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Spatial and temporal changes in ling (*Genypterus blacodes*) population structure on the Chatham Rise and off West Coast South Island

New Zealand Fisheries Assessment Report 2015/03

P.L. Horn

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EXECUTIVE SUMMARY

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Trends in the sex ratio of ling sampled from the Chatham Rise longline fishery between 1993 and 2013 were examined. The population sex ratio of Chatham Rise ling, both juvenile and adult, as indicated by the summer research trawl survey series, was skewed consistently towards males. There was a marked decline throughout the 1990s in the numbers of large female ling on Chatham Rise and this probably contributed to the steep decline in CPUE apparent in the first seven to nine years of the series. The preferred selectivity of the line fishery for large (and, therefore, often female) fish probably resulted in an increase in the proportion of males in the catch over time as the large females were fished down. However, it is unlikely that the increase and then decrease in proportions of males in the sample data could be attributed to this alone. Seasonal or spatial effects are also unlikely to be responsible. Spawning by ling on Chatham Rise occurs primarily from August to September, strongly concentrated on a ground west of Chatham Islands but with concurrent activity around Mernoo Bank.

The likely causal factors investigated did not appear to be responsible for the trends in the proportion of male ling from the winter WCSI trawl fishery targeting hoki. Factors included different levels of fishing in the three strata used to scale sampled length data up to the length distribution for the fishery each year, and differences between years in the temporal and depth distribution of samples.

1. INTRODUCTION

The specific objective of Ministry for Primary Industries (MPI) Project DEE2010-02LINC was to carry out an assessment of the Bounty Plateau ling stock (LIN 6B). However, following consultations with MPI, it was concluded that there was likely to be marginal benefit in assessing the Bounty ling stock because:

- The recent trend of reduced ling longlining in New Zealand waters, and the distance of the Bounty Plateau from mainland New Zealand, meant that the stock was being fished at much lower levels that it had been from 1992–2004.
- There was no separate TACC for this stock (which is part of LIN 6), and extractions from it were likely to be regulated by the degree of willingness of companies to send line vessels there, and the catch rates they achieved when they fished there.
- It was not possible to extend the relative abundance series (CPUE) used in the previous assessment because target longline fishing in the area in recent years has been sporadic and conducted by only one vessel.

Consequently, the resources budgeted for this assessment were used to investigate some problems that had been highlighted in previous ling stock assessments. It was thought that the resolution of these problems (described below) would benefit future assessments of ling stocks.

The stock status of ling on the Chatham Rise (LIN 3&4) is believed to be healthy, but with relatively wide bounds (Horn et al. 2013). There was little contrast in the main abundance series (the summer trawl survey series), but the secondary abundance series (line fishery CPUE) exhibited a marked initial decline. The difference between the two abundance indices was not resolved; it is possible that the longline CPUE series may be inappropriate as an index of relative abundance. There were also concerns about trends in sex ratios in the composition data from the longline fishery. In addition, estimated biomass was very sensitive to relatively small changes in the instantaneous natural mortality rate (M).

An assessment of the West Coast South Island (WCSI) ling stock (LIN 7WC) was also sensitive to M, and when M was estimated in the model it was necessary to use a new informed prior to preclude an unreasonably high value (Dunn et al. 2013). A model with sex in the partition provided poor fits to the proportion-at-age data; trends over time in sex ratio were apparent in the trawl fishery data.

The most recent assessment of the Cook Strait ling stock (LIN 7CK) changed to using a multinomial error structure (rather than lognormal) for the proportion-at-age data (Dunn et al. 2013). This change resulted in the simultaneous estimation of absolute virgin biomass and M being unsuccessful. Models with fixed M values could be run successfully, but they did not provide good fits to the declining CPUE series (the only available index of relative abundance).

Issues with the assessments therefore fall into two broad categories:

- those relating to the estimation of M, and the sensitivity of the models to small changes in this parameter,
- those relating to trends in sex ratios in composition data.

There were systematic changes in the sex ratio of ling in the sampled commercial catch over time in fisheries from at least two stocks (the Chatham Rise longline fishery, and the WCSI trawl fishery). This could be a consequence of: a) fishing activity exploiting one sex more than the other (so changing population sex ratios); b) differential distribution of sexes in space/time (associated with a change in fishing patterns); c) sex ratios of new recruits being determined by environmental or biological factors (that have changed over time); d) changes in sampling protocols over time.

The work presented below analyses the data from the series of summer Chatham Rise trawl surveys since 1992 to indicate whether there is evidence that factors a–c above occurred on the Chatham Rise. If the causes of the changes in sex ratios cannot be established, then it would be desirable to determine how best the trended data might be incorporated in the model (e.g., as unsexed age or length data, but still in a sexed model). In the course of this work, data on the distribution of spawning ling in time and space on the Chatham Rise were also examined, and the results are presented in Appendix A.

The analysis of the Chatham Rise survey data was completed in tandem with a spatial and temporal analysis of commercial catch to look for any systematic changes in fishing patterns over time. This analysis could indicate whether the Chatham Rise longline fishery CPUE series that is currently used in the stock assessment is appropriate as an index of abundance.

Investigations into why the assessment models are often so sensitive to variations in *M*, and what is the best method to estimate *M* in the model will be presented elsewhere.

2. CHATHAM RISE

2.1 The problems

In the most recent assessment of the Chatham Rise ling stock (Horn et al. 2013) the proportion-at-age samples from the trawl survey were persistently skewed slightly towards males, and those from the trawl fishery slightly towards females, and both of these were adequately fitted by the model. However, there was a strong temporal trend in sex ratio in the composition data from the longline fishery, and this could not be fitted by any model run (Figure 1). The longline composition data for 1995–2001 were from length samples collected by the SeaFIC ling longline logbook programme (Langley 2001), and were predominantly female, whilst those from 2002–2009 were from age samples collected by MPI Observers, and were predominantly male.

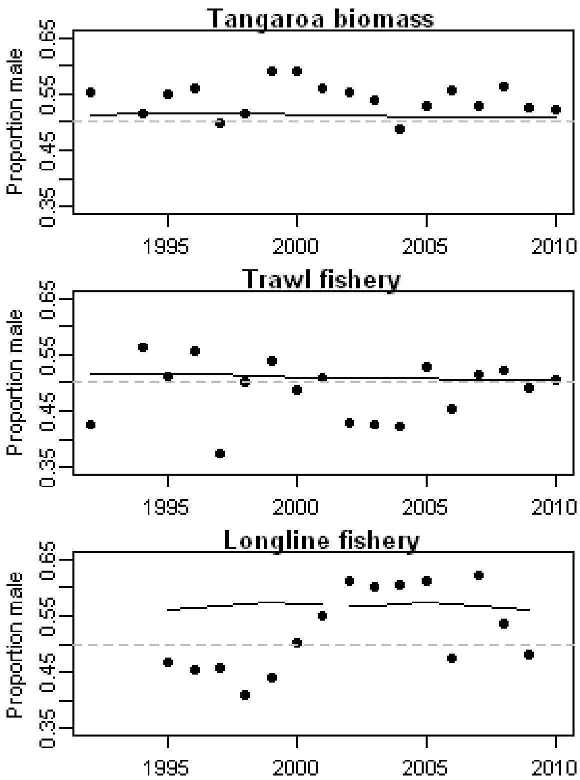

Figure 1: Model fit (lines) to the sex ratio in the ling composition data for the trawl (*Tangaroa*) survey, trawl fishery, and longline fishery (points); figure 3 from Horn et al. (2013).

In the assessment modelling, fits to the abundance indices were given primacy. However, the trend shown by the two abundance indices was different, with the longline CPUE declining during the 1990s, and the trawl survey essentially flat (Figure 2). An attempt was made to fit both abundance indices in the same model run. This seemed reasonable, because the trawl survey caught ling at a younger age than the longline fishery so, in principle, a decline in predominantly older ling could result in the different observed trends. However, attempts to fit both indices in the same model were not successful (Figure 2). Although the fit to the trawl survey was within all of the 95% credible intervals, there were still strong patterns in the residuals, with the first 7 points all below the fitted line.

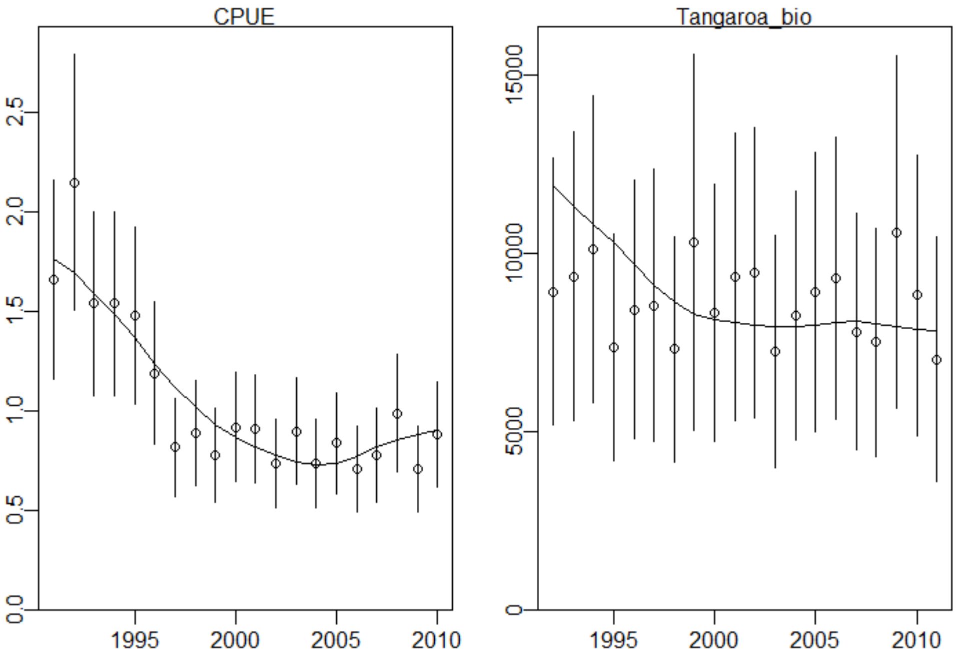

Figure 2: Model fits to the abundance indices for longline CPUE (CPUE) and trawl survey (Tangaroa_bio); figure 6 from Horn et al. (2013).

