The length and age composition of the commercial and research giant stargazer (*Kathetostoma giganteum*) catch off the west coast of the South Island (STA 7) during the 2006–07 fishing year

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EXECUTIVE SUMMARY

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This report presents the results of a second year of a catch sampling programme of the giant stargazer in the mixed-species, bottom trawl fishery off the west coast of the South Island (WCSI) during January–June 2007, and of an analysis of giant stargazer data collected during a research trawl survey of the WCSI during March–April 2007. The results of this report are now somewhat outdated. This is due to the unfortunate passing of the principle investigator, Michael Manning. However, the report is still being published as a historical record of the work that was carried out.

The catch sampling programme collected data from the WCSI fishery at about the same time as the WCSI survey so that comparable age-frequency distributions could be computed and used as inputs for a quantitative stock assessment of stargazer in STA 7. The unit stock defined in both the catch sampling programme and in the stock assessment is "STA 7(W)", i.e., that portion of the STA 7 stock area excluding eastern Cook Strait. Catch sampling effort was allocated proportionally to the two major ports on the WCSI and by month, corresponding to historic trends in catch in the fishery.

A sample target of 24 landings between January and June was set for the fishery. Twenty-two landings were sampled. Some eastern Cook Strait data were collected. This data set was retained in the analyses but treated separately from STA 7(W). The samples for STA 7(W) are assumed to be representative of the fleet as a whole. A target of 30% was set for mean-weighted coefficient of variation (c.v.) on the proportion-at-age estimates. A similar design is recommended for future STA 7 catch sampling programmes.

Unsexed, processed trunk measurements collected from the fishery were converted to scaled, sex-specific age-frequency distributions using an age-length-sex key compiled from otoliths and associated data collected during the trawl survey. Scaled length-frequency data collected during the survey were also converted to scaled age-frequency distributions using an age-length key. The mean-weighted c.v. for the age-frequency distribution derived from the WCSI catch sampling programme was 25.8%. A mean-weighted c.v. of 28.9% was obtained for the age-frequency distribution of all fish pooled across all strata in the survey catch.

The composition of the 2007 survey catch was similar to that of the previous survey in 2005. Fish were 13–80 cm long and 1–20 years old. For both sexes combined over the time series, the median length of fish has dropped from 53 to 48 cm, and median age from 8 to 7 years. Fish in the commercial catch were 26–91 cm long and 1–20 years old. There were some marked differences in the 2007 commercial catch compared to 2005 with a dramatic drop in the proportion of the catch weight made up by males and a corresponding drop in the male to female sex ratio. Older females appear to contribute more to the commercial catch in 2007 than in 2005. No such corresponding change was observed in the survey catch, suggesting that there may have been a change in the behaviour of fishing activity in the commercial fishery.

1. INTRODUCTION

Giant stargazer (*Kathetostoma giganteum*) is a moderate-sized, benthic teleost distributed widely in New Zealand waters. It is found on muddy and sandy substrates in waters to 500 m deep, but is most common between 50 and 300 m on the continental shelf around the South Island (Anderson et al. 1998), where it supports moderate-value commercial-trawl fisheries.

Since the introduction of the Quota Management System (QMS) on 1 October 1986, it has been managed as eight separate Quota Management Areas (QMAs) or fishstocks in the New Zealand Exclusive Economic Zone (NZ EEZ), QMA boundaries are shown in Figure 1. A Total Allowable Commercial Catch (TACC) is set within each QMA. Since 1986, total reported commercial landings have fluctuated between 2000 and 4150 t per fishing year, averaging about 3000 t (Table 1). Landings in fishstock STA 7 off the west coast of the South Island (WCSI) have accounted for between 20 and 35% (approximately 1000 t) of the total catch across all QMAs within a given fishing year (Figure 2, Table 1).

The TACC in STA 7 was increased from 528 to 700 t under the conditions of the New Zealand commercial fisheries Adaptive Management Programme (AMP) at the start of the 1991–92 fishing year. The AMP was a management regime within the QMS for data-poor fishstocks that were considered likely to be able to sustain an increased commercial harvest. Under the AMP, quota owners agreed to collect or arrange to have collected additional data from the fishery (typically fine-scale catch-effort data and basic biological data such as fish length and sex) in return for an increased TACC. The catch in STA 7 exceeded the TACC (702 t) in all but one fishing year since the introduction of the AMP averaging over 900 t per year (Sullivan et al. 2005). The TACC was further increased to 997 t from 2002–03 where it remains.

The relative biomass of STA 7 (Figure 2) is monitored through a biennial research bottom-trawl survey of the WCSI by RV *Kaharoa* during March–April, and by analysis of the sex, size and age structure of the survey catch. The survey series began in 1992 and is ongoing. At the completion of catch sampling programme, eight surveys had been carried out with the most recent survey being undertaken in 2007.

The relative biomass index from the 2003 survey was 827 t with a coefficient of variation (c.v.) of 15% (Stevenson 2004), a 41% decrease from the 1992–1997 survey average of 1413 t. Under the conditions of the AMP, the fishery was referred to the 2003 Fisheries Assessment Plenary for evaluation. The Plenary recommended that no management intervention was required at that time, except to provide for more information on stock status through: (a) the development of a complete stock assessment model incorporating a review of existing and new trawl survey data; and (b) obtaining another relative biomass estimate by bringing the next trawl survey forward one year from 2008 to 2007 and undertaking the survey every two years thereafter (prior to this surveys were undertaken triennially). This resulted in a commercial catch sampling programme that was run in STA 7 during February–July 2005, and an analysis of giant stargazer age and growth data collected aboard RV *Kaharoa* during the 2005 WCSI survey. The catch sampling programme and age and growth analyses were to support a quantitative stock assessment under the New Zealand Ministry of Fisheries project STA2004-01. This resulted in a report on the composition of the commercial and research catch of stargazer on the west coast South Island (Manning & Sutton 2007a) and a quantitative assessment for stargazer in STA 7 (Manning 2008).

The relative biomass estimate from the 2005 survey was more optimistic at 1429 t (c.v. 19%) than the previous two surveys and closer to the early part of the series (Stevenson 2006).

Based on the results of project STA2004-01 and the 2005 WCSI trawl survey the (then) Inshore Fisheries Assessment Working Group concluded that "The stock appears to be at or above the level required to obtain its maximum sustainable yield. It is very unlikely to be below [the maximum sustainable yield]", and the "Development of a final [stock assessment] model should be deferred until after the 2007 WCSI survey data become available". This brought about the Ministry of Fisheries Project STA2007-02 "Stock assessment of stargazer in STA 7". This report, funded by the Ministry of Fisheries under research project STA2007-02, fulfils Reporting Requirement 1 of Specific objectives 1 and 2 of that project:

Specific objective 1: Sample the commercial bottom trawl catch of stargazer in STA 7 during the 2004-05 and 2006-07 fishing years.

Specific objective 2: Prepare and read stargazer otoliths collected during a research trawl survey of the west coast of the South Island during March-April 2007.

In this report, we present the results of a second year of commercial catch sampling from STA 7 during January–June 2007, and the results of an analysis of giant stargazer age and growth from data collected aboard RV *Kaharoa* during the 2007 WCSI survey. As in project STA2004-01, both the catch sampling and trawl survey data are to support a quantitative stock assessment model for STA 7. A target mean-weighted coefficient of variation of 30% across all age classes was set for the catch-at-age to be estimated for the fishery during the 2007 sampling period. No formal variance target was set for the proportions-at-age estimated from the survey catch. Earlier analyses of giant stargazer age and growth that utilised data collected during the WCSI survey series were presented by Manning & Sutton (2004) (five surveys; 1992–2000), Manning & Sutton (2007a) (one survey; 2005), and Manning & Sutton (2007b) (one survey; 2003).

2. METHODS

2.1 Commercial catch sampling programme

2.1.1 Aim

Inshore bottom trawl vessels targeting a variety of different species on the WCSI account for the majority of the total reported landed catch of stargazer in STA 7. They have accounted for 80–90% of the total catch over the 1989–90 to 2003–04 fishing years, depending on how the fishery is classified (see Section 3.1).

The aim of the commercial catch sampling project was the same as that in 2005 for project STA2007-02: to systematically sample landings from this fishery at about the same time as the WCSI trawl survey in March–April 2007 so that comparable fishery-dependent and fishery-independent proportions-at-age distributions could be computed and used as model inputs in the quantitative stock assessment.

2.1.2 Design

Fishstock STA 7 extends north from Jackson Bay on the west coast of the South Island, around the South Island's northern tip including both Tasman and Golden Bays, to just north of Kaikoura on the east coast. The area east of D'Urville Island is part of eastern Cook Strait, and giant stargazer there may belong to a separate biological stock with different biological characteristics. Manning & Sutton (2004) found statistically significant differences in mean length-at-age of fish collected from the west, south, and east coasts of the South Island. They suggested these differences were biologically significant and might indicate separate biological stock units. Assuming that the multiple biological stock hypothesis is true, we also restricted our catch sampling programme to bottom-trawl catches from the west coast of the South Island (WCSI; New Zealand fisheries statistical areas 033–036, 701–706), Tasman and Golden Bays (TBGB; statistical area 038), and western Cook Strait (CKST.W; statistical areas 037, 039–040). Catches from eastern Cook Strait (CKST.E; statistical areas 017–018) were to be ignored. In this report the sampled region is referred to as “STA 7(W)”. This definition of the stock area is the same as that used in STA2004-01 and in the preliminary assessment model (Manning 2008).

As in 2005, sampling in 2007 was carried out from January to June. This was to allow data to be collected from the fishery two months before, two months during, and two months after the trawl survey. An age-length key approach (Fridriksson 1934, Ketchen 1950) was used to estimate the fishery catch-at-age distributions by Manning & Sutton (2007a). In this approach, scaled length distributions computed from the length and catch observations collected from the fishery are converted to scaled age distributions by multiplying the proportions-at-length distributions by a matrix of proportions of age-at-length (the key) derived from otoliths and covariate data (in this case, collected during the 2005 trawl survey). The same approach is applied to data collected in 2007 for this study.

Intermediate age-length keys can be more cost-effective than other approaches to estimating fish proportions-at-age distributions if the sampling period is short and well defined and there is no need to stratify the key to account for confounding spatial or temporal factors such as fish growth or the progression of fish from one age class to the next during the sampling period. Failure to meet the sampling assumptions in the age-length key approach can lead to bias in the proportions-at-age estimated, although this and other limitations of the approach are well understood (see Kimura 1977, Westrheim & Ricker 1978, Kimura & Chikuni 1987, Lai 1987, among others). The generalised spawning date assumed for giant stargazer in STA 7 is 1 July. Continuing sampling beyond this date would require the key to be stratified to account for this, requiring in turn a second complete set of length-at-age observations to be collected with the accompanying expense.

Prior to STA2004-01 being carried out, no suitable data were available on the length or age composition of the fishery with which alternative sampling designs could be quantitatively evaluated (e.g., investigating the optimal number of landings to sample and fish to sample per landing to meet or beat the specified variance target using simulation methods). For this study the allocation of sampling effort and stratification is identical to that used in STA2004-01, which was based on historical trends in the catch. Evaluation of that sampling found that it was adequate to meet the aims of that project. See Table 2 for allocation and stratification of sampling effort, and Manning & Sutton (2007a) for further details.

2.1.3 Overcoming the issue of processing at sea

Giant stargazer catches are typically processed at sea. This usually involves ‘dressing’ each fish by removing the head, gut, and pectoral fins. About 97% of the total landed catch over the 1989–90 to 2003–04 fishing years was processed this way. This presents an obvious problem to shore-based catch-sampling programmes as access to the unprocessed catch is usually impossible. The accepted length measurement method for giant stargazer for scientific purposes in New Zealand waters is total length. Clearly, total length and fish sex observations cannot be obtained from processed trunks, nor can otoliths be collected for age estimation.

This problem was overcome using the same approach as in STA2004-01: by collecting unsexed processed trunk measurements from the landings sampled, computing unsexed scaled length-frequency distributions (i.e., a single scaled dorsal length distribution for all fish of both sexed combined) from these data, and then converting this distribution to scaled, sex-specific age distributions using an age-length-sex key derived from the 2007 WCSI trawl survey length-at-age observations. Another dimension (sex) was added to the age-length key, using matrix algebra to yield the desired array of proportions at age by sex. To facilitate that analysis, a regression was developed relating dorsal to total length and vice versa from the data collected during the 2005 WCSI trawl survey which will again be used in this project.

