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Recalculation of historical landings of porbeagle shark

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EXECUTIVE SUMMARY

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The Western and Central Pacific Fisheries Commission is leading the development of a Southern Hemisphere porbeagle shark (*Lamna nasus*) stock status assessment. A crucial input into any stock assessment is the landings history, which provides a measure of fishing mortality. The current official time series of New Zealand porbeagle landings consists of whole weights aggregated annually by the Ministry for Primary Industries (MPI) from Licensed Fish Receiver Returns (LFRRs) for fishing years 1989–90 to 2001–02 and Monthly Harvest Returns (MHRs) for 2002–03 to 2015–16.

Recent work has shown that MPI conversion factors (CFs) applied to shark fin processed weights to determine whole weights were not always appropriate. Most importantly, chartered Japanese surface longliners have been landing porbeagle shark fins in a different state from that used by domestic surface longliners. Japanese vessels land the whole tail whereas domestic vessels land only the valuable lower lobe of the tail. Different CFs should be applied to these two different landed states, but in practice a single CF has been used for both. Furthermore, the CF for porbeagle shark fins changed from 30 to 45 in October 2004. These variations may have produced major errors in the calculated whole weights (because most porbeagle landings consist of fins only), and inconsistent time series. This study generated an improved time series of annual porbeagle shark landings by fisheries within the New Zealand Exclusive Economic Zone. MPI data were used to determine the landed amounts of processed porbeagle shark, and then appropriate CFs were applied to the landings. The mortality of discards and released live sharks was estimated under several scenarios of post-release mortality rates.

The most plausible time series of porbeagle fishing mortality comprised the landings corrected by applying appropriate CFs and the medium mortality rate scenario (50% mortality of unspecified discards (a mixture of live and dead sharks) and 30% mortality of live releases) from 1998 to 2016. The new time series differs little from the existing LFRR/MHR series, with only 6% more mortality by weight overall and with annual values varying by –22% to +42%. The relatively small impact of the corrections can be attributed to the negating effect of changes in the nationality of the surface longline (SLL) fleet. Although the new time series differs little from the existing time series, the former is based on more appropriate conversion factors, and includes estimates of mortality of discarded sharks and live releases, so it should be used in any future stock assessments.

1. INTRODUCTION

The Western and Central Pacific Fisheries Commission (WCPFC) is leading the development of a Southern Hemisphere porbeagle shark (*Lamna nasus*) stock status assessment. The study involves working with many WCPFC member countries to locate, analyse and assess sources of data from Southern Hemisphere fisheries that catch porbeagle sharks. The goal is to generate suitable 'indicators' of stock abundance, and combine them with data on stock distribution, catches and biological productivity to estimate stock status.

A crucial input into any stock assessment is the landings history, which provides a measure of fishing mortality. The current official time series of New Zealand porbeagle landings consists of whole weights aggregated annually by the Ministry for Primary Industries (MPI) from Licensed Fish Receiver Returns (LFRRs) for fishing years 1989–90 to 2001–02 and Monthly Harvest Returns (MHRs) for 2002–03 to 2015–16 (Ministry for Primary Industries 2016). No porbeagle landings data are available before 1989–90.

Recent work has shown that MPI conversion factors (CFs) applied to shark fin processed weights to determine whole weights were not always appropriate (Francis 2014). Most importantly, chartered Japanese surface longliners have been landing porbeagle shark fins in a different state from that used by domestic surface longliners. Japanese vessels land the whole tail whereas domestic vessels land only the valuable lower lobe of the tail. Different CFs should be applied to these two different landed states, but in practice a single CF has been used for both. Furthermore, the CF for porbeagle shark fins changed from 30 to 45 in October 2004. These variations may have produced major errors in the calculated whole weights (because most porbeagle landings consist of fins only), and inconsistent time series.

This study aims to generate an improved time series of annual porbeagle shark landings (or more precisely, fishing mortality) by fisheries within the New Zealand Exclusive Economic Zone (EEZ), i.e. the POS 1 Fishstock. MPI data were used to determine the landed amounts of processed porbeagle shark, and then appropriate CFs were applied to the landings at the trip level. Dead discards of porbeagle sharks that have been allowed under Schedule 6 of the Fisheries Act since October 2014 were also added to total landings from 2014–15. In addition, mortality of porbeagle sharks discarded before the species was introduced into the Quota Management System (1 October 2004), and mortality of live sharks released under Schedule 6 since 2004–05, was estimated under several hypothetical scenarios of post-release survival rates.

The objective of this study is: *To recalculate a New Zealand porbeagle shark landing history in support of the WCPFC Southern Hemisphere porbeagle shark stock status assessment.* The study does not attempt to determine *catches*, which include live releases, many of which will survive. Rather it estimates *landings*, defined as landed catch (scaled up to whole weights) and dead discards.

2. METHODS

2.1 Data extracts

All porbeagle shark records up to 30 September 2016 were extracted from the MPI catch-effort database *warehou* on 30 November 2016. Data from the 2015–16 fishing year may have been incomplete at the time of the extract. Hereafter, I refer to fishing years, which run from 1 October to 30 September, by the second of the two years spanned; e.g. 2015–16 is referred to as 2016.

The following fields were extracted for specific form types:

- Catch Landing Return (CLR): trip code; start, end and landing dates of each trip; vessel code; flag nationality; landed state; landing destination; whole weight; processed weight. CLRs are completed by most fishing vessels and are based on weight of catch landed into Licensed Fish Receivers. Processed weight is a derived field calculated by MPI as the product of the number of containers of processed fish and the declared container weight.
- Tuna Longlining Catch Effort Return (TLCER): trip code; date; vessel code; flag nationality; landed state; whole weight; processed weight; number caught; discard flag. TLCERs are completed by surface longline vessels targeting mostly tunas and swordfish and they have been used since August 1990. Weights recorded on TLCERs are weighed processed weights, and MPI calculates whole weight by multiplying processed weight by a CF for each landed state. Landed state was not recorded on TLCERs before 2003 and a default code (GGU, gilled and gutted) has been applied by MPI in the database, but no whole weights were calculated (whole weight fields are NULL). GGU is not an appropriate state for porbeagle sharks which are never gilled and gutted. Discarded and released fish were recorded separately as whole weight from April 2003.
- Catch Effort Landing Return (CELR) where method was surface longline (SLL): trip code; start, end and landing dates of each trip; vessel code; flag nationality; landed state; landing destination; whole weight; processed weight. CELRs are comprised of two parts – an estimated catch part and a landed catch part (the latter being similar to the CLR form). Processed weight is a derived field calculated by MPI as the product of the number of containers of processed fish and the container weight in the landed part of the form. CELRs contained only six porbeagle records accounting for only 667 kg whole weight spread over three years between 1995 and 1998, and were omitted from subsequent analysis.

A list of valid porbeagle shark CFs with their start and end dates was obtained from MPI. Most of the CFs have never been used for porbeagles, and Table 1 provides a reduced list of those that have been used. Shark fins were coded as 'FIN' until the end of 2004 (although some fishers continued using the code up to 2006), when it was replaced (in 2005) by 'FIW' (wet fins). The porbeagle shark CF was 30 for FIN and 45 for FIW.

Headed and gutted records (HGU) were recoded as dressed (DRE) as they are the same processing method with the same CF. Similarly, the discarded state (DIS) was used only in 2003 and was recoded as whole (GRE). [The discarded *state* should not be confused with the 'discarded' *destination* D which was commonly used and was retained in the analyses below.]

Table 1: List of porbeagle shark conversion factors used by MPI and fishers to calculate whole weight from processed weight.

Landed state	Code	First used	Last used	CF
Discarded	DIS	1986	2016	1.00
Dressed	DRE	1990	2016	2.00
Fillets: skin-on	FIL	1990	2016	2.70
Fins	FIN	1993	2006	30.00
Wet fins	FIW	2004	2016	45.00
Whole (Green)	GRE	1991	2016	1.00
Gutted	GUT	1991	2016	1.10
Headed and gutted	HGU	1991	2016	2.00
Livers	LIV	1993	2016	3.85
Fish meal	MEA	1991	2016	5.60

Destination codes reported for porbeagles are shown in Appendix 1. These codes were used to allocate landings to one of three mortality categories: full mortality (treatments that resulted in death of all the sharks), partial mortality (treatments that resulted in death of some of the sharks), and zero mortality (treatments that would have resulted in double-counting if they had been scored as mortality; i.e. retained on board, or transferred to a holding facility or another vessel). CLR landings in the full mortality category were used to determine landed whole weight from processed weight as described in Sections 2.3 and 2.4. Reported weights in the partial mortality category were multiplied by estimated mortality rates under several hypothetical scenarios to estimate the weight of sharks dying as described in Section 2.5.