2.2 Trawl survey data

A trawl survey of depths 200–800 m on the Chatham Rise was conducted annually in January from 1992 to 2014 (Stevens et al. 2014). In some years, strata deeper than 800 m were surveyed, but the following analyses used ling data from the core strata only (200–800 m). Scaled length-frequency distributions of ling were created for the entire core survey area, and for the following three sub-areas:

- Western Rise – west of longitude 176°E, and including the Veryan Bank
- Central Rise – between longitudes 176°E and 180°, excluding the Veryan Bank
- Eastern Rise – east of longitude 180°

The resulting length-frequency distributions were examined for trends in fish size and sex ratio over time. For the purposes of this analysis, juveniles of both sexes were defined as fish shorter than 60 cm, large males were those 90 cm or longer, and large females were 105 cm or longer. Proportions of large fish were estimated using post-juvenile specimens only, i.e., the proportion of large males is the number of males 90 cm or longer divided by the number 60 cm or longer.

For the entire core survey area, the sex ratio was consistently skewed towards males (average 54%), and the number of juvenile males was also generally greater than for females (average 54%) (Figure

3). There were no apparent trends over time in the sex ratio, or in the number of juvenile males. Trends over time were apparent in the numbers of large males and females, however (Figure 3). The proportion of large males was quite variable over time, but did exhibit a slight overall decline from just over 30% to just under 30% in the 23 years of surveys. Strong trends were apparent in the proportion of large females. There was a marked drop in the relative abundance of large females in the early 1990s, with a continuing decreasing trend through to 2006. Since then, proportions of large females generally increased, but were still markedly lower than the 1992–93 values.

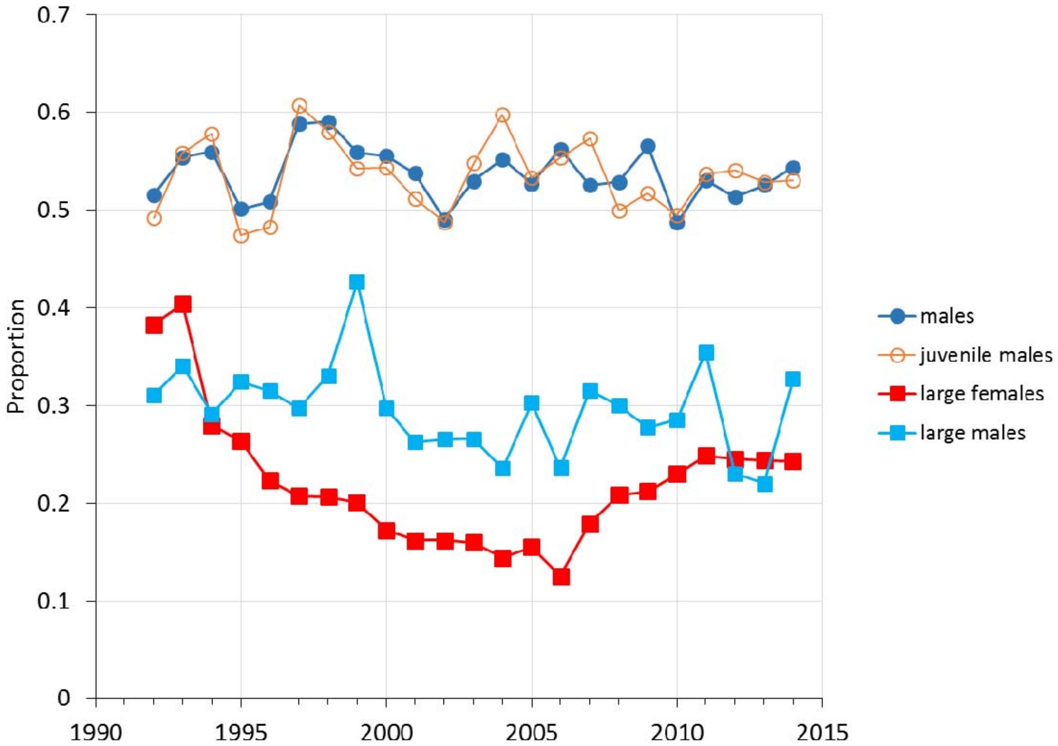

Figure 3: Proportions of all males, juvenile males, large males, and large females in the Chatham Rise ling population, over time, as determined from the research trawl survey series.

An examination of the same data by sub-area showed sex ratios and proportions of juveniles to be similarly skewed slightly towards males (Figure 4). The relative abundance of large females was generally similar in all areas, declining from 1992 to the mid 2000s, and subsequently increasing. However, the trend on the central Rise was flatter than at both the western and eastern areas. The proportion of large males was quite variable over time in all areas, but some differences between areas were apparent. The proportions were relatively constant in the central area, showed a slight but steady decline in the east, and had a trend similar to females (i.e., decline followed by increase) in the west.

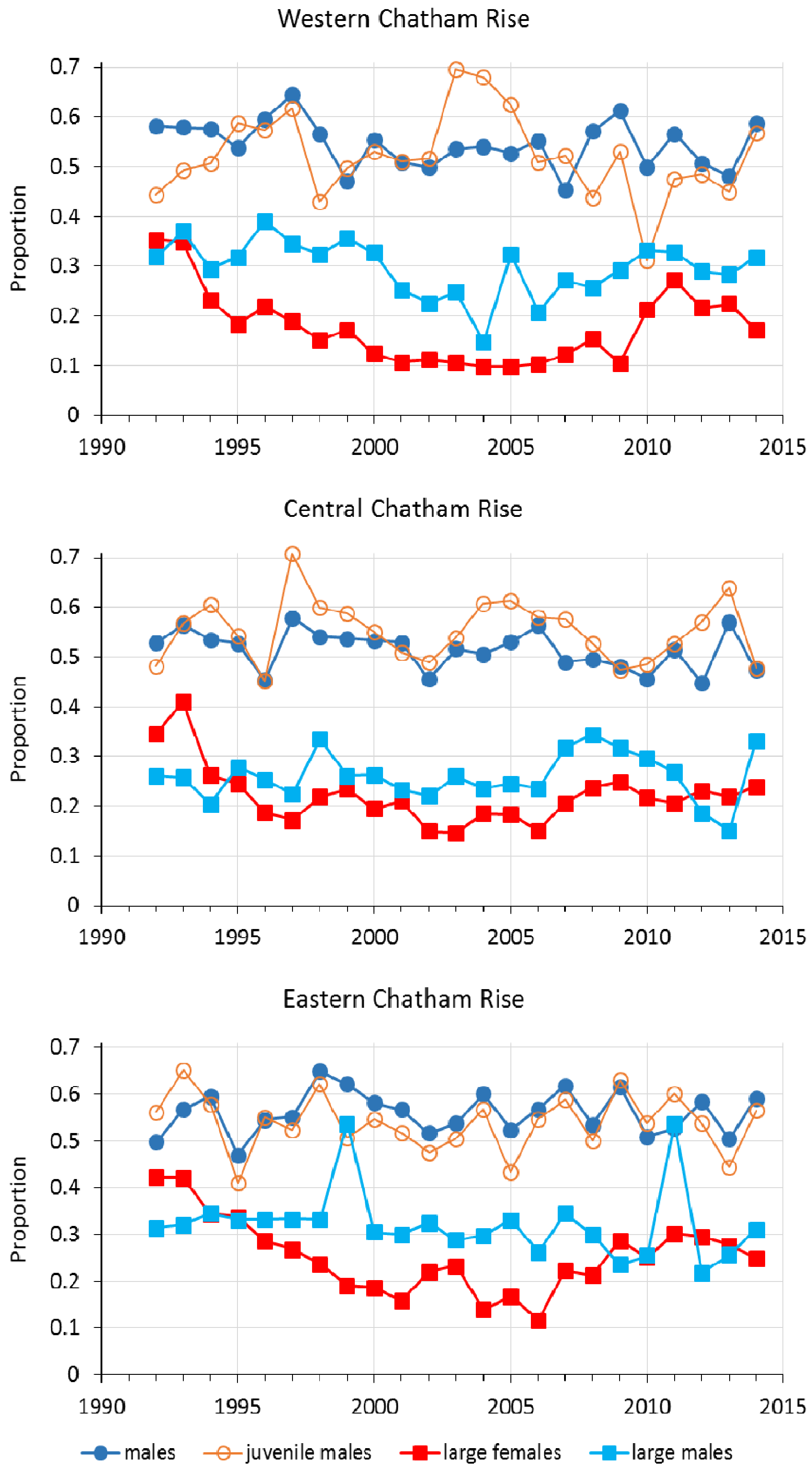

Figure 4: Proportions of all males, juvenile males, large males, and large females in the ling population in sub-areas Western, Central, and Eastern Chatham Rise, over time, as determined from the research trawl survey series.

The mean size of ling in the sampled population showed trends over time, and differences between areas (Figure 5). Mean size of both sexes declined to a minimum around 2000, and subsequently increased; this trend was very marked for females, but less so for males. Fish of both sexes tended to be smallest on the central Rise, but particularly so for males. The mean size for males was largest on the western Rise.