All sampling was carried out by NIWA staff and the procedures used were the same as those used in STA2004-01. Sampling staff were instructed to liaise with Licensed Fish Receivers in their locality and to arrange to collect samples on a "first come, first served" basis within each port and month cell in the sampling effort allocation schedule. Staff were asked to spread their effort throughout the fleet where possible and not to concentrate on a particular vessel or small set of vessels. Once a landing was identified, staff were instructed to collect a simple random sample (an unsorted sample) of processed trunks from the catch with the size of the sample collected depending on the weight of the landing: for landings under 5 t, 100 fish were collected; for landings over 5 t, 200 fish or more were collected. Landings of less than 100 kg were not sampled.

Dorsal lengths were collected from each processed trunk in the sample and recorded. Dorsal length was defined to be the length from the anterior margin of the dorsal fin to the posterior margin of the caudal fin (Figure 3). In 2005, lengths recorded were to the nearest whole centimetre below actual dorsal length. This produced problematic integer effects when dorsal lengths were converted into total lengths. To overcome this, fish in 2007 were measured to the nearest whole *millimetre* below actual dorsal length. The calculation of the age-frequency distributions from these and other data is described in the next subsection.

2.2 Trawl survey data analysis

The eighth in an ongoing series of WCSI research trawl was carried out aboard RV *Kaharoa* in 2007 (voyage KAH0704). The survey series is optimised to monitor giant stargazer, red cod, red gurnard, and tarakihi abundance in the survey area (Figure 4). The survey methods and results, including scaled length-frequency distributions and relative biomass estimates for each target and other associated species, were presented by Stevenson (2007). In this subsection, we describe the methods used to compute scaled age-frequency distributions from the data collected during the survey.

2.2.1 Treatment of Tasman and Golden Bay data

Two earlier studies on the age and growth of giant stargazer in STA 7 (Manning & Sutton 2004, 2007b) did not consider the age and growth of fish caught in Tasman and Golden Bays separately from fish caught on the rest of the survey ground. Although all previous published analyses of the survey results have treated the relative biomass estimates and scaled length-frequency distributions of fish caught in Tasman and Golden Bays separately from fish caught elsewhere on the survey ground, too few otolith pairs have been collected from Tasman and Golden Bays (Manning & Sutton 2007a) to allow differences in growth between these areas to be tested. Until we are able to test whether growth differs we will assume that it does not, although the alternative hypothesis that it does differ seems unlikely given the spatial and oceanographic connectivity between the two regions.

Given that we currently assume that growth does not differ between the two regions, we calculate the age distributions by applying a single age-length key derived from length-at-age observations collected from throughout the survey ground to the scaled length-frequency distributions calculated for each area; that is, a single key applied to separate, area-specific length distributions. The methods used to calculate the age-frequency distributions are discussed in more detail below.

2.2.2 Otolith collection, preparation, and reading

The terminology we use follows the glossary for otolith studies produced by Kalish et al. (1995).

A stratified, fixed-allocation sampling scheme (sensu Davies et al. 2003) was used to collect giant stargazer sagittal otolith pairs from the catch during KAH0704. Fish total length (to the nearest millimetre below actual length), sex, and macroscopic gonad maturity were recorded for all fish from which otoliths were collected. Otoliths were cleaned and stored dry in paper envelopes. All 386 giant stargazer otoliths collected during KAH0704 were retrieved from the otolith collection for ageing and all associated data were extracted from research database *age* (Mackay & George 2000). All trawl survey catch, station, and stratum definitions for KAH0704 were extracted from research database *trawl* (Mackay 2000).

Otolith preparation and reading methods followed those of Manning & Sutton (2004, 2007b) and Sutton (1999, 2004). The right otolith from each pair collected during KAH0704 was selected for preparation. The left otolith was used when the right otolith could not (e.g., due to damage, decalcification etc). The selected otoliths were first baked in a ConTherm Series 5 scientific oven at 285 °C for 4 minutes. The baked otoliths were then embedded in layers in Araldite K142 clear epoxy resin. Once the resin blocks had cured, the embedded otoliths were sectioned transversely along the nuclear plane using a Struers Accutom-2 precision wafering saw turning a single Extec 12205 diamond-edged blade (blade thickness 0.3 mm). The cut surfaces of each resin block were then polished using Struers P1200 carborundum paper.

The sectioned otoliths were then read under reflected light using a Wild M400 binocular microscope at ×25 magnification. A thin layer of paraffin oil was applied to the cut surfaces of each section to improve clarity. All otoliths exhibited alternating light and dark regions under reflected light. Following Manning & Sutton (2004, 2007b) and Sutton (1999, 2004), we assumed that these light and dark regions were opaque and translucent zones (respectively) and that a single light (opaque) and a single dark (translucent) zone corresponded to a single year's growth (annulus). Ageing of stargazer by zone counts has not been validated but for the purposes of this study we presume that zone counts do correspond to a year of growth.

The number of fully formed translucent zones present, a five-point "readability" score, and a three-point "margin-state" score were recorded for each otolith read (see Table 3 for descriptions of states and scores). All otoliths were read "blind" once by one reader (M.J. Manning), that is, without knowing the corresponding length and sex of each fish. Unlike Manning & Sutton (2004, 2007b) and Sutton (1999, 2004), the "six-month" zone was counted explicitly. This is the translucent zone that is presumed to form during each fish's first winter and is apparent in the otolith when the fish is usually not more than about 6 months of age. This simplifies the calculation used to convert translucent zone counts to decimalised age estimates, permitting young-of-the-year fish to be easily and correctly identified by the otolith reader (see below).

In STA2004-01, otolith reading precision was quantified by carrying out within- and between-reader comparison tests after Campana et al. (1995). Precision was found to be very high for both within and between reader tests and was not carried out in this project.

2.2.3 Converting translucent zone counts to age estimates

The same algorithm used in STA2004-01 to convert translucent-zone counts to age estimates was used for this project. The algorithm involves treating estimated fish age, $\hat{a}$, as the sum of three time components. The estimated age of the *i*th fish, $\hat{a}_i$, is

$$\hat{a}_i = t_{i,1} + t_{i,2} + t_{i,3}$$

where $t_{i,1}$ is the elapsed time from spawning to the end of the first translucent zone present in the otolith. This is the so-called six-month zone described above. The variable $t_{i,2}$ is the elapsed time from the end of the six-month zone to the end of the outermost fully formed translucent zone for the *i*th fish. Lastly, $t_{i,3}$ is the elapsed time from the end of the outermost fully formed translucent zone to the date when the *i*th fish was captured. Hence,

$$\begin{aligned} t_{i,1} &= t_{i,\text{ end first translucent zone (the "six-month" zone)}} - t_{i,\text{ spawning date}} \\ t_{i,2} &= (n_i + w) - 1 \\ t_{i,3} &= t_{i,\text{ capture}} - t_{i,\text{ end last translucent zone}} \end{aligned} .$$

where n_i is the total number of translucent zones present (including the "six-month" zone) for fish *i*, and *w* is an edge interpretation correction after Francis et al. (1992) applied to n_i: $w = 1$ if the recorded margin state = "wide" *and* fish *i* was collected *after* the date when translucent zones are assumed to be fully formed, $w = -1$ if the recorded margin state = "narrow" *and* fish *i* was collected *before* the date when translucent zones are assumed to be fully formed, otherwise $w = 0$. Because the survey was run over March–April, *w* always takes the value 0 or 1 in our study.

Because of our inability to precisely estimate spawning and translucent zone completion dates for individual giant stargazer, these dates were generalised for all fish. We followed previous studies and assumed an arbitrary spawning date of 1 July based on the annual reproductive cycle and winter spawning season of giant stargazer. A date of 1 November for completion of all translucent zones was assumed, also following previous studies. We used the matching trawl station start date as the capture date for each fish. Decimalised years were used for all time components. And so the estimated age for a fish captured on 1 April 2007 where a count of three completed translucent zones (including the six-month zone) was observed in the prepared otolith, is $\hat{a} = t_1 + t_2 + t_3 = 0.33 + 3 + 0.42 = 3.75$ years. Note that in the case of stargazer the six-month zone is not strictly six months or 0.5 years. With a *generalized* spawning date of July 1 and with translucent zone formation thought to be complete by November 1, t_1 takes a value of four months, or 0.33 years.

2.2.4 Calculating scaled length- and age-frequency distributions

Catchatage is a package of *R* functions (R Development Core Team 2005) developed and maintained by NIWA (Bull & Dunn 2002). It computes biomass estimates and scaled length-frequency distributions by sex and by stratum for trawl-survey and catch-sampling data using the calculations of Bull & Gilbert (2001) and Francis (1989). If passed a set of length-at-age data, it constructs an age-length key which is then applied to the scaled length-frequency distributions to compute scaled age-frequency distributions also by sex and stratum. It computes the coefficient of variation (c.v.) for each length and age-class and the overall mean-weighted c.v. for each length and age-frequency distribution using a bootstrapping routine (Efron & Tibshirani 1993): fish length records are resampled within each station, stations are resampled within each stratum, and the length-at-age data are simply resampled, all with replacement. The bootstrap length- and age-frequency distributions are computed from each resample and the c.v.s for each length- and age-class and mean-weighted c.v.s for each length and age distribution computed from the bootstrap distributions.

Catchatage was used to calculate length-frequency distributions for each sex in the KAH0704 catch scaled to the giant stargazer relative biomass estimate. Following ageing of otoliths, sex-specific subsets of length-at-age data were passed to *catchatage*. Age-length keys were calculated from these and then applied to the scaled length-frequency distributions to compute scaled age-frequency distributions for each sex. Bootstrapped c.v.s and mean-weighted c.v.s were computed for each length and age-class and length and age distribution from 1000 iterations of the resampling algorithm. The weight-at-length relationship used in these calculations was parameterised using the results of a geometric mean regression of fish weight on length for male, female, and all fish measured during the KAH0704 voyage. The relationships are:

$$\textit{Males}: w = 1.4467\times10^{-5}\,(l^{3.0394})$$

$$\textit{Females}: w = 1.2124\times10^{-5}\,(l^{3.1070})$$

$$\textit{All fish}: w = 1.3326\times10^{-5}\,(l^{3.0707})$$

where *w* is weight in kilograms and *l* is total length in centimetres. *Catchatage* was also used to compute scaled length and age frequency distributions for the sampled commercial bottom trawl catch. A single length-frequency distribution was computed for all fish in the commercial catch from the dorsal length observations (converted to total length) collected during the sampling period. This was scaled to the estimated catch from the fishery during the sampling period. During the 2005 WCSI survey, all stargazer were measured to dorsal length as well as the usual total length. This was so that a relationship between dorsal length and total length could be developed. This relationship was used to convert dorsal length to total length for all catch sample fish and this was input into *catchatage* for the 2007 data. The relationship between total length and dorsal length is:

$$tl = 1.64 \times dl^{1.02}$$

where *tl* is total length (in millimetres) and *dl* is dorsal length (in millimetres). The single length-frequency distribution was converted to separate, sex-specific age-frequency distributions by applying an age-length-sex key to the length distribution. The age-length-sex key is a simple extension of the more common age-length key. It is a three-dimensional array of proportions at age and sex by length where the proportions at age for each length class are calculated across both sexes within the same array instead of for each sex separately in two separate two-dimensional (age, length) arrays. The one-dimensional age-frequency distribution for each sex is obtained by calculating the matrix product of the one-dimensional length-frequency distribution for all fish and an appropriate two-dimensional slice extracted from the three-dimensional age-length-sex array. That is, if $\mathbf{LF}$ is a $1 \times m$ matrix of proportions at m lengths for all fish of both sexes combined that sums to one, and $\mathbf{ALK}$ is an $m \times n \times s$ array of m lengths by n ages by s sexes, the m rows of which sum to one across both levels (male and female) of s, then $\mathbf{AF}_{s=i}$, a $1 \times n$ matrix of proportions at n ages for the i th sex in s that sums to one, is

$$\mathbf{AF}_{s=i} = \mathbf{LF} \times \mathbf{ALK}_{s=i} ,$$

where $\mathbf{ALK}_{s=i}$ is the $s = i$ th two-dimensional slice of $\mathbf{ALK}$, reducing to an $m \times n$ matrix. The m row totals of $\mathbf{ALK}_{s=i}$ do not, therefore, sum to one. $\mathbf{LF}$ ($1 \times m$) and $\mathbf{ALK}_{s=i}$ ($m \times n$) are conformable matrices (arrays); $\mathbf{LF}$ and $\mathbf{ALK}$ ($m \times n \times s$) clearly are not. There is an implicit assumption that the otoliths from which the $\mathbf{ALK}$ array is constructed are representative of the stock by both length and sex. Given that the survey uses a two-stage, stratified sampling design with trawl stations allocated to each survey stratum randomly and with otoliths collected randomly from subsamples of the catch taken at each station for length measurements, this assumption is likely to have been met, less the effect of differences in gear selectivity on younger, smaller fish. Gear selectivity ogives were estimated in the preliminary stock assessment (Manning 2008). Some modifications of the *catchatage* source-code were required to perform these calculations.