2.2 Data grooming

Initial inspection of the raw CLR data revealed some major inconsistencies between reported processed weight (PW) and reported whole weight (WW, also known as greenweight). A series of plots was created to explore this issue further, and to identify erroneous outliers. The following relationships were plotted:

- PW and WW by year
- PW/day and WW/day by year (where day = difference in days between trip start date and trip end date)
- PW and WW by destination by year
- PW and WW by state by year
- PW versus WW by destination
- PW versus WW by state
- Calculated WW (PW × CF) versus reported WW by state
- Calculated WW (PW × CF), reported WW and LFRR/MHR by year
- Calculated WW (PW × CF), reported WW and LFRR/MHR by state and year

Major outliers were inspected manually in an attempt to correct missing or erroneous values. The goal was to generate a plausible dataset of CLR processed weights to which appropriate CFs could be applied in order to generate new estimates of landed whole weight. Processed weights and whole weights were iteratively corrected and the plots were updated. At each step, whole weights were calculated from processed weights by applying the historic CFs, and the calculated whole weights were compared against reported whole weights and LFRR/MHR weights. Convergence of calculated and reported whole weights was judged to reflect successful grooming. Error-grooming plots of the original and groomed datasets are shown in Appendices 2 and 3 respectively.

During the grooming process, CLR data corrections were made as follows (in descending order):

- Missing values of PW or WW were obtained from matched TLCER records where possible
- Missing values of PW or WW were calculated from the other value (WW or PW respectively) obtained from matched TLCER records using historic CFs
- Missing values of PW or WW were calculated from the other value (WW or PW respectively) reported on CLRs using historic CFs
- The above three steps were also applied to inconsistent pairs of PW and WW CLR records. To determine which of each pair (i.e. PW or WW) was most likely erroneous, ancillary information on trip length, porbeagle weight per day, and number of porbeagle sharks reported on TLCERs was taken into account.

2.3 Estimation of processed weight (PW)

A key correction required to the existing porbeagle landings estimates is to take account of the different shark fin states used by different sectors of the fishery. Francis (2014) analysed available observer data on porbeagle shark fin ratios (fin weight as a percentage of whole weight) by fishery sector. Seventeen vessels (13 Japanese SLL vessels, 3 New Zealand trawlers, and 1 Korean trawler) that included the whole porbeagle tail in their fin sets were sampled; the median fin ratio was 4.05%, giving a CF (100/fin ratio) of 24.7. Only one sample was available from a New Zealand SLL vessel, and it consisted of only a single porbeagle shark. The fin set from that shark included only the lower lobe of the tail and had a fin ratio of 2.50, giving a CF of 40. Although the sample size of one was inadequate for estimating the fin ratio of the New Zealand SLL fleet, it was consistent with previous observer reports that New Zealand SLL vessels retained only the lower lobe of the caudal fin (Francis 2013), and it also produced a CF value close to the current gazetted CF for porbeagle shark fins (FIW) of 45. Therefore subsequent analyses assume (a) that all New Zealand SLL vessels landed fin sets that included only the lower lobe of the caudal fin, for which the appropriate CF is 45; and (b) that all other vessels landed fin sets that included the whole tail, for which the appropriate CF is 24.7.

Annual processed weights by landed state were first calculated for all nationalities and methods combined (i.e. all fishery sectors) from CLR data. Then, annual processed weights were calculated for the New Zealand SLL vessels in the CLR data, and subtracted from the weights for all sectors combined to give the annual processed weights for the remaining fishery sectors (i.e. foreign SLL vessels and all nationalities using fishing methods other than SLL).

The CLR data obtained from MPI had very incomplete information on vessel nationality, with over 65% of records having NULL values. New Zealand SLL vessels were therefore identified in the CLR data from the nationality field in the TLCER forms, which had only 1.4% missing values. Missing nationalities in the TLCER data were most likely New Zealand domestic vessels (MPI, pers. comm.) and were recoded as such. One large New Zealand vessel of the same size, construction, and fishing method as chartered Japanese SLL vessels used the same shark finning method as the latter vessels (P. Ballantyne, Solander Group, pers. comm.) so it was recoded as Japanese nationality for this study.

2.4 Estimation of whole weight (WW)

Annual whole weights were calculated by multiplying annual processed weights by appropriate CFs. The CFs used are shown in Table 1, except that (a) the CF for all New Zealand SLL landings in the states FIN and FIW was set as 45; and (b) the CF for all remaining landings of FIN and FIW was set as 24.7.

2.5 Estimation of discard and release mortality

Unwanted porbeagle sharks are often returned to the sea by fishers rather than landed. They include dead discards and live releases. Some of the sharks released alive would subsequently have died from the trauma and stress of capture and handling. The post-release mortality rate of New Zealand porbeagle sharks is unknown, so the effect of a range of plausible levels of mortality for sharks in the destination categories D and X was simulated. [Destination Z records are defined as dead discards (i.e. 100% mortality), so they were included in the weight estimations in Sections 2.3 and 2.4 rather than here.] Three different discard and release mortality scenarios (low, medium and high mortality) were simulated (Table 2). Destination D includes both live releases and dead discards which were permitted before porbeagle sharks entered the QMS in 2005, and was used by fishers mainly up to 2004 before declining to very low levels. Destination X is defined as live releases under Schedule 6 of the Fisheries Act and was first used for porbeagles in 2006. Because destination D includes dead discards, the percentage mortality values used for it in each scenario are higher than those for destination X. Nearly all (99.9%) of the discards and releases were reported as whole weights.

Table 2: Percentage mortality scenarios for discarded and released sharks.

Mortality scenario	Destination D	Destination X
Low mortality	30	10
Medium mortality	50	30
High mortality	70	50

3. RESULTS

3.1 Data grooming and summaries

The ungroomed CLR data contained large positive discrepancies between whole weight calculated from processed weight and reported whole weight over the periods 2000–2003 and 2009–2011, with an especially large discrepancy in 2000 (Appendix Figures A2.1 and A3.1). The discrepancies occurred in most landed states, but particularly for fins (Figures A2.1, A2.3, A2.4). The groomed dataset had a much closer correspondence between calculated and reported whole weights (Figures A3.1, A3.4 [note the different vertical scales between appendices 2 and 3]). Outliers remaining after grooming (Figure A3.3) were from long fishing trips and were considered plausible. The remainder of this report deals exclusively with the groomed dataset.

The most important landing destinations for processed weight were (in descending order) D (live and dead discards), X (live releases), L (landed to a Licensed Fish Receiver), Z (dead discards) and O (transported outside the EEZ) (Figure 1). The picture changed when whole weight is considered, with destination L clearly dominating followed by destinations D and O. The most important landed states for processed weights were whole (GRE) and dressed (DRE), with small percentages of fins (FIN and FIW) (Figure 1). However, whole weights were dominated by fins (FIN and FIW combined), followed by whole and dressed states.

Temporal patterns in processed and whole weight destinations and landed states are shown in Figure A3.2. Major fluctuations were apparent in discards/releases (destinations D, X and Z), reflected also in the trends in processed weight in the GRE state. [Although discards and releases are usually whole (GRE) and are technically not processed, they are included in the processed weight field via MPI's automated process that multiplies the number of containers by container average weight.] Discard/release weights were high in 1997–2004 and 2013–2016, but low in between. A large peak in whole weight in 'Other' destinations and FIN state in 1999 (and to a lesser extent in several subsequent years) was the result of fins being shipped out of the New Zealand EEZ, presumably to or aboard foreign SLL vessels (destination O).

The proportion of porbeagle shark fins landed by New Zealand SLL vessels was low (mostly less than 5%) up to 2001, and then it increased rapidly to peak at 60–70% in 2010–2012 (Figure 2). Since 2012, the quantity of porbeagle fins landed has declined dramatically, reaching zero in 2015–2016 (Figure A3.2), so the proportions taken by New Zealand SLL vessels after 2012 may be unreliable. Changes to the shark fin CF for New Zealand domestic SLL vessels will have most impact after 2001 and changes to the shark fin CF for other fishery sectors will have most impact before 2002.

The most serious errors in the processed weights have apparently been removed by this grooming process (see Results). Nevertheless, the processed weights undoubtedly still contain errors, and the official LFRR/MHR weights probably also contain cryptic errors (in addition to the errors induced by incorrect CFs that we correct below).