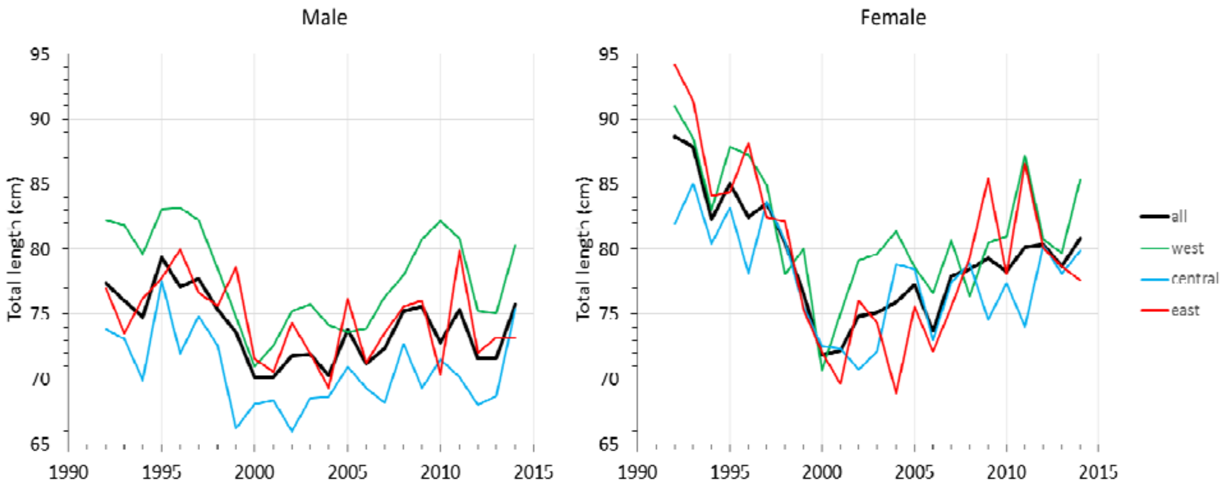

Figure 5: Mean length of ling in the population sampled by the research trawl surveys, by sex, for the entire core survey area, and the three sub-areas.

Changes over time were apparent in the relative abundance of large fish (both males and females) and in the mean size of fish in the population as sampled by the research trawl. Because the commercial longline fishery tends to select larger fish, the lengths and weights of the largest 10% of ling in the sampled population were examined (Figure 6). As expected, mean size declined markedly (by about 25%) between 1992 and 2001, as did the minimum length of the top 10% of fish sampled. Because of the approximately cubic relationship between length and weight, mean weight declined by a greater proportion (i.e., 40%).

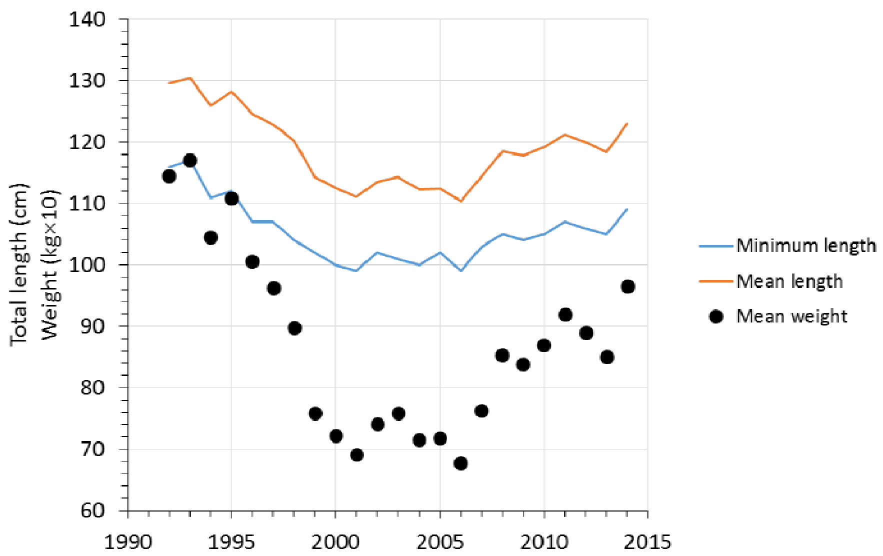

Figure 6: Mean length and weight, and minimum length, of the largest 10% of ling in the population sampled by the research trawl surveys.

There were trends in both mean fish size and sex ratio with changes in depth (Figure 7). Sex ratios were approximately even at depths shallower than 500 m, but became more skewed towards males as depth increased to 800 m. Mean size of male ling increased steadily at depths greater than 400 m. Female mean size also steadily increased from 300 to 550 m, but levelled off then declined at depths greater than 650 m.

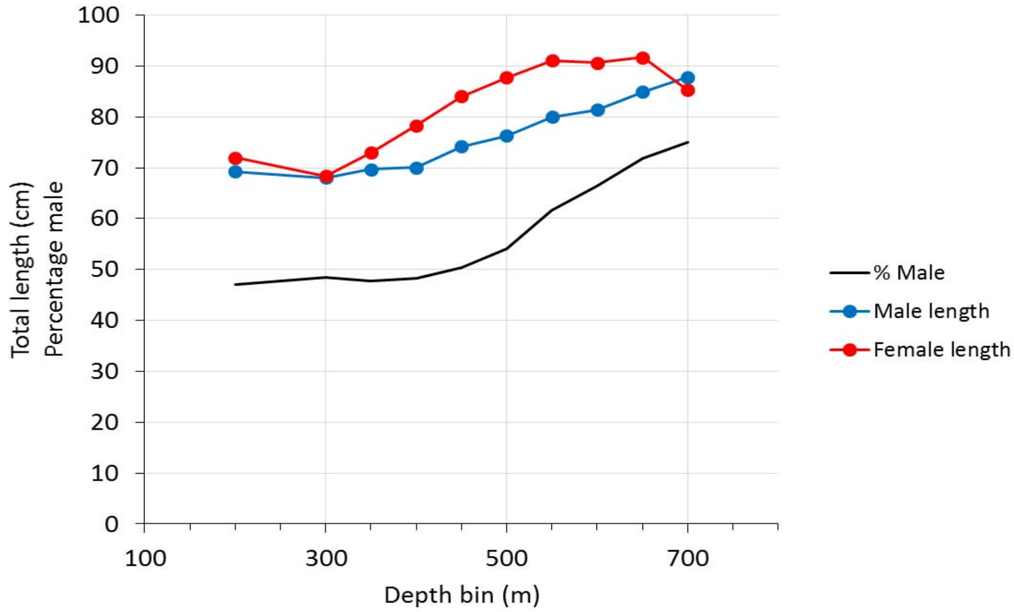

Figure 7: Mean length (by sex), and proportions of male ling, by depth, on the Chatham Rise. Points are plotted at the start of each depth bin (i.e., the points at 300 m refer to ling at depths 300–349 m). All depth bins have a range of 50 m, except for the first (200 m) and last (700 m) which have a range of 100 m.

2.3 Bottom longline data

Biological data on ling caught in the bottom longline fishery on Chatham Rise were available from two sources: the SeaFIC ling longline logbook programme (Langley 2001), and the MPI Observer Programme. The SeaFIC logbook programme, from 1995 to 2006, generally recorded the length and sex of 10 randomly chosen ling per set from a relatively large number of trips. The MPI Observer Programme, with data available between 1993 and 2013, generally recorded length and sex of 10–20 randomly chosen ling per set. From 2002 onwards, otoliths were also collected from the sampled fish (usually 10 per set). In two years (2002 and 2003), six trips were sampled; in all other years the number of sampled trips was 0–3. Consequently, input data for stock assessments comprised estimates of catch-at-length from 1995 to 2001, and estimates of catch-at-age from 2002 to 2009 (see Figure 1).

The bottom longline fishery on Chatham Rise was concentrated at the eastern end of the Rise, to the west of Chatham Islands (Figure 8). The fishery was also concentrated from April to November (Horn et al. 2013), which included the ling spawning season (primarily August–October, Appendix A). To examine changes over time in the structure of the longline catch, only data from FMA 4 sampled in April–November each year were used; this ensured consistency of data spatially and seasonally. The numbers of sampled ling included in this analysis are listed in Table 1.

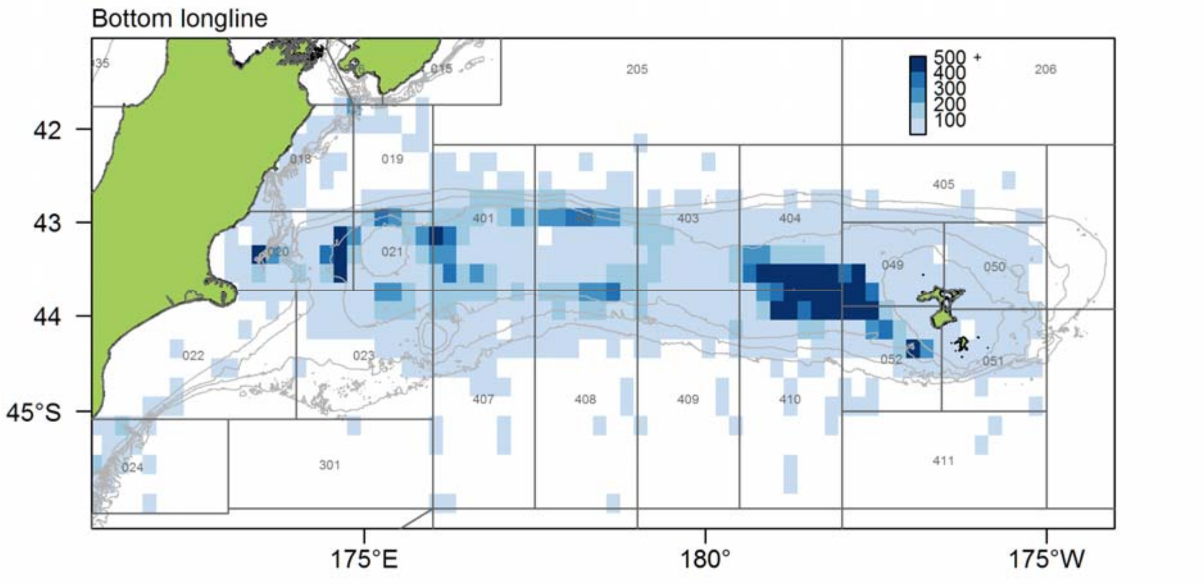

Figure 8: Density plot (in 0.2° rectangles) of total ling catch (t) by bottom longline in all years combined (1993–2013). Statistical Areas are also shown. Depth contours are at 200, 500, and 750 m.

Table 1: Numbers of ling sampled in FMA 4 from April to November each year, by the SeaFIC ling longline logbook programme and the MPI Observer Programme.

