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Tini a Tangaroa

Catch-at-age sampling of *Trachurus novaezelandiae* from JMA 1 in 2019–20 and 2020–21

New Zealand Fisheries Assessment Report 2022/37

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TABLE OF CONTENTS

EXECUTIVE SUMMARY		**1**
1.	**INTRODUCTION**	**2**
2.	**METHODS**	**3**
2.1	Catch sampling	3
2.2	Otolith preparation and ageing	3
2.3	Catch-at-age analysis	4
2.4	Length-weight relationship regression	4
2.5	Estimating growth rates	4
3.	**RESULTS**	**5**
3.1	Catch sampling	5
3.2	Catch-at-age and total mortality estimates	8
3.3	Revised length-weight relationship	9
3.4	Growth rate estimation	10
4.	**DISCUSSION**	**12**
5.	**ACKNOWLEDGEMENTS**	**13**
6.	**REFERENCES**	**13**

EXECUTIVE SUMMARY

Hartill, B.[1]; Middleton, D.A.J.[2]; Walsh, C.[3]; Spong, K.[1]; Ó Maolagáin, C.[1] (2022). Catch-at-age sampling of *Trachurus novaezelandiae* from JMA 1 in 2019–20 and 2020–21.

***New Zealand Fisheries Assessment Report 2022/37.* 16 p.**

The JMA 1 stock comprises three jack mackerel species, with *Trachurus novaezelandiae* accounting for most of the catch. Purse seiners account for 95% of the commercial catch taken from JMA 1. The jack mackerel catch landed by these vessels has been sampled annually since the early 1990s to determine the species and length composition of landed catches. This industry-funded catch sampling programme was extended during the 2019–20 and 2020–21 fishing years to collect catch-at-age data from sampled landings that included catches of *T. novaezelandiae*.

The resulting catch-at-age distributions for the two fishing years show a consistent pattern in year class strength, with a progression of strong and weak year classes seen between the two years. Chapman-Robson total mortality estimates calculated from these two age distributions, for a range of assumed ages at recruitment, are also similar between years and indicate that current levels of fishing mortality are sustainable, given the current natural mortality rate estimate. These mortality rate estimates do not necessarily represent those experienced by the population of *Trachurus novaezelandiae* throughout JMA 1, however, because they were derived almost exclusively from purse seine landings taken from the Bay of Plenty.

Age-length and length-weight data collected as part of this study were also used to review existing parameter estimates to estimate growth rates and the relationship between fish lengths and weights for *T. novaezelandiae*. There is very little difference between the existing von Bertalanffy growth curve and that derived from the parameter estimates provided by this study (L_∞ = 34.5, k = 0.34, t_0 = 0.1) which predicts a faster initial growth rate but a lower maximum size. However, the existing length-weight relationship for *T. novaezelandiae* produces very poor fits to the length-weight data collected during this study, and the authors recommend that the length-weight parameter estimates provided here (a = 0.0093, b = 3.10) are used instead, for future length-weight analyses.

The length-weight relationship parameter estimates provided by this study (a = 0.0093, b = 3.10) are therefore considered to be more reliable than the existing estimates.

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[3] Stock Monitoring Services Limited, New Zealand.

1. INTRODUCTION

New Zealand's second largest jack mackerel (*Trachurus* spp.) fishery occurs off the north-east coast of the North Island, where the Total Allowable Commercial Catch (TACC) for the JMA 1 stock has been 10 000 t since 1 October 1994. Over 95% of the commercial catch landed from this stock has been taken by purse seine vessels and almost all this catch is currently taken in the eastern Bay of Plenty where the seiners are based.

The status of the JMA 1 stock is essentially unknown because it has not been possible to derive a reliable index of abundance for any of the species comprising this stock. Purse seining is usually guided by spotter plane pilots, and the measures of effort reported by the vessels only partially describe the effort required to search for and capture a school of fish. Attempts have been made to derive a Sightings Per Unit Effort index from the data recorded by spotter plane pilots, but these indices suggested implausible rates of change in jack mackerel abundance (Fisheries New Zealand 2021).

Any assessment of the status of the JMA 1 stock is further complicated by the fact that purse seine landings can be composed of up to three species: *Trachurus novaezelandiae* and *T. declivis,* which are endemic to New Zealand, and *T. murphyi*, which has been caught in New Zealand waters since the mid-1980s.

Purse seine landings have been sampled annually since the early 1990s, to estimate the relative contribution of each species to the annual landed catch, which has been dominated by *T. novaezelandiae* throughout this period (Langley et al. 2016).

This study investigates the utility of the age composition of purse seine landings to reliably estimate fishing mortality of *T. novaezelandiae.* in JMA 1.

Overall research objective

The overall objective of Fisheries New Zealand research project JMA2018-01 was to determine the age structure of the *Trachurus novaezelandiae* purse seine catch in JMA 1

Objectives:

1. To conduct representative sampling to determine the sex, maturity state, length and age structure of the commercial catch of *T. novaezelandiae* in JMA 1 2019–20. The target coefficient of variation (CV) for the catch-at-age is 30% (mean weighted CV across all age classes).

2. To conduct representative sampling to determine the sex, maturity state, length and age structure of the commercial catch of *T. novaezelandiae* in JMA 1 2020–21. The target coefficient of variation (CV) for the catch-at-age is 30% (mean weighted CV across all age classes).

3. To estimate total and fishing mortality of *T. novaezelandiae* in JMA 1.

2. METHODS

2.1 Catch sampling

Catch-at-age sampling of *T. novaezelandiae* landings from the JMA 1 purse seine fishery was undertaken during the 2019–20 and 2020–21 fishing years, as an extension to an existing Fisheries Inshore New Zealand (FINZ) funded catch sampling programme. Up to 30 purse seine landings, containing at least 10 tonnes of jack mackerel, have been sampled annually as part of this FINZ catch sampling programme, to determine species and size composition. A subsample of *T. novaezelandiae* was collected for this study, from which otoliths were extracted.

Pelco factory staff have been trained to identify the three jack mackerel species landed by this fishery and to follow sampling protocols designed to determine the species and length composition of sampled landings. Purse seine vessels store their catch in up to eight holds and fish were sampled from any hold that contained jack mackerel to determine the species and length composition of the jack mackerel catch landed from that trip. Catch sampling staff took a fish bin sample from the top, middle, and bottom of each hold, to ensure that each hold was sampled in a representative manner.