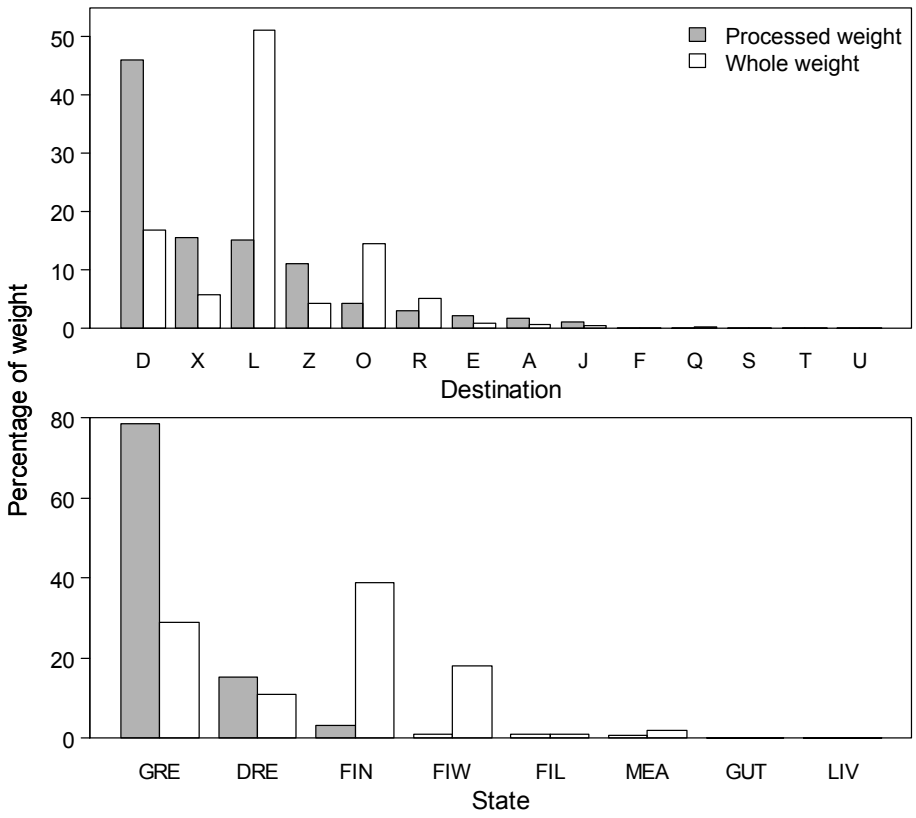

Figure 1: Percentage of processed and whole weight by destination (top) and landed state (bottom) (CLR groomed data). See Appendix 1 for destination codes and Table 1 for state codes.

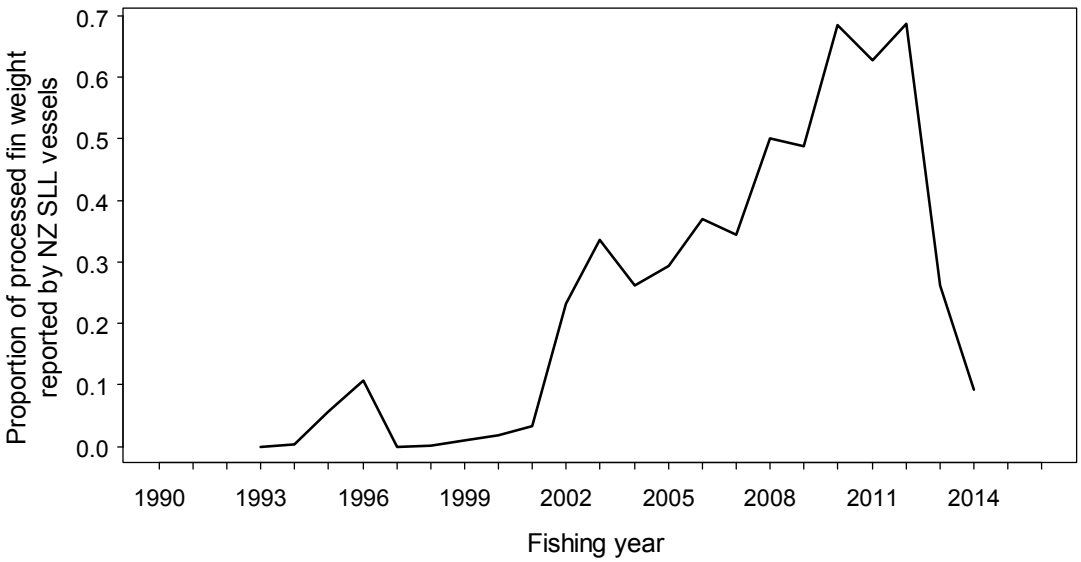

Figure 2: Proportion of processed fin weight (FIN and FIW combined) reported by New Zealand surface longline vessels.

3.2 Revised estimates of porbeagle shark mortality

Corrected whole weights were calculated from destination categories that resulted in full mortality of porbeagle sharks (i.e. 'landings'; see Appendix 1). Corrected weights calculated from groomed processed weights and appropriate CFs were generally similar to uncorrected CLR whole weights (both calculated from processed weights and reported) (Figure 3). The most notable differences were lower corrected whole weights in 1999–2000 and 2006–2013. Corrected weights were similar to the LFRR/MHR weights in most years, but the former were lower in 2000–2003.

The addition of discard/release mortality under low, medium and high mortality scenarios had a relatively small effect, except in 1999, 2002, 2015 and 2016 (Figure 4). If only the period from 1998 onwards is considered (see next paragraph), the new estimates of fishing mortality under low, medium and high discard mortality scenarios respectively were –22% to +20% (mean 0%), –22% to +42% (mean +6%), and –22% to +72% (mean +12%) of the LFRR/MHR values for the corresponding years (Table 3).

Fishing effort by the SLL fishery, which probably accounted for most of the porbeagle catch in the 1990s, was stable at about 4 million hooks per year between 1994 and 1998 (Figure 4). The abrupt increase in estimated mortality in 1998 therefore suggests that porbeagle sharks were under-reported on fishing returns before that (although LFRR/MHR weights increased sharply one year earlier in 1997; Figure 4). Porbeagle shark was included in the QMS in October 2004, so there were few incentives for fishers to report catches fully before then. Furthermore, fishers and observers tended to confuse or group porbeagle sharks and shortfin mako sharks (*Isurus oxyrinchus*) in the 1990s (Francis 2013). Thus all sources of landings data are probably unreliable before 1998.

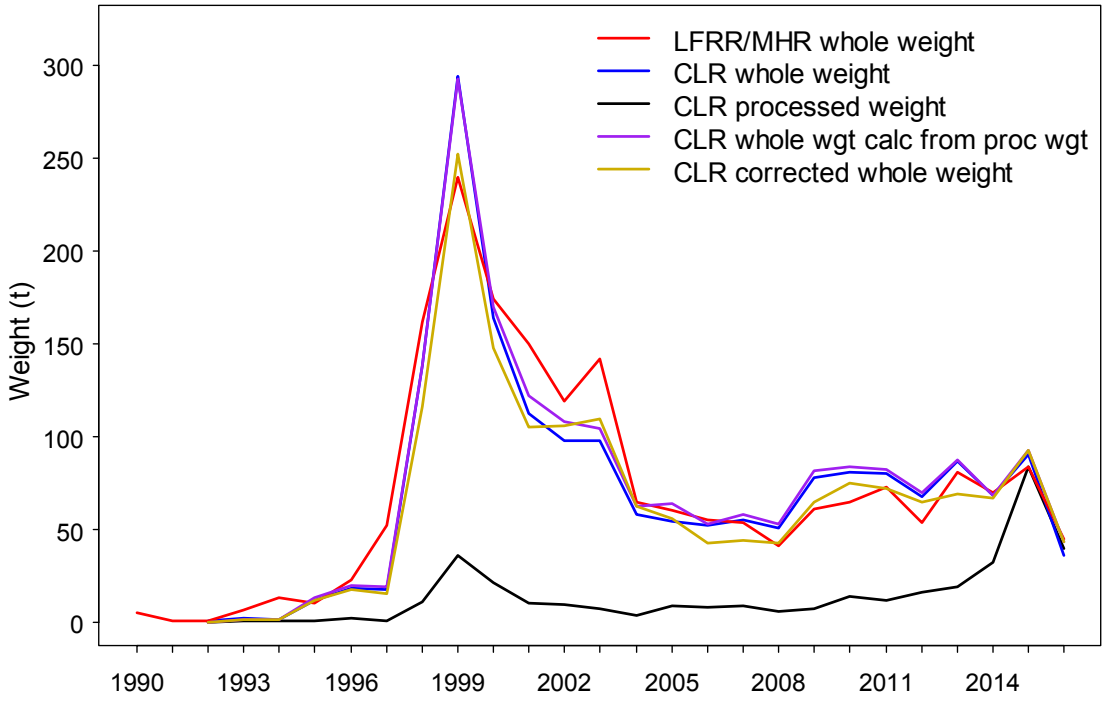

Figure 3: Whole weight corrected by applying appropriate CFs to processed weight (gold line), compared with uncorrected whole weight (calculated and reported), processed weight and LFRR/MHR weight.

