below fork length** and the individual data record written on the sampling form.

6. The tail (caudal) fin **must be spread** on each occasion to properly obtain an accurate measurement of the fish's fork length, the measurement at the minimum point of the tail fin after it has been spread out. It is also important that each fish is laid concave side down, and as straight as possible on the measuring board, to maintain consistency and accuracy in measuring.

7. If the sex of any measured fish cannot be established, it should be recorded as 'unknown'.

Sample processing: instructions for sampling staff	
For each sampled bin	✓ Record data for each bin of fish processed on a new form ✓ Complete the header section of the sampling form ensuring that the bin's identification tag number is accurately recorded ✓ Record measurements from every fish contained in the bin. If there are more than 60 fish in the bin then use an additional sampling form ✓ Bins should only contain fish of one species. Discard any fish of a different species that have accidentally been put in the sampled bin
For each fish measured	✓ Select the next fish to be measured from the bottom right corner of the fish bin ✓ Record fish fork length, and sex
After each sampling event	✓ Collate the sampling forms from all bins sampled from the landing, add the vessel's sampling cover sheet, and attach copies of the TCER and CLR forms from the landing.

Appendix 4: Annual TAR 1 catch by sub-stock (BPLE= Bay of Plenty; ENHG = East Northland/Hauraki Gulf; WCNI = West Coast, North Island).

Fyear	BPLE	ENHG	WCNI	TACC
2001–02	795	306	370	1399
2002–03	849	225	406	1399
2003–04	920	239	350	1399
2004–05	739	379	398	1399
2005–06	653	405	322	1399
2006–07	520	286	373	1399
2007–08	531	250	477	1447
2008–09	679	260	450	1447
2009–10	771	243	298	1447
2010–11	682	234	390	1447

Appendix 5: TAR 1 annual commercial catch (t) by method and area (BLL = bottom longline; BPT = bottom pair trawl; BT = bottom trawl; DS = Danish seine).

			BPLE					ENHG					WCNI		
Fyear	BLL	BPT	BT	DS	other	BLL	BPT	BT	DS	other	BLL	BPT	BT	DS	other
2001–02	10	1	747	36	1	74	0	227	3	1	5	1	354	9	1
2002–03	8	2	796	39	3	65	24	132	2	1	10	14	375	5	2
2003–04	9	4	840	67	0	51	10	172	5	2	5	26	302	12	5
2004–05	6	3	690	39	1	32	7	331	8	2	5	30	357	5	1
2005–06	6	0	617	28	2	40	9	349	6	1	10	15	281	11	5
2006–07	6	0	498	16	1	38	12	226	5	4	13	42	307	4	7
2007–08	8	0	498	23	0	36	18	185	8	2	26	112	322	15	3
2008–09	6	0	634	39	0	39	11	199	10	2	24	70	336	16	4
2009–10	10	0	706	54	1	39	19	166	17	1	11	63	206	11	5
2010–11	11	1	616	53	1	49	6	170	8	1	28	38	304	6	14

Appendix 6: Annual TAR 1 bottom trawl catch (t) by statistical reporting area.

		BPLE				ENHG							WCNI	
Fyear	008	009	010	002	003	004	005	006	007	041	042	045	046	047
2001–02	74	347	326	92	112	7	15	1	0	16	25	27	152	133
2002–03	52	266	477	54	55	1	20	1	0	14	13	50	106	192
2003–04	43	296	500	80	60	13	18	0	1	13	20	38	63	168
2004–05	65	241	384	111	173	34	12	1	1	8	34	71	66	178
2005–06	129	194	294	79	164	99	7	1	1	4	10	20	52	195
2006–07	100	131	267	71	80	65	8	1	1	6	6	34	39	222
2007–08	81	193	224	75	66	28	11	1	0	6	19	80	58	158
2008–09	74	188	372	94	60	26	18	0	0	8	17	55	34	222
2009–10	93	225	387	65	66	16	18	2	0	15	17	31	24	120
2010–11	75	209	331	87	42	30	10	0	0	4	10	66	35	189

Appendix 7: Annual TAR 1 bottom trawl catch (t) by target species.

	BPLE				ENHG				WCNI			
Fyear	TAR	SNA	TRE	other	TAR	SNA	TRE	other	TAR	SNA	TRE	other
2001–02	541	54	64	88	113	17	8	90	266	15	14	58
2002–03	572	46	53	125	70	18	9	35	297	26	11	41
2003–04	622	72	25	120	99	37	10	26	247	26	17	12
2004–05	558	63	27	43	254	30	15	33	272	42	19	24
2005–06	532	37	15	33	297	27	8	18	235	7	12	28
2006–07	429	37	7	25	184	22	9	12	270	3	19	15
2007–08	435	32	16	15	154	11	6	14	260	16	26	19
2008–09	553	50	15	16	156	21	8	14	290	10	22	14
2009–10	624	36	28	17	126	17	4	19	166	14	21	5
2010–11	556	20	26	14	137	21	3	9	260	11	16	17

Appendix 8: Number of samples collected in 2010–11 TAR 1 sampling programme by participating vessels and number of samples that could not be used because they did not subsequently link to viable tow data.