Year	SeaFIC	MPI Obs	Year	SeaFIC	MPI Obs
1993	0	606	2004	2 737	1 811
1994	0	225	2005	3 572	1 368
1995	11 819	1 870	2006	1 654	550
1996	5 166	0	2007	0	499
1997	4 548	5 888	2008	0	882
1998	1 854	0	2009	0	1 098
1999	4 952	0	2010	0	260
2000	4 471	0	2011	0	0
2001	5 124	337	2012	0	0
2002	6 262	6 964	2013	0	998
2003	5 877	5 395			

There was a clear trend in the SeaFIC data of a steadily increasing proportion of males in the catch from 1998 to 2002, with a subsequent steady decline in males to 2006 (Figure 9). The MPI Observer data trends were less clear, owing to the sporadic sampling and the low sample sizes in some years, but they also indicated lower proportions of males in the catch early in the development of the fishery and since 2009, with proportions of males peaking in the early to mid 2000s. Relative to the population structure indicated by the trawl survey sampling, the longline fishery is more selective of females than males, as virtually all the points in Figure 9 are below the 'proportion male' line derived from the survey. However, as with the longline catch data, the survey proportion of males was not constant over time, but had a trend of increasing (to about 2000) and then decreasing proportions.

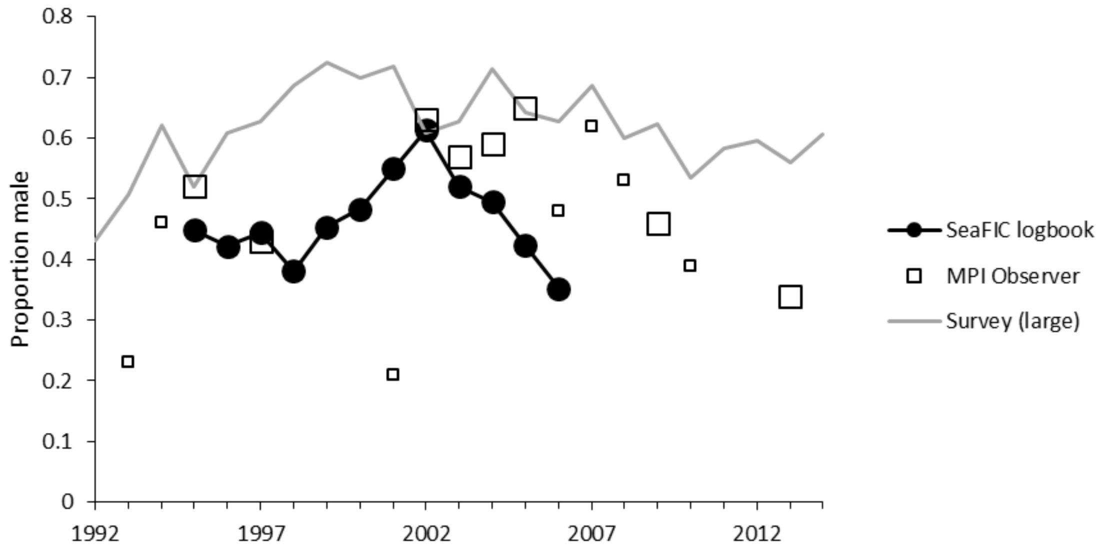

Figure 9: Proportions of male ling sampled from bottom longline catches in LIN 4, by SeaFIC and MPI Observer programmes. For MPI data, large squares are where sample sizes are 998 or greater, and small squares are where samples sizes are 882 or fewer. The grey line indicates the proportions of large fish (male ≥ 80 cm, female ≥ 90 cm) in the trawl survey population that were male: these 'large fish' length categories were chosen as they are the minimum lengths of 90% of the male and female longline-caught ling.

The proportions of large fish in the sampled longline catch were examined for trends (Figure 10). For this analysis, the proportion of large males was the number of males 110 cm or longer divided by the number 80 cm or longer, and the proportion of large females was the number of females 130 cm or longer divided by the number 90 cm or longer. The minimum and maximum lengths for each sex were chosen to represent (approximately) the smallest 10% and the largest 15% of sampled fish in the overall longline catch, respectively.

Trends in the proportions of large fish caught over time were similar to those identified for the trawl survey series. There was a slight but steady overall decline in the proportions of large male fish, but a much more pronounced decline in proportions of large females, particularly early in the series (Figure 10).

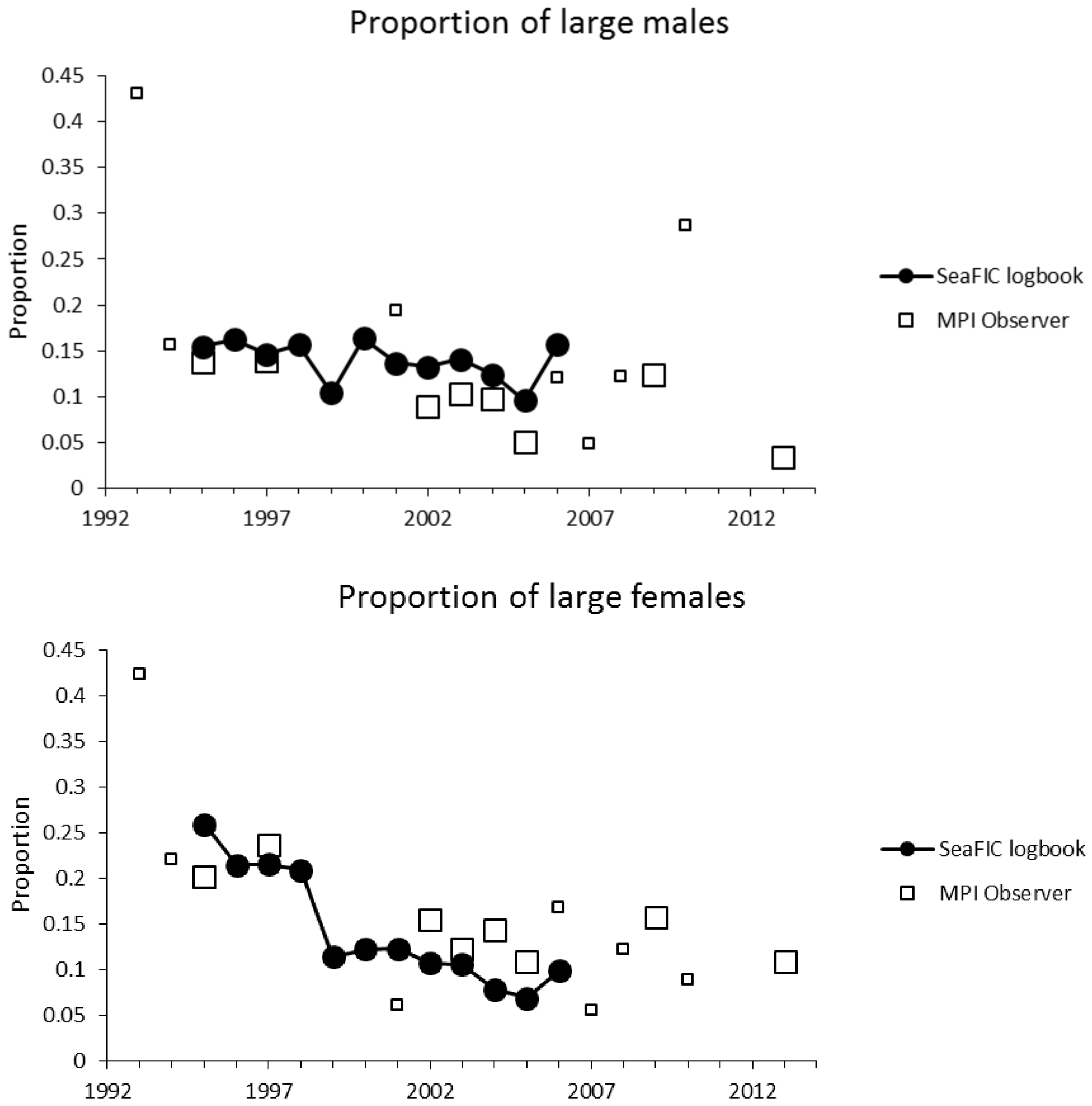

Figure 10: Proportions of large ling in samples from bottom longline catches in LIN 4, by SeaFIC and MPI Observer programmes. For MPI data, large squares are where sample sizes are 998 or greater, and small squares are where samples sizes are 882 or fewer.

The line fishery for ling on Chatham Rise has produced substantial landings since 1991, with virtually all the catch taken using bottom longline targeting ling (Figure 11). A CPUE series, with indices annually since 1991, has been used as an index of relative abundance in assessments of the Chatham Rise ling stock (e.g., Horn et al. 2013). Information on the size- and sex-composition of the longline catch was negligible before 1995; data were available for MPI Observer samples of 606 ling from April 1993, and 225 ling from November 1995, with both data sets from single trips on the eastern Rise. About 14 000 t of ling was caught by longline on Chatham Rise between 1990 and 1994. Large samples of length and sex data were available from 1995 to 2006, and from 2009 and 2013.