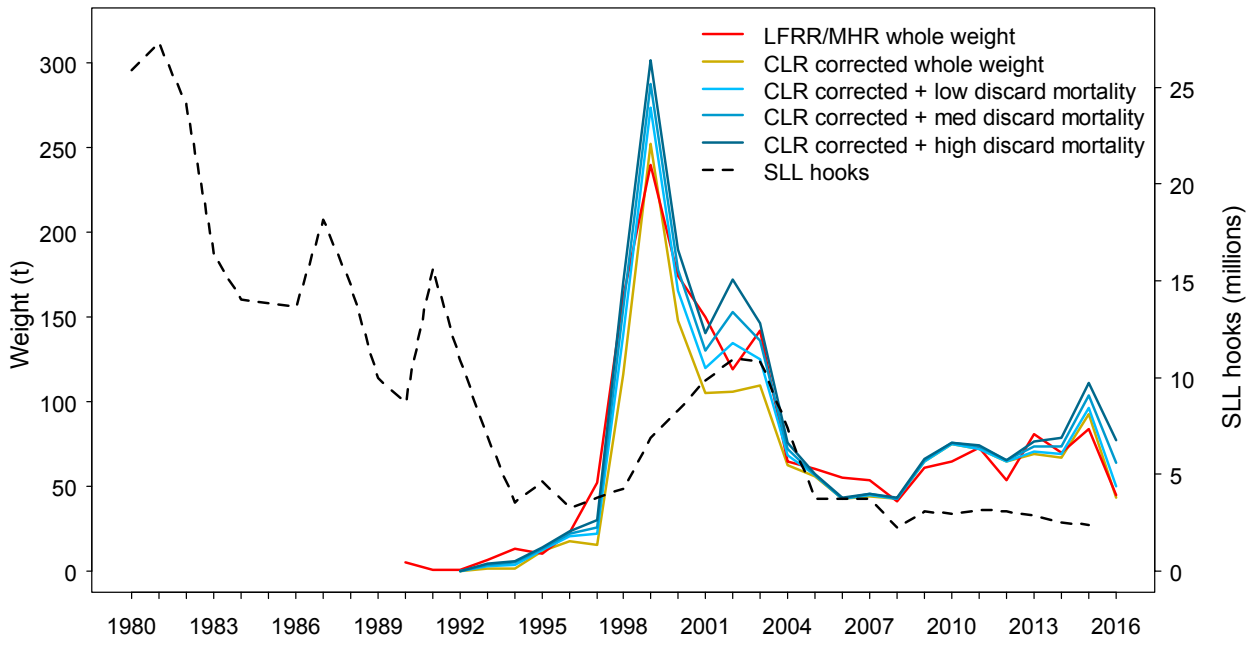

Figure 4: Whole weight corrected by applying appropriate CFs to processed weight (gold line), with three added levels of discard mortality (low, medium and high; blue lines) compared with LFRR/MHR weight. Also shown is the number of hooks set by SLL vessels annually in the New Zealand EEZ since 1980.

Table 3: Annual porbeagle shark landings (derived from LFRR/MHR and corrected whole weights), estimated weight of dead discards under three mortality rate scenarios, corrected whole weights plus dead discards under three scenarios, and percentage deviations from LFRR/MHR weights. The most plausible time series of fishing mortality is shown in column 8 (see Discussion).

			Weight of dead discards under mortality rate scenarios			Corrected weight plus dead discards under mortality rate scenarios			Deviation from LFRR/MHR weight under mortality rate scenarios		
Fishing year	LFRR/MHR weight (t)	Corrected whole weight (t)	Low (t)	Medium (t)	High (t)	Low (t)	**Medium (t)**	High (t)	Low (%)	Medium (%)	High (%)
1990	5	–	–	–	–	–	–	–	–	–	–
1991	1	–	–	–	–	–	–	–	–	–	–
1992	1	0.0	0.1	0.2	0.3	0.1	0.2	0.3	-90.0	-80.0	-70.0
1993	7	1.5	1.3	2.2	3.1	2.8	3.8	4.7	-60.0	-45.7	-32.9
1994	13	1.5	2.0	3.4	4.8	3.5	4.9	6.2	-73.1	-62.3	-52.3
1995	10	11.7	1.0	1.6	2.3	12.7	13.4	14.0	27.0	34.0	40.0
1996	23	18.0	2.3	3.8	5.3	20.3	21.8	23.3	-11.7	-5.2	1.3
1997	52	15.7	6.1	10.2	14.2	21.8	25.9	29.9	-58.1	-50.2	-42.5
1998	162	116.4	23.2	38.6	54.0	139.5	**154.9**	170.4	-13.9	-4.4	5.2
1999	240	252.1	21.3	35.5	49.6	273.4	**287.6**	301.8	13.9	19.8	25.8
2000	174	147.5	18.2	30.3	42.4	165.7	**177.8**	189.9	-4.8	2.2	9.1
2001	150	105.1	15.1	25.2	35.2	120.2	**130.3**	140.3	-19.9	-13.1	-6.5
2002	119	106.1	28.2	47.0	65.8	134.3	**153.1**	171.9	12.9	28.7	44.5
2003	142	109.4	16.0	26.6	37.2	125.4	**136.0**	146.7	-11.7	-4.2	3.3
2004	65	62.9	5.6	9.3	13.1	68.5	**72.2**	76.0	5.4	11.1	16.9
2005	60	55.9	0.5	0.9	1.3	56.5	**56.8**	57.2	-5.8	-5.3	-4.7
2006	55	42.9	0.1	0.2	0.3	43.0	**43.1**	43.2	-21.8	-21.6	-21.5
2007	54	44.5	0.3	0.8	1.3	44.8	**45.3**	45.8	-17.0	-16.1	-15.2
2008	41	42.5	0.2	0.5	0.8	42.7	**43.0**	43.3	4.1	4.9	5.6
2009	61	64.5	0.4	1.1	1.8	64.9	**65.6**	66.3	6.4	7.5	8.7
2010	65	75.0	0.2	0.7	1.2	75.2	**75.7**	76.2	15.7	16.5	17.2
2011	73	72.0	0.4	1.3	2.1	72.5	**73.3**	74.2	-0.7	0.4	1.6
2012	54	64.6	0.2	0.7	1.1	64.8	**65.3**	65.7	20.0	20.9	21.7
2013	81	69.5	1.3	4.0	6.7	70.8	**73.5**	76.2	-12.6	-9.3	-5.9
2014	70	66.8	2.4	7.1	11.8	69.2	**73.9**	78.7	-1.1	5.6	12.4
2015	84	92.6	3.6	10.9	18.2	96.2	**103.5**	110.8	14.5	23.2	31.9
2016	45	43.2	6.9	20.6	34.3	50.0	**63.8**	77.5	11.1	41.8	72.2

4. DISCUSSION

This study has generated a more accurate time series of New Zealand porbeagle shark landings than was previously available. The changes resulted from the use of more accurate and consistent CFs for porbeagle fins, and the addition of mortality estimates for discarded and released sharks.

Mortality rates of discarded and released sharks have not been determined empirically in New Zealand. However, there is some pertinent information on the post-release mortality of live porbeagles (as in destination X releases in this study). Porbeagles appear to be relatively hardy animals with 100% survival recorded for 10 porbeagles caught and electronically tagged from SLL vessels in New Zealand waters (Francis et al. 2015). However, the tagged sharks were not randomly selected and may have been in better condition than average. A larger study that tagged 33 porbeagles off eastern Canada estimated an overall post-release mortality rate, weighted by shark status (healthy or injured) at release, of 27%. A plausible mortality rate for destination D discards is harder to determine as that category includes both dead discards and live releases, with the proportions of each being unknown. Observer data indicate that about two-thirds (average 64%, range 47–77%)[1] of SLL-caught porbeagles are alive at the time the line is hauled aboard (Ayers et al. 2004; Francis et al. 2004; Griggs et al. 2007, 2008; Griggs & Baird 2013). If the destination D discards comprised alive and dead sharks in the same proportions (i.e. 64% alive and 36% dead), and the post-release mortality rate of live discards was 27%, the overall mortality rate would have been 53%. The 'base case' medium mortality rate scenario used here had mortality rates similar to these observed values, viz. 50% of destination D discards and 30% of destination X discards. The low and high mortality scenarios may be regarded as lower and upper bounds respectively. Consequently, the most plausible time series of porbeagle fishing mortality is the corrected landings under the medium mortality rate scenario (i.e. column 8 in Table 3) from 1998 to 2016.