	Link		
Vessel	Yes	No	Total samples
A	33	1	34
B	97	4	101
C	0	3	3
D	0	1	1
E	0	1	1
F	6	0	6
G	0	2	2
H	31	3	34
I	0	1	1
J	0	2	2

Appendix 9: Scaled proportional tarakihi age frequencies and coefficients of variation (CV) of the 2010–11 BPLE commercial bottom trawl catch.

	Proportion			Coefficient of variation (CV)		
Age class	Males	Females	Total	Males	Females	Total
1	0.001	0.001	0.002	1.28	1.49	0.95
2	0.028	0.009	0.037	0.44	0.79	0.41
3	0.058	0.066	0.124	0.32	0.25	0.22
4	0.154	0.120	0.274	0.20	0.22	0.13
5	0.130	0.078	0.208	0.20	0.23	0.14
6	0.068	0.056	0.124	0.25	0.27	0.18
7	0.039	0.051	0.091	0.35	0.31	0.23
8	0.019	0.021	0.040	0.47	0.45	0.32
9	0.008	0.011	0.018	0.75	0.64	0.48
10	0.002	0.011	0.013	1.31	0.66	0.60
11	0.002	0.002	0.004	0.97	1.38	0.88
12	0.004	0.014	0.018	0.96	0.63	0.53
13	0.002	0.004	0.005	1.34	0.93	0.76
14	0.008	0.001	0.008	0.74	1.48	0.69
15	0.007	0.000	0.007	0.85	0.00	0.85
16	0.000	0.002	0.002	0.00	1.33	1.33
17	0.000	0.000	0.000	0.00	0.00	0.00
18	0.003	0.004	0.008	0.89	0.95	0.67
19	0.003	0.000	0.003	0.99	0.00	0.99
20+	0.010	0.005	0.015	0.58	0.67	0.46
MWCV	0.31	0.33	0.23			
No. sampled	256	231	487			
No. Fishery	1 100 143	923 452	2 023 596			

Appendix 10: Scaled proportional tarakihi age frequencies and coefficients of variation (CV) of the 2010–11 Statistical Area 004 commercial bottom trawl catch.

	Proportion			Coefficient of variation (CV)		
Age class	Males	Females	Total	Males	Females	Total
1	0.000	0.000	0.000	0.00	0.00	0.00
2	0.000	0.000	0.000	0.00	0.00	0.00
3	0.004	0.000	0.004	1.50	0.00	1.50
4	0.000	0.093	0.093	0.00	0.48	0.48
5	0.166	0.146	0.313	0.41	0.34	0.30
6	0.068	0.076	0.145	0.60	0.50	0.37
7	0.077	0.101	0.178	0.75	0.58	0.39
8	0.056	0.030	0.086	0.57	0.81	0.47
9	0.021	0.004	0.025	0.98	1.61	0.87
10	0.023	0.009	0.032	1.13	1.38	0.85
11	0.000	0.000	0.000	0.00	0.00	0.00
12	0.004	0.003	0.006	1.57	1.51	1.13
13	0.000	0.028	0.028	0.00	0.90	0.90
14	0.000	0.019	0.019	0.00	1.19	1.19
15	0.037	0.003	0.040	0.95	1.50	0.86
16	0.000	0.008	0.008	0.00	1.09	1.09
17	0.000	0.000	0.000	0.00	0.00	0.00
18	0.000	0.003	0.003	0.00	1.56	1.56
19	0.000	0.000	0.000	0.00	0.00	0.00
20+	0.010	0.011	0.022	0.91	1.05	0.85
MWCV	0.65	0.59	0.48			
No. sampled	41	52	93			
No. Fishery	43 078	49 265	92 343			

Appendix 11: Scaled proportional tarakihi age frequencies and coefficients of variation (CV) of the 2010–11 Statistical Area 008 commercial bottom trawl catch.

	Proportion			Coefficient of variation (CV)		
Age class	Males	Females	Total	Males	Females	Total
1	0.000	0.000	0.000	0.00	0.00	0.00
2	0.000	0.000	0.000	0.00	0.00	0.00
3	0.013	0.013	0.025	1.30	1.32	1.11
4	0.073	0.068	0.141	0.93	0.66	0.61
5	0.160	0.191	0.351	0.42	0.42	0.31
6	0.044	0.066	0.110	0.72	0.56	0.43
7	0.012	0.047	0.059	0.98	0.74	0.64
8	0.044	0.030	0.073	0.67	0.78	0.51
9	0.000	0.007	0.007	0.00	1.26	1.26
10	0.000	0.029	0.029	0.00	0.90	0.90
11	0.005	0.008	0.013	1.32	1.27	0.93
12	0.003	0.024	0.027	1.32	0.91	0.83
13	0.000	0.025	0.025	0.00	0.83	0.83
14	0.005	0.000	0.005	1.27	0.00	1.27
15	0.029	0.004	0.032	0.82	1.30	0.74
16	0.022	0.000	0.022	0.96	0.00	0.96
17	0.000	0.000	0.000	0.00	0.00	0.00
18	0.000	0.000	0.000	0.00	0.00	0.00
19	0.015	0.016	0.031	0.87	1.01	0.67
20+	0.042	0.008	0.050	0.60	0.82	0.54
MWCV	0.69	0.66	0.53			
No. sampled	47	46	93			
No. Fishery	99 927	114 512	214 439			

Appendix 12: Scaled proportional tarakihi age frequencies and coefficients of variation (CV) of the 2010–11 Statistical Area 009 commercial bottom trawl catch.