The *T. novaezelandiae* catch-at-age subsamples used for this study were taken from the three fish bin samples taken from each hold. Target catch-at-age sample sizes were specified for each landing, which varied depending on the number of holds containing *T. novaezelandiae* (Table 1).

Table 1: Target number of *Trachurus novaezelandiae* to be subsampled for otolith collection from each hold sample.

Number of holds containing *T. novaezelandiae*	Number of fish per hold	Total sample size
1	12	12
2	12	24
3	8	24
4	6	24
5	5	25
6	4	24
7	4	28
8	4	32

Each fish was measured and placed in its own labelled bag before freezing. Otoliths were then extracted from these fish at a later date by a Fisheries New Zealand trained Fisheries Observer who also verified that all sampled fish were *T. novaezelandiae.*

2.2 Otolith preparation and ageing

The otoliths were prepared using the thin section method described by Stevens & Kalish (1998). Each otolith was marked across an intended sectioning plane that passed through the nucleus. Each marked otolith was then embedded in a disposable epoxy mould with three other otoliths, so that intended sectioning planes were at the same level. Once the resin hardened, a thin transverse section was cut out of each epoxy block with a Struers Accutom-2 low speed saw. One side of this section was then ground, polished, and mounted with the polished side facing down on a slide using 5-minute epoxy resin. After at least one hour, the material attached to each slide was ground down to a thickness of approximately 250 to 350 µm, and then briefly polished with 400 grit carborundum paper.

To improve clarity, a thin layer of immersion oil was brushed over each slide, which was read under transmitted light. Two readers initially interpreted the thin sectioned otoliths independently of each other, and then resolved any disagreements while viewing these otoliths at the same time. The two readers used were Caoimhghin Ó Maolagáin, who is a very experienced jack mackerel otolith reader, and Cameron Walsh (Stock Monitoring Services), who is one of New Zealand's most experienced otolith readers.

A forced margin was implemented to anticipate a priori the otolith margin type (wide, line, narrow) for the month in which the fish was sampled, to provide guidance when determining an otolith's age. The forced margin method reduces any misinterpretation of a fish's age that may arise when otoliths are collected over a prolonged period, given variable rates of otolith material deposition between fish. A 1 January birth date was initially assumed when the otoliths were aged, but subsequent analysis of the data suggests that a 1 October birth date is more appropriate for this fish stock, and the decimalised ages were therefore adjusted to account for this.

The precision of otolith readings was quantified by comparing initial readings provided by the two readers, and also by comparing initial reads with final agreed ages for each reader, as recommended by Campana et al. (1995). An Index of Average Percentage Error (IAPE, Beamish & Fournier 1981) statistic and mean weighted coefficient of variation (MWCV, Chang 1982) was calculated for each comparative test.

2.3 Catch-at-age analysis

A Random Age Frequency (RAF) approach was used to calculate proportion-at-age and bootstrap variance estimates, using NIWA's C++ software tool CALA (Catch-at-age and -length, Francis & Bian 2011). Landing-specific age samples were weighted together given the estimated number of fish in each landing, to produce proportion-at-age estimates for the purse seine fishery for each fishing year. A two-stage bootstrapping procedure was used to produce estimates of variance at age for these age distributions, with fish bootstrapped with replacement within bootstrapped landings, that were also resampled with replacement.

Chapman-Robson total mortality estimates (Chapman & Robson 1960) were then derived from these annual catch-at-age distributions for differing assumed ages at recruitment into the fishery, ranging from three to six years old. Estimates of uncertainty for these Chapman-Robson estimates were based on the bootstrapped age frequencies described above.

2.4 Length-weight relationship regression

A sample of 200 fish were measured to the nearest millimetre and weighed to the nearest gram during each quarter of the fishing year. This was done because previous analyses presented to the Northern Inshore Working Group on the 18th of April 2018 suggested that the length-weight parameters published in plenary reports since the 1990s for *T. novaezelandiae* were inaccurate, resulting in over-estimates of fish weight.

The statistical methods used to estimate length frequency parameters for this species followed those used by Walsh et al. (2022). Log-log linear regressions were initially performed on the full data set to identify outlier data points, defined as those more than 3 standardised deviations outside the predicted relationship. These outliers were then removed and log-log linear regressions were fitted to the remaining data. The a parameter for each linear model was corrected for estimation bias by taking the mean of logs before each linear model was exponentiated so that it could be plotted with the observed data in raw form.

2.5 Estimating growth rates

Ages were converted to decimalised ages for estimating grow rate. Non-linear regression was used to estimate von Bertalanffy growth parameters from these age data, by fishing year and for both fishing years combined. There were no fish younger than two years old in the landings sampled from the purse seine fishery in either fishing year. The Northern Inshore Working Group suggested that fish lengths for 0+ and 1+ age-class fish could be inferred from modes in the length distribution of *T. novaezelandiae* measured during the 2021 trawl survey of the Bay of Plenty (KAH2102, Parsons & Bian 2022). Purse seine sampled fish in the 2+ and 3+ age classes were ultimately dropped from the regression data set because a plot of fish ages against their lengths suggested that these age classes were only partially represented in the purse seine catch, i.e. the purse seine fishery selected larger fish from these age classes.

3. RESULTS

3.1 Catch sampling

Jack mackerel were landed by purse seine vessels throughout 2019–20 and 2020–21. Landings were not sampled at the beginning of the 2019–20 fishing year, however, because sampling protocols were still being developed at that time. Landings were also not sampled in late July and August 2021 because Covid-19 lockdown procedures prevented catch sampling at that time (Figure 1). Catch sampling in most other months was conducted in a broadly representative manner. Most of the jack mackerel purse seine landings that were sampled as part of the FINZ catch sampling programme contained *T. novaezelandiae* in both years. Catch-at-age data for *T. novaezelandiae* were therefore available from 22 landings sampled in 2019–20 and 19 landings sampled in 2020–21 (Table 2).