The new time series differs little from the existing LFRR/MHR times series, with only 6% more mortality by weight over the period 1998–2016 and with annual values varying by –22% to +42%. The relatively small impact of our corrections can be attributed to the negating effect of changes in the nationality of the SLL fleet. Before 2004, when the CF for porbeagle fins (state FIN) was 30, most SLL fishing was carried out by Japanese vessels (Figure 2) which included whole tails in their fin sets, resulting in an actual CF of about 24.7. From 2005 onwards, when the CF for porbeagle fins (state FIW) was 45, most SLL fishing was carried out by New Zealand vessels which included only the lower lobe of the tails in their fin sets, resulting in an actual CF of about 40. Thus the corrections required were minimal.

The mortality estimates in Table 3 omit at least two potentially major sources of fishing mortality. Between 1994 and 1998, 5–21% (mean 11.9%) of SLL hooks set in New Zealand waters were reported on CELRs (Griggs & Baird 2013). In other years, the percentage of hooks on CELRs was less than 5%, and it has been less than 1% since 2002. However, the amount of porbeagle shark reported on CELRs has been negligible (Section 2.1), indicating a significant amount of non-reporting in the mid to late 1990s. In addition, there was a large amount of foreign SLL effort in the New Zealand EEZ during the 1980s (Figure 4) for which no catch information is available. Missing landings could be estimated from the reported effort and assumed values of catch-per-unit-effort (CPUE), preferably stratified by fleet nationality and region (northern and southern New Zealand) as those factors are known to affect porbeagle CPUE (Francis et al. 2014). However CPUE has fluctuated markedly among years, even within strata (Francis et al. 2014), making the selection of appropriate CPUE values problematic. Accounting for these missing landings was beyond the scope of the present study, and they would only become important if future stock assessments require landings histories before 1998.

[1] The values in the cited sources were based on a mixture of annual and multi-year percentages with varying sample sizes. The percentages of live sharks varied across strata (region and fleet nationality) but the estimates presented here have not been weighted by stratum fishing effort. Hence they should be regarded as approximate.

5. MANAGEMENT IMPLICATIONS

An improved time series of porbeagle shark landings for the period 1998–2016 has been developed. Although the new time series differs little from the existing 'official' time series of LFRR/MHR landings, the former is based on more appropriate conversion factors, and includes estimates of mortality of discarded sharks and live releases, so it should be used in any future stock assessments.

6. ACKNOWLEDGMENTS

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7. REFERENCES

Ayers, D.; Francis, M.P.; Griggs, L.H.; Baird, S.J. (2004). Fish bycatch in New Zealand tuna longline fisheries, 2000–01 and 2001–02. *New Zealand Fisheries Assessment Report* 2004/46. 47 p.

Francis, M.P. (2013). Commercial catch composition of highly migratory elasmobranchs. *New Zealand Fisheries Assessment Report* 2013/68. 79 p.

Francis, M.P. (2014). Estimation of fin ratios and dressed weight conversion factors for selected shark species. *New Zealand Fisheries Assessment Report* 2014/68. 31 p.

Francis, M.P.; Clarke, S.C.; Griggs, L.H.; Hoyle, S.D. (2014). Indicator based analysis of the status of New Zealand blue, mako and porbeagle sharks. *New Zealand Fisheries Assessment Report* 2014/69. 109 p.

Francis, M.P.; Griggs, L.H.; Baird, S.J. (2004). Fish bycatch in New Zealand tuna longline fisheries, 1998–99 to 1999–2000. *New Zealand Fisheries Assessment Report* 2004/22. 62 p.

Francis, M.P.; Holdsworth, J.C.; Block, B.A. (2015). Life in the open ocean: seasonal migration and diel diving behaviour of Southern Hemisphere porbeagle sharks (*Lamna nasus*). *Marine Biology 162*: 2305–2323.

Griggs, L.H.; Baird, S.J. (2013). Fish bycatch in New Zealand tuna longline fisheries 2006–07 to 2009–10. *New Zealand Fisheries Assessment Report* 2013/13. 73 p.

Griggs, L.H.; Baird, S.J.; Francis, M.P. (2007). Fish bycatch in New Zealand tuna longline fisheries 2002–03 to 2004–05. *New Zealand Fisheries Assessment Report* 2007/18. 58 p.

Griggs, L.H.; Baird, S.J.; Francis, M.P. (2008). Fish bycatch in New Zealand tuna longline fisheries in 2005–06. *New Zealand Fisheries Assessment Report* 2008/27. 47 p.

Ministry for Primary Industries. (2016). Fisheries Assessment Plenary: stock assessments and stock status, November 2016. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 459 p.

APPENDIX 1: MPI DESTINATION CODES AND DEFINITIONS.

The last column indicates how each category was treated for assessing mortality in this study.

Destination	Destination code	Treat as mortality?
Missing code	NULL	No
Fish or fish product of the species or classes of fish subject to the quota management system established under Part 4 of the Act that are returned to the sea, abandoned in the sea, or accidentally lost at sea, except for fish or fish product to which another destination type code applies	A	Yes
Fish or fish product of the species or classes of fish not subject to the quota management system established under Part 4 of the Act that are returned to the sea, abandoned in the sea, or accidentally lost at sea	D	Partial
Fish or fish product used for human consumption on board a vessel	E	Yes
Fish landed under an approval under section 111 of the Act	F	Yes
Fish or fish products of the species or classes of fish subject to the quota management system established under Part 4 of the Act that are returned to, or abandoned in, the sea in accordance with the requirements set out in section 72(5)(c)(i) to (iii) of the Act	J	Yes
Fish or fish product conveyed or sold to a licensed fish receiver at the time of landing	L	Yes
Fish or fish product conveyed or transported on a vessel leaving the exclusive economic zone by its seaward boundary having been granted permission to do so under section 110 of the Act	O	Yes
Fish or fish product placed in a holding receptacle on land	Q	No
Fish or fish product retained on board a vessel at the time of landing	R	No
Fish or fish product seized by a Fishery Officer under section 207 of the Act or taken by a scientific observer under Part 12 of the Act	S	Yes
Fish or fish product transferred from a vessel to another vessel or foreign fishing vessel	T	No
Fish or fish product taken or used for bait during the period of a trip	U	Yes
Fish of the species or classes subject to the quota management system stablished under Part 4 of the Act that are-··(a) listed in Schedule 6 of the act; and··(b) not listed in Part 6A or Part 6B of this schedule; and··(c) returned to the water in accordance with the requirements set out for the relevant species or class of fish in Schedule 6 of the Act	X	Partial
Fish of the species or classes subject to the quota management system established under Part 4 of the Act that are listed in Part 6B of this schedule and are returned to the water dead or near-dead in accordance with the requirements set out for the relevant species or class of fish in Schedule 6 of the Act	Z	Yes

APPENDIX 2: ERROR GROOMING PLOTS – ORIGINAL DATA

Figure A2.1: Comparison of original annual calculated CLR whole weight (processed weight × historic conversion factor) with reported CLR whole weight, LFRR/MHR whole weight, and other landed weight statistics by fishing year. Top panel shows data for all landed states combined, and the bottom four panels show data for the main landed states.