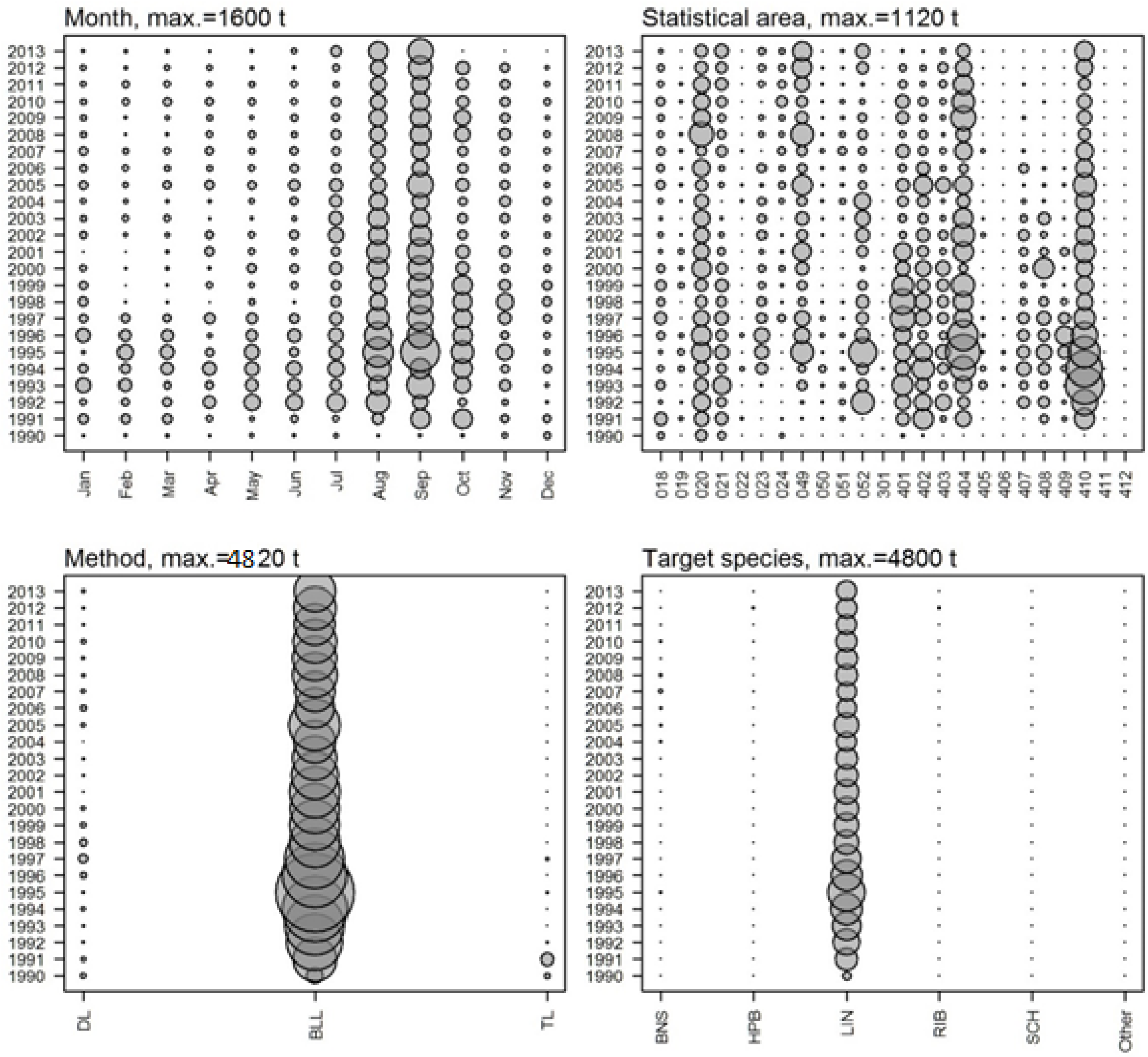

Figure 11: Distribution of Chatham Rise ling line catch by month, Statistical Area, method, and target species from 1990 to 2013 calendar years. Circle size is proportional to catch; maximum circle size is indicated on the top left hand corner of each plot. Method definitions: BLL, bottom longline; DL, dahn line; TL, trot line. Species codes: BNS, bluenose; HPB, hapuku and bass; LIN, ling; RIB, ribaldo; SCH, school shark.

2.4 Conclusions

The sex ratio of the Chatham Rise ling population, for both juveniles and adults, was skewed consistently towards males. It is recommended that future assessments estimate the proportion of recruits that are male (p_male), rather than assuming the previously used constant value of 0.5. A suggested prior for the estimation was a normal distribution with mean 0.5 and CV 0.15.

It is possible that the preferred selectivity of the longline fishery for large (and, therefore, often female) fish would result in an increasing proportion of males in the catch over time as the large females were fished down. However, it seems unlikely that the marked trend of an increase and then decrease in proportions of males in the SeaFIC data could be attributed to this alone. Given the consistency of the fishery, seasonal or spatial effects are also unlikely to be responsible. It is recommended that as in the previous assessment (Horn et al. 2013), longline composition data be input as unsexed catch-at-length and catch-at-age. Although this is not an ideal solution, Horn et al. (2013) did show that inputting the longline composition data as either sexed or unsexed had little impact on the final model outputs.

Clearly, there was a marked decline throughout the 1990s in the numbers of large female ling on Chatham Rise. The trawl survey indicated that the number of females 105 cm or longer halved (relative to other adult female ling sizes) between 1992 and 1997. Data from the longline fishery indicated a similar halving of the number of females 130 cm or longer between 1995 and 1999. The proportion of large males also decreased, but not to the same extent as females. It is most likely that these reductions were a consequence of the development of the longline fishery, which consistently caught ling with a larger average size than trawl-caught fish. The fishing down of large ling would, clearly, result in a reduced mean weight of the large fish that are taken by the line fishery. Using the research trawl survey as an index of the population, it was apparent that the mean weight of the largest 10% of ling in the population reduced from 11.7 kg in 1992 to 7.6 kg in 1999, a 35% reduction. This will have ramifications for CPUE, where a unit of effort (a hook) can catch only one ling. A comparison of the length-frequency distributions of the sampled female ling catch in 1995 and 1999 (Figure 12) indicated that the mean fish size reduced by 10 cm (117 to 107 cm), equating to a reduction in mean weight from 8.2 kg per fish in 1995 to 6.1 kg in 1999, a 25% reduction. Given that the fishery had already been operating for four years before 1995, it is likely that the reduction since 1991 in the mean weight of line-caught ling would be even greater.

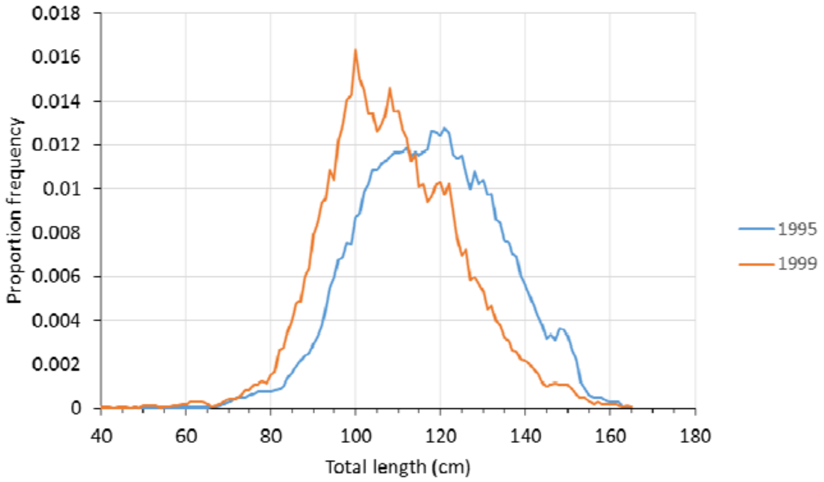

Figure 12: Length-frequency distributions of female ling recorded by the SeaFIC logbook programme from the fishery in LIN 4, in 1995 and 1999.

It appears likely, therefore, that much of the marked decline in CPUE apparent in the first seven to nine years of the series (see Figure 2) was attributable to a reduction in the mean size of ling selected by that fishing method. This could occur even if the overall ling biomass declined only slightly or not at all. It is recommended that in future assessments the longline CPUE be included only in a sensitivity model run that excludes the trawl survey relative abundance series. This run would be likely to represent a 'worst case' scenario for the Chatham Rise stock.

3. WEST COAST SOUTH ISLAND

3.1 The problem

The most recent assessment of WCSI ling (Dunn et al. 2013) included sex in the partition in the initial model run, but a trend in sex ratio (Figure 13) resulted in selectivities with strong sex differences. The Deepwater Fisheries Working Group considered the strong trends in observed sex ratio, and resulting shapes of selectivity ogives, to be doubtful, and recommended that sex be excluded from the observations and model partition. The final model therefore did not have sex in the partition, and all observations (age frequencies) and associated parameters (selectivities), and biological parameters (growth, maturity, etc), were unsexed.

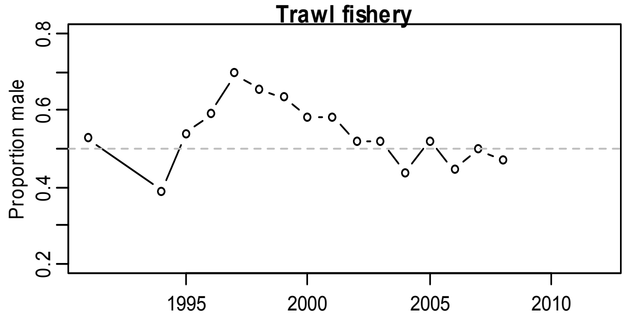

Figure 13: LIN 7WC sex ratio in trawl fishery age frequency observations (as proportion male); figure 7 from Dunn et al. (2013).

3.2 Trawl fishery data

Age frequency distributions for the trawl fishery off WCSI were estimated if there were sufficient length data and otoliths collected by the MPI Observer Programme between 1 June and 30 September each year, and were stratified using the following three strata (Horn & Sutton 2014):

- Deep (bottom depth ≥ 498 m)
- North shallow (bottom depth < 498 m, latitude < 42.42° S)
- South shallow (bottom depth < 498 m, latitude ≥ 42.42° S)

Distributions were available for all years from 1991 to 2013, excluding 1992, 1993, and 2011 (when insufficient otoliths were collected), and 2009 and 2010 (when insufficient lengths and otoliths were collected) (Table 2).

Table 2: Numbers of ling sampled in the trawl fishery off WCSI from June to September each year, by the MPI Observer Programme.

Year	No. of fish	Year	No. of fish
1991	1 050	2003	2 623
1992	1 327	2004	2 908
1993	645	2005	1 893
1994	2 115	2006	1 681
1995	1 921	2007	488
1996	1 019	2008	1 636
1997	2 577	2009	310
1998	1 860	2010	354
1999	3 136	2011	751
2000	1 769	2012	1 260
2001	2 253	2013	2 572
2002	2 979		

Raw length-frequency data available from all years except 2009 and 2010 were examined for trends in the proportion of males, for the overall fishery and for each of the three strata separately (Figure 14). The ‘all data’ ratios were variable (proportion male ranging from 0.40 to 0.62) with an initial decline to 1994, a peak around 1998, and a subsequent decline to 2004. The trends for each of the three strata were very similar to those of the ‘all data’ series.