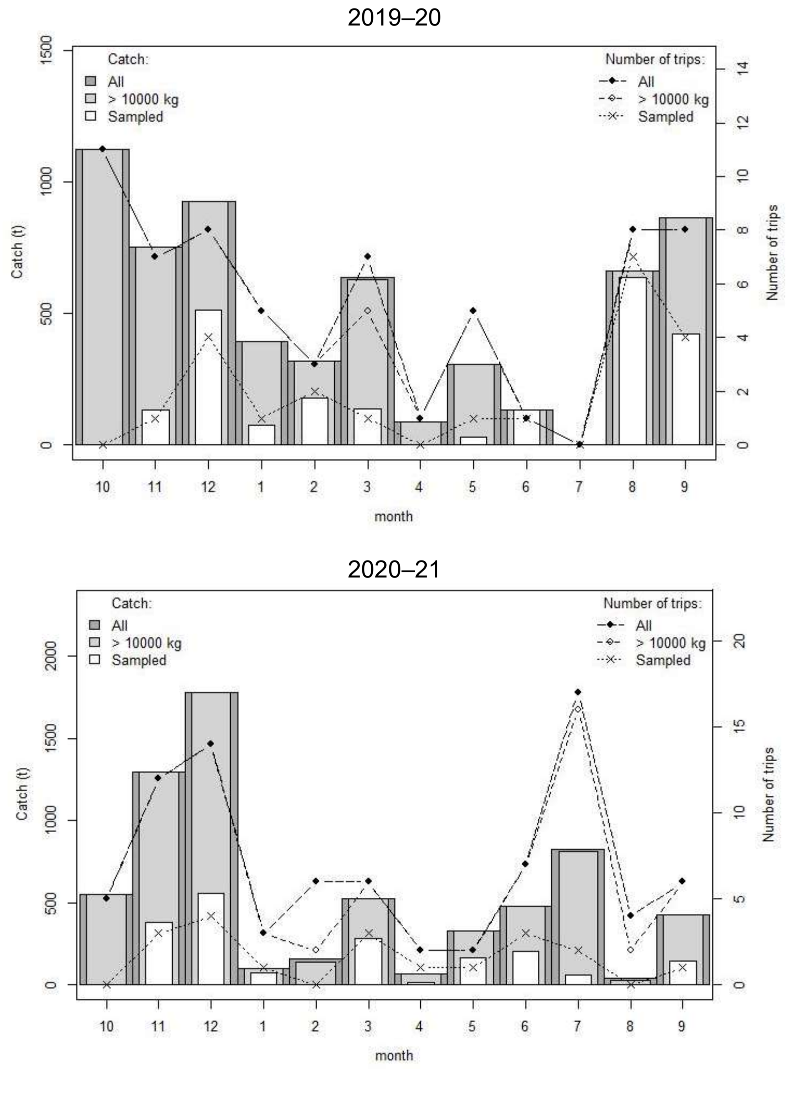

Figure 1: Representativeness of purse seine landings sampled from JMA 1 during the 2019–20 and 2020–21 fishing years, in terms of catch weight and number of landing events.

Table 2: Landing summary statistics by fishing year for purse seine trips where any of the three jack mackerel species (JMA) was landed and for sampled *Trachurus novaezelandiae* (JMN) trips.

	2019–20		2020–21	
	Weight (t)	Trips	Weight (t)	Trips
All trips landing JMA	6 204	64	6 563	84
Trips landing >10 t JMA	9 198	62	6 523	77
Sampled JMN trips	2 256	22	1 890	19

Almost all purse seine events targeting jack mackerel in 2019–20 and 2020–21 occurred in the Bay of Plenty. The spatial distribution of fishing events reported for trips that were sampled for *T. novaezelandiae* covered a similar extent (Figure 2).

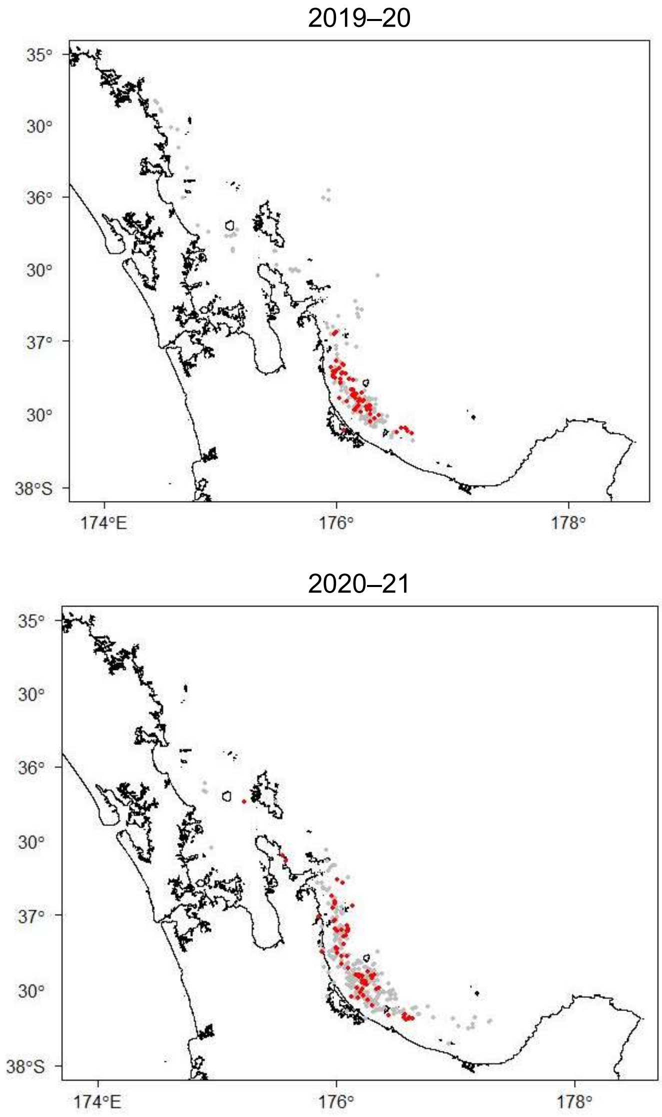

Figure 2: Spatial distribution of purse seine fishing events where jack mackerel (all three species combined) was targeted during the 2019–20 and 2020–21 fishing years. Grey dots denote the location of all fishing events and red dots denote the location of fishing events that were sampled for *Trachurus novaezelandiae*.

The length distributions of the species composition sample and of the fish that were subsampled for age in both years were unimodal, but the 2020–21 length distributions were broader, with a higher proportion of fish in the 25–30 cm length classes, indicating a strong recruiting age class in the second year (top panels of Figure 3). The sex ratios of the aged fish were broadly equal, across all age classes. The cumulative length distribution of the fish sampled for age in each year is almost identical to the cumulative length distribution of the much larger species composition sample that the otolithed fish were taken from, indicating representative subsampling for age (bottom panels of Figure 3).

