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Cover photographs

Front cover, from left: blue-eye trevalla (top), jackass morwong, orange roughy, deepwater flathead, pink ling, blue-eye trevalla, gummy shark.

Report structure

Part 1 of this report describes the Tier 1 assessments of 2008. Part 2 describes the Tier 3 and Tier 4 assessments, catch rate standardisations and other general work contributing to the assessment and management of SESSF stocks in 2008.

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2008

Part 1: Tier 1 assessments

G.N. Tuck
October 2009
Report 2008/801

Australian Fisheries Management Authority

Stock Assessment for the Southern and Eastern Scalefish and Shark Fishery: 2008
Part 1

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6. Data analysis and preliminary updated stock assessment of Blue warehou (*Seriolella brama*) based on data up to 2008[4]

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6.1 Summary

A data summary and a preliminary assessment of the two stocks of blue warehou (*Seriolella brama*) (eastern and western) were conducted using Stock Synthesis 3. The data on which the assessment is based differs from those on which the 2006 assessment was based because: a) data for 2006 and 2007 are now available, b) the age-reading error matrix has been updated, and c) a minimum age-at-maturity is imposed. In common with recent assessments, discards are added to the landed catches when conducting the assessment for the western stock, but the model is fitted to the estimates of discard rate for the eastern stock.

The results for the eastern stock are qualitatively identical to those from the most recent three assessments; the stock is depleted to well below the target reference point and there is no evidence for a recovery. In contrast to the situation for the eastern stock, the western stock recovered from below the overfished threshold of $0.2B_0$ to close to the B_{MSY} proxy of $0.4B_0$ in 2005, but has declined since owing primarily to lack of good recruitment. The model predicts that the western stock will drop below the overfished threshold by 2008 if the landed catches for 2008 are as assumed. The assessment is more data-poor and less reliable than prior assessments because the most of the data for 2007 are unusable. The lack of data for 2007 for blue warehou presents more difficulties than for many other SESSF species owing to the short lifespan of this species.

6.2 Background and fishery

Blue warehou (*Seriolella brama*) are found in continental shelf and upper slope waters throughout south-eastern Australia (NSW, Victoria, Tasmania and South Australia). The species is also found in New Zealand waters. Adults are caught in depths to 500 m (Smith, 1994), although most commercial catches occur from 50 to 300 m. Spawning occurs during winter-spring in various locations throughout the adult distribution of the species (Knuckey and Sivakumaran, 2001) and larvae are widely distributed (Bruce *et al.*, 2001). Small juveniles are pelagic, commonly occurring in association with jellyfish in open coastal waters, and sub-adults often occur in the sheltered waters of large marine embayments. Growth is rapid, with a mean length of about 20 cm LCF being attained after one year. In Australia, the species has a maximum age of about 15 years, although higher maximum ages have been recorded for blue warehou in New Zealand (Horn, 2001). Recent studies suggest that maturity occurs at 3–4 years of age (Knuckey and Sivakumaran, 2001).

[4] Paper presented to the Slope Resource Assessment Group on 17-18 November, 2008

Assessments prior to 2000 were based on the assumption that blue warehou form a single stock off southeast Australia, given an absence of evidence to support a more complicated stock structure. However, there was increasing, though indirect, evidence for separate stocks to the east and west of Bass Strait: (a) two main spawning areas, (b) differences in the size- and age-compositions of the catch east and west of Bass Strait, and (c) differences in growth between areas. Recently Talman *et al*. (2003) found that several techniques, including MtDNA, morphometrics, otolith microchemistry and otolith shape analysis indicated significant differences east and west of Bass Strait. Given this strong evidence for separate stocks east and west of Bass Strait, recent assessments have been based on the assumption of two stocks.

6.2.1 Previous assessments

Quantitative analyses based on fitting population dynamics models to catch, catch-rate and catch-at-age data have formed the basis for stock assessments since the establishment of the Blue Warehou Assessment Group (BWAG) in 1997. Prior to 1997, management advice for blue warehou was based on the results of a yield-per-recruit analysis (Smith *et al*., 1994) and from visual examination of trends in catch and in nominal and GLM-standardized catch-rates (Smith and Wayte, 2004).

The 1997 and 1998 assessments of blue warehou were based on the application of a fleet-disaggregated Virtual Population Analysis to catch-at-age and standardized fishing effort data (Punt, 1998). These assessments involved three fleets (‘west trawl’, ‘east trawl’ and ‘non-trawl’). From 1999 onwards, assessments of blue warehou (Punt, 1999, 2000; Punt and Smith, 2005; Punt, 2006a, b) have been based on the ‘integrated analysis’ approach (e.g. Methot, 2006; Haist *et al*., 1993; Smith and Punt, 1998). This approach forms the basis for the bulk of the assessments of species in Australia’s South Eastern and Southern Shark Fishery (Smith *et al*., 2001; Tuck and Smith, 2005). Information on catches, discard rates, catch-rates, and the length/age structure of the discards and the landed catch were included in the 1999, 2000, 2004, 2005 and 2006 assessments. The last four assessments of blue warehou were based on four (rather than three) fleets (‘west trawl’, ‘east trawl’, ‘non-trawl’ and the Tasmanian meshnet fishery). The 2006 assessment was the first to use the age- and size-structured stock assessment package Stock Synthesis 2.

6.2.2 Summary of the 2006 and 2007 fisheries

The landings east and west of Bass Strait during 2006 were 33t / 25t (Commonwealth / Tasmania) and 393t respectively while the comparative values for 2007 were 21t, 25t and 174t respectively (Table 6.1). The landed catch in the east continues to be a low fraction of historical values, while the landed catch in the west during 2007 is the lowest since 1989. This is attributable in no small part to the TAC for 2007 of 288t (both stocks). The standardized catch-rates for both stocks continued to be low in 2006 and 2007 (Table 6.1).

6.2.3 Modifications to the 2006 assessment

A number of modifications have been made to the data and model on which the 2006 assessment (Punt, 2006a) was based.

a) The data for 2006 and 2007 are included in the assessment (see Sections 3.1–3.4).
b) The age-reading error matrix has been updated (see Section 3.4).
c) The constraint that blue warehou cannot mature before age 2 has been imposed.
d) The assessment is based on Stock Synthesis 3 rather than Stock Synthesis 2 (see Sections 4.1 and 4.2).

6.3 Data available for assessment purposes

There are many sources of data for blue warehou. These include values for biological parameters, landed catches, discard rates (defined here as the ratio of the discard catch (in mass) to the total (i.e. discarded and landed) catch), catch-rates, length-frequencies for the landed and discarded catches, and age-length keys.

As was the case for the 1999, 2000, 2004, 2005, and 2006 assessments, the following four ‘fleets’ are considered in the assessment:

a) the otter trawl fishery in zones 10, 20 and 30 of the SESSF (denoted ‘east trawl’),
b) the otter trawl fishery in zones 40, 50 and 60 of the SESSF (denoted ‘west trawl’),
c) the meshnet fishery off Tasmania (denoted ‘Tas meshnet’), and
d) the Commonwealth gill-net fishery (denoted ‘non-trawl’).

These four ‘fleets’ were selected by BWAG after consideration of their catch length-frequency distributions, and the likely impact of management measures (e.g. the Tasmanian meshnet fishery is not covered by the *TAC*s set by AFMA). The following sections outline the data available for assessment purposes. The analyses are conducted assuming that the ‘west trawl’ fleet is fishing a different biological stock from the other three fleets.
Some of the previous assessments have been based on the assumption of a ‘biological year’ lifecycle (defined as ‘May – April’, based on spawning starting in winter) as well as that of a calendar year lifecycle (birth at the start of January each year). The results of assessments based on these two lifecycles have been qualitatively the same (e.g. Punt and Smith, 2005). In common with assessments since 2005, this assessment only considers a calendar year lifecycle.

6.3.1 Catches

Information on catches is available from the SEF1 and GNO1 logbooks, the SEF2 and SAN2 catch validation databases, from State reporting systems, and from historical records (for the years prior to 1986 (SEF1) and 1997 (GNO1) – data for only a few months of 1985 are included in the SEF1 database). Blue warehou are closely related to silver warehou and mixed catches do occur. Early catch statistics were recorded for all warehou species combined, commonly referred to as ‘Tassie trevally’. Comparisons between logbook and ‘verified’ catch data in the late 1980s also indicated problems with correct recording of each species. However, consideration by SEFAG of the two data sets indicated that records in the SEF1 logbook gave the best data on individual species.

6.3.1.1 Trawl catches - Commonwealth

For the Commonwealth trawl fishery, the annual catches by fleet were extracted from the SEF1 database. These catches were then rescaled so that the total (over fleet) catch by species equals the total validated catch based on the SEF2 records, i.e.:

$$\tilde{C}_y^f = \tilde{C}_y^{f,\mathrm{SEF1}} \frac{\tilde{C}_y^{\mathrm{SEF2}}}{\sum_{f'} \tilde{C}_y^{f',\mathrm{SEF1}}} \qquad (1)$$

where $\tilde{C}_y^f$ is the catch (in mass) by fleet f (‘east trawl’ and ‘west trawl’) during year y used in the analyses,

$\tilde{C}_y^{f,\mathrm{SEF1}}$ is the catch (in mass) by fleet f during year y recorded in the SEF1 database, and

$\tilde{C}_y^{\mathrm{SEF2}}$ is the catch (in mass) during year y recorded in the SEF2 database.

Ideally Equation 1 should have been applied by fleet. Unfortunately, it remains currently infeasible to link the SEF2 records with the SEF1 records to enable an appropriate comparison to be made (the SEF2 records are by port and vessel callsign whereas the SEF1 records are shot-by-shot).

SEF2 catches are only available from 1992. It is therefore not possible to apply Equation 1 directly for the years prior to 1992. For the purposes of the analyses of this report therefore, the catches prior to 1992 have been adjusted using the formula:

$$\tilde{C}_y^f = \tilde{C}_y^{f,\mathrm{SEF1}} \frac{\sum_{1993 \le y \le 1998} \tilde{C}_{y'}^{\mathrm{SEF2}}}{\sum_{1993 \le y \le 1998} \sum_{f'} \tilde{C}_{y'}^{f,\mathrm{SEF1}}} \qquad (2)$$

The adjustment factor for the pre-1992 catches is 1.17.

6.3.1.2 Non-trawl catches

The catches by the non-trawl fleet for the years 1997–2007 were extracted from the GN01 logbook records. These catches were rescaled to match the SAN2 catches using Equation 1 and divided by 0.92 to account for an 8% discard rate (evident from the observer data). The non-trawl catches for 1986–96 were provided by Dr David Smith (CMAR, pers. commn).

6.3.1.3 State catches

Catches of blue warehou are made off the northwest and southeast of Tasmania, but the bulk of the catch is taken off the southeast (82% - 1996–2002; Punt 2006a). Given the lack of data on length-frequency for the Tasmanian catches, and the fact that most of the catch is taken from the southeast of Tasmania, all of the catches off Tasmania are assumed to be taken from the eastern stock.

Catches of blue warehou are recorded in NSW state logbooks. However, the data in these logbooks prior to 2000 contained many fish taken in Commonwealth waters (K. Rowling, NSW Fisheries, pers. commn). The NSW state catches for 2001-7 are assumed not to be recorded in the SEF1 logbook and are therefore added to the catch history for the 'east trawl' fleet calculated using Equation 2.

Year	2001	2002	2003	2004	2005	2006	2007
Catch (kg)	265	303	323	1630	2373	644	678

6.3.1.4 Catches used in the assessment

The catch for 2008 has been set to 214t (western stock) and 33t (eastern stock) based on the catches during 2007 and proration. The catch by the Tasmanian fleet has been set equal to that for 2007. Table 6.1 lists the catches by fleet included in the analyses. In common with the 2006 assessment, the catches by the 'west trawl' fleet are inflated by the observed discard rates.

6.3.2 Catch-rates

Catch-rate data constitute the primary source of information to determine trends in population size for the species in the South Eastern and Southern Shark Fishery. However, the catch and effort data need to be standardized to (attempt to) eliminate the impact of factors other than changes in abundance on trends in catch-rates (Gavaris, 1980; Kimura, 1981; Vignaux, 1994; Maunder and Punt, 2004).

6.3.2.1 Catch-rate indices based on logbook data

Catch-rate indices were developed for the 'east trawl', 'west trawl' and 'non-trawl' fleets by fitting a linear model (with normal error structure) to log-transformed catch rate data. This approach has been used widely to standardize catch and effort data for SESSF species (e.g. Klaer, 1994; Punt *et al*., 2001; Haddon and Thomson, 2005). The 'best' model selected for the 'east trawl' and 'west trawl' fleets using AIC (Haddon, 2008) was:

$$\mathrm{Log}(C/E) = \mathrm{Constant} + \mathrm{Year} + \mathrm{Vessel} + \mathrm{Month}*\mathrm{Zone} + \mathrm{Depth}+\mathrm{DayNight}$$

where year, month, zone, depth, daynight, and vessel are categorical variables. The depth of the catch was transformed from a continuous variable to a discrete variable by dividing the range of depths into 20 m intervals (Haddon, 2008), restricted to 0-400 m for the 'east fleet' and 150-400 m for the 'west fleet'. Only those vessels active in the fishery for more than two years were included in the analyses. In contrast, the 2006 assessment was based on vessels that had a median catch of at least 4 t and had been in the fishery for at least two years, while the covariates were year, month, zone, vessel, and 50 m depth interval. However, the resulting standardized catch-rate indices for the current assessment are not markedly different from the geometric means of the catch rates nor from the standardized index on which the 2006 assessment was based (Figure 6.1). The most marked differences in Figure 6.1 are for the earliest years for the western stock. This is perhaps not surprising because there are very few data points for this stock. For example, the catch rate index for 1989 is based on only nine shots and hence cannot be considered to be reliable (it has a CV that is twice those for the remaining years). The index for 1989 is consequently not included in the preliminary assessment for the western stock.