The mean sampling period in all but three years occurred in that last two weeks of July (Figure 14). In most years, 90% of the sampled landings were taken between the start of July and the third week of August. There were no trends in the temporal distribution of sampling that matched with trends in proportion of males.

The mean size of ling sampled from the WCSI trawl fishery did exhibit trends over time, and the trends were virtually identical between sexes (Figure 14). Fish size declined from 1991 to 1995, increased to about 2000, and declined again to 2005. This trend had some similarities to that exhibited by the proportion of males in samples, except that it was delayed by about 1 year.

The mean depth fished by the sampled tows (where depth was defined as the mean of recorded start and end depths) was relatively tightly distributed between 450 and 500 m in most years (Figure 14). However, in most years the depth range that encompassed about 90% of the sample tows ranged from about 350 to 620 m. The trend in mean depth is similar to the trend in proportions of males, i.e., a decline from 1991 to 1994, an increase to 1999, and a decrease to 2003 (although the correlation coefficient between proportion male and mean depth fished, across years, was non-significant at 0.14). However, the relationship between depth and both mean fish size by sex and proportion of males was still examined (Figure 15). Males appeared to be slightly more prevalent than females at depths shallower than 400 m. Fish of both sexes were, on average, consistently longer at depths greater than 500 m, but by relatively small amounts (i.e., 3 cm for males, 6 cm for females).

Proportions of male ling are also available from three comparable winter trawl surveys, and these values were compared with those from the commercial fishery samples in the same years (Table 3). The survey values were all slightly higher than the fishery values. However, no survey values were available from years when the proportions of males in the commercial catch were particularly high or low.

Table 3: Proportions of male ling in comparable WCSI winter trawl survey population estimates, with values from the sampled commercial fishery in the same years.

Year	Trawl survey	Trawl fishery
2000	0.532	0.513
2012	0.569	0.542
2013	0.565	0.494

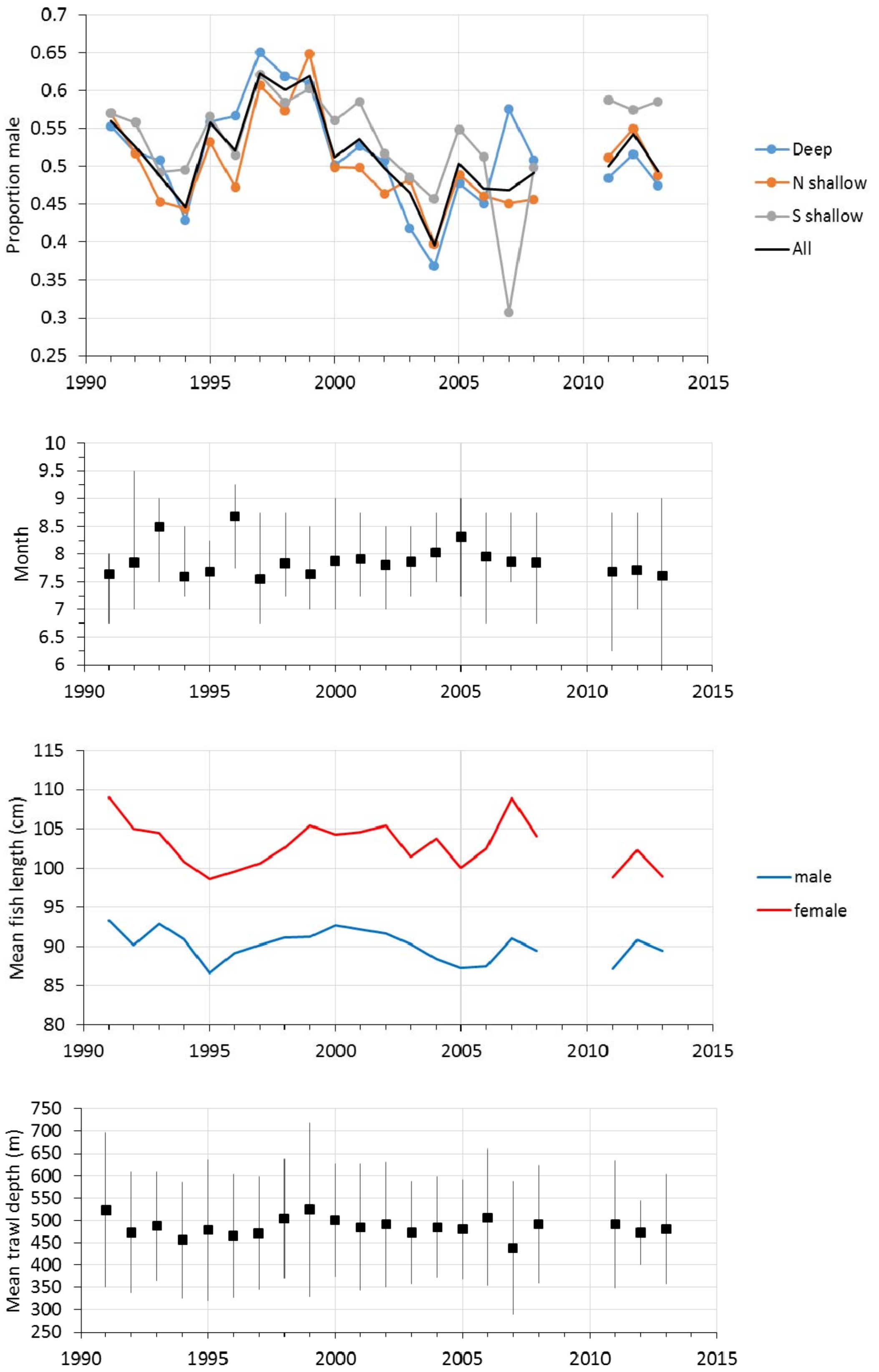

Figure 14: Sex ratios (by stratum), mean time (month) of sampling, fish length, and sampled trawl depth, by year. Vertical bars represent 90% confidence intervals. Month: 6, June; 7, July; 8, August.

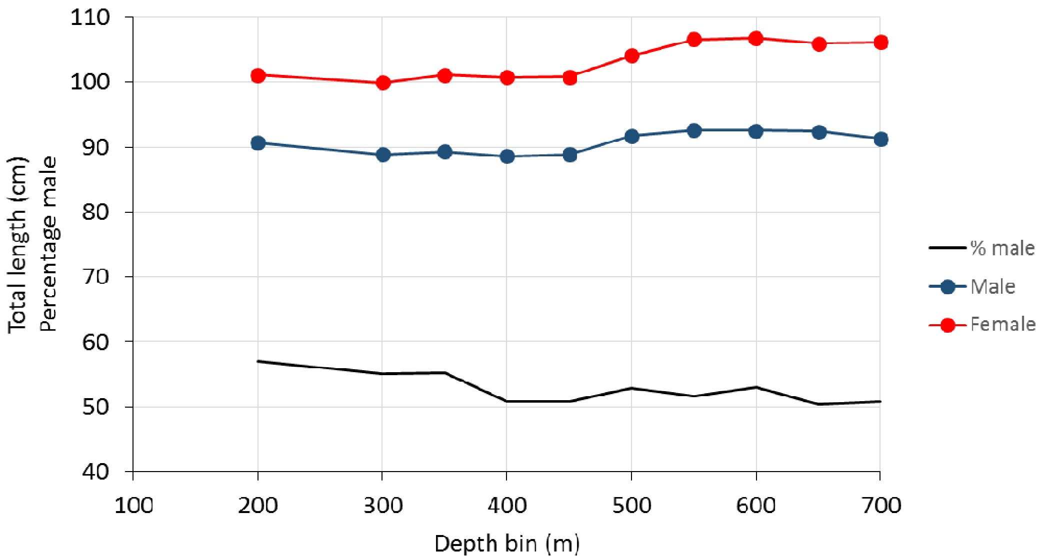

Figure 15: Mean length (by sex), and proportions of male ling, by depth, from WCSI trawl fishery samples. Points are plotted at the start of each depth bin (i.e., the points at 300 m refer to ling at depths of 300–349 m). All depth bins have a range of 50 m, except for the first (200 m) and last (700 m) which have ranges of 100 m and 150 m, respectively.

3.3 Conclusions

Trends in the proportion of male ling were apparent in Observer samples from the winter WCSI trawl fishery targeting hoki. However, the trends were similar across strata, so were not related to different levels of fishing in the three strata used to scale sampled length data up to the length distribution for the fishery each year. There was also no indication that differences between years in the temporal distribution of samples has caused the sex ratio trends.

Trends in the mean trawl depth of samples do bear some resemblance to the trends in the proportion male. However, confidence bounds around the mean depths are wide, there was no significant correlation across years between mean depth sampled and proportion male, and an analysis of proportion male by depth indicated no trend in depths greater than 400 m, which includes most of the fishery samples.

It is possible that the trend was environmentally driven but correlations between proportion male and any environmental variables were not examined.

It is recommended that the WCSI stock continue to be modelled without sex in the partition, even though the marked differences between sexes in productivity parameters make this a sub-optimal solution. However, the trawl fishery provides most of the composition data for the assessment because the only other samples currently available are two years of data from the longline fishery and three trawl survey data sets.

4. ACKNOWLEDGMENTS

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5. REFERENCES

Dunn, M.R.; Edwards, C.T.T.; Ballara, S.L.; Horn, P.L. (2013). Stock assessment of ling (*Genypterus blacodes*) in Cook Strait and off the West Coast South Island (LIN 7), and a descriptive analysis of all ling fisheries, for the 2012–13 fishing year. *New Zealand Fisheries Assessment Report 2013/63*. 102 p.

Horn, P.L. (2005). A review of the stock structure of ling (*Genypterus blacodes*) in New Zealand waters. *New Zealand Fisheries Assessment Report 2005/59.* 41 p.