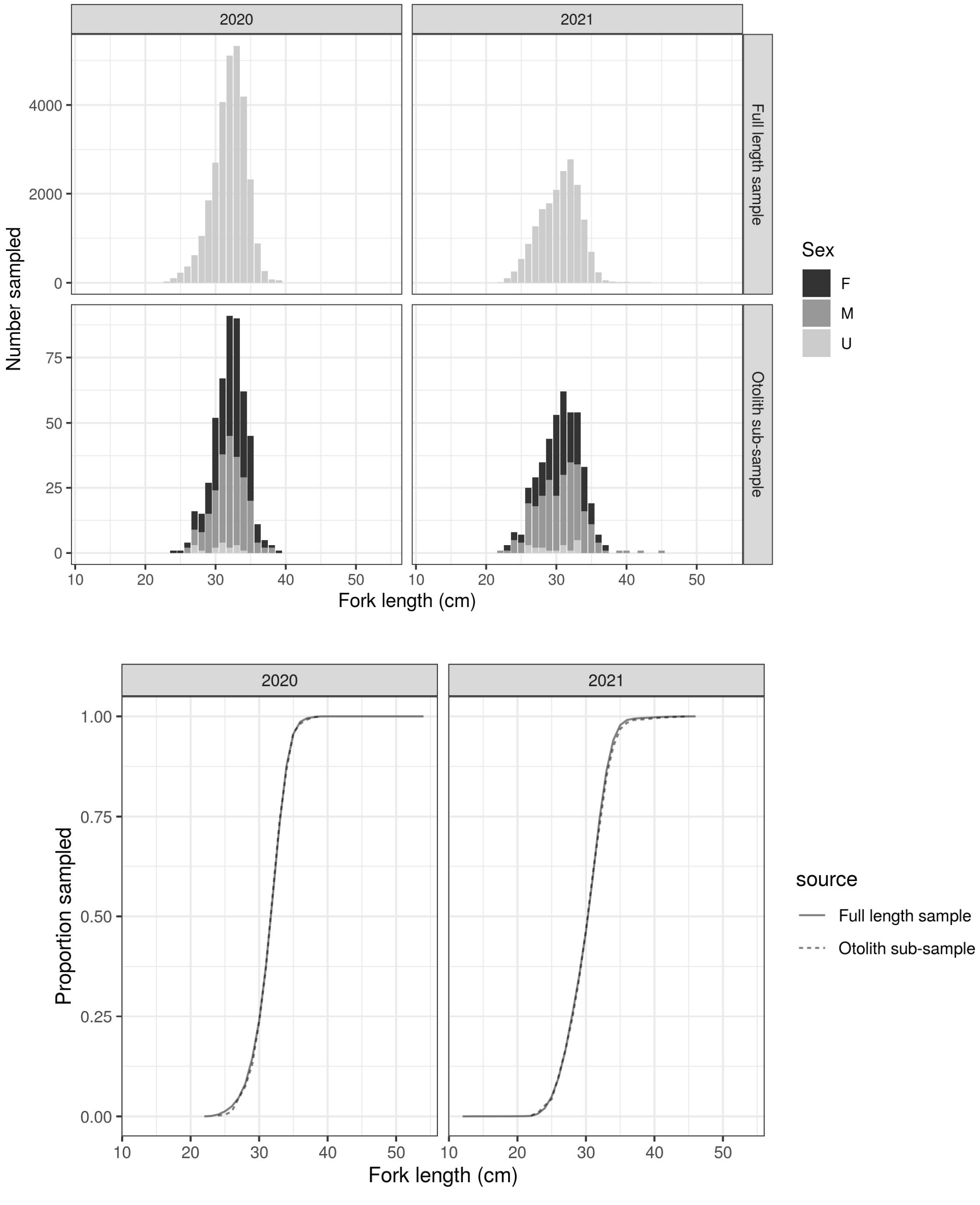

Figure 3: Comparison of the combined length composition of *Trachurus novaezelandiae* samples, collected as part of the FINZ species composition sampling programme, with the length composition of those fish that were subsampled for ageing by fishing year for 2019–20 and 2020–21. The upper and middle panels show the length frequency distributions for the combined length sample and otolith subsample taken in each fishing year. The bottom panels show a cumulative comparison of the two data sets.

3.2 Catch-at-age and total mortality estimates

The length and age compositions of the *T. novaezelandiae* catch landed by purse seiners in 2019–20 and 2020–21 were estimated with reasonable precision, with mean weighted coefficient of variation (mwcv) of 0.26 and 0.34 for length and 0.23 and 0.31 for age, respectively (Figure 4). There is clear evidence of year class progression between these consecutive age distributions. In particular, the weak 8+ year class and strong 9+ year classes in 2019–20, can be seen in the following year, as weak 9+ and strong 10+ year classes, respectively.

This consistency in year class strengths across the two fishing years is also evident when ratios are calculated of proportions-at-age for each year class in 2020–21, relative to their respective proportions-at-age in 2019–20 (Figure 5).