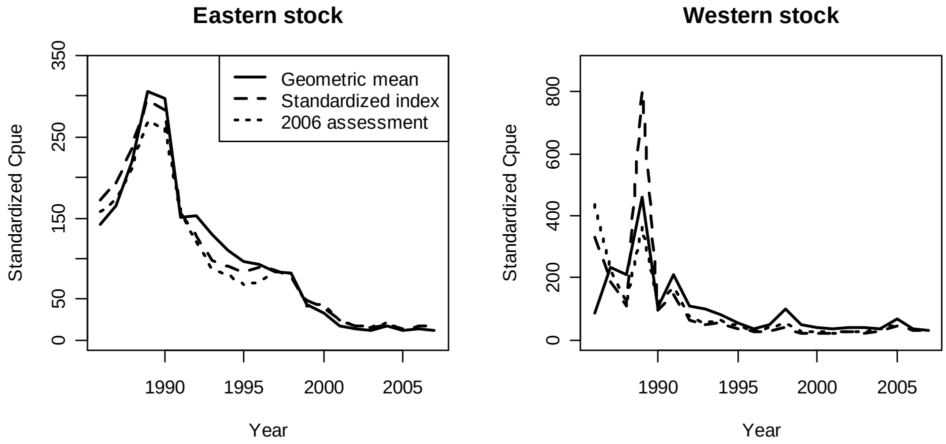

Figure 6.1. Standardized trawl catch-rate indices, geometric mean trawl catch-rates, and the trawl catch-rate indices on which the 2006 assessment was based. Each index is standardized to its mean for improved clarity.

The non-trawl catch-rate indices (Table 6.1) were supplied by Dr David Smith (CMAR, pers. commn) based on the application of a GLM model to catch and effort data for a subset of the non-trawl fleet. The number of records drops over time. The analyses consequently ignore the data point for the last year of this index (1999).

The standardized catch-rate indices used in the analyses are listed in Table 6.1. The catch-rate indices for the 'west trawl' fleet are inflated by the discard-rates for this fleet because Punt (2006a) showed that the discards for the western stock have essentially the same age- and size-structure as the landed catch (i.e. the selectivity ogive for the discarded catch is the same as that for landed catch) while this is clearly not the case for the eastern stock.

The assessment results are highly dependent on the standardized catch rate index. The following section provides a more in-depth summary of the data and conducts some analyses to identify whether the trends in Figure 6.1 may be spurious, owing to the way the data have been analysed.

6.3.2.2 Data exploration for the catch and effort data

Appendix A (Section 6.9) plots the distributions by year for month, depth, zone and day/night separately for the positive catches (hashed bars) and the zero catches (solid bars). Results are shown separately for the eastern and western stocks in Appendix A (Section 6.9). In general, the distribution of shots among months, depths, and time-of-day differ markedly between 1986-89 and 1990+ for the western stock, although this can be attributed in part to the small number of shots which caught fish from this stock for the early years. The number of shots catching blue warehou in the west at night is low until 2000, after which the proportion of night shots and shots during the night and day (mixed shots - "Mi" in Section 6.9, Appendix A.4) increased markedly.

The bulk of the shots which caught blue warehou in the east occurred towards the end of the year in the early years (with a peak in September in 1986, 1987, and 1990-92), but since then non-zero catches of blue warehou have occurred almost uniformly across all months (Figure 6.17). The proportion of the shots which caught blue warehou that occurred in zone 10 was much higher in 1986 and 1987 than thereafter, while there was an increase in this proportion for zone 30 after about 2002 (Figure 6.19). The pattern that more shots catching blue warehou occurred at night that is strongly evident for the western stock is also evident for the eastern stock (Figure 6.20), but not to the same extent as is the case for the western stock.

The patterns in Appendix A (Section 6.9) could be consequential for the purposes of the assessment if there are interactions between year and one or more of these factors (the standardizations in Haddon (2008) ignore interactions with year). The left panels of Figure 6.2 therefore show time-trajectories of catch rate by zone. The catch-rate series based on data for zone 50 only is nearly identical to that for the zones 40+50 combined, which is hardly surprising because there are few data for zone 40 (Figure 6.19). The catch-rate series by zone for the eastern stock are very similar after 1997, but vary markedly among zones before this (the results for zone 30 for the years prior to 1997 are unreliable owing to small sample sizes). The catch-rate series for the eastern stock are insensitive to whether the analyses are based on shots conducted during the day, at night, or shots that occurred during the day and night (lower right panel of Figure 6.2). However, the results for the western stock are less pessimistic when the analyses are restricted to shots that took place during the day only (upper right panel of Figure 6.2).

Figure 6.3 examines the consequences of dropping the data for the years before 1991 on the trajectories of standardized catch-rate. Figure 6.3 shows that the trends after 1992 are not impacted by the inclusion or otherwise of the data for 1986-90.

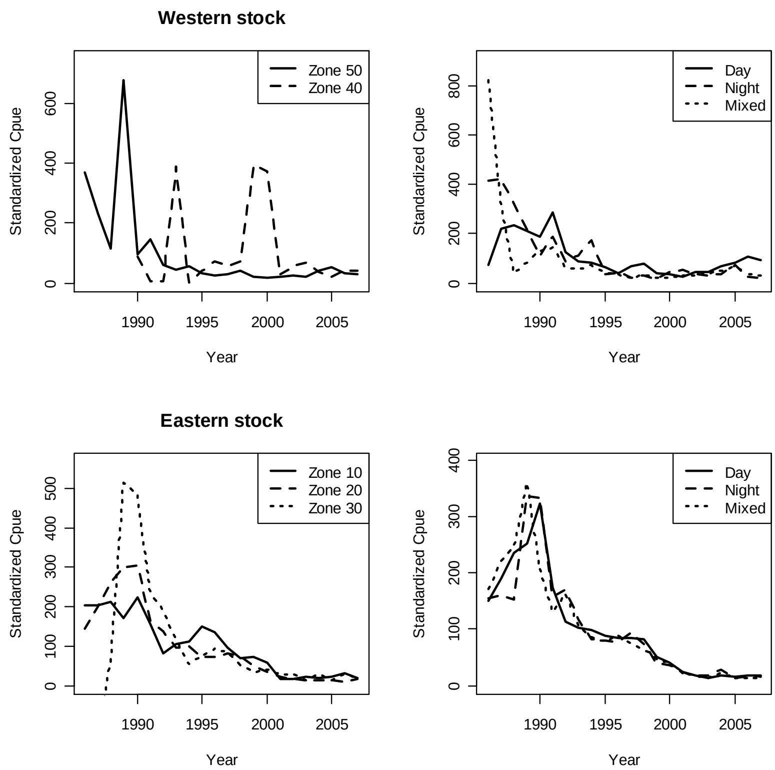

Figure 6.2. Standardized trawl catch-rate indices for the western (upper panels) and eastern (lower panels) stocks. The left panels show standardized trawl catch-rate indices by zone and the right panels show standardized trawl catch-rate indices by time of shot.

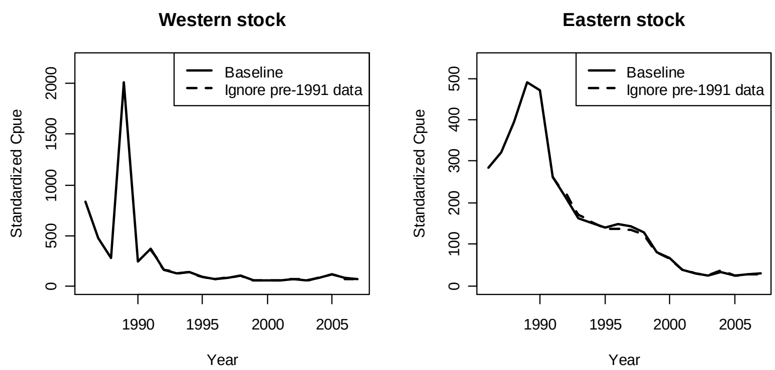

Figure 6.3. Base-case standardized trawl catch-rate indices and those obtained using data for 1991-2007 only.

Figure 6.4 illustrates the development of the fishery over time in terms of the spatial distribution of the shots that have non-zero catches of blue warehou. The shading is based on the ¼ power of the catch-rate (to enable low catch-rates to be resolved from very low catch-rates). The expansion of the fishery in the west from 1989 until 1996 is particularly noticeable. Although there are more shots that have caught blue warehou in the east, the areas of highest catch-rate have consistently been in the west. It is clear from Figure 6.4 that although catch-rate series are developed based on zones, the distribution of shots within zones has changed quite markedly over time. The quantitative impact of this on standardized (or nominal) catch-rate is unknown, but could be a topic for future work.

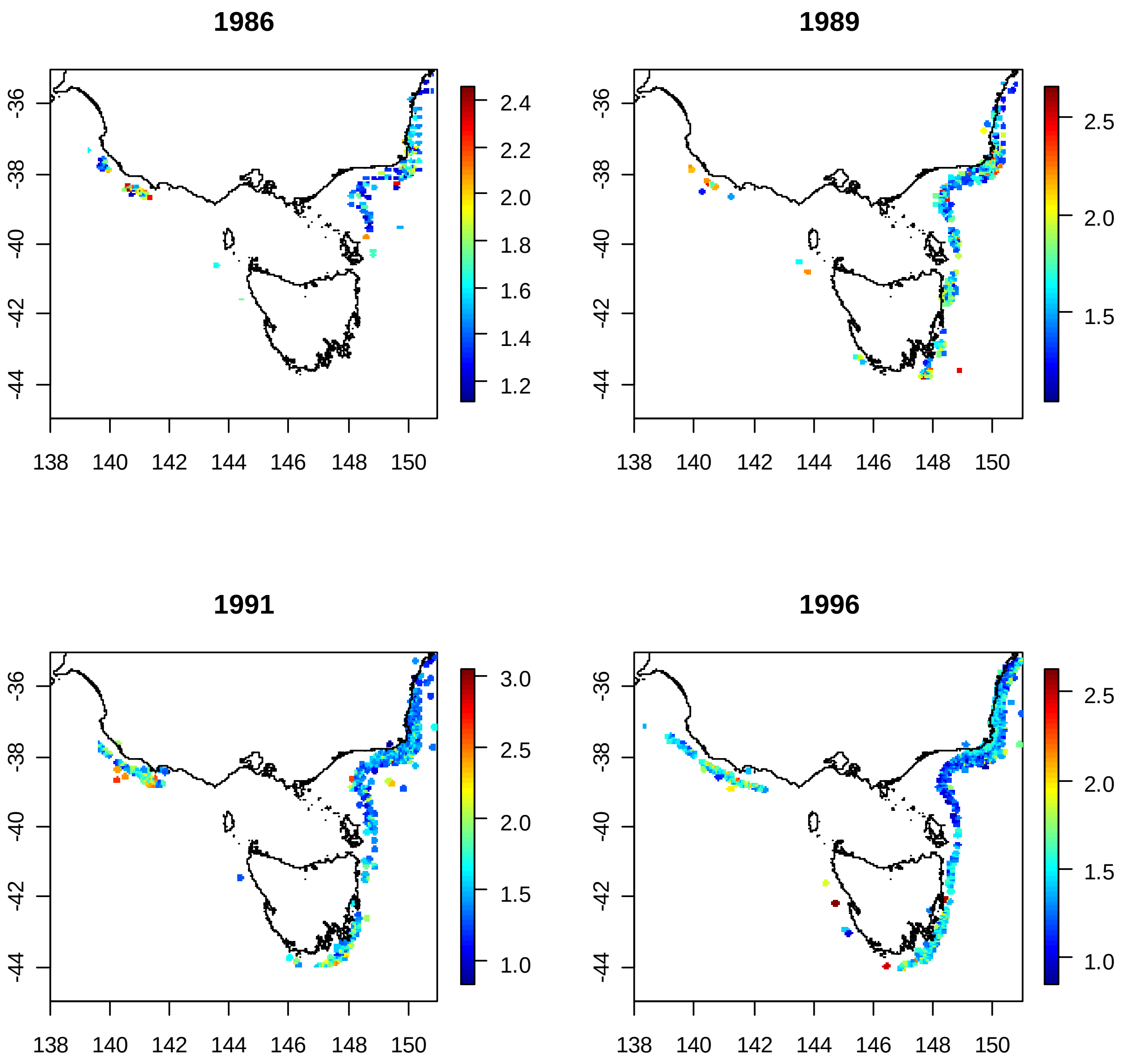

Figure 6.4. Locations of the shots that had non-zero catches of blue warehou. The colours denote the ¼ root of catch-rate.

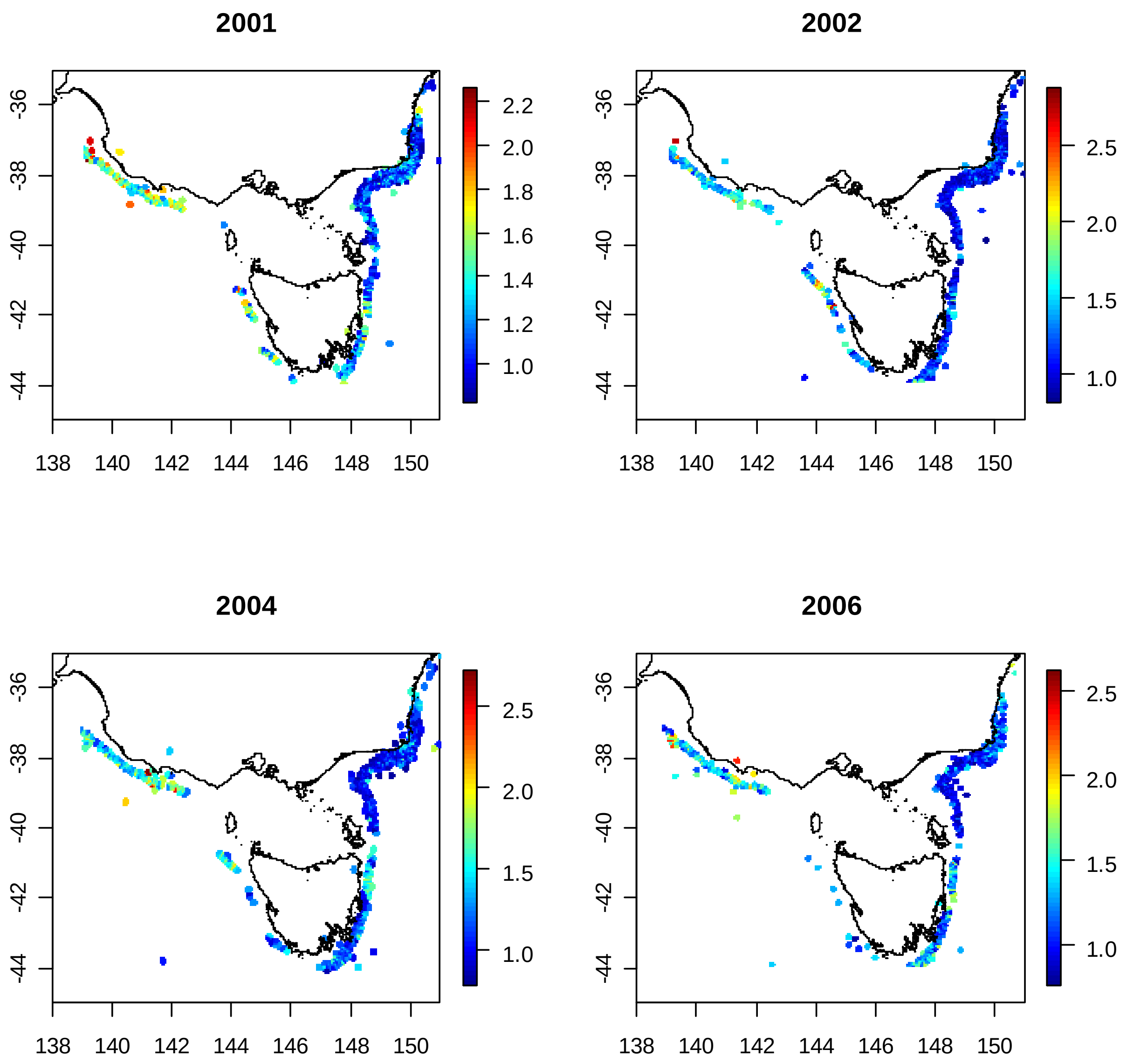

Figure 6.4. (Continued) Locations of the shots that had non-zero catches of blue warehou.