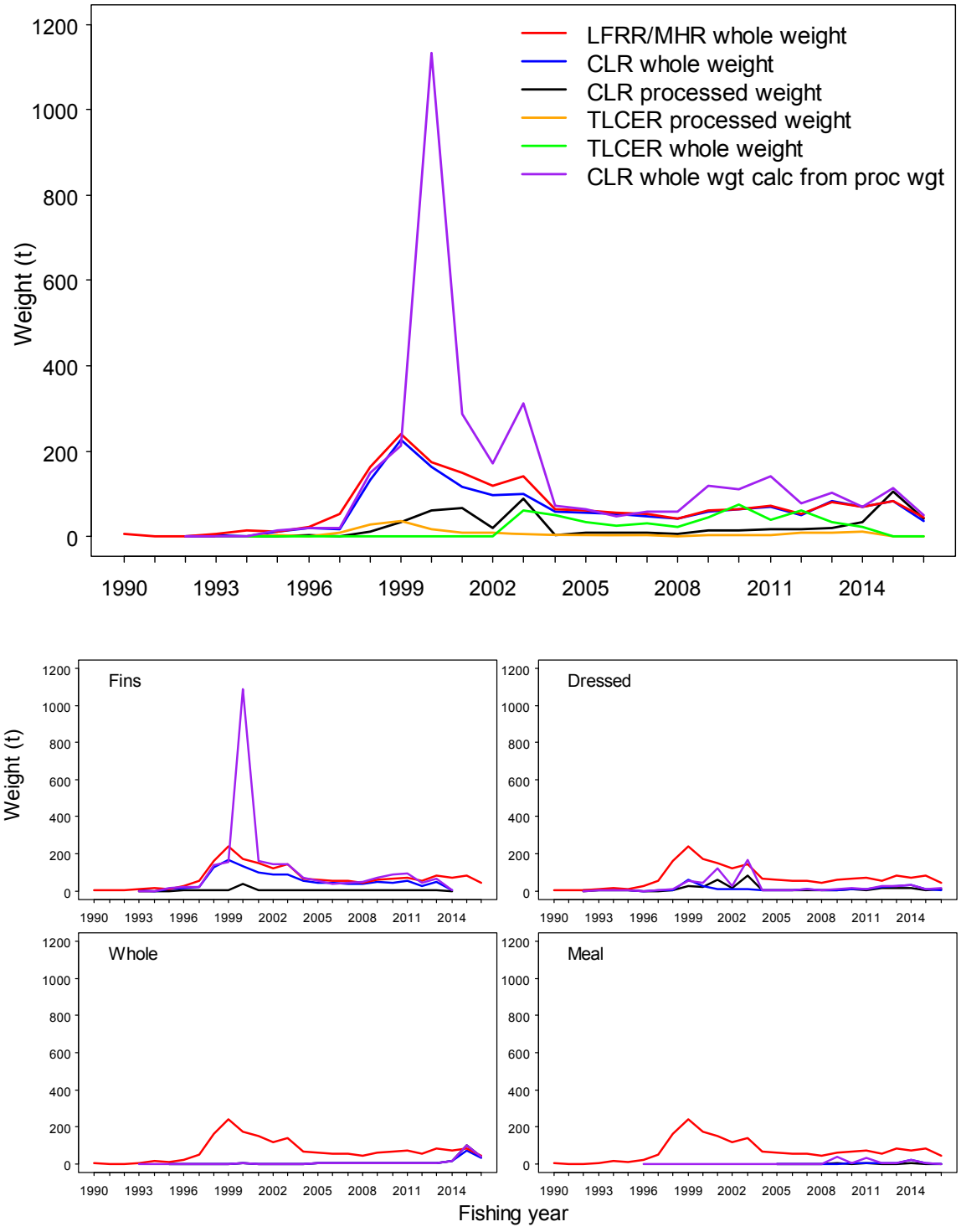


Figure A2.2: Original reported annual processed weight and whole weight by destination and landed state. See Appendix 1 for destination codes and Table 1 for state codes.

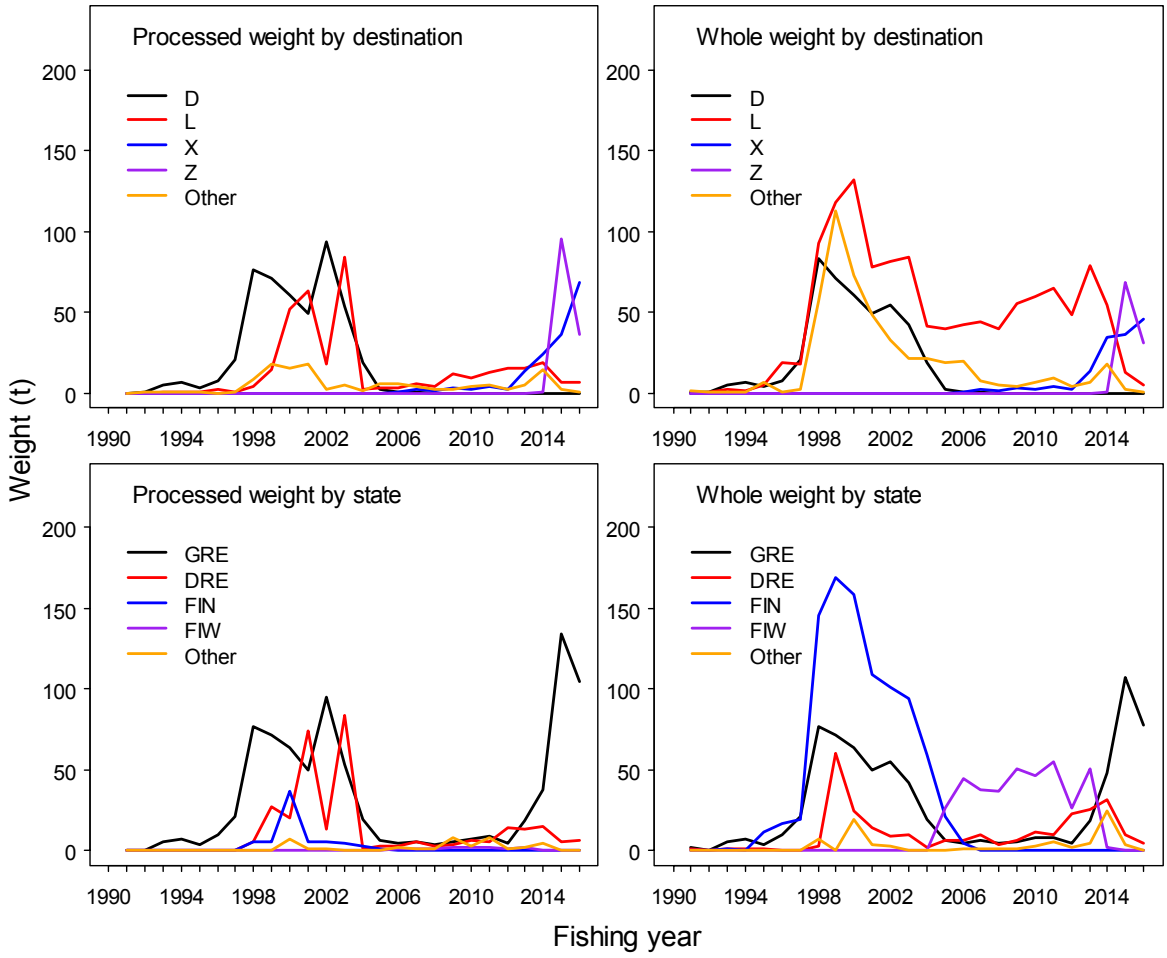


Figure A2.3: Original individual records of processed weight and whole weight (top panels), processed weight per day and whole weight per day (middle panels), and processed weight versus whole weight by destination and landed state (bottom panels). See Appendix 1 for destination codes and Table 1 for state codes.