	Proportion			Coefficient of variation (CV)		
Age class	Males	Females	Total	Males	Females	Total
1	0.000	0.000	0.000	0.00	0.00	0.00
2	0.000	0.000	0.000	0.00	0.00	0.00
3	0.052	0.019	0.071	0.50	0.96	0.48
4	0.105	0.085	0.190	0.39	0.43	0.28
5	0.244	0.074	0.318	0.22	0.43	0.18
6	0.117	0.051	0.168	0.34	0.46	0.29
7	0.091	0.038	0.128	0.35	0.69	0.27
8	0.015	0.043	0.059	0.85	0.51	0.45
9	0.004	0.008	0.012	1.42	1.08	0.89
10	0.013	0.002	0.014	0.97	1.45	0.87
11	0.000	0.008	0.008	0.00	1.36	1.36
12	0.000	0.011	0.011	0.00	1.29	1.29
13	0.004	0.000	0.004	1.39	0.00	1.39
14	0.000	0.000	0.000	0.00	0.00	0.00
15	0.000	0.000	0.000	0.00	0.00	0.00
16	0.000	0.000	0.000	0.00	0.00	0.00
17	0.000	0.004	0.004	0.00	1.32	1.32
18	0.000	0.000	0.000	0.00	0.00	0.00
19	0.000	0.000	0.000	0.00	0.00	0.00
20+	0.002	0.009	0.012	1.36	0.98	0.85
MWCV	0.36	0.59	0.32			
No. sampled	100	57	157			
No. Fishery	390 512	212 788	603 299			

Appendix 13: Scaled proportional tarakihi age frequencies and coefficients of variation (CV) of the 2010–11 Statistical Area 010 commercial bottom trawl catch.

	Proportion			Coefficient of variation (CV)		
Age class	Males	Females	Total	Males	Females	Total
1	0.000	0.000	0.000	0.00	0.00	0.00
2	0.000	0.000	0.000	0.00	0.00	0.00
3	0.027	0.043	0.070	0.66	0.46	0.35
4	0.103	0.122	0.224	0.29	0.24	0.18
5	0.171	0.104	0.274	0.25	0.30	0.17
6	0.070	0.087	0.157	0.38	0.27	0.23
7	0.055	0.077	0.132	0.41	0.28	0.24
8	0.035	0.018	0.053	0.57	0.66	0.42
9	0.018	0.027	0.045	0.69	0.58	0.42
10	0.000	0.009	0.009	0.00	0.98	0.98
11	0.000	0.004	0.004	0.00	1.32	1.32
12	0.009	0.005	0.014	0.92	1.37	0.76
13	0.000	0.005	0.005	0.00	1.08	1.08
14	0.000	0.004	0.004	0.00	1.28	1.28
15	0.004	0.000	0.004	1.30	0.00	1.30
16	0.000	0.000	0.000	0.00	0.00	0.00
17	0.000	0.000	0.000	0.00	0.00	0.00
18	0.000	0.000	0.000	0.00	0.00	0.00
19	0.000	0.002	0.002	0.00	1.29	1.29
20+	0.004	0.000	0.004	1.34	0.00	1.34
MWCV	0.38	0.37	0.27			
No. sampled	108	127	235			
No. Fishery	467 305	477 962	945 265			

Appendix 14: Comparing Length Frequency distributions by bootstrapping the Kolmogorov-Smirnov d-statistic.

Descriptions of the Kolmogorov-Smirnov test for comparing two frequency distributions can be found in most good statistical texts, e.g., Sokal & Rohlf (2012). In order to derive the KS test statistic (d-statistic) the two frequency distributions have to be first expressed as cumulative proportional curves (curves ranging from 0–1). The maximum proportional difference between the two curves is the KS d-statistic. The d-statistic random variable is described by the KS probability density function and this function underlies the classical KS parametric test. This test is typically too sensitive for fisheries data which generally have very large sample sizes and hence the test is prone to Type II error (falsely rejecting the null hypothesis). To overcome these problems a bootstrap procedure was used to derive expected distributions of the d-statistic against which the observed d-statistic could be compared. The bootstrap process was repeated 1000 times to generate an expected distribution for the d-statistic. The original d-statistic was then compared to generated distribution. The proportion of bootstrap d-statistic values less than the observed value is the probability of the null hypothesis (Type I rejection probability). The test is by nature only one-tailed in that very small d-statistic values, although unlikely, represent almost perfect correspondence between the two compared distributions. We are therefore interested only in the rejection tail corresponding to large d-statistic values (i.e., the right hand tail).

Sokal, R.R.; Rohlf, F.J. (2012). Biometry: the principles and practice of statistics in biological research. 4th edition. W. H. Freeman and Co.: New York. 937 p.