6.3.2.3 Catch-rate indices based on the ISMP programme

Data on catch-rates of blue warehou are available from the ISMP programme. These data can be standardized by applying the delta method (Lo *et al.*, 1992; Stefánsson, 1996). The probability of a non-zero catch was modeled using the binomial distribution, while the non-zero catch rates were modeled assuming a log-gamma error structure.

The results of the catch-effort standardization (Figure 6.5; Table 6.2) suggest that there are too few targeted shots for the eastern stock to form the basis for acatch-effort standardization. There are sufficient data for the western stock to conduct an analysis (Table 6.2), but the results are fairly imprecise (approximate coefficient of variation of 74%).

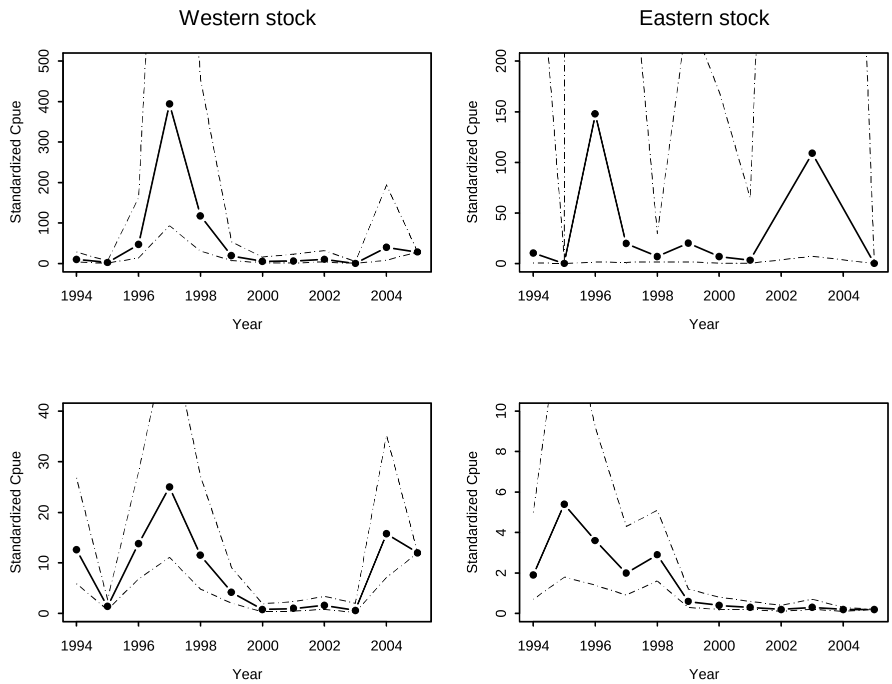

Figure 6.5. Standardized catch-rate indices based on the ISMP programme (estimates and approximate 95% confidence intervals). Results based on the targeted shots are shown in the upper panels and those based on all shots in the lower panels.

The ISMP catch-rate series have not been updated for the current assessment. Given the high CVs in Figure 6.5, these data are uninformative anyway (Punt, 2006a).

6.3.3 Discard rates

Information on the fraction of the catch (in mass) that is discarded annually is available from onboard observers. Two observer programmes, the SMP (Liggins, *et al.*, 1997) and the ISMP (Knuckey, *et al.*, 1999) have collected onboard data that can be used to estimate discard rates. The data collected by the observers are estimates by shot of the mass retained and the mass discarded. The discard rate used in this report is the ratio of the mass discarded (summed over all shots by a given fleet in a given year) to the total mass (retained plus discarded). Any records for which the gear code was not bottom trawl and in which the catch did not occur in one of SESSF zones 10, 20, 30, 40, 50 or 60 were ignored when determining discard rates for inclusion in the model (Table 6.3).

Discard rates by stock are computed by totalling the estimates of discard for each of the zones in which the stock is found (10, 20, and 30 for the eastern stock and 40, 50, and 60 for the western stock) and then dividing by the total (discarded and retained) catch from the stock. The boundary between zones 10 and 20 was set to $37^0$30S for the purposes of these calculations to avoid extrapolating discards between $37^0$15S and $37^0$30S to all of zone 20. The data prior to 1996 are not included in the analyses of this report due to small sample sizes.

The resultant discard rates are listed (by year and fleet) in Table 6.1 along with measures of their precision, expressed as coefficients of variation. The coefficients of variation in Table 6.1 are based on a bootstrap procedure; for each combination of year and stock, 1,000 pseudo data sets were generated by resampling shots at random and with replacement from the actual observer data for the fleet, year and stock under consideration. Table 6.1 does not list discard rates for 2007 for the east owing to lack of data. The discard rate estimate for 2007 for the west is very imprecise, owing to low sample sizes.

6.3.4 Age- and length-frequency data

Length-frequency data are available from port measurers and from onboard sampling. The former generally involve much larger sample sizes than the latter (Table 6.4). In contrast, the onboard sampling programmes provide information on the length-frequencies of the discarded as well as the landed catch. As for the 2005 and 2006 assessments, the length-frequency and age-composition data included in the assessment are restricted to those based on at least 100 fish (Table 6.4 indicates the data omitted from the assessment owing to the sample sizes not satisfying this criterion by means of asterisks).

6.3.4.1 Port length-frequencies

The port length-frequencies for a given fleet are constructed from the raw data collected by the measurers using the equation:

$$N^f_{y,L} = \sum_v \tilde{N}^{f,v}_{y,L} / R^{f,v}_y \qquad (3)$$

where $N^f_{y,L}$ is the number of animals in the component of the landed catch by fleet f during year y that was measured that are in length-class L,

$\tilde{N}^{f,v}_{y,L}$ is the number of animals in the v^{th} sample collected from the landed catch by fleet f during year y that are in length-class L, and

$R^{f,v}_y$ is the fraction of the catch of the v^{th} sample collected from the landed catch by fleet f during year y that was measured.

This approach to constructing catch length-frequencies is based on the assumption that the samples for a given fleet are a simple random sample of the catch by that fleet. In principle, this approach to constructing length-frequencies could be generalized so that, for example, port-specific length-frequencies are constructed and these then weighted by the port-specific contribution to the overall catch. Table 6.3 lists the restrictions imposed on the data.

Figure 6.6 plots the port-based length-frequencies from the ISMP database for 1991–2006[5]. Results are shown in Figure 6.6 for the three key ports (Eden, Lakes Entrance, and Portland) and for three SESSF zones (East A, East B, and West). Eden, Lakes Entrance and Portland constitute the majority of the length-frequency records. The other ports for which notable amounts of data are available are Hobart, Beachport, and Bermagui. As expected, the length-frequencies for the western stock are based almost exclusively on the data for vessels from Portland. The picture in the east is less clear because: a) the length-frequencies for vessels based in Eden and those based in Lakes Entrance often differ substantially, and b) there is not a clear match between the port-based length-frequencies by port and the port-based length-frequencies by SESSF zone.

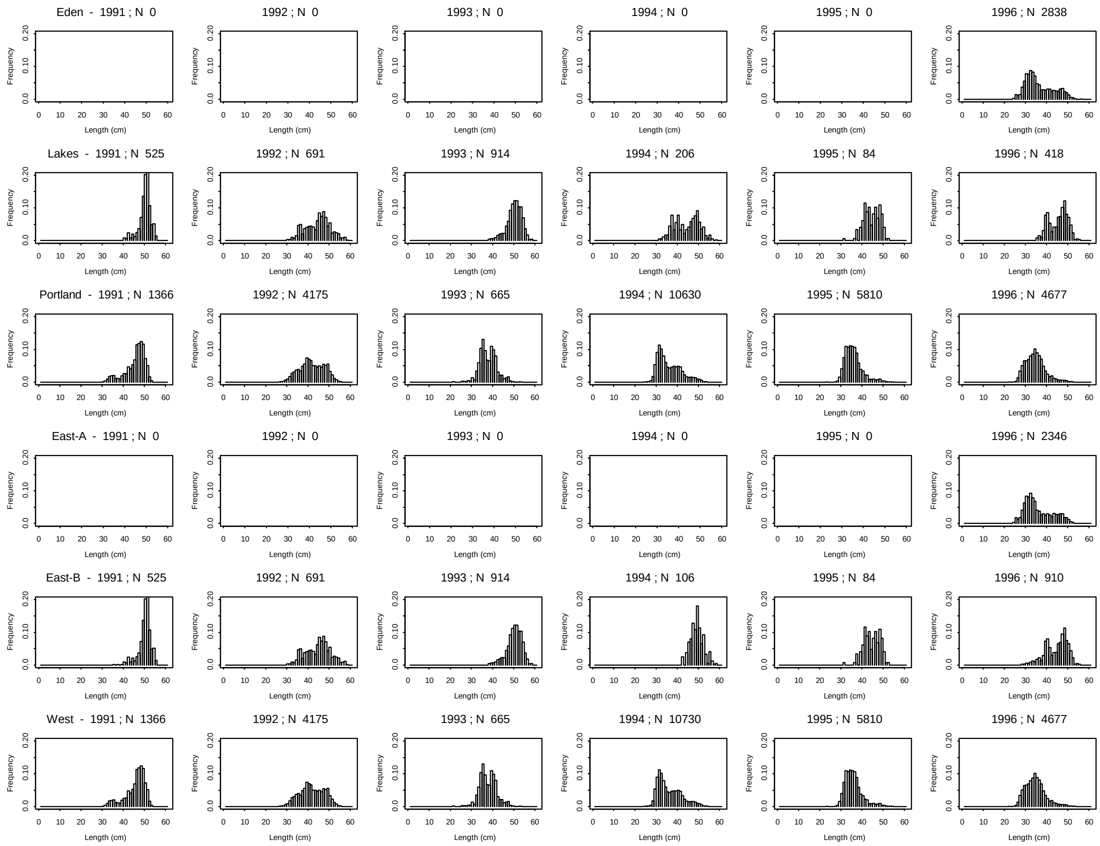

Figure 6.6.a Port-based length-frequency data from the SMP and ISMP for blue warehou. Results are shown by port of landing (Eden, Lake Entrance, Portland) and by SESSF zone (East A, East B, and West).

The port-based length-frequencies on which the analyses of this report are based were constructed as follows: 'west trawl' – the port-based length-length-frequencies for vessels from Portland; 'east trawl' – the port-based length-frequencies for vessels from Eden (1998–2006) and data collected at sea and in port from Eden-based vessels (1994–97) by the SMP. The latter data are included in the assessment because the sample sizes prior to 1997 in Figure 6.6 are very small. In contrast, the SMP sample sizes for 1994–97 are 2,889, 2,260, 2,833 and 3,730 respectively (Table 6.4). The data set 'west trawl'

[5] Results are not shown for 2007 because almost all of the port-based samples were collected from Lake Entrance vessels (presumably Danish seiners) while catch and sample weights are missing from the remaining port-based samples. The onboard samples for 2007 cannot be used for assessment purposes because the catches were not split between discarded and retained components.

starts in 1991 (Figure 6.6). However, data on length-frequency are also available for the western stock for 1987 and 1988 based on sampling during a research project (Smith *et al*., 1995).

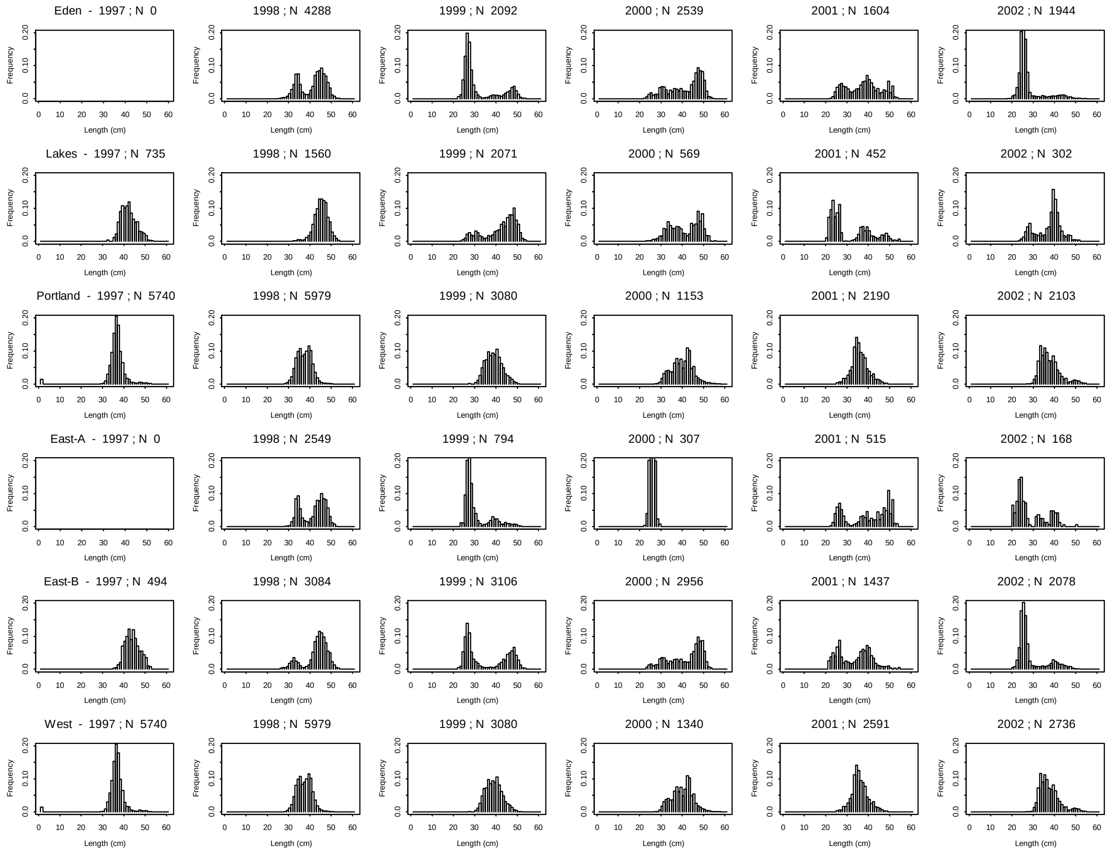

Figure 6.6.b Port-based length-frequency data from the SMP and ISMP for blue warehou. Results are shown by port of landing (Eden, Lake Entrance, Portland) and by SESSF zone (East A, East B, and West).