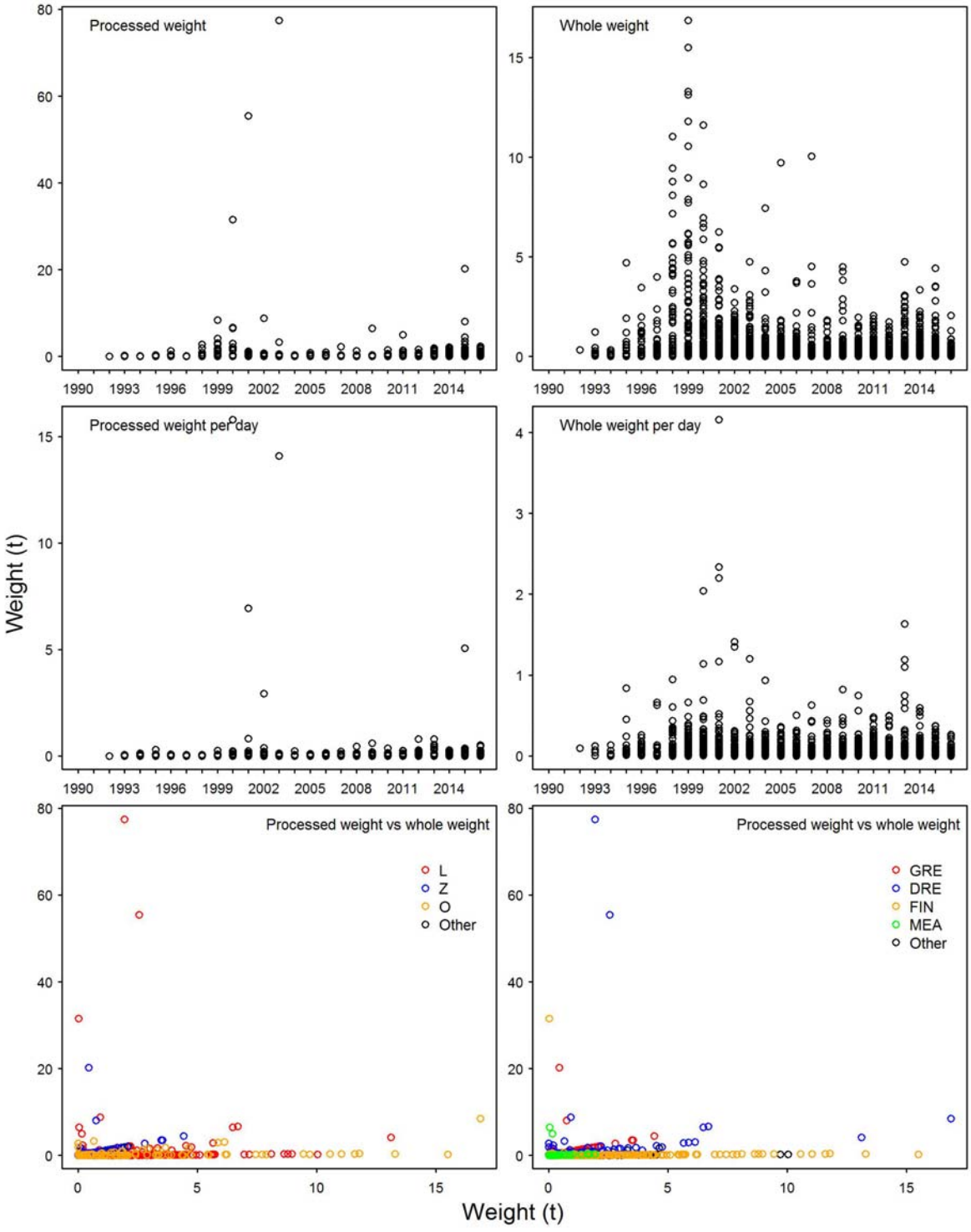
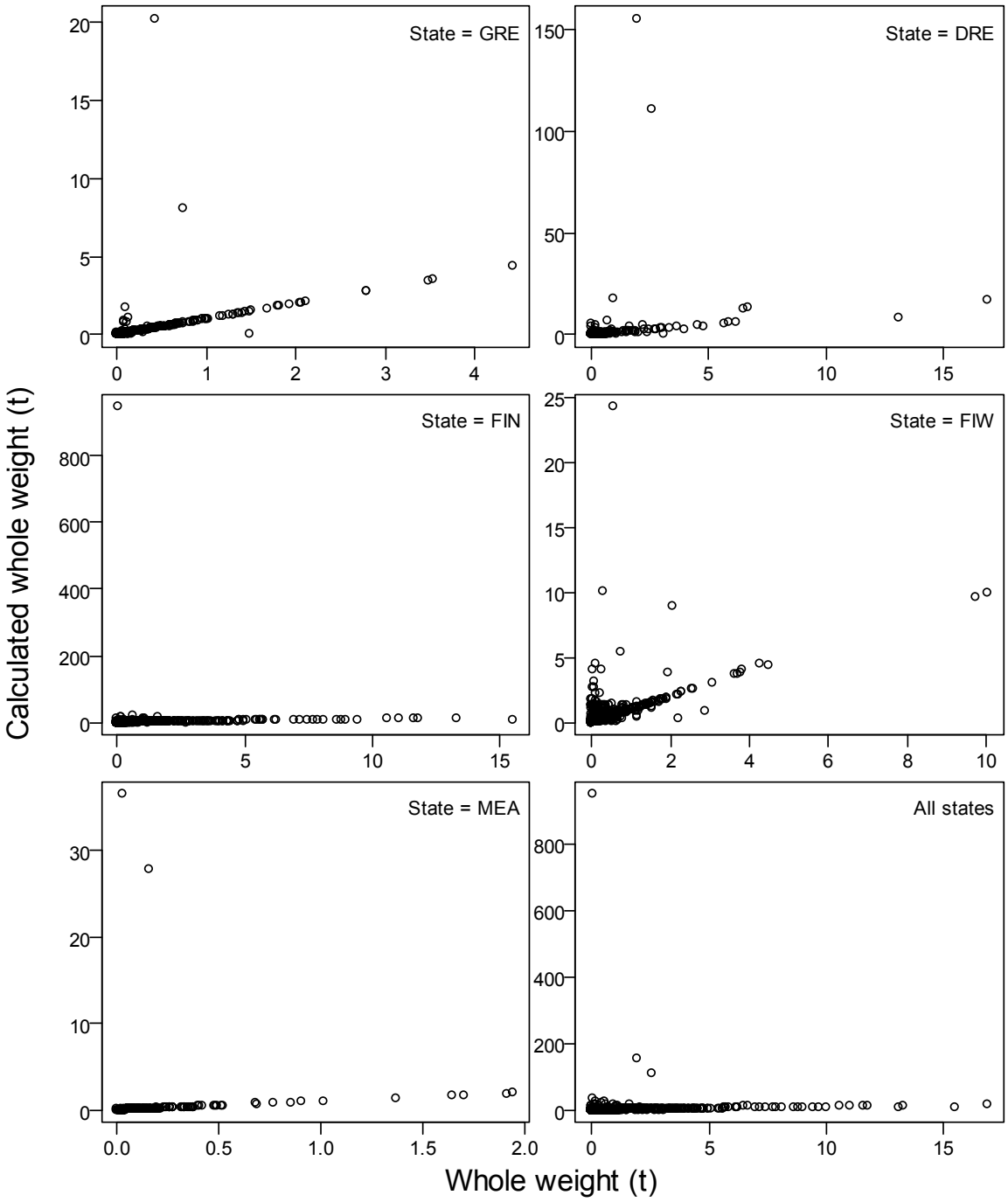


Figure A2.4: Original calculated whole weight versus reported whole weight by landed state (all years combined). See Table 1 for state codes.



APPENDIX 3: ERROR GROOMING PLOTS – GROOMED DATA

Figure A3.1: Comparison of groomed annual calculated CLR whole weight (processed weight × historic conversion factor) with reported CLR whole weight, LFRR/MHR whole weight, and other landed weight statistics by fishing year. Top panel shows data for all landed states combined, and the bottom four panels show data for the main landed states.

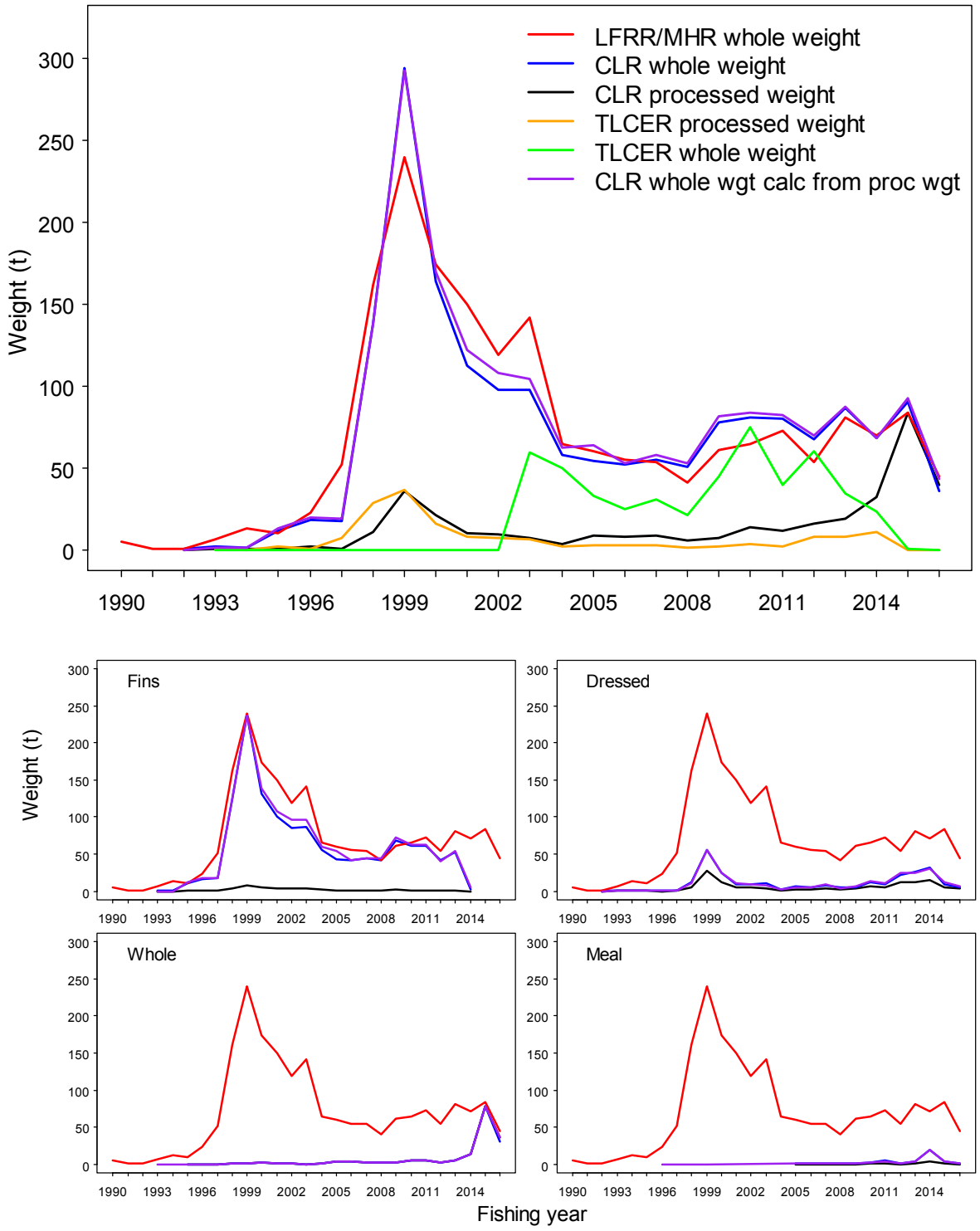


Figure A3.2: Groomed reported annual processed weight and whole weight by destination and landed state. See Appendix 1 for destination codes and Table 1 for state codes.