3. RESULTS

3.1 A brief description of the fishery

A series of characterisations and standardised catch-per-unit-effort (CPUE) analyses of the STA 7 fishstock have been presented by SeaFIC (2002, 2003, 2005) on behalf of quota owners as part of the AMP annual review process. We do not attempt to update those analyses in this report, but we do summarise important features of the fishery to support the other analyses that we present. The groomed and merged STA 7 catch is plotted by fishing year for each of month, statistical area, method, and target species separately in Figure 5 (a–d), and by fishing year conditioning on method, target species, stock area, and form type in Figure 6 (a–c). Several features of the catch are immediately apparent.

Smaller, typically domestic, bottom-trawl vessels completing CELR forms and fishing on the open west coast of the South Island dominate the catch. Catches by larger vessels completing TCEPR forms are relatively unimportant, accounting for only 12% of the merged catch between 1990 and 2007.

Catches by methods other than bottom trawling by any vessel class in any area are also unimportant, accounting for only 3% of the merged catch over all fishing years.

Statistical areas 033 and 034 are by far the most important (accounting for 80% of the total merged catch). Areas 017 and 018 in eastern Cook Strait are of secondary importance (13% of the total merged catch), but these are outside the definition of the unit stock in this study. Catches in other statistical areas are negligible.

Fishing effort directed at barracouta (*Thyrsites atun*) and tarakihi (*Nemadactylus macropterus*) accounts for the majority of the stargazer catch with 44 and 20%, respectively. Target fishing does occur on the open west coast and in eastern Cook Strait but accounts for only 10% of the merged catch. Red cod (*Pseudophycis bachus*), hoki (*Macruronus novaezelandiae*), and flatfishes (Pleuronectidae), account for 8, 6 and 4%, respectively.

Although there are some declines in the catch during the winter months in some fishing years, overall there is no real evidence of seasonality in the catch. As a result, SeaFIC (2002, 2003, 2005) partition the catch into one major, mixed-species bottom-trawl fishery that operates on the west coast of the South Island in their standardised CPUE analyses, excluding the catch (and associated effort data) from all other sources. If we define the fishery similarly in terms of fishing method (bottom trawling), target species (barracouta, flatfishes, red cod, giant stargazer, and tarakihi), and the area fished (the WCSI as defined in Section 2.1), then fishing trips with fishing effort matching these definitions account for 74% of the total catch across all fishing years (64–85% in any given fishing year). During the 2006–07 fishing year, fishing trips matching this definition accounted for 66% of the total reported catch of 1049 t.

3.2 Catch sampling results

Twenty-two landings were sampled and 2495 unsexed dorsal length observations were collected from the BT-MIX fishery from STA 7(W) during January–June of the 2006–07 fishing year. This was an improvement on both the number of landings and individual fish measured for STA2004-01. No landings of giant stargazer could be sampled in Nelson in June that passed the lower weight limit of 100 kg, however. Allocated and achieved sampling effort and numbers of fish measured throughout the entire sampling period are shown in Table 2. As occurred in 2005, information obtained after sampling suggested that some catches were actually caught in Cook Strait East (CKST.E) which is outside the definition of the stock for this project. As was done in STA200401, these samples were retained in the analysis but treated as a separate stratum from STA 7(W).

A summary of fishing and sampling effort (weight of landed catch, numbers of landings) is provided in Figure 7. The sampled catch accounted for 13% of the landed catch in the fishery during the January–June sampling period and 6% throughout the entire fishing year (Table 4). The estimated giant stargazer catch and the numbers of trawl shots by statistical area and target species by the sampled vessels and by all the vessels in the fishery are compared in Figure 8. Although there is some over- and under-representation of these variables for some statistical areas and target species for the sampled vessels relative to all the vessels in the fishery, overall they are broadly comparable. Although the target of 24 sampled landings in January–June was not met, the comparability of the distributions of estimated catch and trawl effort across these factors by the sampled vessels and the fleet as a whole, and the distribution of the sampled and all landings in the fishery by month plotted in Figure 7, suggest that the sampled landings are representative of the fishery.

3.3 Otolith readings

One sagittal otolith from each of the 386 pairs collected during the 2007 WCSI survey was prepared and read; 16 otoliths were deemed unreadable and discarded. The age estimates derived from the zone counts ranged from 0.74 to 20.8 years. Within- and between-reader comparisons in STA200401 showed no systematic bias in ageing of otoliths and so the original first readings were used for subsequent analyses. For this reason, the first readings by the same first reader in STA200401 (M.J. Manning) were used in all analyses for this project.

3.4 The length and age composition of the fishery and survey catches

3.4.1 The fishery catch

Dorsal lengths sampled from the commercial fishery were converted to total lengths using the relationship given in Section 2.2.4. Scaled length-frequency distributions were calculated for the fishery for the two area strata (STA 7(W), CKST.E) separately from the dorsal length measurements collected during the 22 landings sampled between January and June. These were scaled to our estimates of the January–June 2007 catch in the CKST.E and STA 7(W) subregions by the BT-MIX fishery using the groomed and merged catch-effort and landings dataset.

The scaled length frequencies for 2005 and 2007 are plotted in Figure 9(a–b). The total length-frequencies from the 2007 fishery appear to be slightly bimodal as did the dorsal length-frequencies in 2005. Fish range in size from 26 to 91 cm total length with one mode centred on about 50 cm and a second, larger mode at about 60 cm. An age-length-sex key was generated from the estimated ages, total lengths, and sex observations of the 370 fish sampled during the trawl survey from which age estimates could be made. The key was applied to the scaled total length distributions to yield scaled age-frequency distributions for each sex and stratum in the commercial fishery. The scaled age-frequencies for 2005 and 2007 are plotted in Figure 10(a–b). Fish range in age from 1 to 20 years, although most are between 5 and 11 years, and there are very few fish present in the catch older than 15 years. The distributions appear fairly unimodal and asymmetrical. The right hand, older limb has a longer tail than the left hand, younger limb.

Mean-weighted c.v. for the fishery age- and length-frequency distributions are given in Table 5. Mean-weighted c.v.s of 41% and 26.8% were obtained for the age-frequency distribution of all fish in the CKST.E and STA 7(W) catches respectively, and 25.8% pooled across both strata in the analysis. The c.v. value of 41% for CKST.E exceeds the 30% target set for the fishery. This is of little concern however, as CKST.E is actually outside the definition of the stock unit for this study and the c.v. for both areas together is within target.

3.4.2 The survey catch

Scaled length-frequency distributions were calculated for each sex from the 2007 survey catch. The (total) length observations from each tow were scaled first to the catch for each tow and then to the area of each stratum (in km^2) using the catch per tow per km^2 swept by the survey gear during each tow. Only data from valid biomass tows identified by Stevenson (2007) were included in the analysis. The biomass estimates for all earlier surveys in the series were recomputed using the 2007 strata in this analysis. The scaled length-frequencies for males, females, and all fish pooled across all strata are plotted separately by survey in Figure 11. Length frequencies for both sexes from the 2007 survey are similar to previous surveys. Males ranged from 13–75 cm total length (median 47 cm) and females range from 16–80 cm total length (median 54 cm). Most fish are between 30 and 70 cm total length. As in previous surveys, there are small modes at about 20–25 cm and 25–30 cm. The smaller length modes are not thought to correspond to discrete year classes. These probably include fish 1–2 and 1–3 years of age, respectively (Manning 2007). The larger mode represents all other, older year classes on the survey ground.

Separate, sex-specific age-length keys were constructed from the total length and age estimate observations for all of the 370 fish from the 2007 survey for which age estimates were available and applied to the scaled length-frequency distributions to yield scaled age-frequency distributions. These are plotted by sex and survey pooled across all survey strata in Figure 12, along with all previous surveys. The 2007 age distributions appear comparable with those in previous surveys, with virtually all fish ranging in age from 1 to 15 years, and most between the ages of 3 to 10 years.

Year class progressions over the course of the survey series and from the 2004–05 and 2006–07 commercial catch are plotted by sex in Figure 13. These suggest that there are no extremely weak (or strong) year classes in either the 2007 survey or commercial catch. The median fish length in the survey catch has dropped from 53 to 48 cm, and the median age from 8 to 7 years over the time series (Figures 11 and 12).

Comparing the cumulative proportions-at-age distributions for the survey catch pooled across all strata and the WCSI stratum in the fishery catch (Figure 14) suggests that the WCSI fishery contains significantly fewer male fish of all ages than the survey catch. Given the smaller mesh size on the codend of *Kaharoa's* research trawl (compared with the regulated commercial codend mesh size) the higher proportion of younger fish is unsurprising. Manning & Sutton (2007a) found that the commercial catch in 2005 also contained significantly fewer fish less than 5 years of age compared to the survey catch of the same year. That all age classes of males now appear to have declined in the commercial catch is puzzling. There has been a corresponding dramatic drop in the male to female sex ratios with one female for every 0.63 males in the commercial fishery from January to June (Table 6). In 2005 the ratio was 1.2 to 1 in favour of males. With the exception of KAH9204, males have outnumbered females in the survey catch every year. This includes the 2007 survey, which at 1.65 males per female is the highest for the time series. For females, there are fewer fish younger than 5 years in the commercial catch compared with the survey catch. After about age 5, the 2005 commercial and survey catches had similar proportions at age. However, there has been a dramatic shift in 2007, with significantly more female fish aged 10 years or more caught in the commercial catch compared with the survey catch.

Mean-weighted coefficients of variation for the survey length and age-frequency distributions are also given in Table 5. Values of 36.2%, 39.1%, and 28.9% were obtained for males, females, and all fish pooled across all survey strata, respectively. Although no formal variance target was set for the survey age frequency distributions, the value for all fish pooled is also within the 30% target set for the fishery catch-at-age.

4. DISCUSSION

4.1 The efficacy of the catch sampling programme

The aim of the catch-sampling programme undertaken in this project was to sample the giant stargazer catch in the mixed-species bottom trawl fishery in the STA 7(W) region of the STA 7 QMA. A target mean-weighted c.v. of 30% was set for the proportions-at-age distribution pooled across both sexes and all strata in the analysis. Even though fewer than the target of 24 landings in the STA 7(W) stock region in the January–June sampling period were achieved, the variance target was still met.

It was necessary to determine whether the data we sampled from the commercial catch was representative of the commercial catch as a whole. We did this by comparing the catch-effort data from the fishing trips that we sampled to the catch-effort data for the whole fleet for the sampling period. Estimated catch and effort by statistical area and by recorded target species by both the sampled vessels and the fleet as a whole are comparable. This suggests that the sample data are representative of the fishery and that extrapolating from one to the other is valid.

The sampling design for 2007 was the same as in 2005. Again it was possible to collect representative data from the fishery and beat the variance target, despite not meeting the target number of sampled landings during the sampling period. As such it is strongly recommend that future catch sampling programmes in this fishery adopt a similar design with a similar number of target landings. It has been demonstrated twice now that the design works, allowing the handicap of at-sea processing to be overcome.

Although a reduction in the target number of landings to be sampled may be possible in the future, there are still too few data available to optimise the number of landings and number of fish per landing that should be sampled using quantitative methods. Until sufficient data (perhaps from three separate fishing years) are available to permit an optimisation exercise, we still maintain that a reduction in the target sampling effort would be premature and unwise, given our lack of knowledge of the composition of the fishery.

As discussed in Manning & Sutton (2007a), the justification for extrapolating otoliths (and other data) collected from fish caught on the west coast of the South Island to fish caught in eastern Cook Strait, is questionable given that fish in eastern Cook Strait may belong to another biological stock unit. As happened during sampling in 2005, some samples taken in 2007 believed to be from STA 7(W) at the time of sampling turned out to be from the CKST.E subregion which was not a part of the sampling design. As in Manning & Sutton, these data were treated as a separate stratum in the analysis and all comparisons between the fishery and the survey catches made above were restricted to the WCSI fishery stratum only.