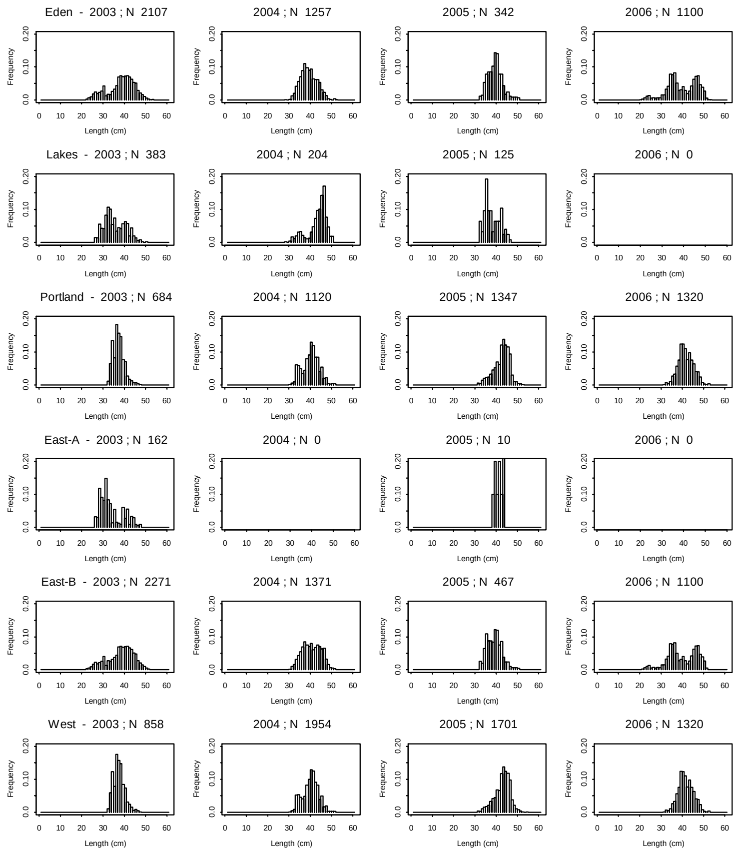

Figure 6.6.c Port-based length-frequency data from the SMP and ISMP for blue warehou. Results are shown by port of landing (Eden, Lake Entrance, Portland) and by SESSF zone (East A, East B, and West).

The use of SMP and port-based ISMP data is based on the assumption that the onboard length-frequency data and the port-based length-frequency data are sampling the same underlying “populations”. This is examined in Figure 6.7 which compares the length-frequencies for the retained catch from onboard sampling with the length-frequencies based on port-based sampling for vessels based in Eden, Lakes Entrance and Portland. Although there are differences between the port-based and onboard retained samples, the differences are not marked.

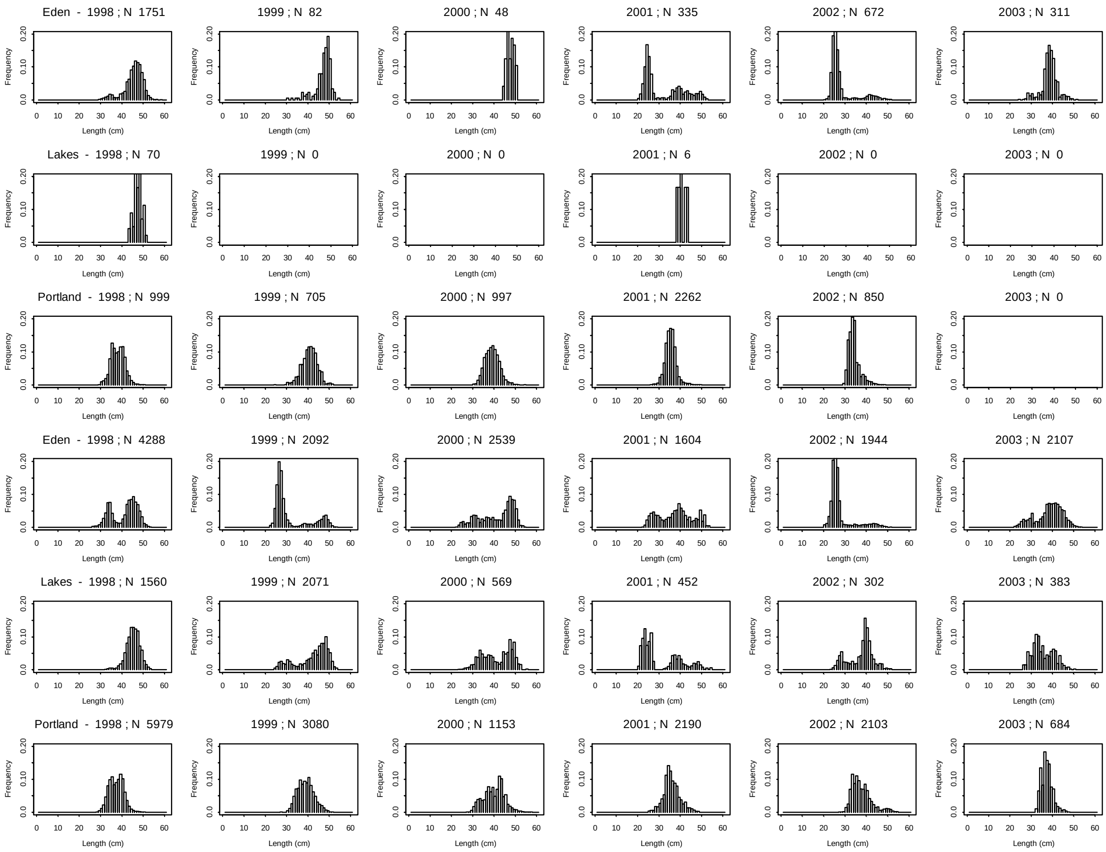

Figure 6.7.a Onboard and port-based retained length-frequency data from the ISMP for blue warehou. Results are shown by port of landing (Eden, Lake Entrance, Portland) based on the onboard data (upper panels) and from port sampling (lower panels)

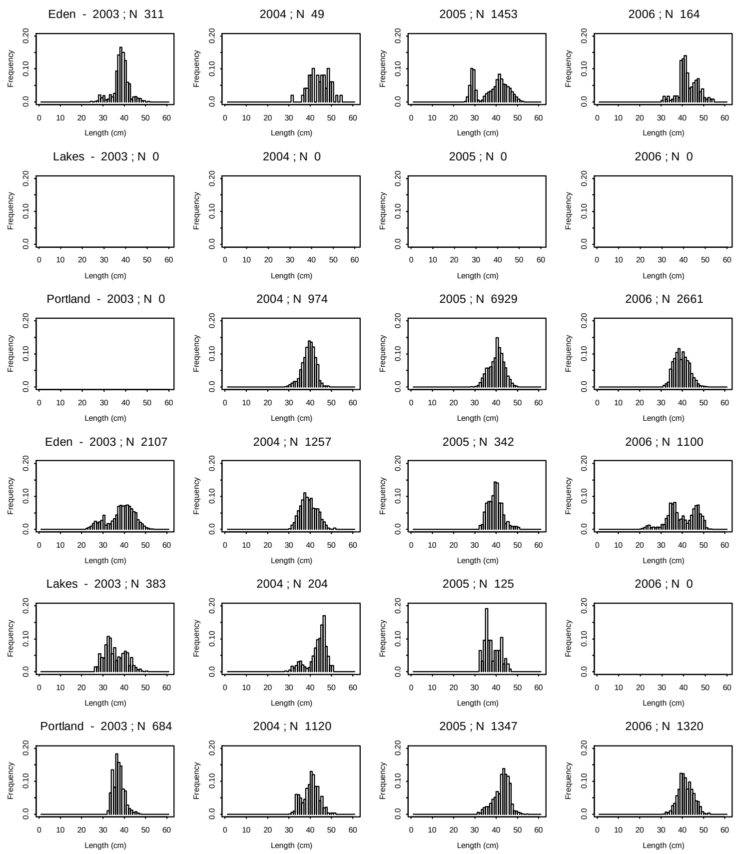

Figure 6.7.b Onboard and port-based retained length-frequency data from the ISMP for blue warehou. Results are shown by port of landing (Eden, Lake Entrance, Portland) based on the onboard data (upper panels) and from port sampling (lower panels)

Figure 6.8 compares the retained (upper panels) and the discarded (lower panels) length-frequencies based on onboard sampling. Comparisons are difficult owing to low sample sizes (particularly for the discards). However, it possible to conclude that discards in the east tend to be small fish while in the west, fish of all sizes are discarded.

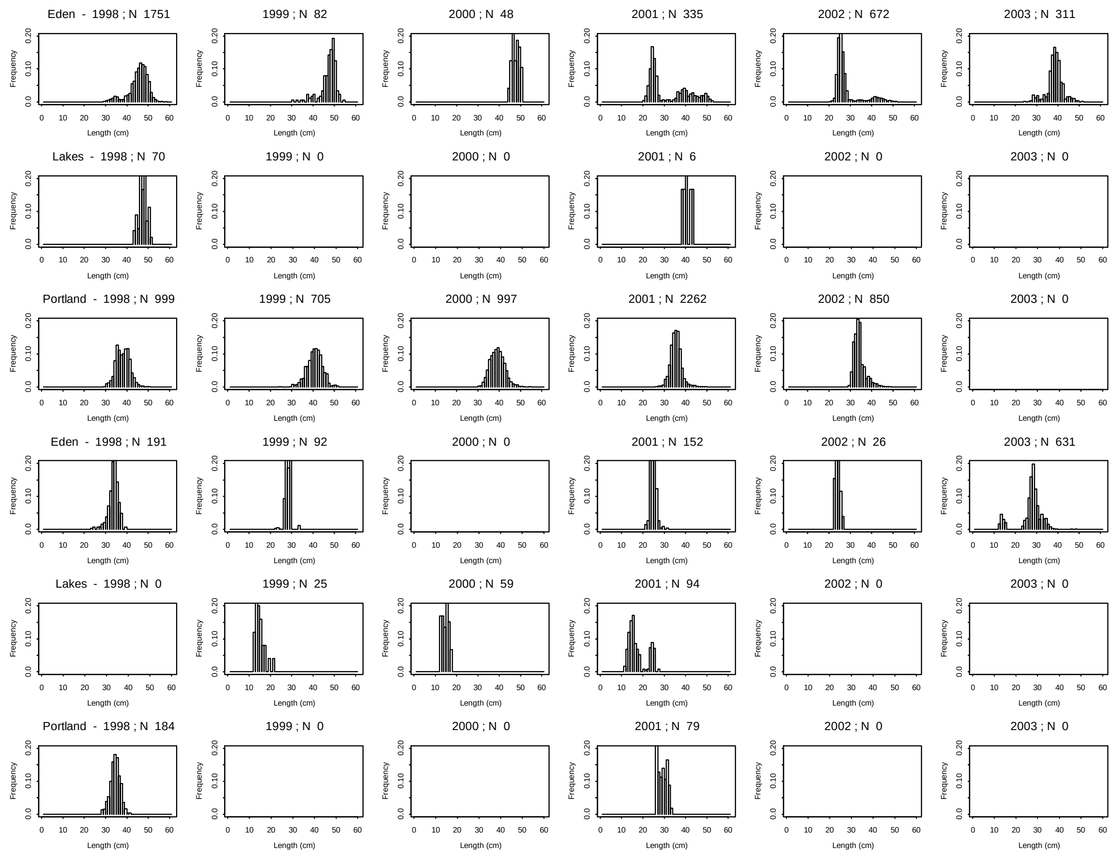

Figure 6.8.a Onboard length-frequency data from the ISMP for blue warehou. The upper panels show the retained length-frequencies and the lower panels the discard length frequencies.

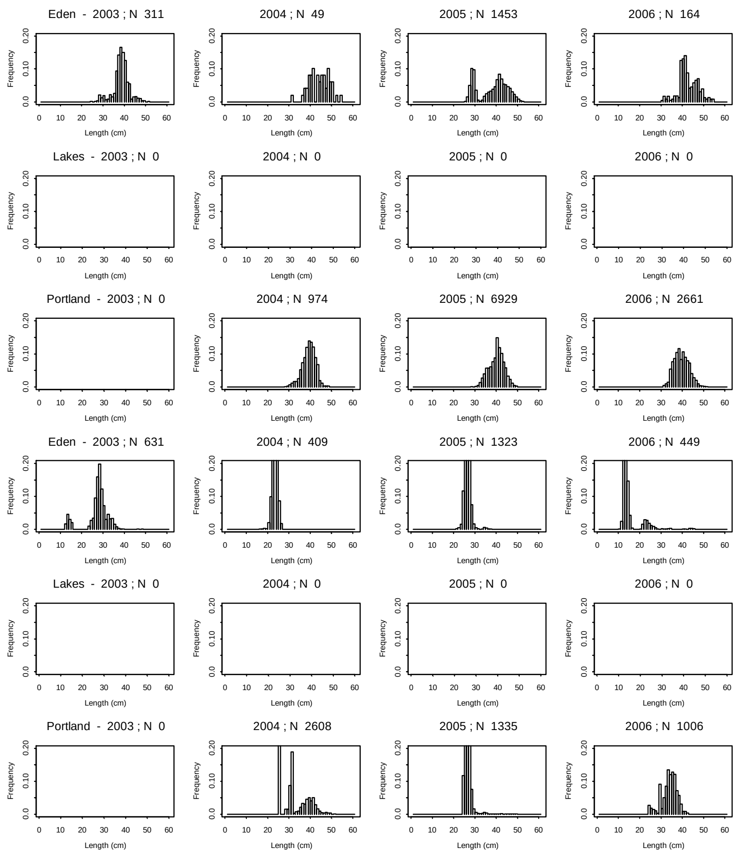

Figure 6.8.b Onboard length-frequency data from the SMP and ISMP for blue warehou. The upper panels show the retained length-frequencies and the lower panels the discard length frequencies.