Horn, P.L.; Dunn, M.R.; Ballara, S.L. (2013). Stock assessment of ling (*Genypterus blacodes*) on the Chatham Rise (LIN 3&4) and in the Sub-Antarctic (LIN 5&6) for the 2011–12 fishing year. *New Zealand Fisheries Assessment Report 2013/6*. 87 p.

Horn, P.L.; Sutton, C.P. (2014). Catch-at-age for hake (*Merluccius australis*) and ling (*Genypterus blacodes*) in the 2012–13 fishing year and from trawl surveys in 2013–14, with a summary of all available data sets from the New Zealand EEZ. *New Zealand Fisheries Assessment Report 2014/39.* 64 p.

Langley, A.D. (2001). Summary of biological data collected by the ling longline logbook programme, 1994–95 to 1999–2000. *New Zealand Fisheries Assessment Report 2001/71*. 37 p.

Stevens, D.W.; O'Driscoll, R.L.; Oeffner, J.; Ballara, S.L.; Horn, P.L. (2014). Trawl survey of hoki and middle depth species on the Chatham Rise, January 2013 (TAN1301). *New Zealand Fisheries Assessment Report 2014/02*. 110 p.

APPENDIX A: LING SPAWNING ON CHATHAM RISE

In a review of the stock structure of ling, Horn (2005) examined the distribution of running ripe male and female fish recorded by MPI observers and found that the spawning season on Chatham Rise was from July to November. It was also concluded that there were two apparent areas of relatively intense spawning; one to the west of Chatham Islands, and the other to the east of Mernoo Bank.

Previous analyses by NIWA for MPI to determine the composition and extent of bycatch resulted in the grooming of data collected by observers on both trawl and longline vessels. It became apparent that the position data recorded for some longline sets had longitudes recorded as degrees east rather than degrees west. These errors (which were subsequently corrected in the *cod* database, with the approval of MPI) resulted in the erroneous conclusion of substantial spawning by ling east of Mernoo Bank. Because this error was identified, and because considerably more information on the location and timing of spawning ling was collected since 2005, a reanalysis of the data was completed to better define the location and timing of ling spawning on the Chatham Rise.

The analysis used only data from female ling. Males with ripe and running ripe gonads were often recorded at times when there was clearly no female reproductive activity. The date and location of all trawl tows and longline sets on Chatham Rise producing gonad stage data on female ling were extracted from the *cod* database. Over 50 000 female ling were measured and staged between 1986 and 2014. Gonad stage was recorded using a 5-stage scale (Table A1). Immature fish occurred throughout the year, but with a trough from July to September. Maturing fish peaked in August–September. Ripe and running ripe females occurred almost exclusively from August to October, with spent fish almost exclusively from August to November. A spawning season from August to October was clearly indicated.

Table A1: Gonad stage descriptions and samples sizes (*N*) of staged female ling available from the Chatham Rise.

Gonad stage	Description	*N*
1	Immature	37 723
2	Maturing	5 907
3	Ripe	5 006
4	Running ripe	1 564
5	Spent	757

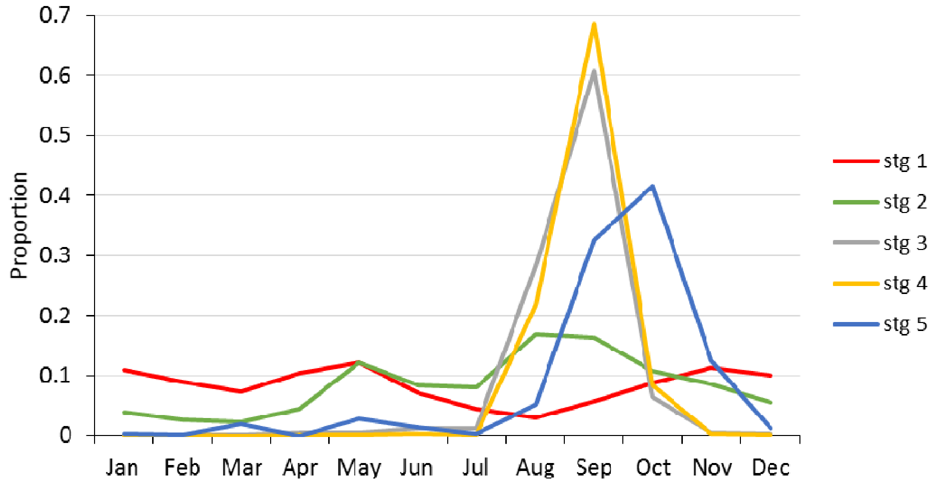

Figure A1: Proportions by month of female ling in each of the five gonad stages (defined in Table A1).

Distributions of females classified as stage 3, 4, or 5 showed that spawning occurred primarily on a single, but relatively extensive, ground to the west of Chatham Islands, but with some spawning also occurring around the Mernoo Bank and along the northern Chatham Rise (Figure A2).

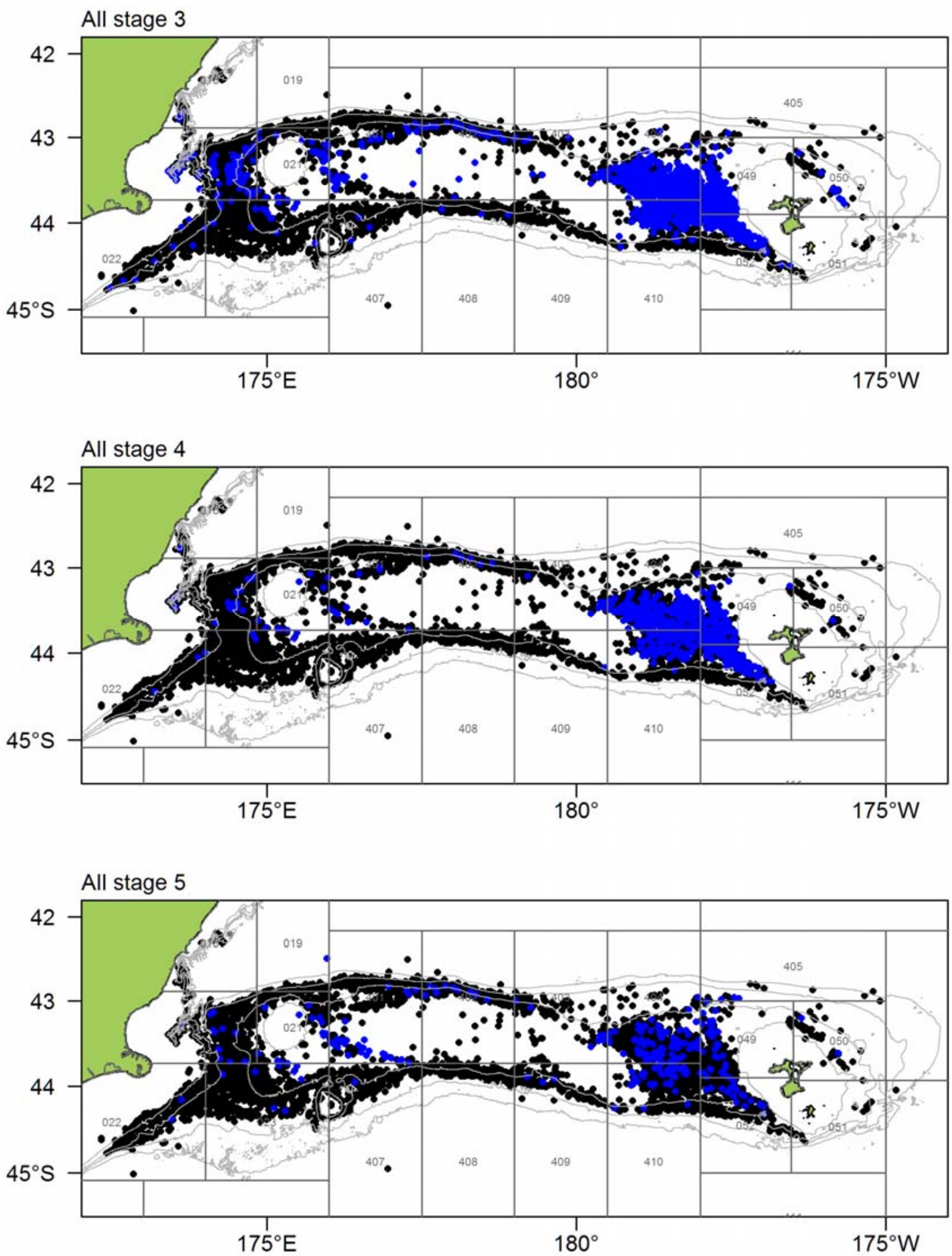

Figure A2: Distributions of ripe (stage 3), running ripe (stage 4), and spent (stage 5) female ling (blue dots) overlain on the distribution of all staged female ling (black dots). Statistical areas and depth contours (200, 500, 750 and 1000 m) are also shown.

Distributions of stages 3 and 4 females by month (for June to October) showed most recorded spawning occurred in August and September on the large ground west of Chatham Islands (Figure

A3). A much less intensive area of spawning on the western Chatham Rise (i.e., around Mernoo Bank and in the Pegasus Canyon northeast of Banks Peninsula) was active primarily from August to October. However, it was clear that the sampling intensity and distributions of staged ling varied markedly between months, e.g., there were no samples from the main spawning area in June, and sampling around the Mernoo Bank in August occurred only in one concentrated area to the west and was relatively sparse in September.