4.2 Trends in the fishery and survey catches at length and at age

The length- and age-frequency distributions of fish caught during the 2007 survey appear to be consistent with those from earlier in the time series. The age-frequency distributions are broad, composed of several successful year classes, with nearly all fish ranging in age from 1 to 20 years, but most between 3 and 10 years. The 2007 data is consistent with the suggestion by Manning & Sutton (2007a) of a decline in the numbers of larger, older fish present over the time series, with smaller, younger fish becoming proportionally more important in numbers in the survey catch in more recent years. Assuming that older fish are fully selected by commercial bottom trawls and that all other things are equal, observations of a change in the length and age composition of an exploited fish population in response to increased exploitation are not uncommon. The average annual stargazer catch in STA 7 from the 1991–92 to 2006–07 period has increased substantially with an annual average of 845 t compared to the 1986–87 to 1990–91 period with an average of 572 t. Most is caught by small bottom trawl vessels on the west coast of the South Island. Therefore, our observations of a reduction in the proportions of larger and older fish in the WCSI survey catch are not unreasonable.

The WCSI commercial catch-at-age for January–June 2007 has a broad range. While overall scaled population numbers have decreased in 2007, fish 10 years and older appear to make up a greater proportion of the commercial catch compared with 2005. The commercial fishery in 2007 contains significantly fewer younger (0–3 year old) fish than the survey catch, as was the case in 2005. The lack of younger fish in the commercial fishery is likely to be due to the different gear selectivity of the average commercial bottom trawl compared with the survey gear. RV *Kaharoa*’s research trawl gear has a 60 mm codend (74 mm knot-to-knot), smaller than that allowed by commercial vessels. The regulated codend mesh of commercial trawl gear used in the WCSI inshore trawl fishery is likely to be at least 100 mm (knot-to-knot). As such the commercial fishery is likely to have a lower proportion of smaller, younger fish than the survey catch.

The sex ratio in the 2005 commercial fishery was consistent with previous survey sex ratios at 1.2 males for every female. This dropped dramatically in 2007 to 0.6 males for every female. This is inconsistent with the ratio of 1.65 males to every female for the survey of the same year. Cumulative proportions of the catch-at-age for both sexes have also changed in 2007. In 2005 they were similar for the commercial and survey catches after about 5 years of age (with higher proportions of under 5 year old fish in the survey catch). In 2007 there has been a large drop in the proportion of males in the commercial catch with a marked increase in the proportion of females in the commercial fishery catch. The commercial catch has significantly more females older than about 10 years than the survey catch. Total landings are about the same for the 2004–05 and 2006–07 fishing years at 1028 t and 1049 t respectively. The survey biomass index increased from 1458 t (c.v. 19%) in 2005 to a series record of 1630 t (c.v. 12%) in 2007. The larger mean size of females compared with males may explain the lack of change in landings by weight despite the apparent drop in actual numbers. The cause of this is unknown but may be due to a change in the location of fishing activity to area(s) where females are more abundant than males. The important statistical areas for stargazer have not changed. If there has been a change in the location of fishing activity within statistical areas we cannot tell as most of stargazer is caught by vessels reporting on Catch Effort Landing Return (CELR) forms which summarise daily fishing activity but give no locality information at the level of individual fishing events. Another possibility is the discarding of smaller fish while retaining larger fish (which tend to be female). While the age- and length-frequencies of the commercial fishery are scaled up to the catch for the sampling period (rather than the entire fishing year), the catch from January to June is not significantly lower than the rest of the fishing year, and scaled numbers were calculated in the same way in 2005.

4.3 Age validation

Although a validation experiment was attempted to test our assumed otolith chronology using chemical (oxytetracycline) methods, no chemically tagged fish have yet been recovered. Possible reasons for the failure to recover any tagged fish were discussed by Manning (2006). This experiment is assumed to have been a failure and we recommend that attention should be given to devising an alternative validation experiment.

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Table 1: The total reported landed giant stargazer catch by fishing year and QMA (Ministry of Fisheries 2006). *, New Zealand Fisheries Statistics Unit data (1983–86); †, New Zealand QMS data (1986–87 to 2006–07).

Fishstock	STA 1		STA 2		STA 3		STA 4		STA 5	
FMA(s)	1 & 9		2		3		4		5 & 6	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983*	8	–	34	–	540	–	168	–	843	–
1984*	5	–	24	–	588	–	143	–	1023	–
1985*	9	–	15	–	438	–	82	–	695	–
1986*	12	–	24	–	415	–	95	–	566	–
1986–87†	10	20	31	30	644	560	72	2 000	738	1 060
1987–88†	3	20	46	33	783	581	110	2 005	886	1 144
1988–89†	3	20	41	37	675	591	134	2 005	1 215	1 173
1989–90†	9	21	53	37	747	703	218	2 009	1 150	1 175
1990–91†	8	21	125	37	674	734	790	2 014	1 061	1239
1991–92†	18	50	105	100	756	900	366	2 014	1 056	1 500
1992–93†	19	50	115	101	811	901	231	2 014	1 247	1 500
1993–94†	8	50	73	101	871	902	113	2 014	1 327	1 500
1994–95†	10	50	74	101	829	902	223	2 014	1 216	1 525
1995–96†	17	50	69	101	876	902	259	2 014	1 159	1 525
1996–97†	22	50	77	101	817	902	149	2 014	977	1 525
1997–98†	29	21	54	38	667	902	263	2 014	544	1 264
1998–99†	27	21	46	38	641	902	137	2 014	1 145	1 264
1999–00†	36	21	42	38	719	902	161	2 014	1 327	1 264
2000–01†	26	21	45	38	960	902	233	2 014	1 439	1 264
2001–02†	34	21	58	38	816	902	391	2 158	1 137	1 264
2002–03†	31	21	41	38	863	902	308	2 158	967	1 264
2003–04†	23	21	27	38	578	902	186	2 158	1 193	1 264
2004–05†	27	21	28	38	646	902	366	2 158	1 282	1 264
2005–06†	34	21	30	38	824	902	359	2 158	1 347	1 264
2006–07	22	21	31	38	719	902	296	2 158	1 344	1 264

Fishstock	STA 7		STA 8		STA 10			
FMA(s)	7		8		10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983*	323	–	3	–	0	–	1 919	–
1984*	444	–	3	–	0	–	2 230	–
1985*	328	–	4	–	0	–	1 571	–
1986*	362	–	3	–	0	–	1 477	–
1986–87†	487	450	7	20	0	10	1 990	4 150
1987–88†	505	493	5	20	0	10	2 338	4 306
1988–89†	520	499	5	20	0	10	2 593	4 355
1989–90†	585	525	1	22	0	10	2 763	4 502
1990–91†	762	528	6	22	0	10	3 426	4 605
1991–92†	920	700	18	22	0	10	3 239	5 296
1992–93†	861	702	5	22	0	10	3 289	5 300
1993–94†	715	702	4	50	0	10	3 111	5 329
1994–95†	730	702	7	50	0	10	3 089	5 354
1995–96†	877	702	4	50	0	10	3 261	5 354
1996–97†	983	702	10	50	0	10	3 034	5 354
1997–98†	564	702	10	22	0	10	2 132	4 973
1998–99†	949	702	2	22	0	10	2 946	4 973
1999–00†	1 184	702	3	22	0	10	3 472	4 973
2000–01†	1 440	702	4	22	0	10	4 146	4 973
2001–02†	802	702	4	22	0	10	3 238	5 117
2002–03†	957	997	4	22	0	10	3 171	5 412
2003–04†	934	997	6	22	0	10	2 947	5 412
2004–05†	1 028	997	5	22	0	10	3 381	5 412
2005–06†	1 010	997	3	22	0	10	3 606	5 412
2006–07	1 049	997	4	22	0	10	3 461	5 411

Table 2: Allocated and achieved sampling effort and numbers of fish measured in the coastal mixed-species trawl fishery in the STA 7(W) stock area during the 2004–05 fishing year.

Allocated sampling effort

	Numbers of landings						
Port	Jan	Feb	Mar	Apr	May	Jun	Total
Greymouth	3	3	3	2	2	2	15
Nelson	2	2	2	1	1	1	9
Total	5	5	5	3	3	3	24

Achieved sampling effort

	Numbers of landings						
Port	Jan	Feb	Mar	Apr	May	Jun	Total
Greymouth	3	3	3	2	2	1	14
Nelson	1	3	1	2	1	0	8
Total	4	6	4	4	3	1	22

Numbers of fish measured

	Numbers of fish measured						
Port	Jan	Feb	Mar	Apr	May	Jun	Total
Greymouth	300	300	300	200	200	100	1400
Nelson	100	308	204	272	211	0	1095
Total	400	608	504	472	411	100	2495

Table 3: Readability and margin-state scores used in otolith readings.

Five-point readability score

Score	Description
1	Otolith very easy to read; excellent contrast between translucent and opaque zones; ± 0 between subsequent translucent-zone counts of this otolith
2	Otolith easy to read; good contrast between translucent and opaque zones, but not as marked as in “1”; ± 1 between subsequent translucent-zone counts of this otolith
3	Otolith readable; less contrast between translucent and opaque zones than in “2”, but alternating zones still apparent; ± 2 between subsequent translucent zone counts of this otolith
4	Otolith readable with difficulty; poor contrast between translucent and opaque zones, deemed to be worse than in either “2” or “3”; ± 3 or more between subsequent counts of this otolith
5	Otolith unreadable

Table 3 continued: Three-point margin state score

Score	Description
Narrow	Last translucent zone present deemed to be fully formed; a very thin, hairline layer of opaque material is present outside the last translucent zone
Medium	Last translucent zone present deemed to be fully formed; a thicker layer of opaque material, not very thin or hairline in width, is present outside the last translucent zone; some new translucent material may be present outside the thicker layer of opaque material, but generally does not span the entire margin of the otolith
Wide	Last translucent zone present deemed not to be fully formed; a thick layer of opaque material is laid down on top of the last fully formed opaque zone, with new translucent material present outside the opaque layer, spanning the entire margin of the otolith

Table 4: Summary of fishing and sampling activity. The catch (t) and numbers of landings by all vessels reporting an STA 7 landing, by all vessels in the bottom-trawl fleet fishing in the STA 7(W) stock area, and by all sampled vessels during the 2006–07 fishing year are provided by month. Sampled catches as a percentage (by weight) of the corresponding fleet catch are also provided.

		Landed catch (kg)				Number of landings		
Year	Month	All	Fleet	Sampled	(%)	All	Fleet	Sampled
2006	10	85 920	55 870	-	-	65	53	-
2006	11	183 788	166 605	-	-	103	89	-
2006	12	86 762	77 432	-	-	93	81	-
2007	1	109 329	93 045	11 978	13	89	68	4
2007	2	80 509	73 657	15 766	21	59	47	6
2007	3	63 812	48 544	7 855	16	54	37	4
2007	4	115 742	111 008	7 886	7	61	51	4
2007	5	56 507	50 747	5 155	10	51	41	3
2007	6	40 755	35 750	5 897	16	65	54	1
2007	7	109 763	95 803	-	-	86	62	-
2007	8	89 958	56 456	-	-	109	64	-
2007	9	151 602	67 530	-	-	92	63	-
	Total	1 174 447	932 446	54 537	6	927	710	22

Table 5: Mean-weighted coefficients of variation (%) for the length- and age-frequency distributions in the STA 7 fishery and WCSI survey (KAH0704) catches during the 2006–07 fishing year.

			Sex			
Sector	Distribution	Stratum	Males	Females	Unsexed	All fish
Fishery	Length	CKST.E	–	–	53.9	53.9
		WCSI	–	–	24.6	24.6
		Pooled	–	–	24.0	24.0
	Age	CKST.E	51.1	50.1	–	41.0
		WCSI	37.8	35.6	–	26.8
		Pooled	36.1	34.4	–	25.8
Survey	Length	Pooled	41.6	52.5	–	35.7
	Age	Pooled	36.2	39.1	–	28.9

Table 6: Male to female sex-ratios in the WCSI survey series (1992–2007). These are calculated from the scaled length-frequency distributions (total numbers of fish) by sex in each survey and are expressed as the number of males for each female fish. The sex ratios from the January–June 2005 and 2007 WCSI fishery catch are provided for comparison. These were calculated from the corresponding fishery scaled age-frequency distribution.