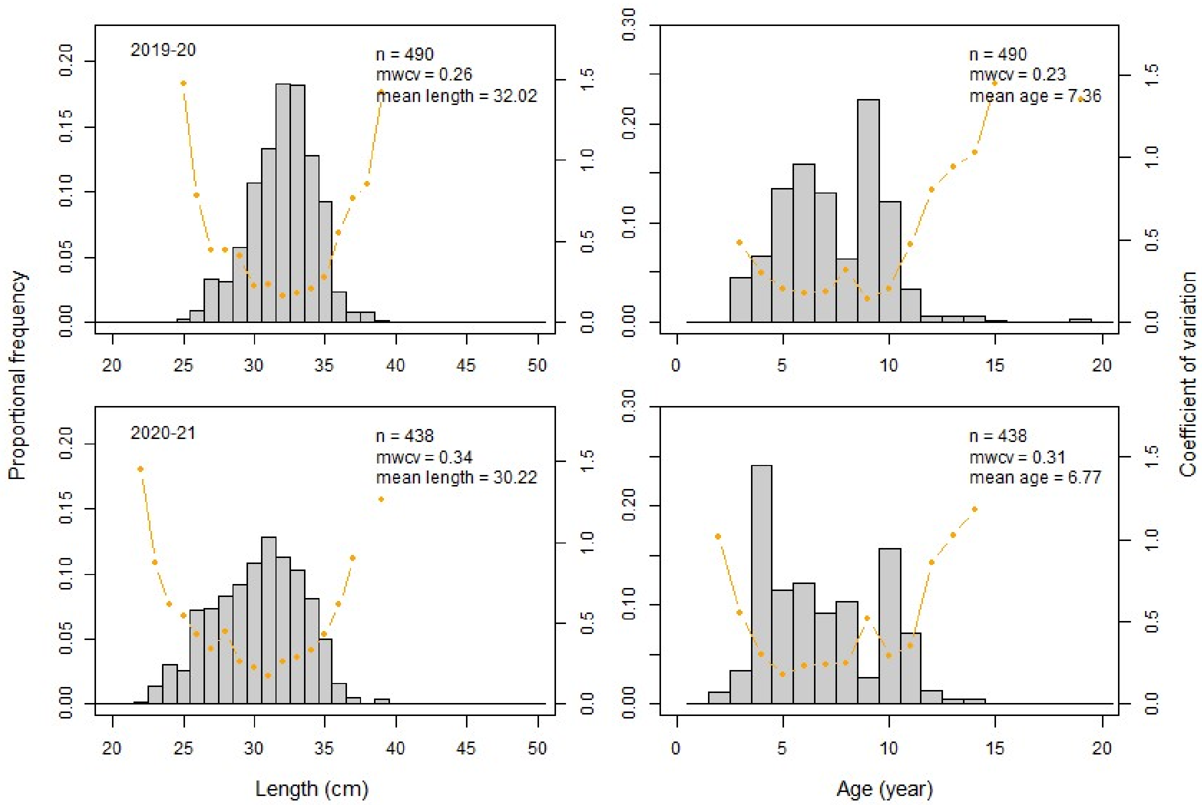

Figure 4: Length (left) and age (right) compositions of *Trachurus novaezelandiae* sampled from the JMA 1 purse seine fishery in 2019–20 and 2020–21. Orange lines denote CVs calculated for each length and age class, *n* indicates the number of fish sampled, and mwcv is the overall mean weighted coefficient of variation.

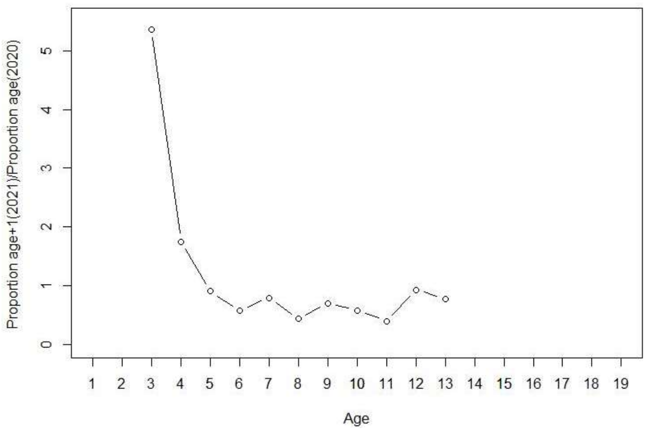

Figure 5: Ratio of proportions-at-age in 2020–21 relative to the proportions-at-age in 2019–20 for each cohort.

Chapman-Robson total mortality (*Z*) estimates calculated for a range of ages at recruitment into the fishery from the 2019–20 age distribution were broadly similar to corresponding estimates derived from the 2020–21 age distribution, despite the progression of a couple of very strong and weak year classes across the two years (Table 3). The year class strength ratio plot shown in Figure 5 suggests that *T. novaezelandiae* recruited to the Bay of Plenty purse seine fishery at around five years of age, which suggests that the most appropriate *Z* estimates were 0.302 for 2019–20 and 0.290 for 2020–21.

Table 3: Chapman-Robson total mortality estimates for alternative ages at full recruitment by fishing year. Bootstrap coefficients of variation are in parentheses.

Age at recruitment	2019–20	2020–21
3	0.206 (0.06)	0.232 (0.11)
4	0.247 (0.06)	0.290 (0.12)
5	0.302 (0.06)	0.290 (0.10)
6	0.356 (0.05)	0.331 (0.09)

3.3 Revised length-weight relationship

A linear log-log regression fitted to 1200 paired fish length and weight measurements collected during six of the eight fishing quarters in 2019–20 and 2020–21 identified 13 outlier data points that fell three or more standard deviations outside the predicted relationship (left hand panels of Figure 6). When a second regression was fitted to the remaining 1187 data points, there was a marked difference between the predicted length-weight relationship of *T. novaezelandiae* with that documented in the most recent annual plenary report (Fisheries New Zealand 2021), which overestimated the weight of all but two of the fish measured and weighed as part of this study. The length-weight relationship parameter estimates provided by this study (a = 0.0093, b = 3.10) are therefore considered to be more reliable than the existing estimates.

When separate length-weight relationships were fitted to the 200 fish measured and weighed in each quarter (excluding outliers identified by the initial regression of all data points), the predicted relationships were close to, but not the same as that predicted from all data combined (see Appendix 3). Much of the observed difference could be attributed to differences in the length ranges of the fish measured and weighed during each quarter.