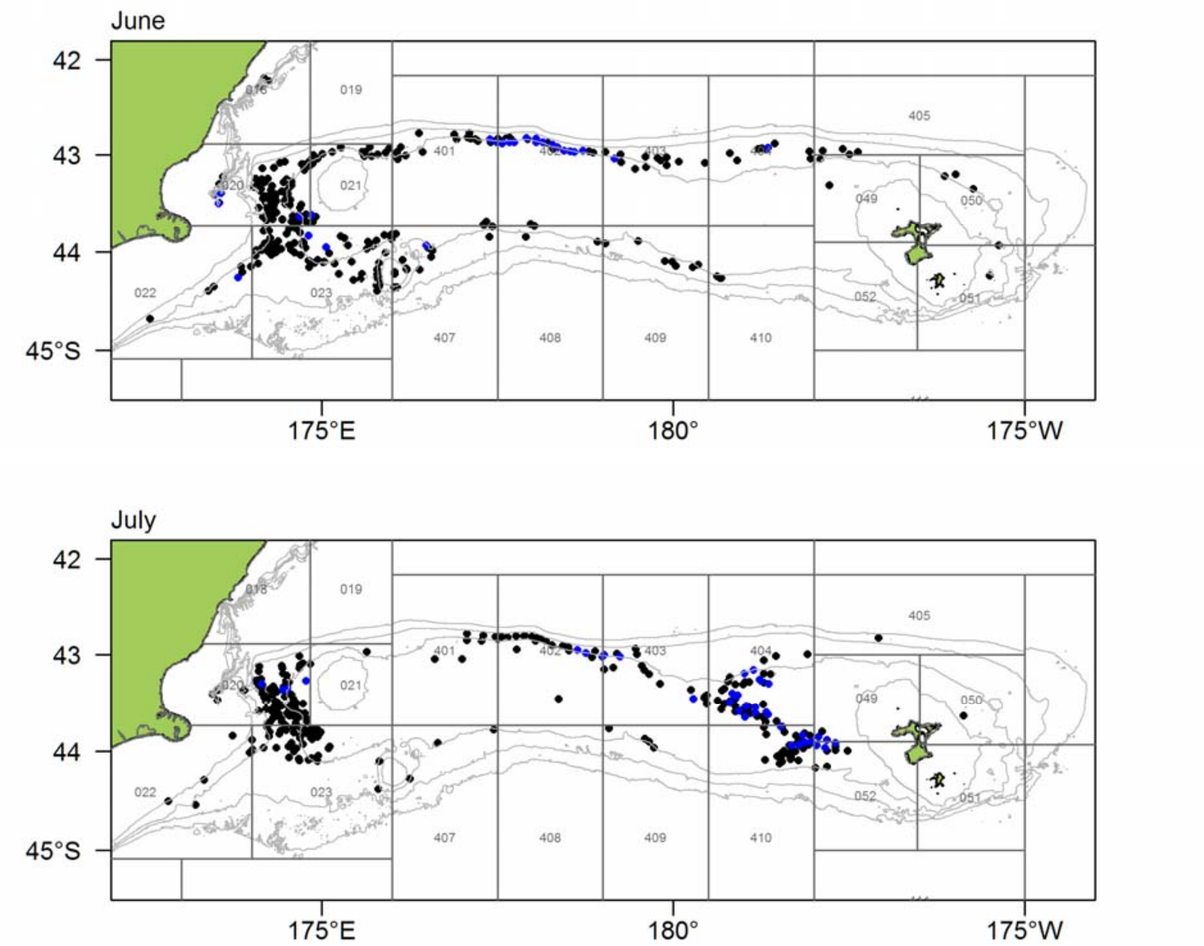

Figure A3: Distributions of ripe and running ripe (stages 3 and 4) female ling (blue dots), by month from June to October overlain on the distribution of all staged female ling (black dots) sampled in the same month. Statistical areas and depth contours (200, 500, 750 and 1000 m) are also shown.

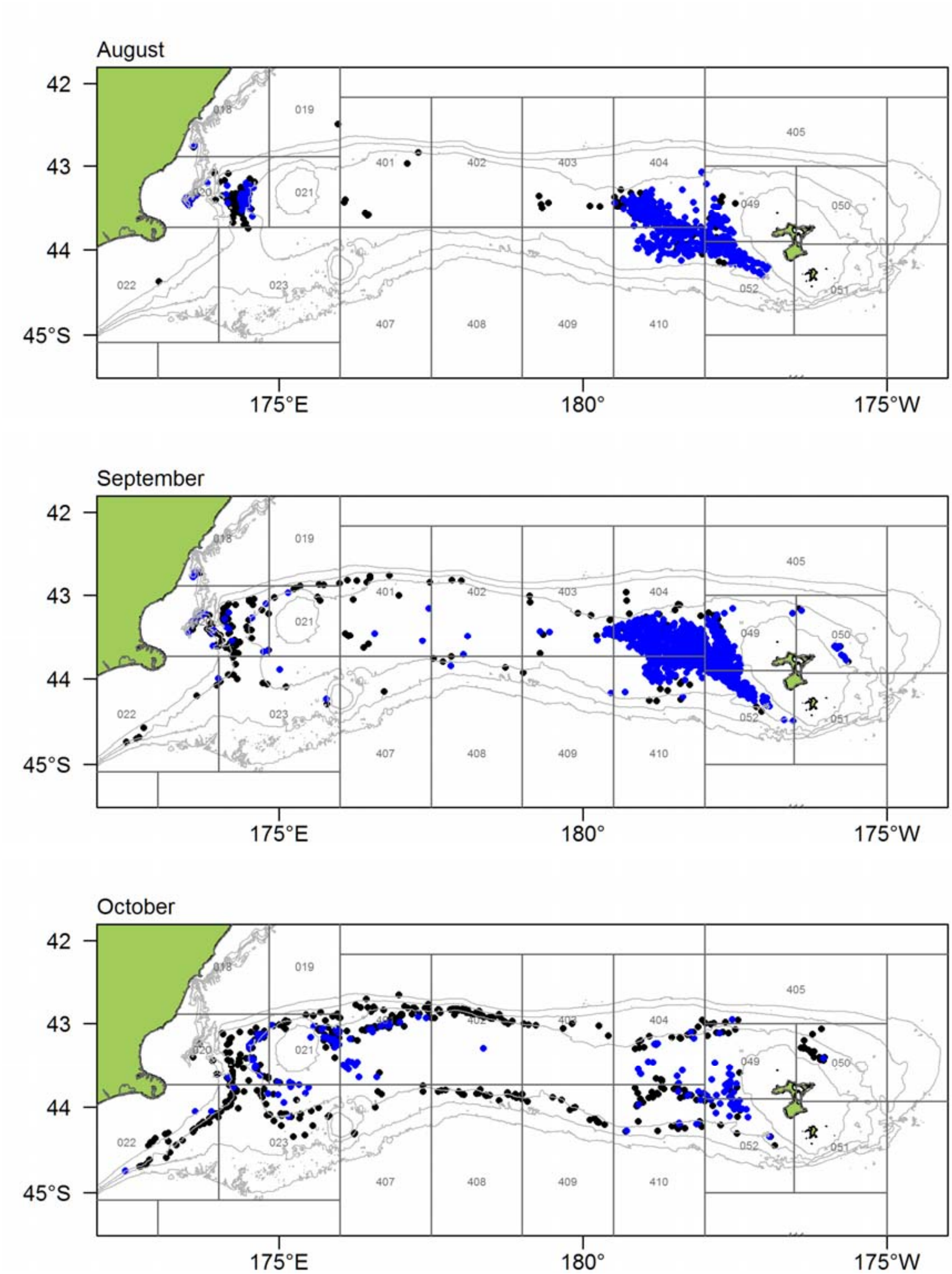

Figure A3 ctd.

The size distributions of reproductively active female ling differed between the eastern and western Chatham Rise (Figure A4). The western distribution was broader than in the east, with relatively more large and small fish. However, only 7% of the eastern fish had been sampled from trawl catches, compared to 41% of western fish, and differences in fishing selectivity (i.e., trawlers catch more smaller fish than line vessels) would be likely to explain the greater proportion of smaller reproductive fish in the west. Sample sizes differed markedly between the two areas, and the western distribution was very spiky.

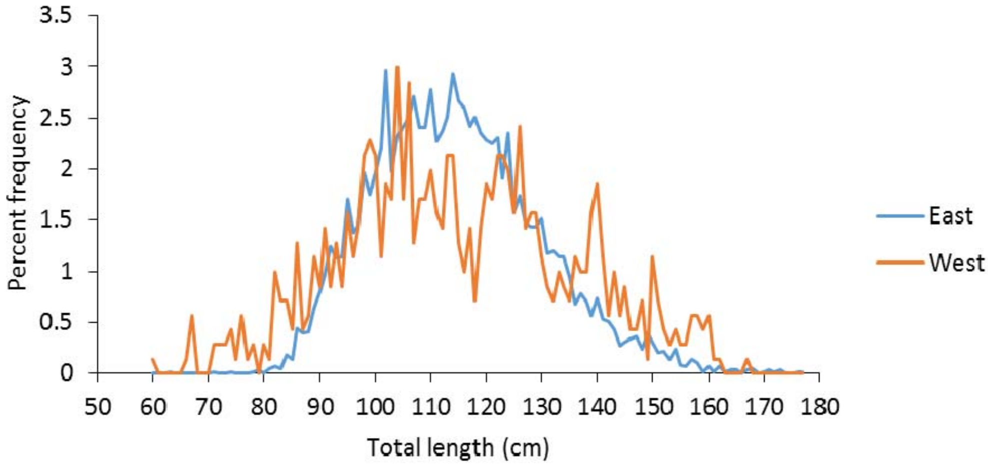

Figure A4: Length-frequency distributions of ripe and running ripe (stages 3 and 4) female ling, from the eastern and western Chatham Rise (divided at longitude 180°). Sample sizes: 5865, east; 703, west.

Conclusions

The reanalysis of ling reproductive data presented above has corrected a previous conclusion that there were two major spawning grounds on the Chatham Rise (Horn 2005). There is one major ground, situated to the west of Chatham Islands, active primarily in August and September, but continuing into October. Simultaneous spawning occurs on the western Rise, probably at a lower intensity than in the east, although observer sampling intensity was also clearly lower in the west that the east. However, if a substantial spawning aggregation occurs on the western Rise it is likely that a target line fishery would also have developed in that area (which has not occurred). The reanalysis supports the current hypothesis that ling on Chatham Rise comprise a single biological stock, but clearly demonstrates that spawning, although concentrated in a single time and place, does occur at numerous locations across the Rise. Multiple spawning locations were also demonstrated for ling on the Southern Plateau (Horn 2005), and it too is currently assumed to comprise a single stock.