The length-frequency data for Tasmania for 1997–99 were supplied by Jeremy Lyle (TAFI, pers. comm.). Table 6.4 lists the sample sizes on which the analyses are based and which are used when weighting the data during model fitting.

6.3.4.2 Discard length-frequencies

The proportion of the trawl catch which is discarded by length-class can be determined from the onboard length-frequency data using Equation 3. Information on discards is available for the years 1993–2006. However, the discard data (discard rates and length-frequencies) for the years 1993–95 are ignored (Table 6.1) because they are based on small sample sizes (Table 6.4), were collected from a pilot programme, and appear anomalous in several respects.

6.3.4.3 Age-composition data

Over 4,000 blue warehou have now been aged using sectioned (rather than whole) otoliths by the Central Ageing Facility in Queenscliff. Unlike results from ages estimated using whole otoliths, it now appears possible to track age classes between years. Table 6.4 lists the sample sizes for each year and stock.

Punt *et al.* (in press) developed an approach to estimate the extent of age-reading error by fitting a model based on the assumption that the coefficient of variation of age-reading error is a non-linear function of age to the results of inter-reader calibration experiments (i.e. from the age-estimates for otoliths that were read by more than one reader or twice by the same age-reader). For the purposes of this assessment, the model was fitted to three data sets in which otoliths (both stocks) were read multiple times (Kyne KrusicGolub (MAFRI, pers. commn)): a) 3,017 otoliths read twice by the primary reader based on sectioned otoliths, b) 1,062 otoliths read once based on sectioned otoliths, and once based on whole otoliths, and c) 247 read twice based on sectioned otoliths and once based on whole otoliths. Simulations by Punt *et al.* (2005) and Punt et al. (in press) suggest that this data set is more than sufficient to determine the relationship between age and the coefficient of variation of age-reading error adequately. Figure 6.9a shows diagnostic plots based on the fit of this model to the three data sets: upper panels – coefficient of variation and standard deviation of age-reading error versus true age; lower panels – expected age versus true age and the underlying distributions of ages in each of three data sets. Table 6.5 lists the standard deviations of the age-reading errors for whole and sectioned otoliths, as well as the expected age for whole otoliths, for various true ages. The results in Figure 6.9a and Table 6.5 show that age estimates based on whole otoliths are biased (under-estimating true age) and imprecise (more so than for sectioned otoliths for the bulk of the ages in the catches).

Figure 6.9.a explores how well the model fits the data for three data sets. In general, the model fits well. However, there is some evidence for overdispersion, particularly for the larger data set.

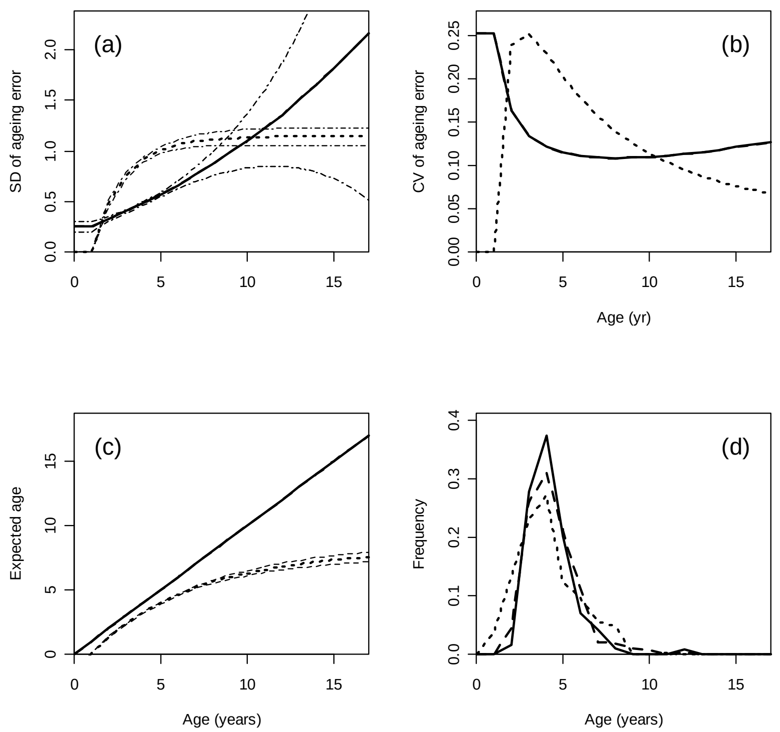

Figure 6.9.a Diagnostic plots for the fit of the age-reading error model of Punt *et al*. (in press) to the data for blue warehou. Best estimates and 95% confidence intervals are shown in (a) and (c). Solid lines in (a) - (c) denote results for sectioned otoliths and dashed lines those for whole otoliths.

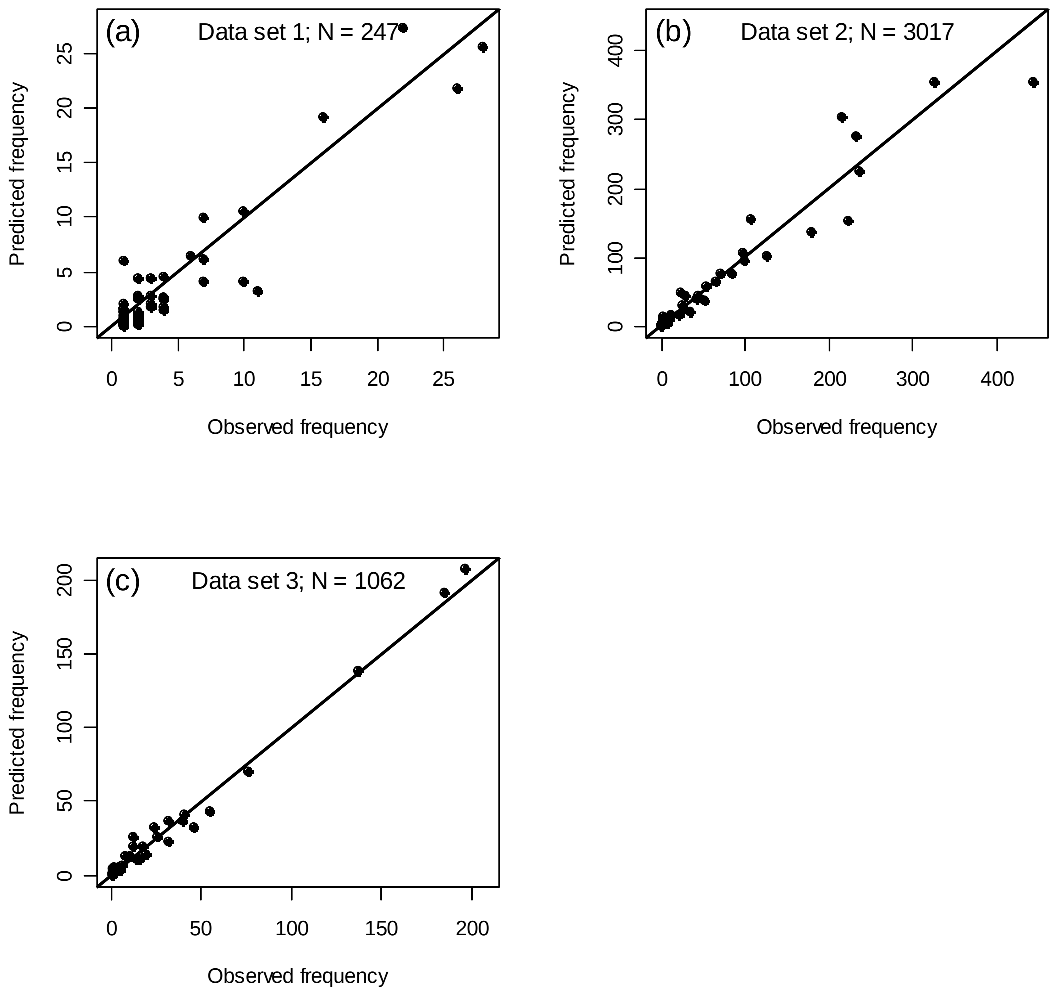

Figure 6.9.b Diagnostic plots for the fit of the age-reading error model of Punt *et al*. (in press) to the data for blue warehou.

6.3.5 Evaluation of the representativeness of the onboard and port-based data[6]

Assessments of the two stocks of blue warehou (particularly that of the eastern stock) have been very uncertain historically. The section therefore examines the length data on which the assessments are based to assess whether there is evidence for non-random sampling.

Figure 6.10 compares the SEF2 catches for the major ports of Eden, Portland, Lakes Entrance, and Hobart, and for all remaining ports with the weights of fish sampled during port-based and at-sea measuring. In general, there are no indications of major differences between the port-based and at-sea samples and the SEF2 catches, in that most of the samples are taken from the major ports. However, there is a suggestion that boats from Hobart and Lakes Entrance are under-represented in the on-board sampling compared to what would be expected given the amount of fish landed in these two ports.

[6] This section is identical to that in Punt (2006a) because data on the port associations of the vessels sampled on board are not available for 2006 and 2007.

There are more port-based measurements in Lakes Entrance than would be expected given the landings there. Although the sampling is not exactly what would be expected given the SEF2 catches, the observations above are likely inconsequential for the assessment because the assessment is based on data from Portland and Eden only.

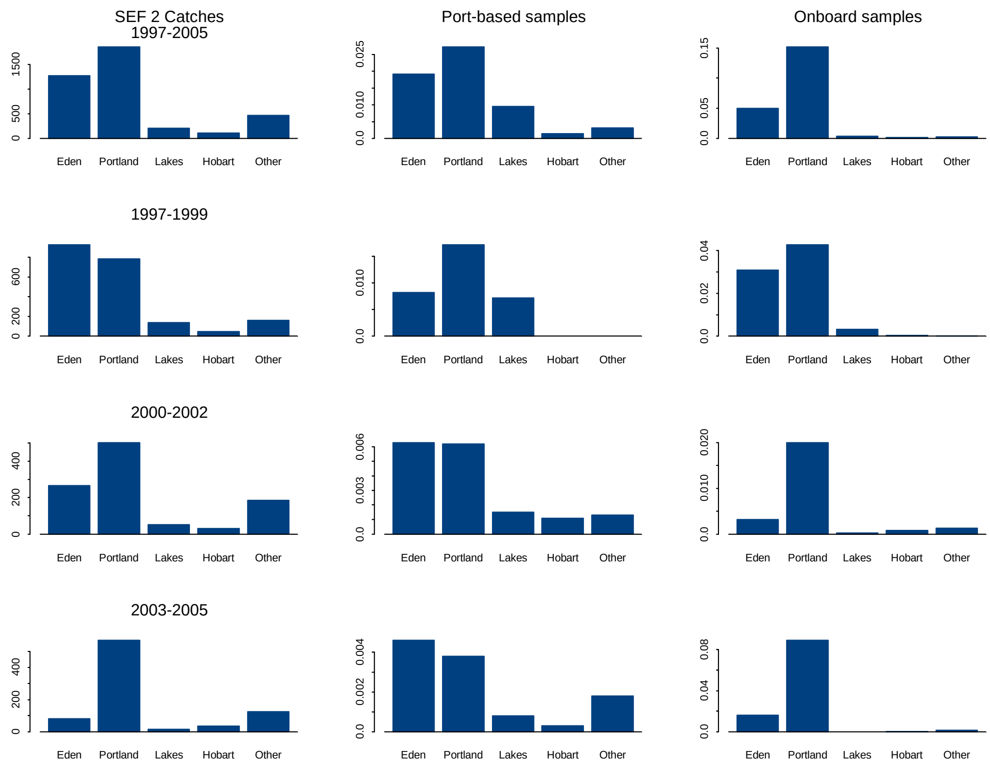

Figure 6.10. SEF2 catches, weight of blue warehou measured in port and weight of blue warehou measured by onboard observers. Results are shown for the period 1997-2005.

Figure 6.11 explores the data further by plotting the fraction of the SEF2 catch by port (Eden and Portland) that is measured by three-month period. There is again little evidence for major discrepancies between the sampling and catches.

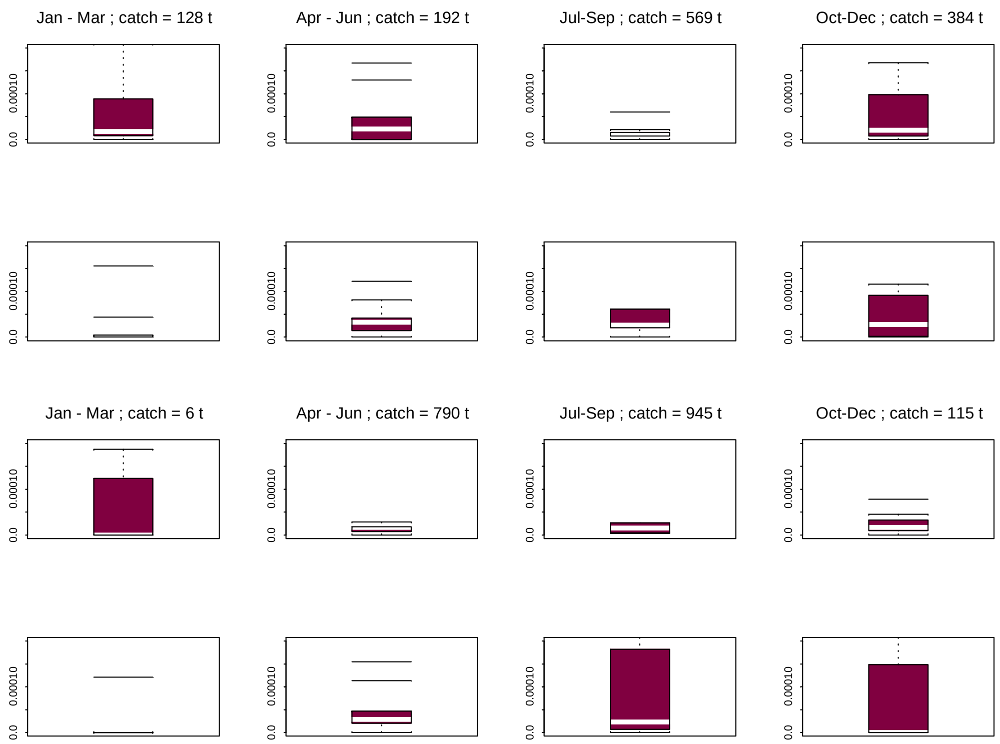

Figure 6.11. Fraction of the total SEF2 catch that is measured in-port and at-sea by three-month period. Results are shown for Eden in the upper panels and in Portland in the lower panels.