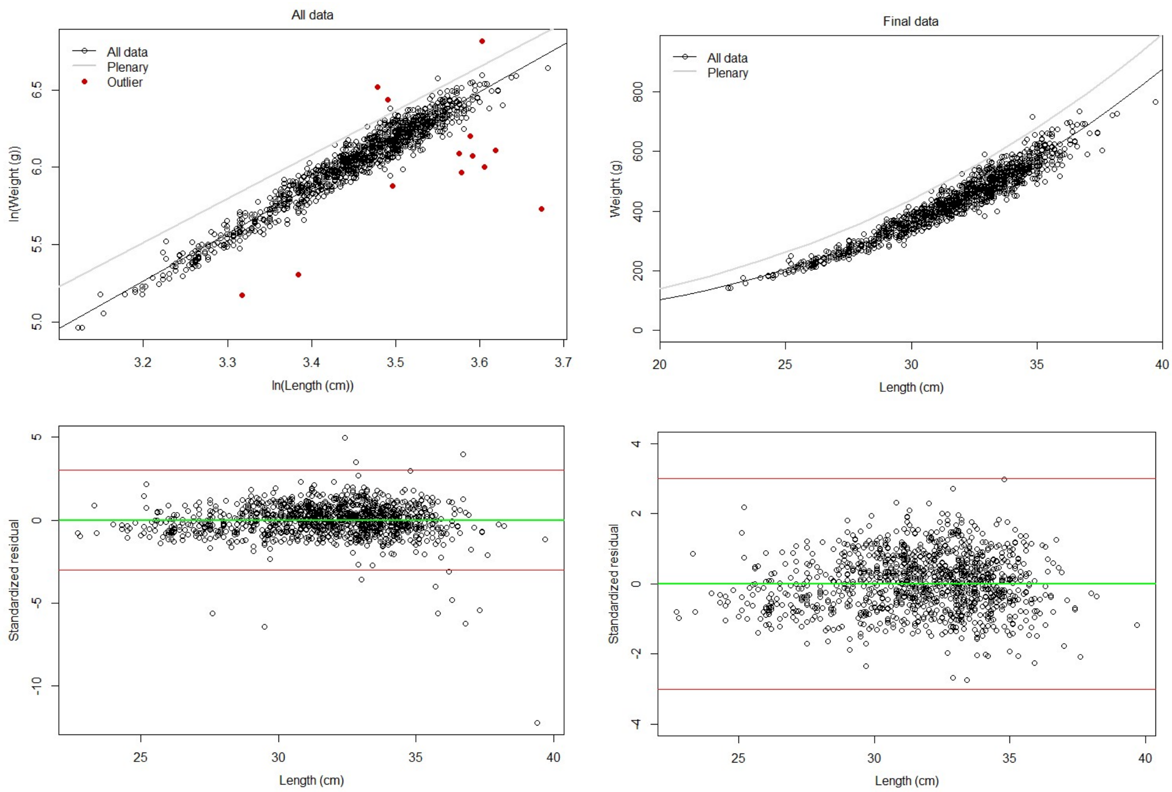

Figure 6: Length-weight relationships (top panels) and the distribution of residuals to those fits (bottom panels). The left panels show the fits to all data, which are plotted in log-log space, and the right panels show the subset of the data that fell within three standard deviations of the relationship fitted to all data.

3.4 Growth rate estimation

Two distinct length modes were evident in the 2021 Bay of Plenty trawl survey length frequency data that were used to infer age-length data for younger age classes that were not selected by the purse seine fleet (Figure 7). These two length modes were attributed to the 0+ and 1+ age classes. The fit to these two age classes was poor if a 1 January birthdate was assumed; however, this birth date was considered to be implausible because the trawl survey was conducted soon after that date, in early February. Significantly better fits to the data were achieved when all ages were decimalised to a 1 October birth date, which corresponded to the beginning of the prolonged six-month *T. novaezelandiae* spawning season (Denham Cook, Pelco, pers. comm.).

The von Bertalanffy growth curve estimated from these data was similar to that published in the 2021 plenary report (Fisheries New Zealand 2021). However, the current fit predicted faster initial growth, yet achieved a lower $L\infty$ for the older age classes compared with that presented in the plenary report (Figure 8).

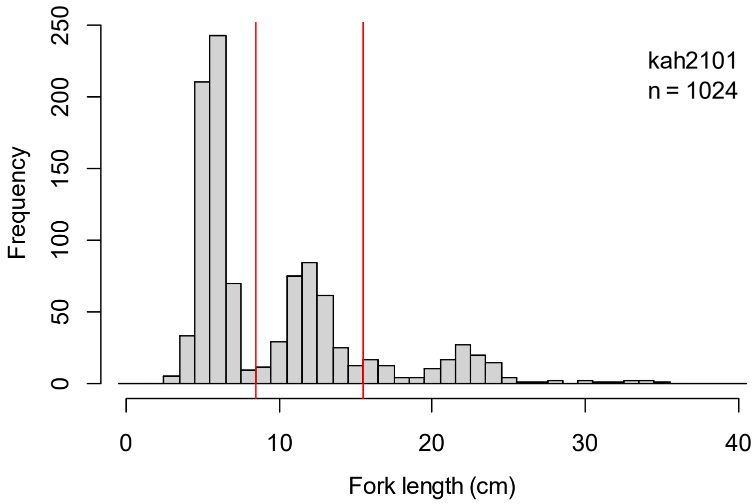

Figure 7: Length frequency distribution for *Trachurus novaezelandiae* caught during the 2021 Bay of Plenty trawl survey (KAH2101). Red vertical lines delineate the upper and lower length classes of the 1+ cohort.

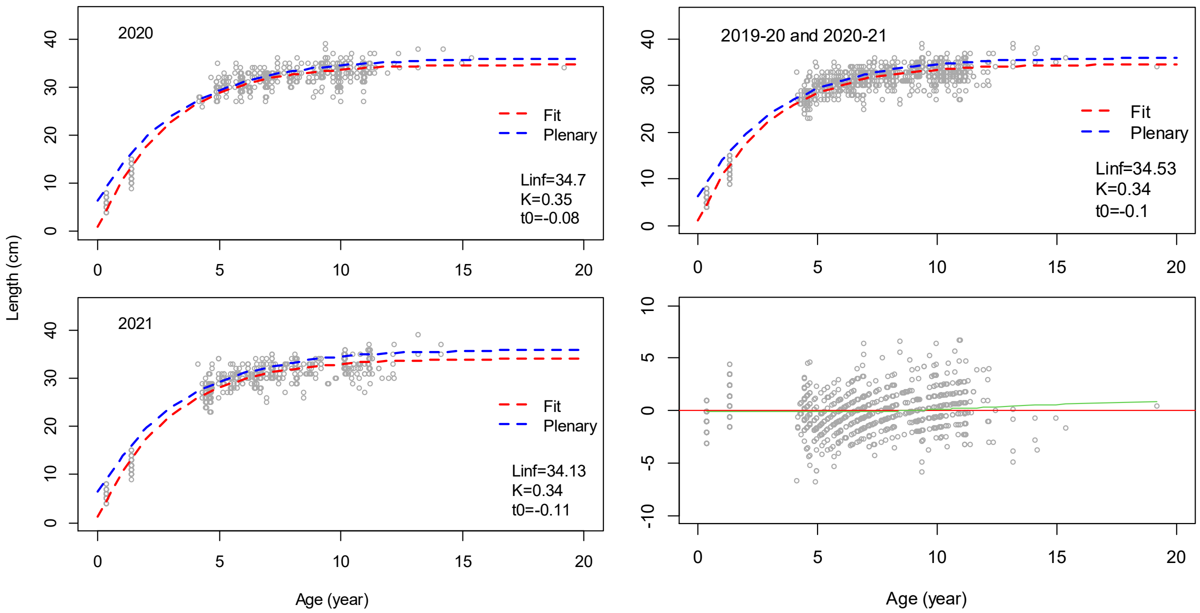

Figure 8: von Bertalanffy growth curves fitted to *Trachurus novaezelandiae* age-length data collected in 2019–20 and in 2020–21 (left panels) and both years combined (top right panel), with the distribution of residuals to the combined year fit (bottom right panel). Each regressed data set was augmented by age-at-length data for the 0+ and 1+ cohorts inferred from the 2021 Bay of Plenty trawl survey (KAH2101) (see Figure 7).