	Sex			Sex	
Survey	M	F	Survey	M	F
WCSI fishery 2005	1.2002	1			
WCSI fishery 2007	0.6348	1			
WCSI fishery both years	1.0183	1			
KAH9204	0.9438	1	KAH0004	1.3748	1
KAH9404	1.3735	1	KAH0304	1.4369	1
KAH9504	1.4624	1	KAH0503	1.3049	1
KAH9701	1.2486	1	KAH0704	1.6514	1
			Over all surveys	1.3568	1

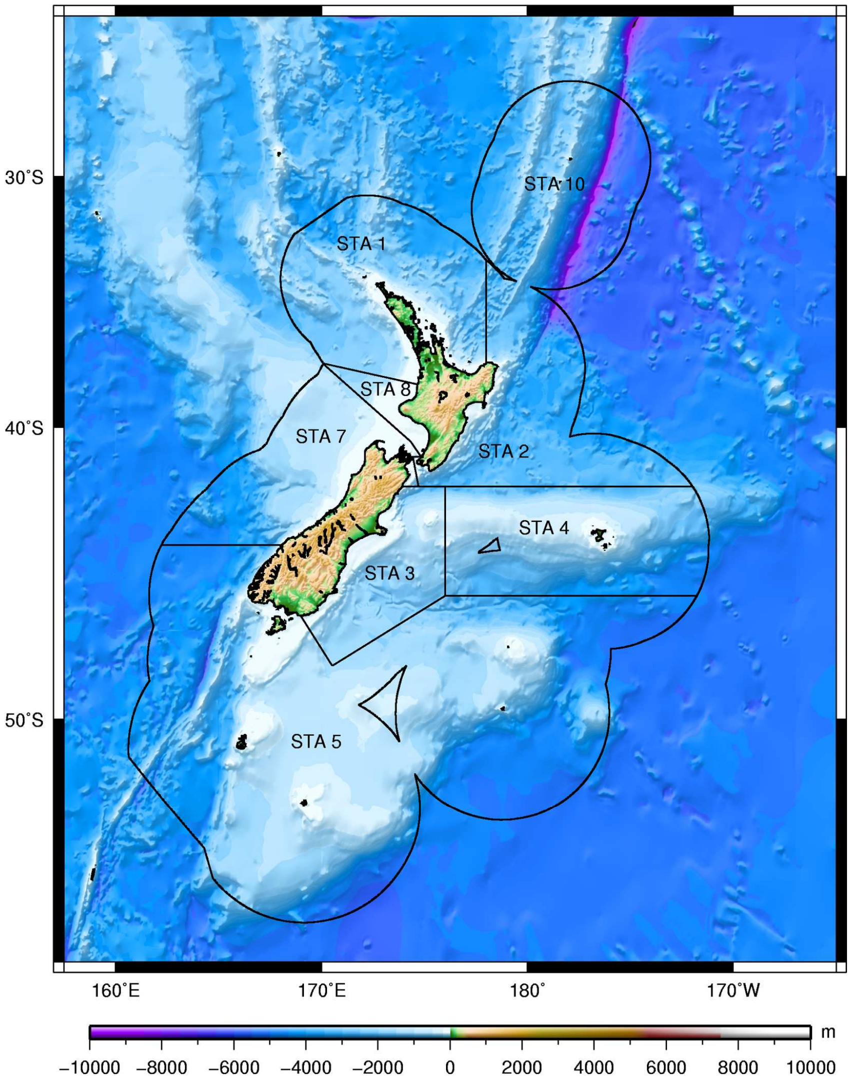


Figure 1: Giant stargazer Quota Management Areas (QMAs) within the New Zealand EEZ. The individual QMAs do not necessarily correspond to individual biological stock units or populations.

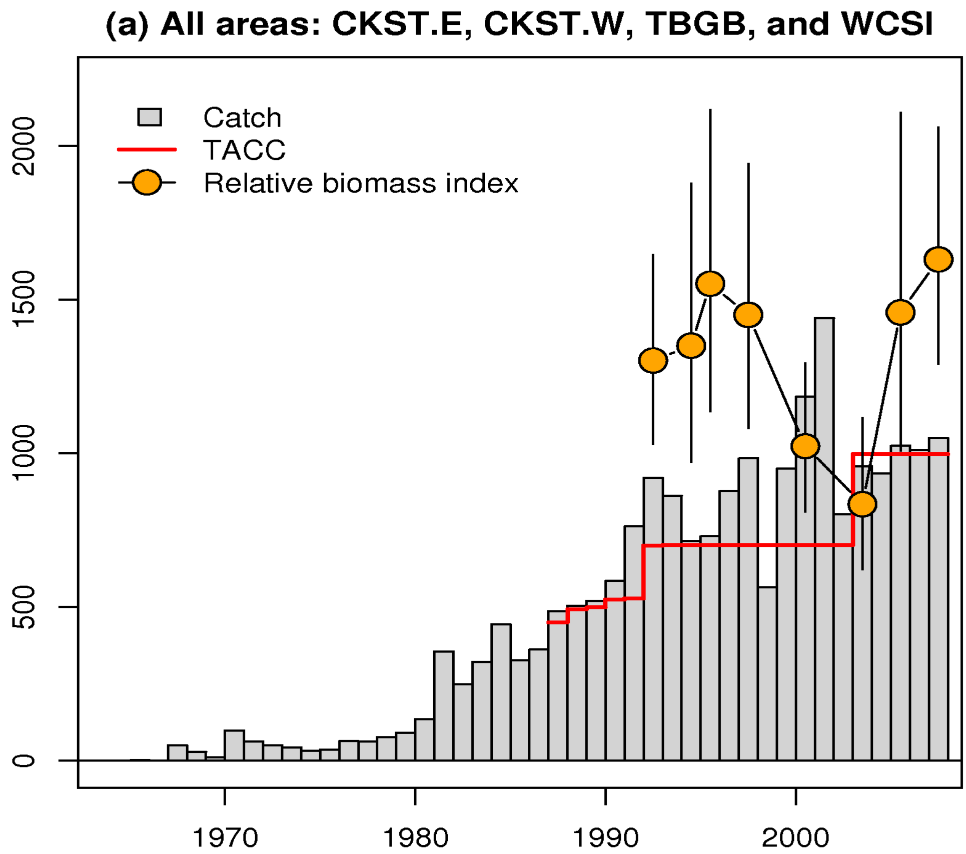


Figure 2: The commercial catch, total allowable commercial catch (TACC) and WCSI survey relative-biomass indices, 1992–2007, in STA 7.

Figure 3: Measurement method for dressed giant stargazer trunks. All giant stargazer trunks in 2007 were measured to the nearest millimetre below dorsal length, i.e., the nearest millimetre below the actual length from the anterior margin of the dorsal fin to the posterior margin of the caudal fin.

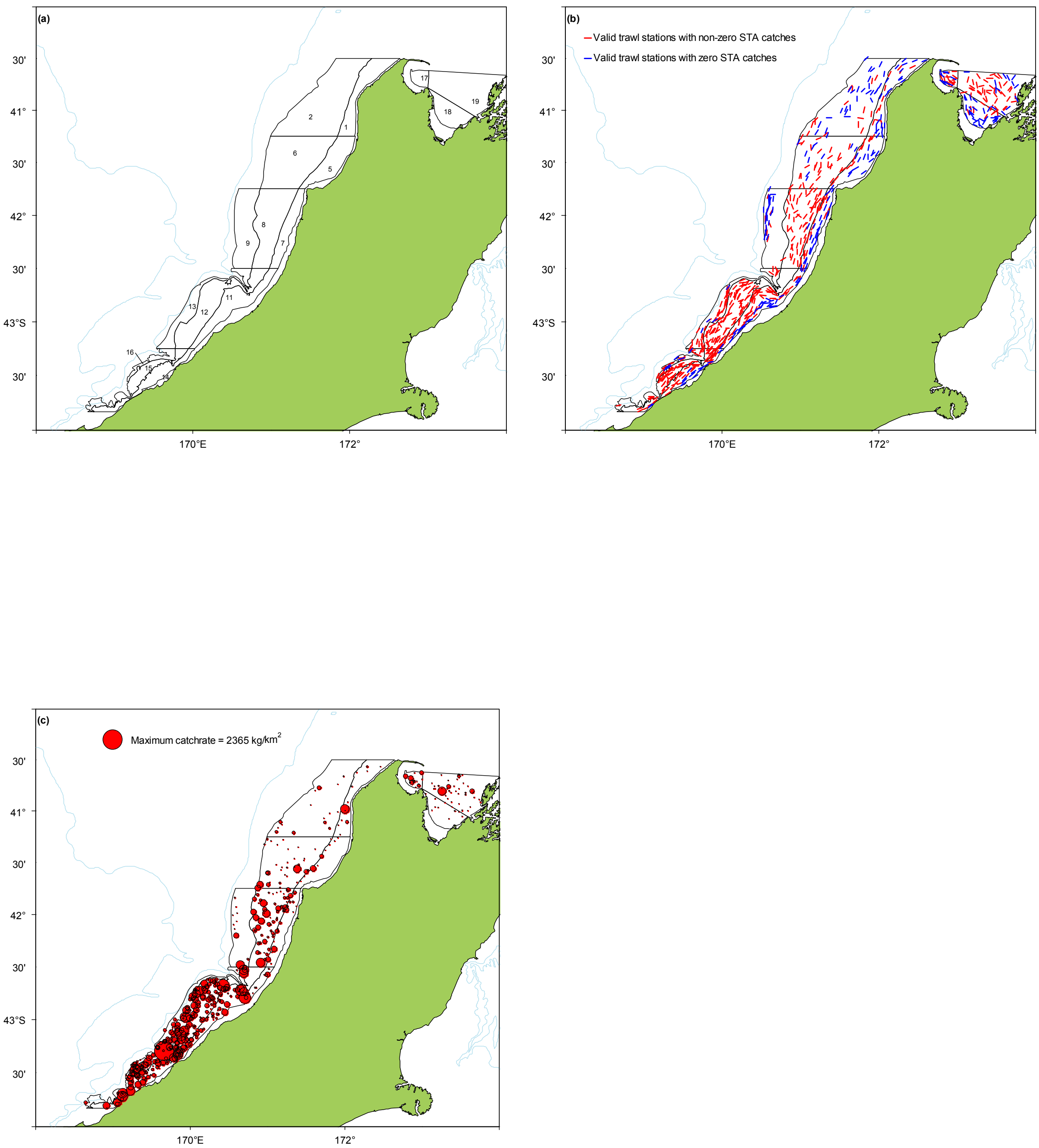


Figure 4: The distribution of giant stargazer on the WCSI survey ground: (a) survey strata used during the March–April 2007 voyage; (b) survey trawl positions, 1992–2007; (c) catch rates of giant stargazer throughout the survey series, 1992–2005.