6.3.6 2005 Industry-based survey

An industry-based survey was conducted to the west and east of Bass Strait during August-October 2005 (Hudson and Knuckey, 2006). This survey was designed to be similar to that which was conducted in the Great Australia Bight Fishery. It was conducted over three months in five strata (three in the west and two in the east) with the aim that 10 shots would be conducted in each of two months. In principle, the results from this survey could be compared with past catch rates (Hudson and Knuckey, 2006). However, the survey was designed with the aim of optimizing areas and times when the availability/catchability of blue warehou was at its peak. Therefore, it is ideally considered to be the first in a new time-series, rather than a basis to compare with the results of past commercial catch-rates. However, it is possible to include the data from the survey in the assessment if the survey data can be standardized to make these data comparable with past catch rates (to the extent that this is possible).

Haddon (pers. commn) standardized the catch and effort and survey data for four of the five strata (the data for the Beachport stratum could not be standardized) by fitting a linear model to the logarithms of the catch-rates that occurred in the survey strata. The model fitted was log(C/E)= Year + Vessel + Month. It was impossible to include depth as a covariate in the analysis owing to lack of data. Table 6.6 lists the resulting indices of relative abundance (and their associated coefficients of variation). These indices are fairly imprecise and perhaps even contradictory to some extent. The data are not included in the 2008 preliminary assessment of blue warehou.

6.4 Stock assessment method

6.4.1 Overview of the model and the likelihood function

The 2008 assessment of blue warehou is based on the age-length model Stock Synthesis 3 (SS3) (Methot, pers. commn). SS3 is a generalized stock assessment package based on the integrated analysis paradigm. It can allow for multiple seasons, areas and fleets although most applications are based on a single season and area. Recruitment is governed by a stochastic Beverton-Holt stock-recruitment relationship, parameterized in terms of the steepness of the stock-recruitment (h), the average recruitment in an unfished state (R_0), and the extent of variability about the stock-recruitment relationship (σ_R). SS3 allows the user to choose among a large number of age- and length-specific selectivity patterns. The values for the parameters of SS3 are estimated by fitting it to data on catches, catch-rates, catch length-frequencies, survey length-frequencies, mean lengths-at-age, and conditional age-at-length data. Figure 6.12 compares the time-trajectories of spawning biomass from the version of SS2 on which the 2006 assessment was based, that used for the 2007 round of assessments, and SS3 (version 3.01a). The results from the version of SS2 used for the 2007 assessment round and SS3 are essentially identical while there are some differences between the results from the 2006 assessment and the version of SS2 on which the 2007 assessment round was based. These differences relate to how bias-correction factors are applied to year-classes the strengths of which are not estimated (2005 and 2006), and to the treatment of the length of age-0 animals.

Figure 6.12. Time-trajectories of spawning biomass based on the version of SS2 on which the 2006 assessment was based, the version of SS2 used for 2007 assessment round, and SS3.

Table 6.6 outlines the structural assumptions of the base-case assessments for the two stocks. The assumptions are identical to those for the 2006 assessment, except that a minimum age-at-maturity of 2 has been imposed.

6.4.2 Parameter estimation

In principle, it is possible to estimate the values for all of the parameters of the model, but paucity of data precludes this in practice (see Table 6.8 for the list of estimated parameters). Thus, for example, the rate of natural mortality, M, is pre-specified rather than being estimated. The value for M in the reference case assessment is set equal to

0.45yr^{-1} and sensitivity could be explored to choices for M of 0.35yr^{-1}, and 0.55yr^{-1}. Similarly, the extent of variation in recruitment, σ_r , is taken to be 1 and the steepness of the stock-recruitment relationship is set to 1, for consistency with assumptions made during the 2005 and 2006 assessments. Maturity is assumed to be related to length by a logistic curve with 50 and 95%^{iles} of 33.4 and 42.9 cm (Knuckey and Sivakumuran, 2001) and animals aged 1 year and younger were assumed to be immature irrespective of size.

The multinomial sample sizes for the length-frequency data are tuned so that these match (on average) the effective sample sizes. Within each data series, years are weighted in proportion to the number of fish actually measured. The sample sizes for the age-length keys are set to 0.05 of the number of animals actually aged.

6.5 Results and discussion

6.5.1 Model selection and base-case analyses

The first step in the assessment is to determine the implications of the changes to the data, and hence the selection of a "reference case" analysis. Figure 6.13 shows the time-trajectories of spawning biomass (in absolute terms and relative to B_0) and recruitment for an assessment based on the data used in the 2006 assessment ("2006 assessment" in Figure 6.13), an assessment in which the 2006 and 2007 data are added to the assessment ("New data" in Figure 6.13), a variant of "New data" in which account is taken of the revised age-reading matrices in Table 6.5 ("With ageing error" in Figure 6.13), and extension to "With ageing error" in which all animals are assumed to be immature until at least age 2 ("Ref" in Figure 6.13).

The results in Figure 6.13 show that modifying how ageing error is represented, adding the 2006 and 2007 data, and assuming that blue warehou cannot mature before age 2 has no major impact on the results of the assessment. The fits of the two "reference case" models to the catch-rate data are good, as would be expected given the high weight assigned to these data (Figure 6.14). However, the fit to the discard data for the eastern stock remains poor (Figure 6.14). The computed effective sample sizes are roughly the same as the input effective samples sizes for the length-frequency data.

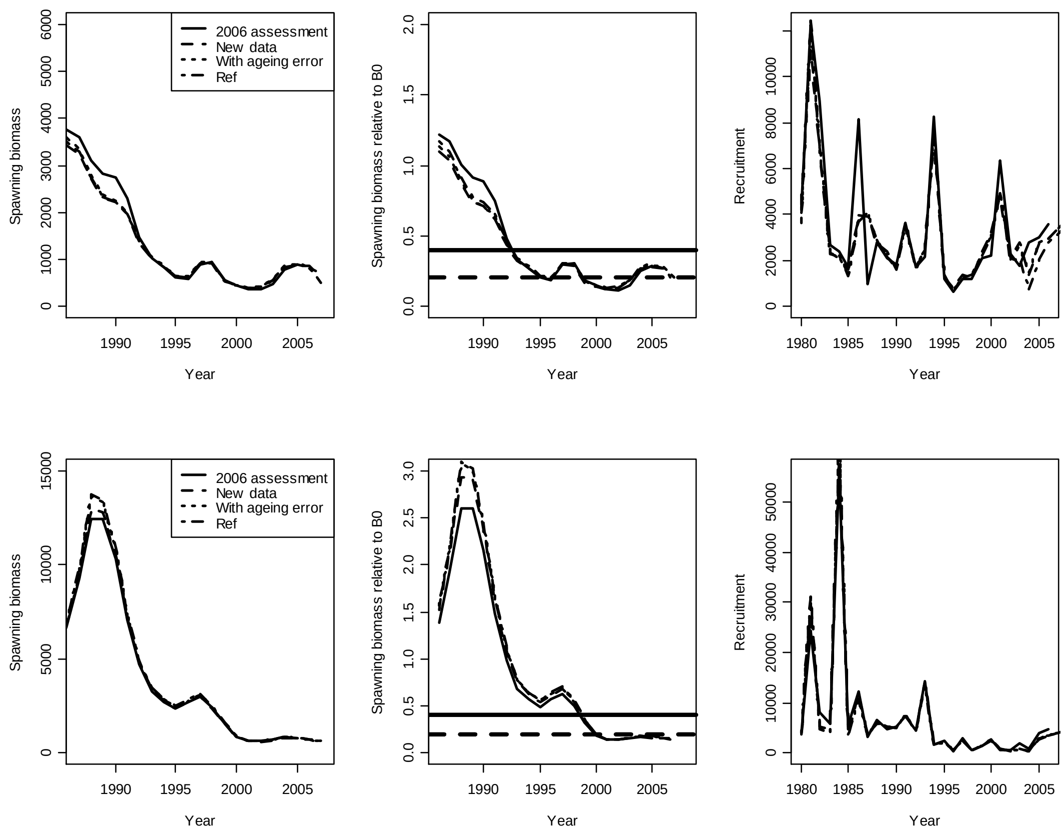

Figure 6.13. Time-trajectories of spawning biomass (in absolute terms and expressed relative to B_0) and recruitment for four assessments. The results for the western stock are shown in the upper panels and those for the eastern stock in the lower panels.

The plots of the fits to the length-frequency data are particularly voluminous. These fits are therefore shown in Appendix B (Section 6.10) ('reference case' only) rather than in the main text. The fits to the landed length-frequency data are adequate for the Tasmania meshnet fishery, and for the non-trawl fishery for the years during which the catch by this fleet was substantial. The fits to the data for the east trawl fishery are much poorer than those to the data for west trawl fishery. It is perhaps noteworthy that the fits to the length-frequency data for the west trawl fishery are quite poor in recent years. Consideration should be given to estimating a separate selection ogive from 2003 in future assessments.

Figure 6.15 plots the overall selectivity patterns and the probability of a fish being retained as a function of length for the two 'reference case' analyses. The probability of discarding for the Tasmanian meshnet and non-trawl fleets within the model is zero (discard is added to the catches by the non-trawl fleet before the catches are included in the assessment). The Tasmanian meshnet selectivity pattern is dome-shaped whereas that for the non-trawl fleet is focused exclusively on large animals. The difference in selectivity pattern between the Tasmanian and non-trawl fleets is not unexpected given the length-frequencies in Appendix B (Section 6.10) which show that the Tasmanian fleet catches somewhat smaller animals than the non-trawl fleet.

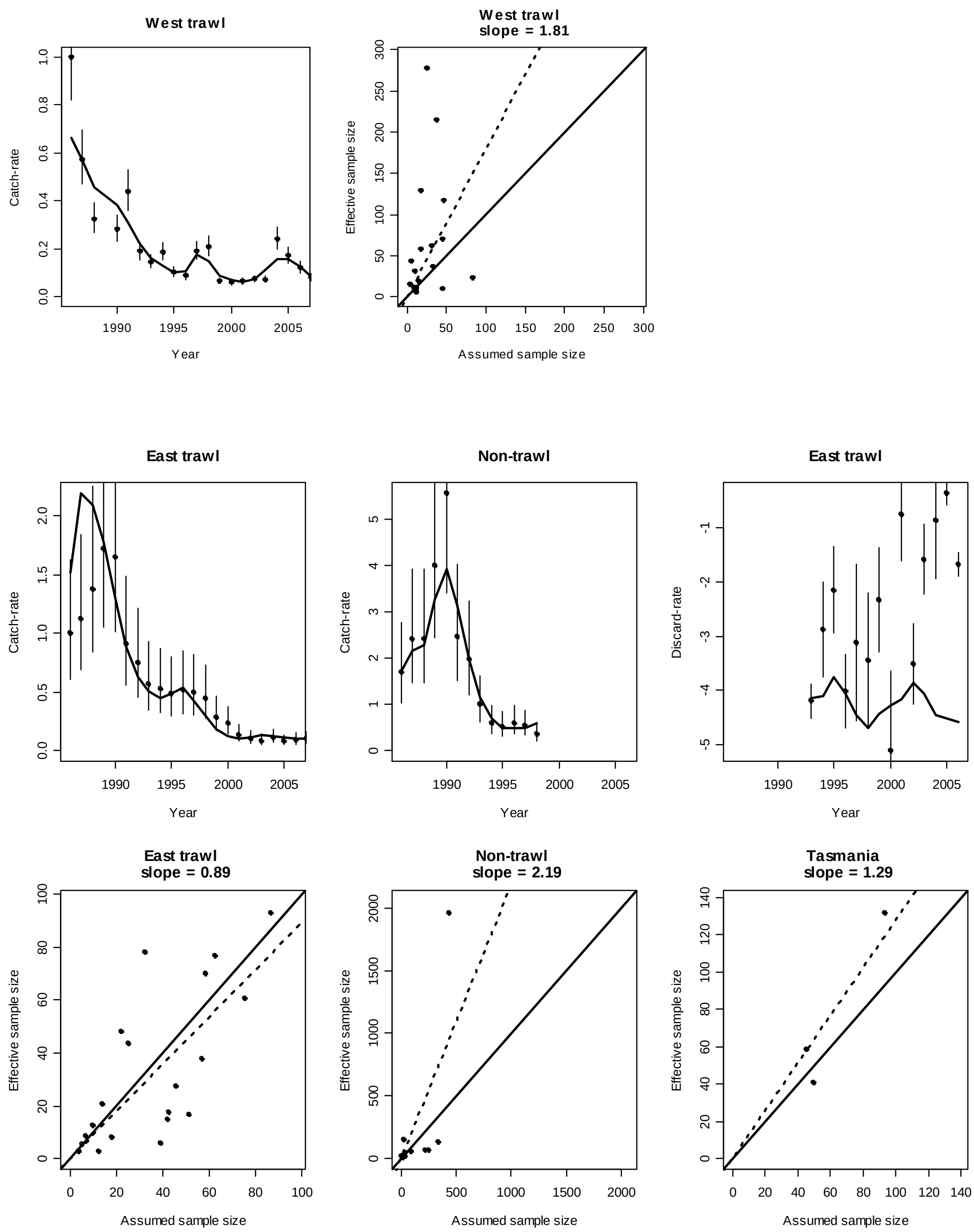

Figure 6.14. Diagnostic statistics (fits to the catch-rate and discard data and the relationship between the effective and input sample sizes for the length-frequency data) for the “reference case” analysis of Figure 6.13.