4. DISCUSSION

Any assessment of the status of the JMA 1 fish stock is problematic because the relative abundance of the three jack mackerel species that comprise the stock will vary over time (Langley et al. 2016), Regardless, there is no way of deriving a viable index of abundance from purse seine catch effort or aerial sightings data (Fisheries New Zealand 2021). Purse seine landings have been sampled to characterise the species and length composition of the jack mackerel catch since the early 1990s (Langley et al. 2016), but the status of the JMA 1 stock has not been inferred from these data. One way this catch sampling programme could be used to monitor the status of the JMA 1 stock is to collect additional catch-at-age data from the sampled landings, so that fishing mortality rates can be estimated and monitored over time, as trialled here. The ongoing species composition catch sampling programme provides both a cost effective and essential platform for this monitoring approach, because accurate species identification is a prerequisite for such work.

The majority of the purse seine catch landed from JMA 1 since the early 2000s has been identified as *T. novaezelandiae*, although landings of *T. declivis* have increased to 34–46% of the catch landed by purse seiners since 2017–18 (Fisheries New Zealand 2021). Catch-at-age sampling of *T. novaezelandiae* from the JMA 1 purse seine fishery was last undertaken between 1994–95 and 1996–97, but the resulting annual age distributions bore little resemblance to each other, with no evidence of any progression of strong or weak year classes (Taylor 1998). The discrepancy between these age distributions may have been partly due to the small number of fish aged in the first two years (250 in 1994–95 and 153 in 1995–96). There may have been other contributing factors which have not been documented, such as the number of landings sampled, and where the sampled fishing events occurred, because purse seining in JMA 1 was far more widespread historically.

There is, however, a strong resemblance between the age distributions of the purse seine catches sampled as part of this study, with clear evidence of the progression of strong and week year classes between the two years. This degree of consistency is not surprising given the number of landings sampled (22 and 19, respectively), the number of fish aged in each year (490 and 438), and the limited spatial extent of purse seine fishing in the Bay of Plenty in each fishing year.

The consistency of the age distributions and the similar magnitude of the Chapman-Robson total mortality estimates between years suggests that the methods used in this study could be used to monitor the status of the exploited *T. novaezelandiae* component of the JMA 1 stock. Further catch sampling in the future is still required, however, to demonstrate that the consistency of the results obtained in 2019–20 and 2020–21 was not simply fortuitous. Since all the sampled *T. novaezelandiae* came from the Bay of Plenty, sampling from further afield is also required to determine whether the age composition of the purse seine catch was representative of the entire population of this species in JMA 1. Catch-at-age sampling of *T. declivis* should also be considered if this secondary species continues to account for a significant component of the purse seine catch landed from JMA 1.

The age at which *T. novaezelandiae* recruit to the purse seine fishery appears to be somewhere around five or six years old, but regardless of the assumed age at recruitment, the Chapman-Robson total mortality estimates provided by this study suggest that current levels of fishing mortality are sustainable, given the assumed rate of natural mortality (0.18; Fisheries New Zealand 2021). These total mortality rate estimates may even be overestimates for the wider *T. novaezelandiae* population in JMA 1 because almost all the purse seine jack mackerel catch landed from this stock is currently taken within the eastern Bay of Plenty, with relatively little fishing pressure occurring elsewhere.

This study has also provided an opportunity to review the length-weight relationship for *T. novaezelandiae* and the growth rate parameter estimates for this species, which are currently based on data collected from the JMA 7 fishery. The existing length-weight relationship for *T. novaezelandiae* provided by Horn (1991) produced very poor fits to the length-weight data collected during this study, and the authors recommend that the parameters provided here are used instead for future length-weight analysis. The von Bertalanffy growth curve fitted to the age-length data collected during this study is very similar to that based on the parameters documented for *T. novaezelandiae* by Horn (1991), but the parameter values provided in this report may be more appropriate for this fishery, because growth rates change over time and will differ by fish stock.