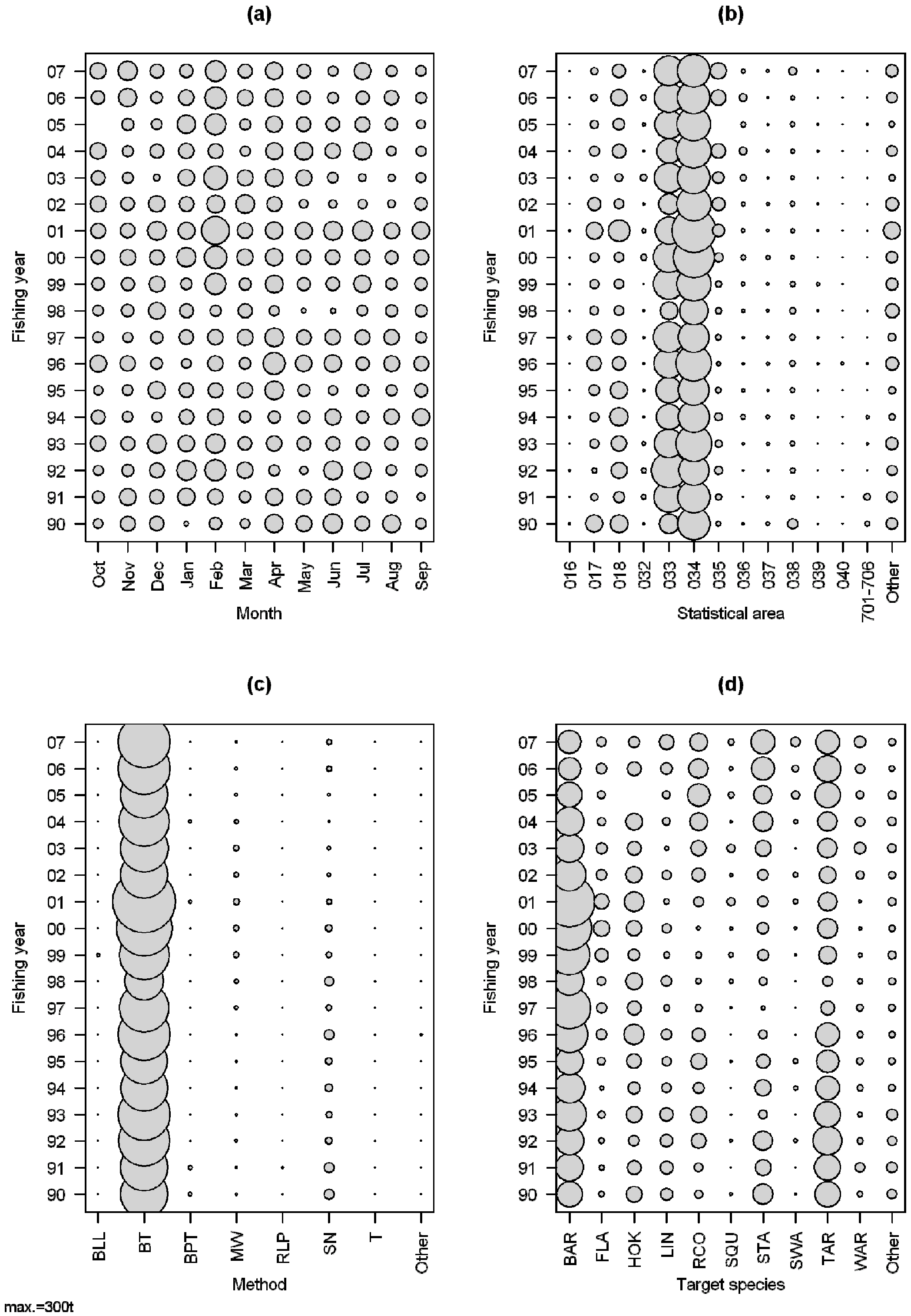
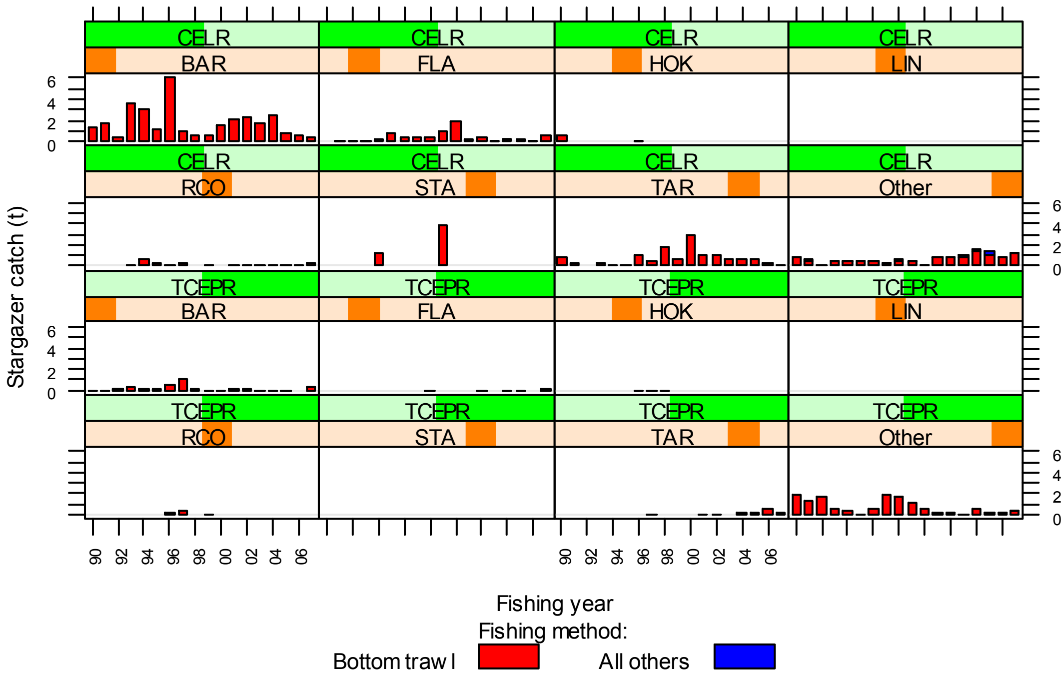


Figure 5: The groomed and merged STA 7 catch for each fishing year by: (a) month, (b) statistical area, (c) method, and (d) target species. Circle areas are proportional to the amount of catch in each factor level and fishing year combination.

(a) Cook Strait West



(b) Tasman and Golden Bays

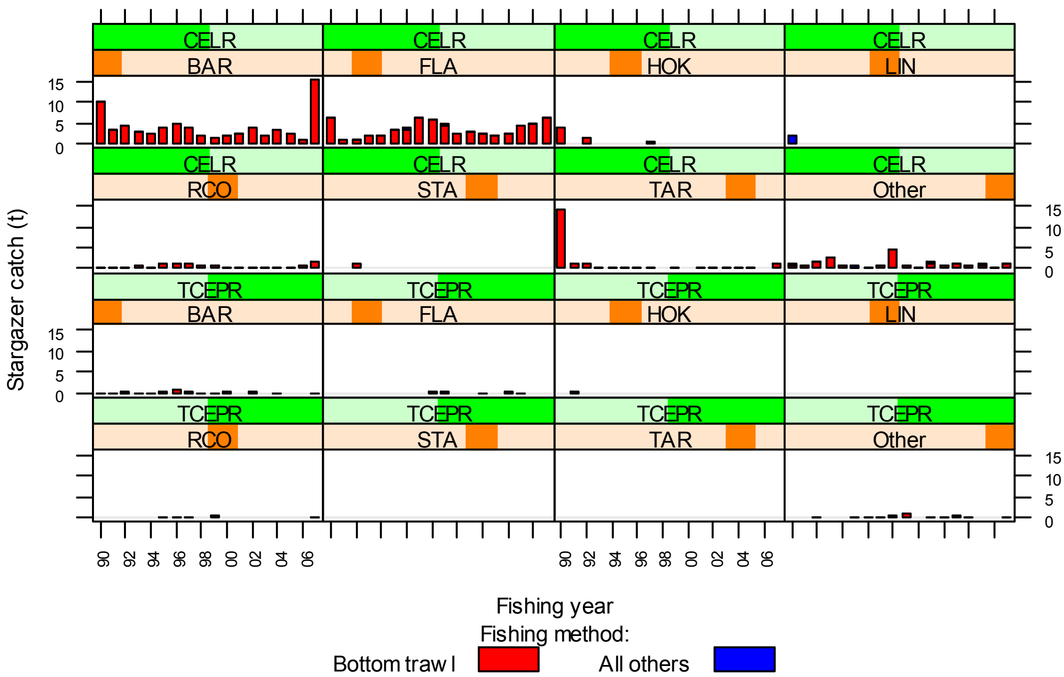


Figure 6: The groomed and merged STA 7 catch by fishing year (1989–90 to 2006–07), target species (BAR, barracouta; FLA, flatfishes; HOK, hoki; LIN; ling, RCO, red cod; STA, giant stargazer; TAR, tarakihi), stock area (panel a, CKST.W; panel b, TBGB; and panel c, WCSI) as defined by Manning (2008), catch-effort form type (CELR and TCEPR), and fishing method (bottom trawling and all other methods). Note the different *y*-axis scales on each panel.

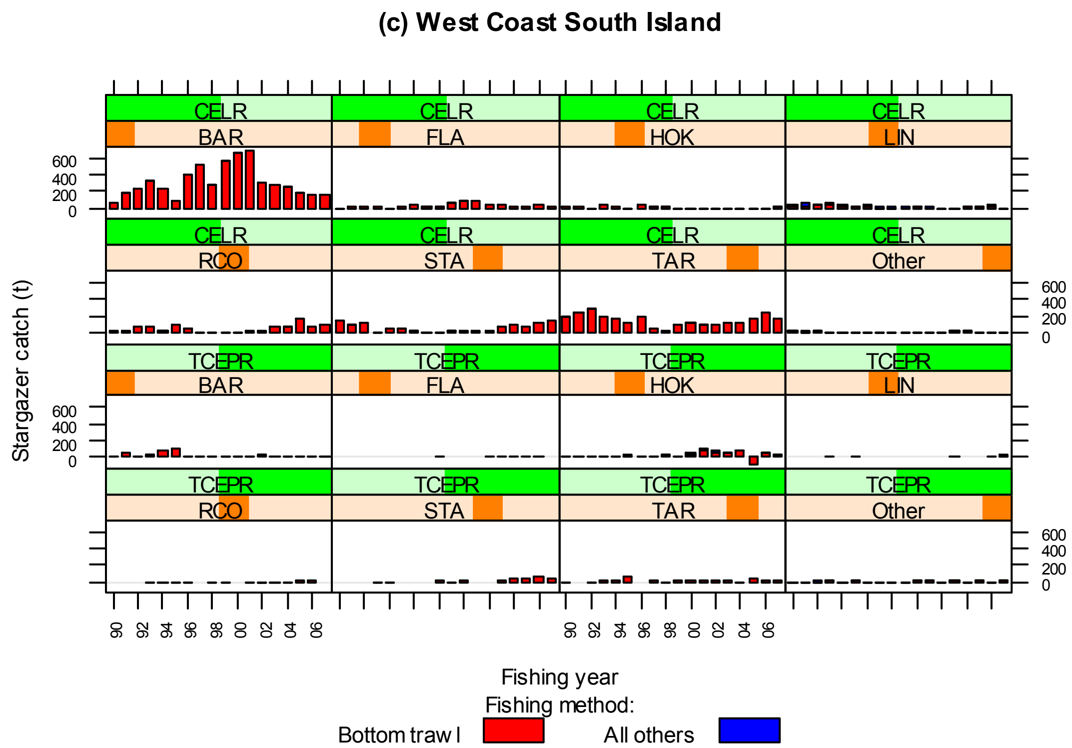


Figure 6 continued: The groomed and merged STA 7 catch by fishing year (1989–90 to 2006–07), target species (BAR, barracouta; FLA, flatfishes; HOK, hoki; LIN; ling, RCO, red cod; STA, giant stargazer; TAR, tarakihi), stock area (panel a, CKST.W; panel b, TBGB; and panel c, WCSI) as defined by Manning (2008), catch-effort form type (CELR and TCEPR), and fishing method (bottom trawling and all other methods). Note the different *y*-axis scales on each panel.

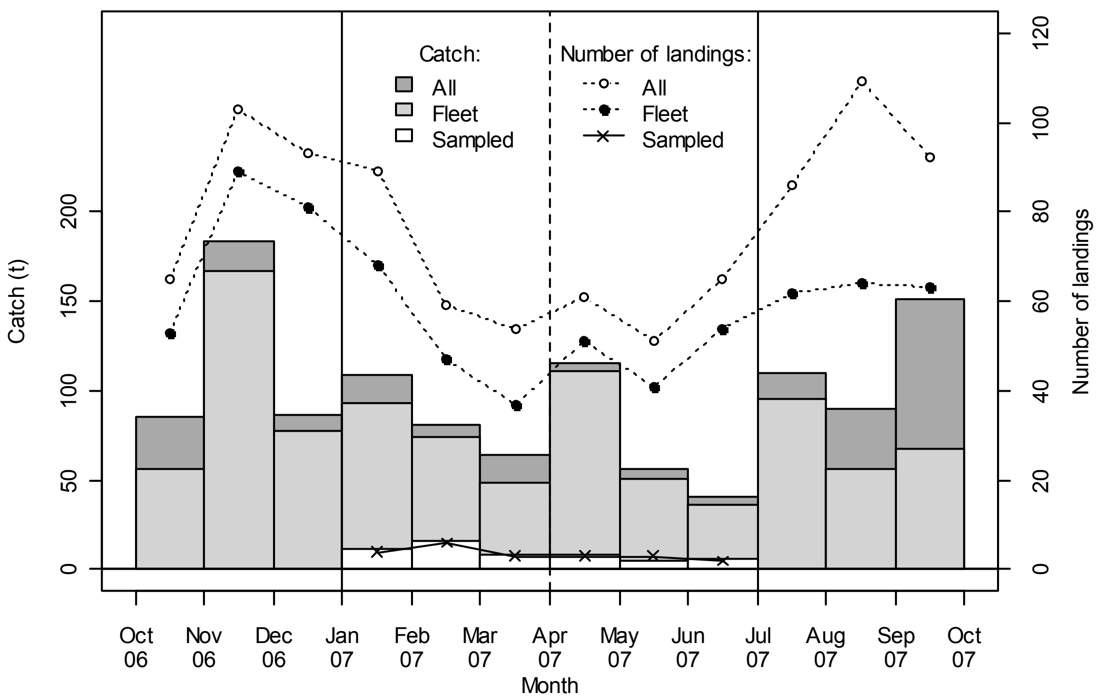
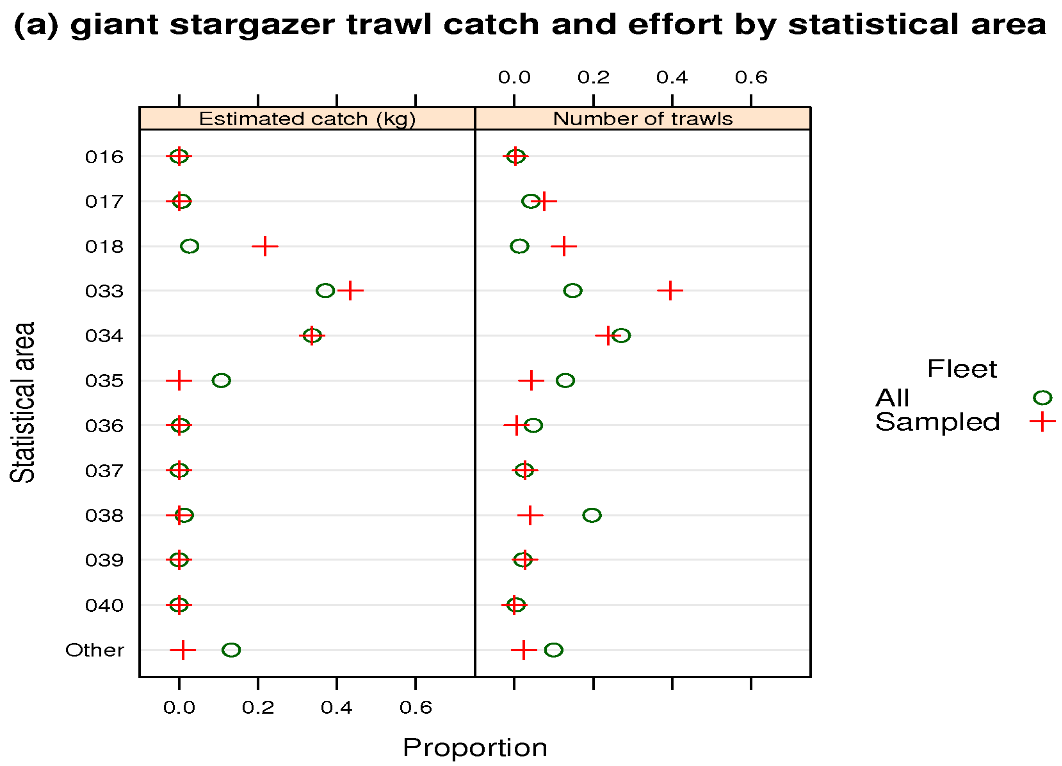