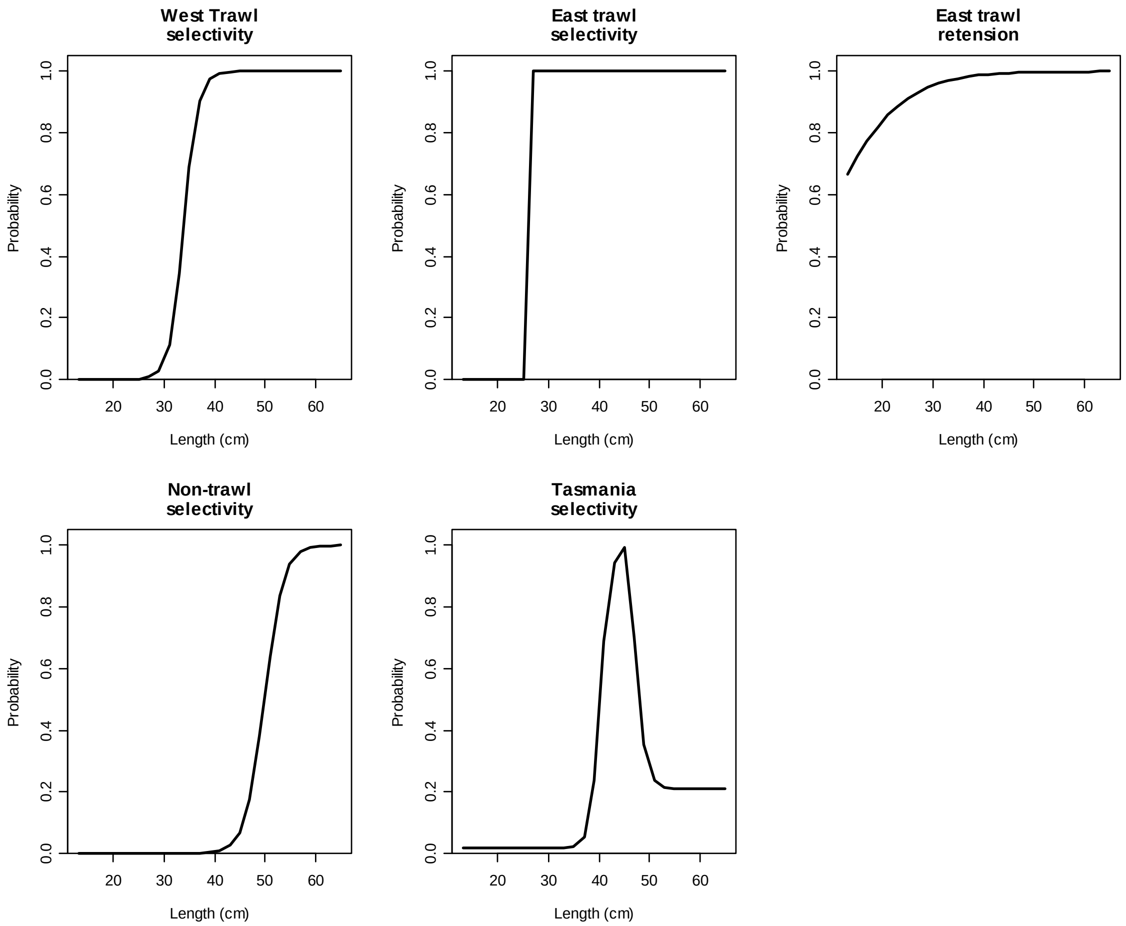

Figure 6.15. Length-specific selectivity patterns and, for the east trawl fishery, the probability of being retained as function of length. The results in this Figure are based on the “reference case” analysis.

6.5.1.1 Assessment outcomes

Figure 6.16 summarizes the results of the two reference case assessments in terms of phase plots. The results of the two ‘reference case’ assessments are qualitatively identical to the expectations based on the 2006 assessment. Specifically, the 2006 assessment estimated the spawning biomass of the western stock to be depleted in the early 2000s, to have recovered somewhat because of strong recruitment after 2002, and to decline again owing to additional poor recruitment. It also estimated that the eastern stock continues to be at a small fraction of its average unfished level, with no sign of recovery evident.

Notwithstanding the above, this preliminary assessment is more data-poor and less reliable than prior assessments because the data for 2007 are unusable owing to low sample sizes. The lack of data for 2007 for blue warehou presents more difficulties than for many other SESSF species owing to the short lifespan of this species. This is reflected in this assessment by the fact that it was not possible to estimate recruitment for the two most recent years of the assessment period (2006 and 2007). While it would not be expected to be possible to estimate the 2007 recruitment (age-0 in 2007), the inability to estimate the 2006 recruitment means that any RBC calculation for 2009 would be based on assuming average recruitment for ages 0, 1, 2 and 3 (the 2006 to 2009 recruitments).

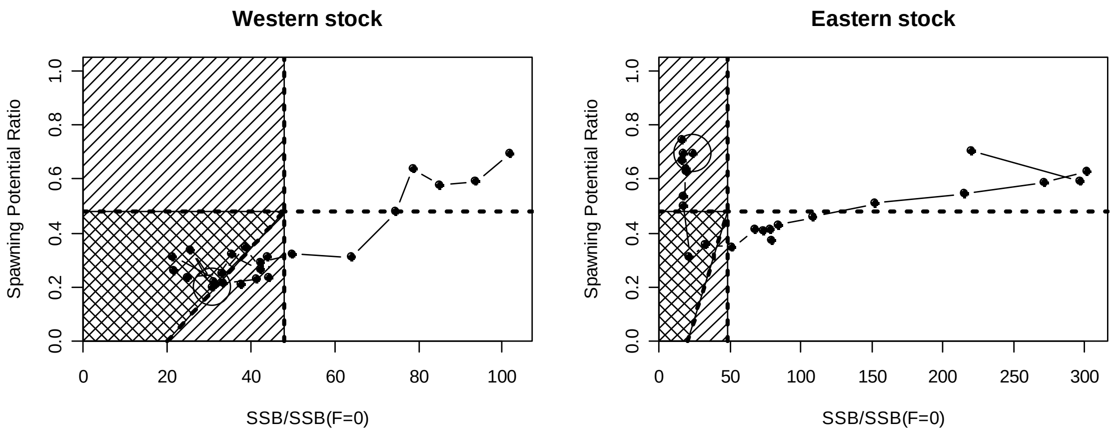

Figure 6.16. Phase plots for the two reference case assessments. The dots denote the annual depletion of the spawning biomass (x-axis) and the spawning biomass-per-recruit corresponding to the fishing mortality rates during the year concerned (y-axis). The lightly shaded area denotes depletion to below the target level (48% of B_0 for this plot) while the heavily shaded area denotes being depleted to below the target level and with an exploitation rate that is predicted not to lead to recovery. The large open circles denote the status at the start of 2008.

6.6 Further work

a) Consideration should be given to including sex-structure into the population dynamics model. Although the length-frequency data are not sex-specific, much of the recent ageing data include the sex of the animal.
b) The fishery catches are very low at present. This leads to lower sample sizes for length-frequency and further concern regarding the validity of catch-rates as indices of abundance.
c) Consideration should be given to evaluating objective methods for detecting resource recovery. Such methods may also be of value for several of the other species in the SESSF (e.g. eastern gemfish).
d) There is a need to collect additional length-frequency data for the Tasmanian component of the fishery (owing to the present size of this sector relative to the rest of the fishery in the east).
e) The impact of the catches from northwestern Tasmania coming from the western rather than the eastern stock should be examined. Such an examination requires information on the length-composition of the catches from northwestern Tasmania.
f) There is a data source that is currently ignored when conducting assessments of blue warehou. In principle, the ages obtained from reading of whole (rather than sectioned) otoliths (see Table 6.4 for sample sizes) can be included in the assessment, but whether inclusion of ages based on readings of whole otoliths will improve the assessment is unclear because the relationship between ages based on whole and sectioned otoliths is clearly fairly imprecise (Figure 6.9a).
g) Consideration should be given to estimating selectivity patterns for various time-blocks (particularly for the western stock).
h) The approach used to derive the standardized indices of abundance based on the logbook data ignores zero catches (and particularly trends in zero catches). There

is value in examining the potential for the use of "delta" methods (Maunder and Punt, 2004) and/or techniques that select which shots should have been capable of capturing blue warehou (e.g. Stephens and MacCall (2004)).

6.7 Acknowledgements

Kyne KrusicGolub (Primary Industries Vic), Neil Klaer (CSIRO), and Malcolm Haddon (TAFI) are thanked for providing the data on which the analyses of the assessment are based. Rick Methot (NWFSC, NOAA) is thanked for advice regarding some of the options of SS2.

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Vignaux, M. 1994. Catch per unit effort (CPUE) analysis of west coast South Island Cook Strait spawning hoki fisheries, 1987-93. *New Zealand Fisheries Assessment Research Document* 94/11.

Table 6.1. Reported catches (tonnes), discard rates (with coefficients of variation in parenthesis) and catch-rates by fleet. The catches for the 'east trawl' fleet include NSW State catches after 2000. The discard rates indicated by asterisks are included in these tables, but not in the calculations owing to low sample sizes. The 1999 catch-rate for the non-trawl fishery (indicated by the ampersand) is excluded from the analyses. The catches and catch-rates in parenthesis for the western stock are the values after correction for discarding. A '+' indicates an assumed value and a "&" indicates a value that is ignored when assessments are conducted.

Year	Commwlth	Catches				Discard rates		Catch-rates		
	TAC	East	West	Non-trawl	Tas	East	West	East	West	Non-trawl
1986		164	84	254	165	-	-	1.000	1.000	1.700
1987		211	264	1033	278	-	-	1.125	0.573	2.410
1988		399	238	835	170	-	-	1.380	0.324	2.410
1989		787	116	1061	52	-	-	1.720	2.428&	4.000
1990		633	372	1746	172	-	-	1.646	0.282	5.580
1991		587	765	1386	154	-	-	0.912	0.437	2.470
1992		491	508	842	249	0.000*	-	0.747	0.188	1.990
1993		539	440	487	168	0.015 (0.158)*	-	0.569	0.145	1.000
1994		554	519 (592)	389	257	0.056 (0.448)*	0.123 (0.693)	0.532	0.164 (0.187)	0.600
1995		564	396 (410)	199	138	0.117 (0.405)*	0.034 (0.449)	0.490	0.100 (0.104)	0.530
1996		632	222 (253)	213	119	0.018 (0.344)	0.124 (0.610)	0.520	0.076 (0.087)	0.600
1997		494	296 (652)	291	127	0.044 (0.734)	0.546 (0.468)	0.501	0.087 (0.191)	0.540
1998		523	409 (681)	81	246	0.032 (0.638)	0.400 (0.544)	0.447	0.126 (0.210)	0.360
1999		154	201 (217)	292	268	0.097 (0.487)	0.074 (0.004)	0.286	0.062 (0.067)	1.000&
2000		207	227 (227)	84	108	0.006 (0.752)	0.001 (0.618)	0.232	0.060 (0.060)	-
2001		70	228 (238)	32	24	0.467 (0.429)	0.042 (0.629)	0.136	0.062 (0.064)	-
2002		72	242 (243)	5	70	0.030 (0.379)	0.004 (0.776)	0.104	0.073 (0.073)	-
2003		48	204 (211)	2	40	0.206 (0.332)	0.037 (0.829)	0.086	0.069 (0.072)	-
2004		62	200 (497)	2	29	0.423 (0.545)	0.598 (0.264)	0.111	0.097 (0.241)	-
2005	300	27	287 (369)	1	12	0.698 (0.111)	0.223 (0.319)	0.082	0.133 (0.171)	-
2006	650	33	393 (544)	1	25	0.188 (0.209)	0.278 (0.390)	0.094	0.087 (0.121)	-
2007	288	21	174 (179)	1	25	-	0.026 (0.726)	0.103	0.079 (0.081)	-
2008	412	33+	214	1+	25+	-	-	-	-	-

Table 6.2. Standardized catch-rate indices based on the ISMP programme. Results are shown for indices based on targeted and all shots (source: Anne Gason, PirVic, pers. Commn). The column “# obs” indicates the number of shots included in the catch-effort standardization.

Western stock						Eastern stock					
Targeted shots			All shots			Targeted shots			All shots		
Year	Index	# obs	Year	Index	# obs	Year	Index	# obs	Year	Index	# obs
1994	10.2	40	1994	12.6	122	1994	10.3	8	1994	1.9	101
1995	2.6	30	1995	1.4	188	1995	0.0	2	1995	5.4	66
1996	47.2	18	1996	13.8	152	1996	148.0	10	1996	3.6	101
1997	394.3	13	1997	25.0	151	1997	19.8	1	1997	2.0	218
1998	118.1	13	1998	11.5	194	1998	7.0	30	1998	2.9	374
1999	19.5	22	1999	4.2	178	1999	20.2	6	1999	0.6	640
2000	5.2	20	2000	0.8	117	2000	6.9	2	2000	0.4	517
2001	6.3	22	2001	1.0	137	2001	3.2	2	2001	0.3	658
2002	10.3	13	2002	1.6	219	2003	108.9	3	2002	0.2	486
2003	0.3	5	2003	0.6	151	2005	0.1	36	2003	0.3	606
2004	40.0	11	2004	15.8	141				2004	0.2	560
2005	28.4	70	2005	12.0	244				2005	0.2	578

Table 6.3. Restrictions imposed on the port length-frequency, onboard length-frequency, onboard weight, and aging data.

Restrictions	Exclusions
Port Length-frequency data	
Gears code OT, TW, MN, MS or M6	PT, DS, -99
7 ≤Length ≤ 200cm	0-6 cm
Length code LCF or 99	STL
Zone is 10, 20, 30, 40, 50, or 60	GAB, Other & unknown
Port is Eden (east) or Portland (west)	Other
Catch weight > 0; Sample Weight > 0	One or both missing
At least 100 fish measured per year	< 100 fish measured
Onboard length-frequency data	
Gear codes OT, B, TW	MN, MS, M6, DS
Catch is discarded or retained	Unspecified or discarded and retained combined
Length code LCF or -99	STL & Unknown
Zone is 10, 20, 30, 40, 50 or 60	Other & unknown
> 100% discarded	200% is common
At least 100 fish measured per year	< 100 fish measured
Onboard weight data	
Gear codes B	-99, DS, MN, MS, M6, -99, GILLNET, LONGLINE, AUTO-LLINE
Retained and discard weight is recorded	Missing or <0 or > 100
Zone is 10, 20, 30, 40, 50, or 60	Other & unknown
Age data	
At least 100 fish measured per year	< 100 fish measured

Table 6.4. Sample sizes for age-length keys and length-frequencies for the landed / discarded catches. Values annotated by an asterisk are samples sizes that are too low for inclusion in the assessment.