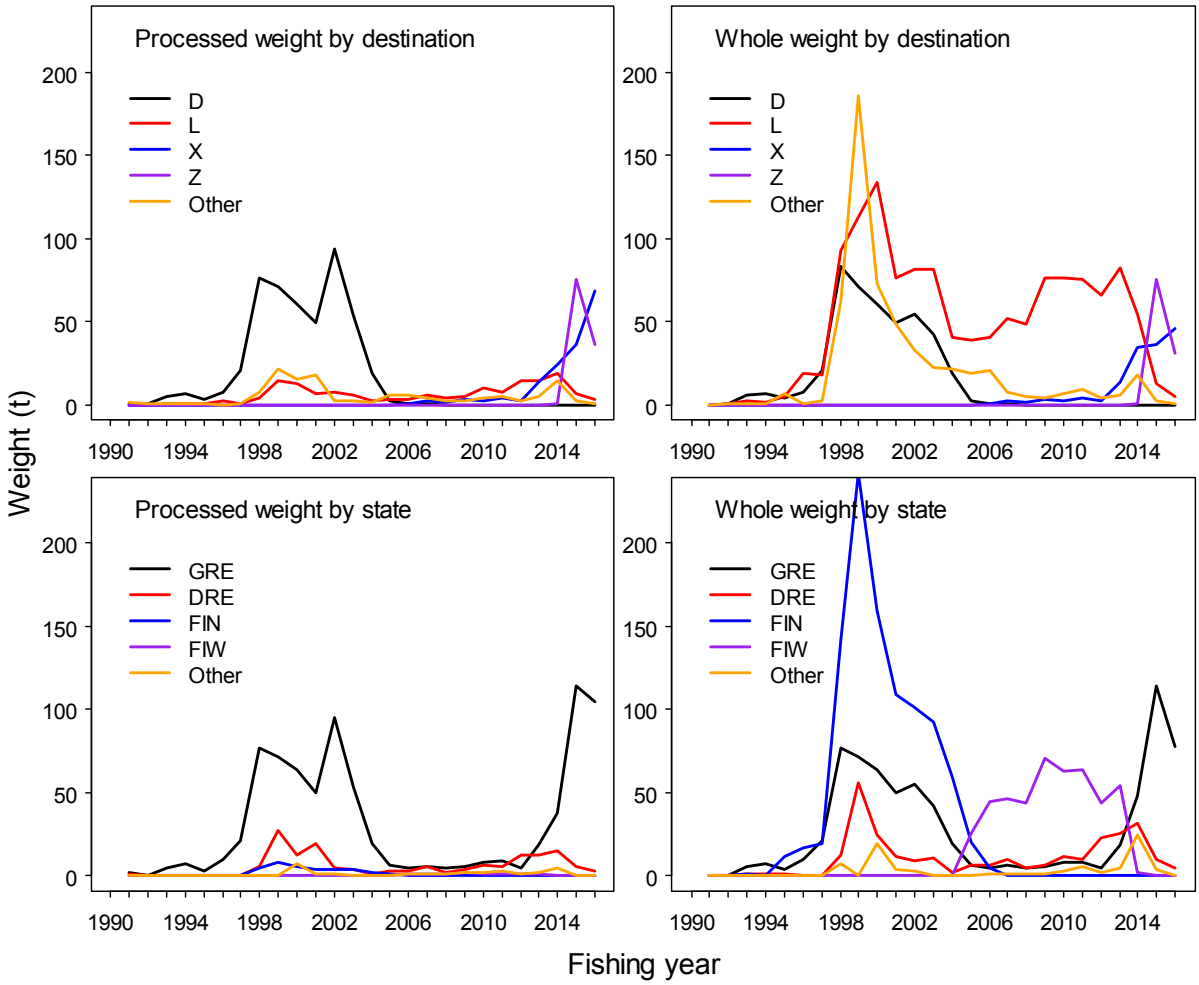


Figure A3.3: Groomed individual records of processed weight and whole weight (top panels), processed weight per day and whole weight per day (middle panels), and processed weight versus whole weight by destination and landed state (bottom panels). See Appendix 1 for destination codes and Table 1 for state codes.

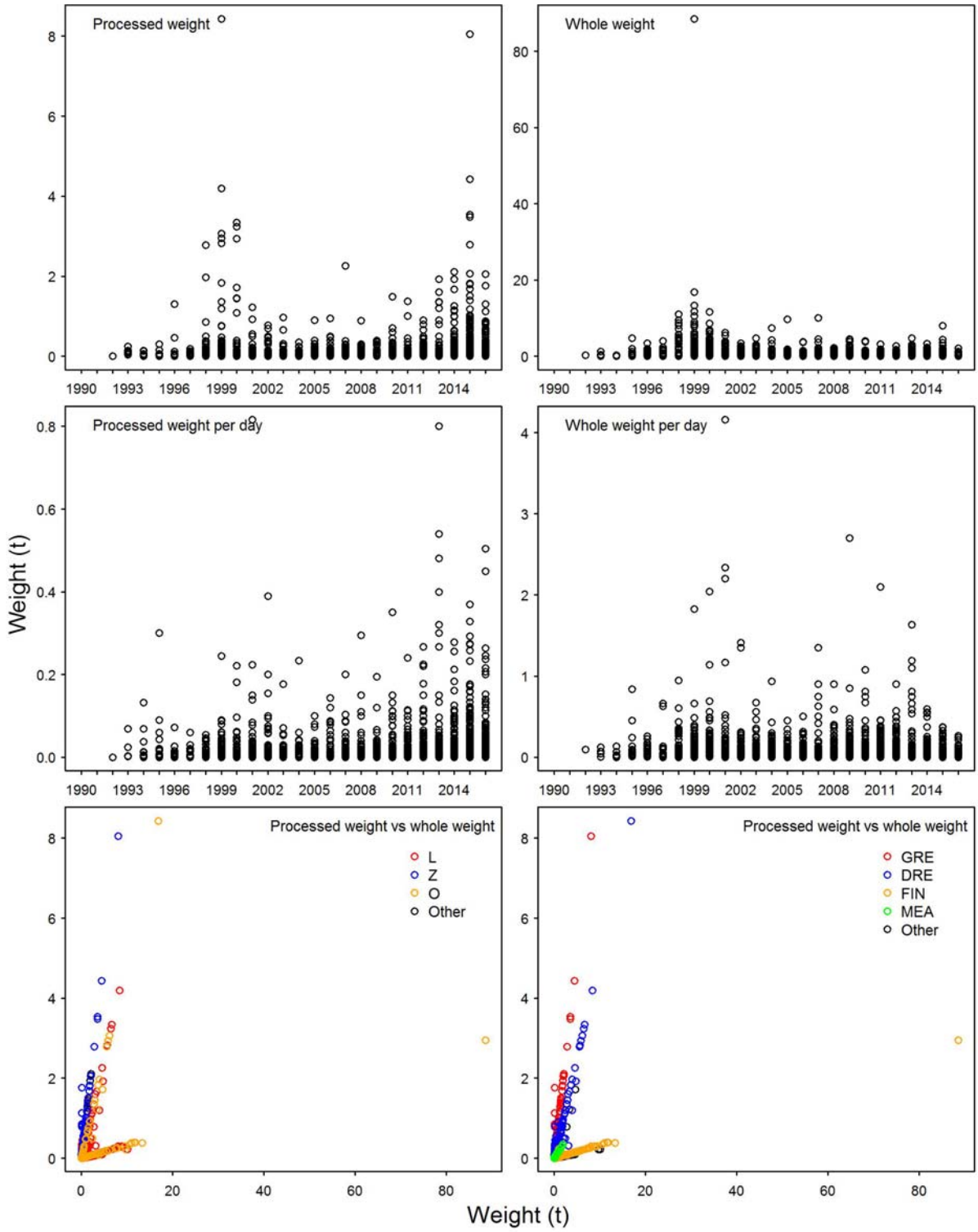


Figure A3.4: Groomed calculated whole weight versus reported whole weight by landed state (all years combined). See Table 1 for state codes.