Figure 7: Summaries of fishing and sampling activity in STA 7(W) during the 2006–07 fishing year. Histograms of the total reported landed catch (dark-grey bars), total reported landed catch by all vessels in the BT-MIX fishery (light-grey bars) and the sampled BT-MIX catch (white bars) are overlaid on each plot. Numbers of landings by each fleet are also overlaid for comparison with the sampled landings. The sampling period (solid vertical lines) and approximate date of the WCSI trawl survey (March–April = 1 April; dashed vertical line) are also noted.



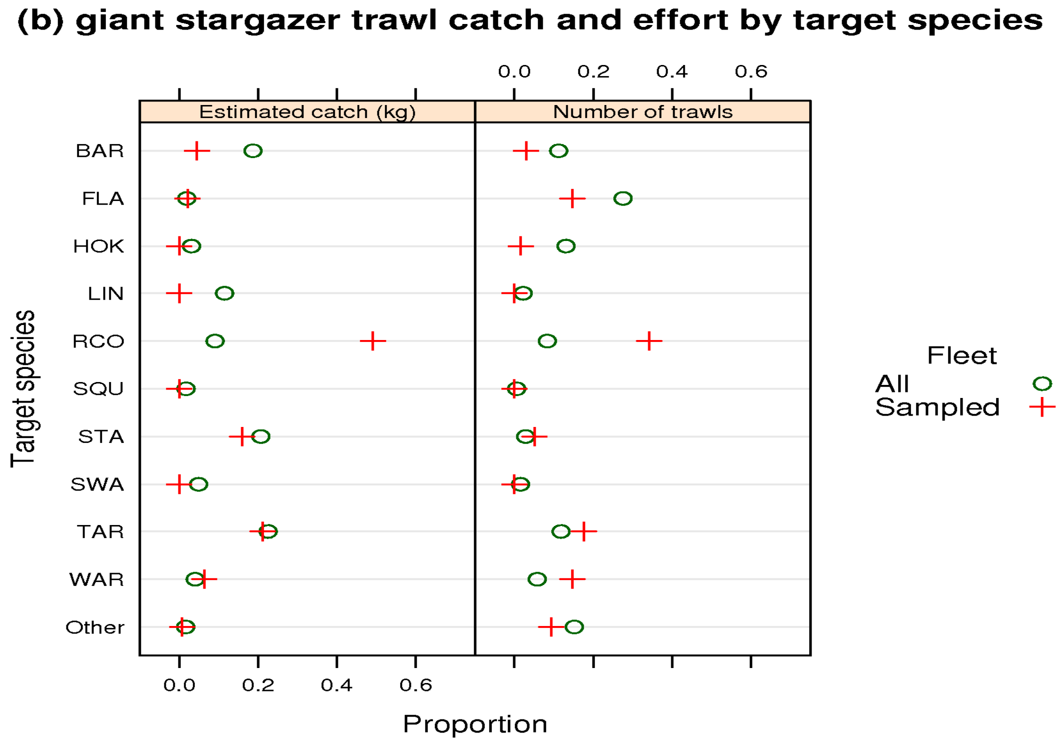


Figure 8: Comparing the sampled and fleet catch and effort by two covariates for the 2006–07. Proportions of the estimated stargazer catch and of the number of trawl shots by (a) statistical area and (b) target species for all vessels in the STA 7(W) trawl fleet are compared with the corresponding proportions by the sampled fleet sector.

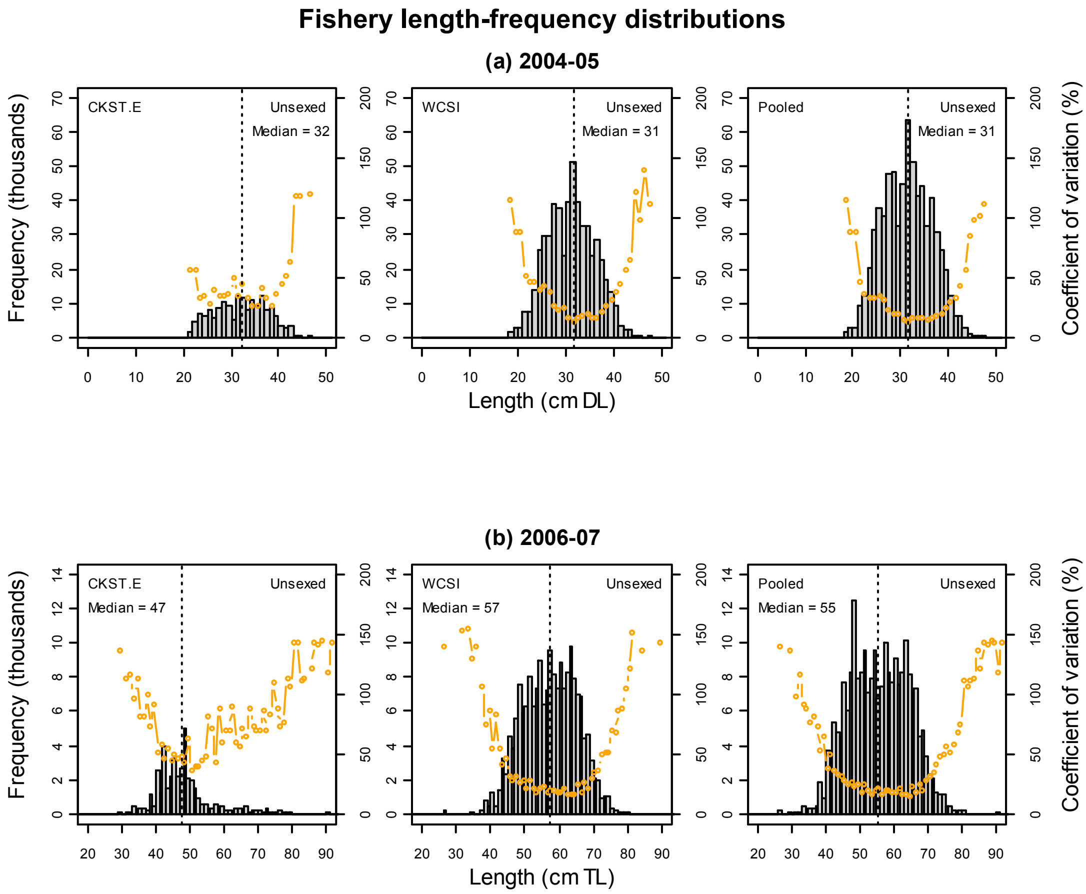


Figure 9: Length-frequency distributions of the commercial bottom-trawl catch in STA 7(W) by stratum during Feb–Jun 2005 (a), and Jan–Jun 2007 (b). CKST.E, Cook Strait East; WCSI, West Coast of the South Island, Tasman and Golden Bays and Cooks Strait West. Bootstrapped coefficients of variation for each length and age class are overlaid (orange lines). Note the differing y-axis limits between the two years and that length is given in cm *total* length in 2006–07.

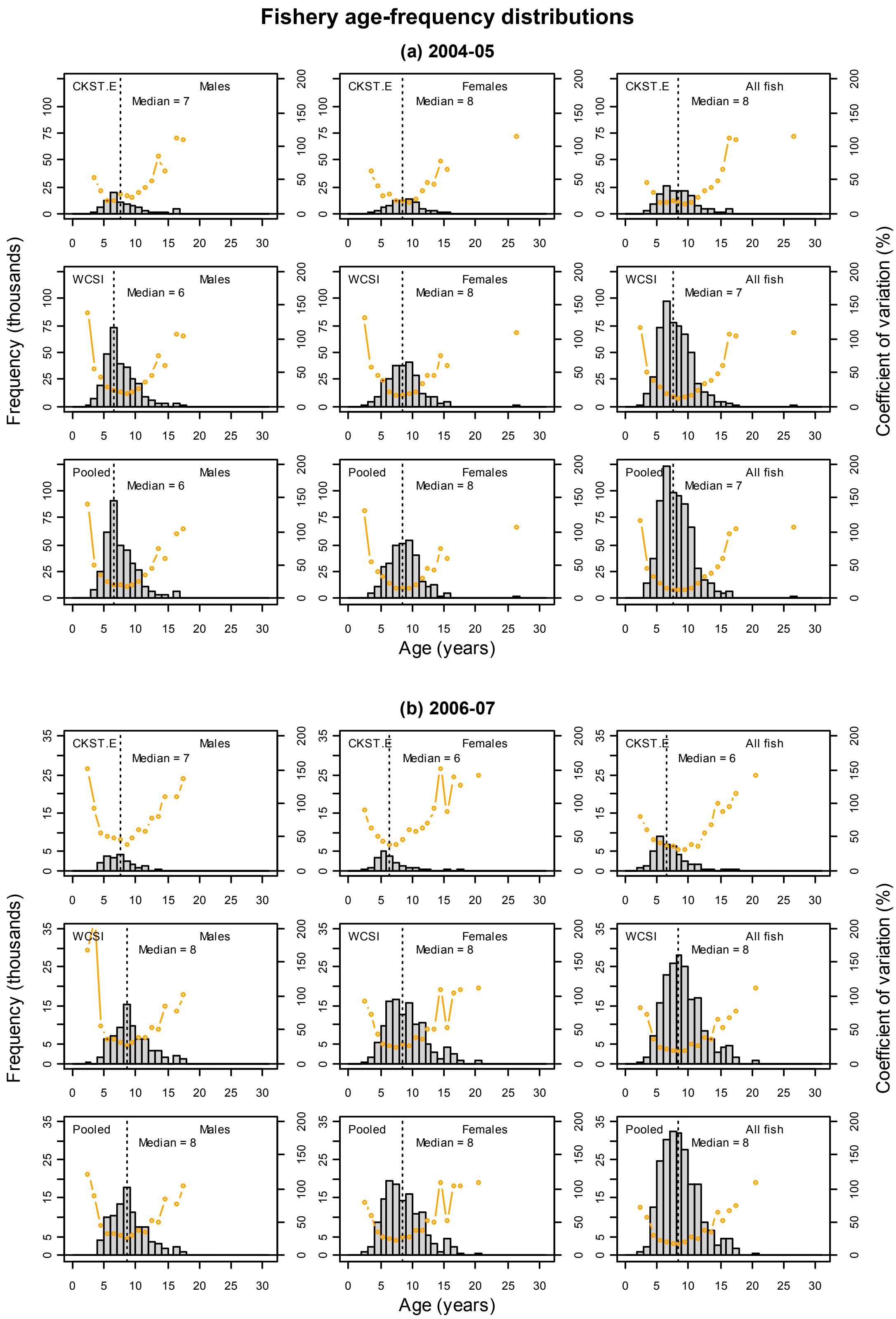


Figure 10: (a) age-frequency distributions of the commercial bottom-trawl catch in STA 7(W) during Feb–Jun 2005 by stratum. (b) age-frequency distributions of the commercial bottom-trawl catch in STA 7(W) during Jan–Jun 2007 by stratum. CKST.E, Cook Strait East; WCSI, West Coast of the South Island, Tasman and Golden Bays and Cooks Strait West. Bootstrapped coefficients of variation for each length and age class are overlaid (orange lines). Note the different y-axis limits between 2005 and 2007.