5. ACKNOWLEDGEMENTS

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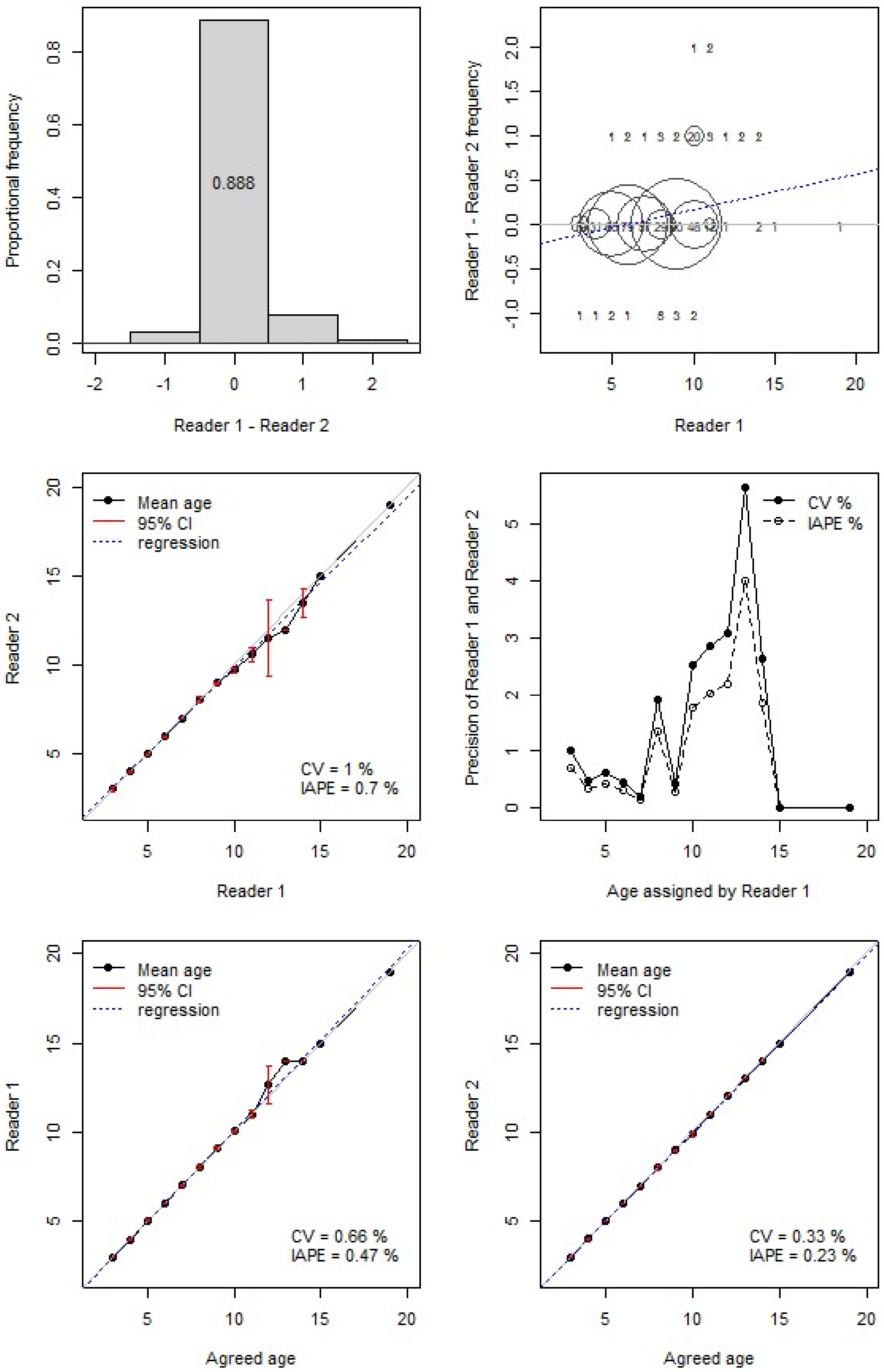
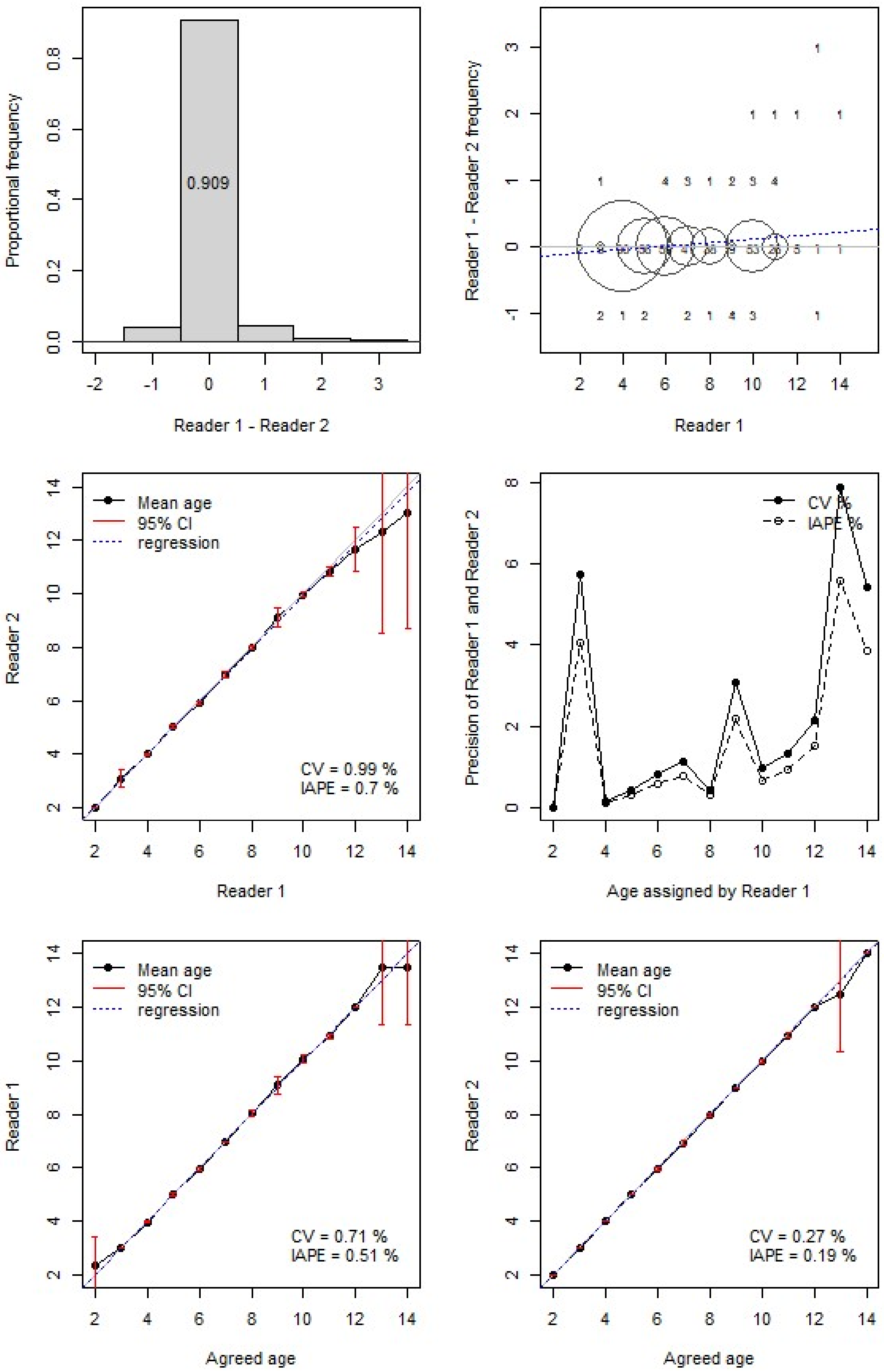
APPENDIX 1: Age bias diagnostic plots for *Trachurus novaezelandiae* sampled from JMA 1 in 2019–20 (n = 490).



APPENDIX 2: Age bias diagnostic plots for *Trachurus novaezelandiae* sampled from JMA 1 in 2020–21 (n = 438).



APPENDIX 3: Length-weight relationships fitted to quarterly length-weight data and residual plots for *Trachurus novaezelandiae.*