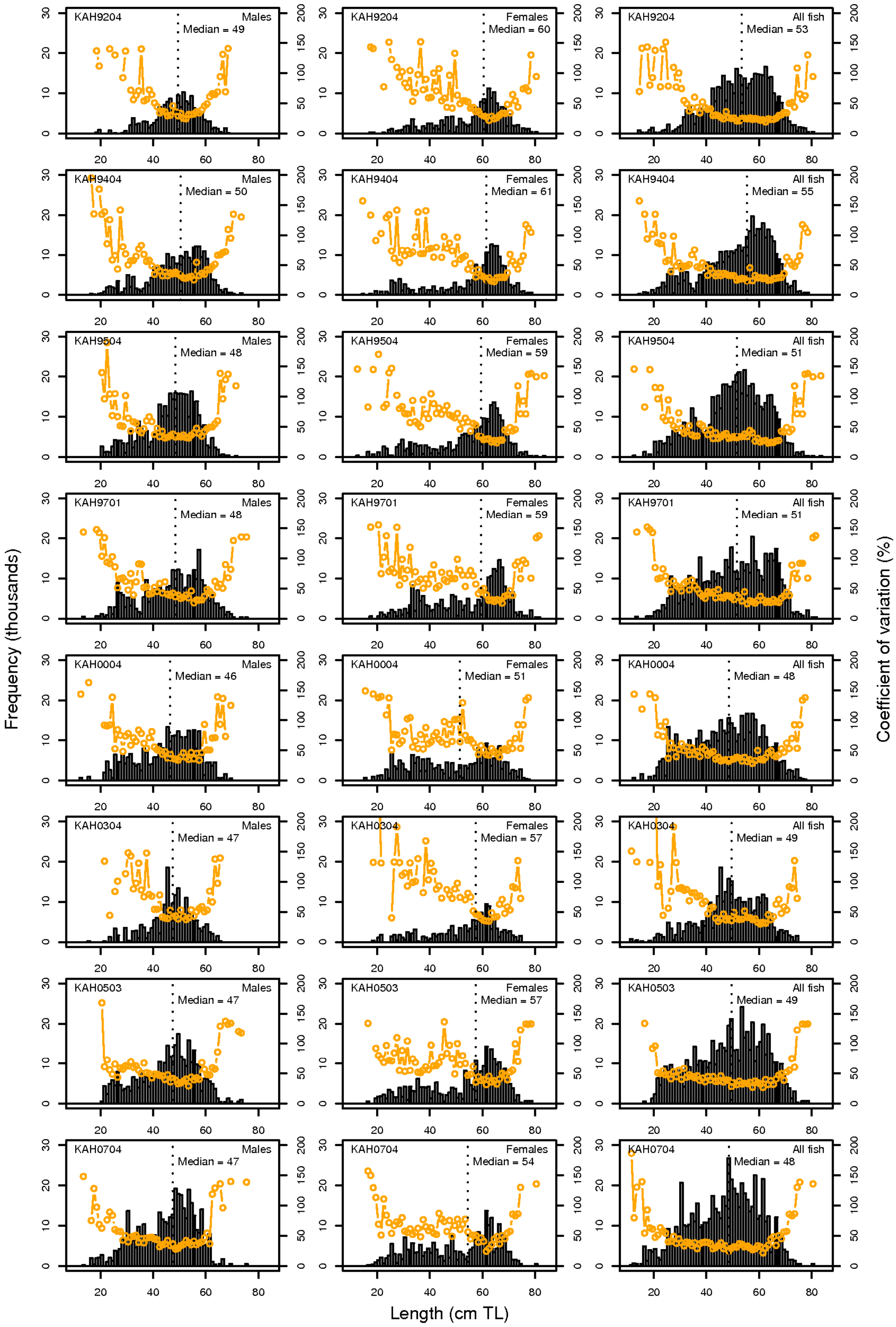


Figure 11: Length-frequency distributions for the WCSI survey series (1992–2007) by sex (males, females, and all fish) and survey pooled across all survey strata. Boot-strapped coefficients of variation for each length class are overlaid (orange lines). Fish median lengths (by sex and survey) are noted on each panel.

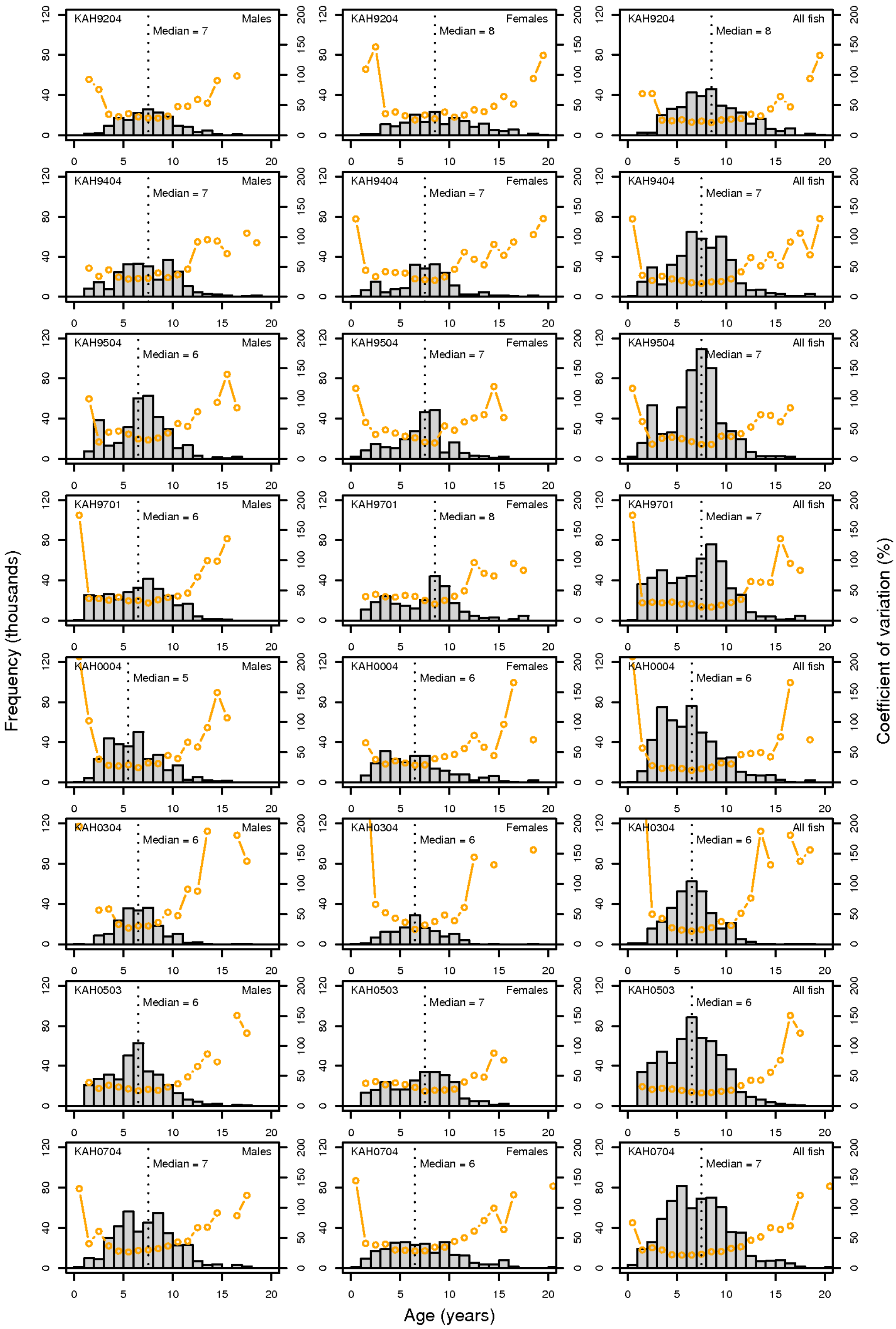


Figure 12: Age-frequency distributions for the WCSI survey series (1992–2005) by sex (males, females, and all fish) and survey pooled across all survey strata. Boot-strapped coefficients of variation for each length class are overlaid (orange lines). Fish median ages (by sex and survey) are noted on each panel.

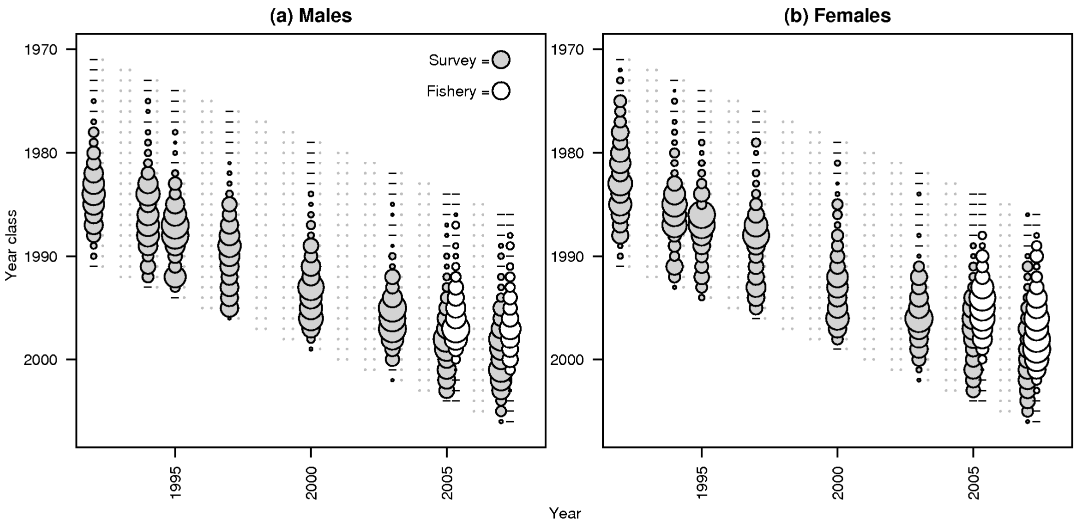


Figure 13: Visualising year-class progression. The age-frequency distributions of (a) males and (b) females in the WCSI survey catch are plotted by the (calendar) year during which each survey was carried out as year classes. Ages range from 0–15 years with 15 years being a plus-group containing all fish estimated to be 15 years of age or older in each survey. The areas of each circle are proportional to each age-frequency (year class). Dashes represent year classes for which no fish were observed during a particular survey.

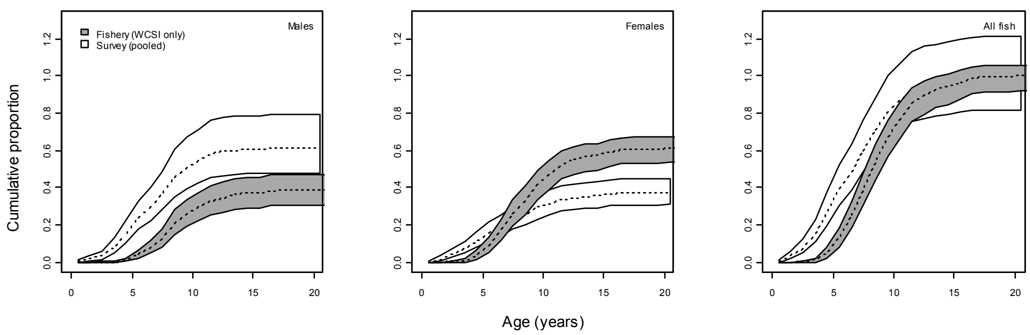


Figure 14: Cumulative proportions at age by sex for the WCSI subregion of the BT-MIX fishery and the 2007 survey (pooled across all survey strata). The dotted lines are the cumulative proportions at age. The surrounding regions are bootstrapped 95% confidence intervals about the cumulative proportion at age. The proportions have been scaled to sum to one in the WCSI fishery stratum and pooled across the survey strata.