Year	Age-length keys				Landed length-frequencies			Discard length-frequencies		
	Sectioned		Whole							
	East	West	East	West	East	West	Non-trawl	Tas	East	West
1986	-	-	-	-	-	-	-	-	-	-
1987	-	139	-	-	-	4031	-	-	-	-
1988	-	238	-	-	-	1882	-	-	-	-
1989	-	-	-	-	-	-	-	-	-	-
1990	-	-	-	-	-	-	-	-	-	-
1991	192	-	398	83	-	1366	6920	-	-	-
1992	90*	-	-	66*	-	4175	3475	-	-	-
1993	-	173	110	432	-	665	5442	-	26[&]	-
1994	162	120	598	1170	2889	10518	630	-	102[&]	120
1995	85*	139	298	1619	2260	5810	110	-	73[&]	90
1996	113	74*	1557	1116	2833	4677	312	-	17[&]	-
1997	147	58*	1223	672	3730	5708	1478	1325	-	241
1998	120	-	282	205	4288	5872	561	2758	191	351
1999	208	-	-	-	2092	3080	4038	1456	135	-
2000	590	366	-	-	2539	1153	410	-	-	59
2001	540	484	-	-	1604	2190	284	-	348	634
2002	320	437	-	-	1944	2103	244	-	26*	-
2003	110	189	-	-	2107	480	18	-	645	-
2004	125	995	-	-	1257	1120	-	-	447	2837
2005	126	617	-	-	342	1347	-	-	2227	2758
2006	93*	649	-	-	1100	1320	-	-	486	2017
2007	78*	30*	-	-	-	-	-	-	-	-
2008	15*	-	-	-	-	-	-	-	-	-

& length measurement code is now “unknown”

Table 6.5. The parameter values used to construct the age-reading error matrix.

	Age						
	1	2	3	4	5	6	7+
Sectioned otoliths							
SD	0.253	0.326	0.403	0.485	0.527	0.666	0.764
Whole otoliths							
Expected age	0.1	1.32	2.36	3.24	3.98	4.62	5.15
SD	0	0.476	0.754	0.916	1.011	1.066	1.099

Table 6.6. Indices of relative abundance based on commercial catch-rates and survey data (Haddon, pers. commn). Results are shown for two strata in each of the western and eastern areas. The average coefficient of the variation for the years for which the annual index is based on commercial data is given in the row 'CV – non survey', while the coefficient of variation for the survey index is given in the row 'CV – survey'.

	Eastern stock				Western stock			
	Eden		Horseshoe		Main drag		Port McDonell	
CV - non-survey	0.207	0.148	1.086	0.904	0.349	0.354	0.661	0.715
CV - survey	0.438	0.430	1.095	1.200	0.522	0.543	0.752	0.875
1986	1.000	1.000	1.000	1.000				
1987	1.853	1.804	34.082	53.904				
1988	1.339	1.291	19.589	28.908				
1989	1.828	1.705	3.920	5.678				
1990	1.290	1.292	12.546	18.756	1.000	1.000		
1991	0.557	0.560	1.568	2.355	0.654	0.658		
1992	0.647	0.673	1.908	2.411	0.255	0.247	1.000	1.000
1993	0.487	0.508	0.503	0.670	0.163	0.162	0.808	1.003
1994	0.463	0.487	1.363	2.074	0.122	0.115	3.235	2.140
1995	0.386	0.395	0.796	1.126	0.213	0.198	2.062	1.984
1996	0.574	0.593	1.401	1.747	0.043	0.037	0.236	0.277
1997	0.656	0.651	0.593	0.850	0.338	0.324	0.218	0.306
1998	0.786		1.458		0.120		0.443	
1999	0.400		0.809		0.095		0.258	
2000	0.307		0.176		0.038		0.326	
2001	0.093		0.681		0.075		1.183	
2002	0.166		0.142		0.177		0.479	
2003	0.234		0.084		0.170		1.018	
2004	0.086		6.538		0.123		2.025	
2005 *	0.252		0.294		0.353		1.136	
2005 Survey	1.102	1.189	0.077	0.100	0.727	0.575	0.234	0.095

* Data replaced by the survey index when included in the stock assessment.

Table 6.7. Key structural assumptions made when conducting the reference case assessments for the two stocks of blue warehou. Quantities annotated by an asterisk denote aspects of the reference case analysis that could be varied in the tests of sensitivity

Assumption	Eastern Stock	Western Stock
Biological parameters		
Sex-structure	No, single sex	
Age classes	Ages 0-12	
Length-classes	12 - 64 cm (2cm length-classes)	
Natural mortality *	Age-independent; pre-specified (reference M = 0.45yr^{-1})	
Length-weight regression	W = 0.00003 $L^{2.90}$	
Variation in length-at-age	Linear increase with age; estimated	
Length- and age-specific maturity	See Section 4.2	
Stock-recruitment relationship		
Steepness *	Pre-specified (reference h=1)	
σ_R *	Pre-specified (reference σ_R =1)	
Recruitments estimated for	1980-2005$^+$	
Catches and discards		
Equilibrium (pre-1986) catch*	East: 150t Non-trawl: 200t Tasmania: 100t	West: 200t
Length-specific selectivity	East: logistic Non-trawl: logistic Tasmania: double-logistc	West: logistic
Discards	East: fitted to Non-trawl: added to catches Tasmania: none	West: added to catches
Length-specific discarding	East: logistic Non-trawl; Tasmania: N/A	West: N/A
Initial state	Exploited non-equilibrium age-structure (1986)	
Data utilized		
Catch-rates	East: CV = 0.25 Non-trawl: CV=0.25 Tasmania: N/A	West: CV=0.1
Discard rates	East: CV = see Table 6.1 Non-trawl; Tasmania: N/A	West: N/A
Landed length-frequency	East, non-trawl, Tasmania: Yes	West: Yes
Discarded LF	East: Yes Non-trawl; Tasmania: No	West: No
Age-length keys	Weight is 5% of the numbers aged	

\+ The 2006 recruitments are not estimated because of the lack of 2007 length-frequency data.

Table 6.8. The estimable parameters of the model. The number associated with each stock denotes the number of estimable parameters of each type.

Parameter	Eastern Stock	Western Stock
Virgin recruitment	1	1
Recruitment deviations	26	26
Length-at-age	5	5
Fishing mortality pre-1986	3	1
Catchability*	2	1
Selectivity	11	2
Retention	2	0
Total estimated	48	35

* Estimated analytically so not included in the total number of estimable parameters

6.9 Appendix A: Overview of the data available for catch-effort standardization

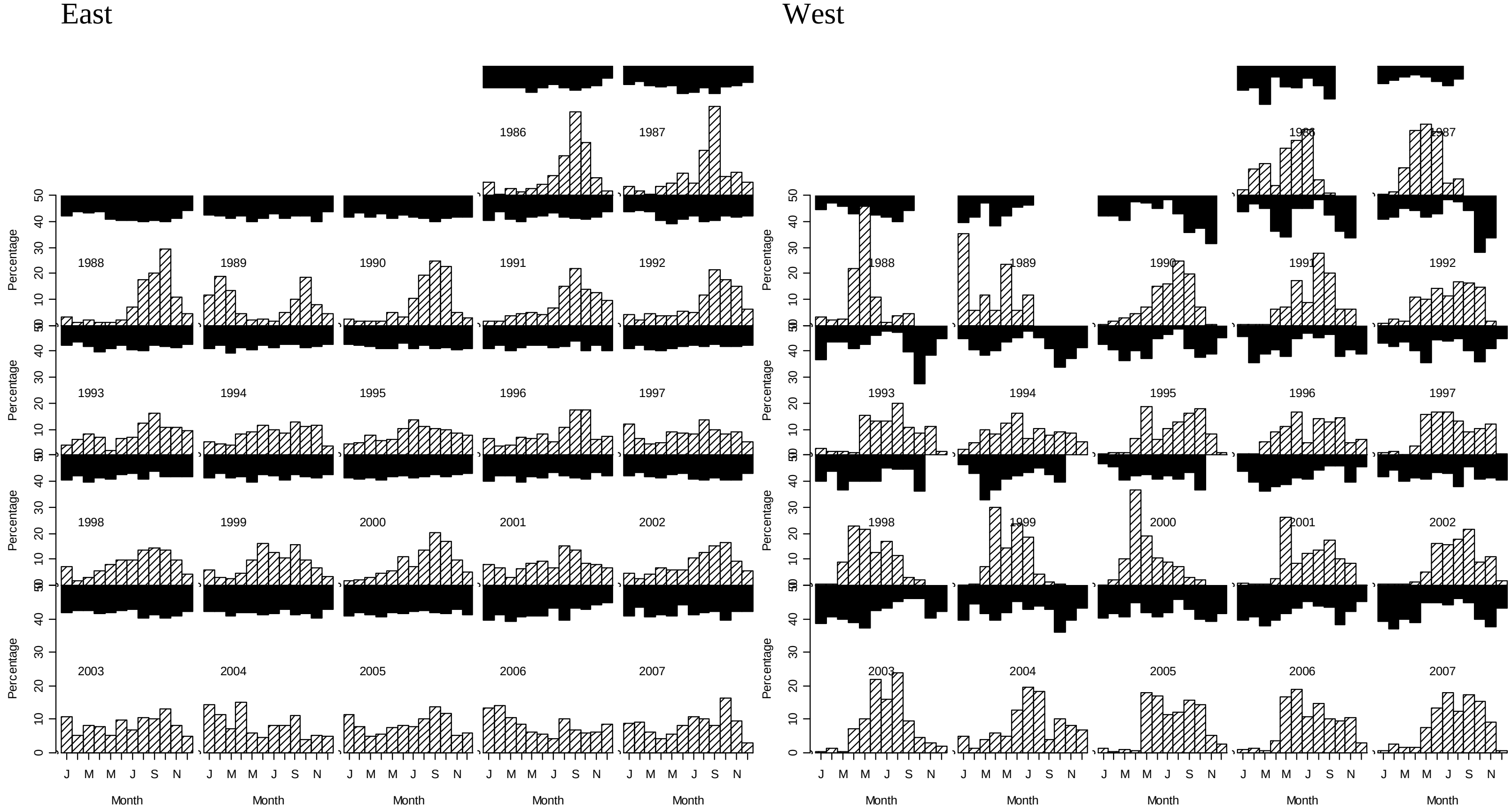


Figure 6.17. Breakdown of the catch and effort data by month. The upper histograms (filled) show results for the zero catches and the hashed bars those for the non-zero catches. The data in this figure are restricted to records for which effort is non-zero.

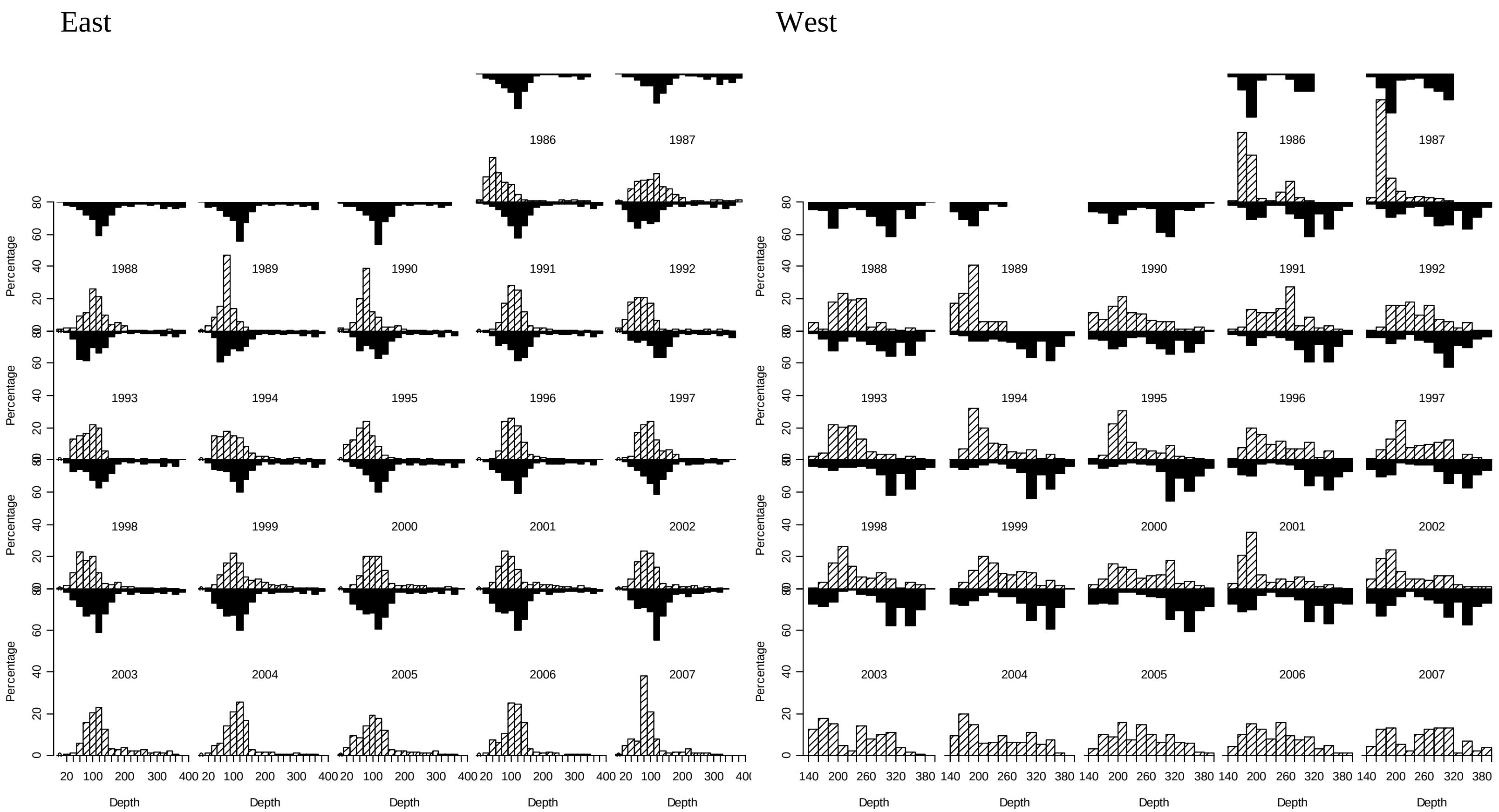


Figure 6.18. Breakdown of the catch and effort data by depth category. The upper histograms (filled) show results for the zero catches and the hashed bars those for the non-zero catches. The data in this figure are restricted to records for which effort is non-zero.

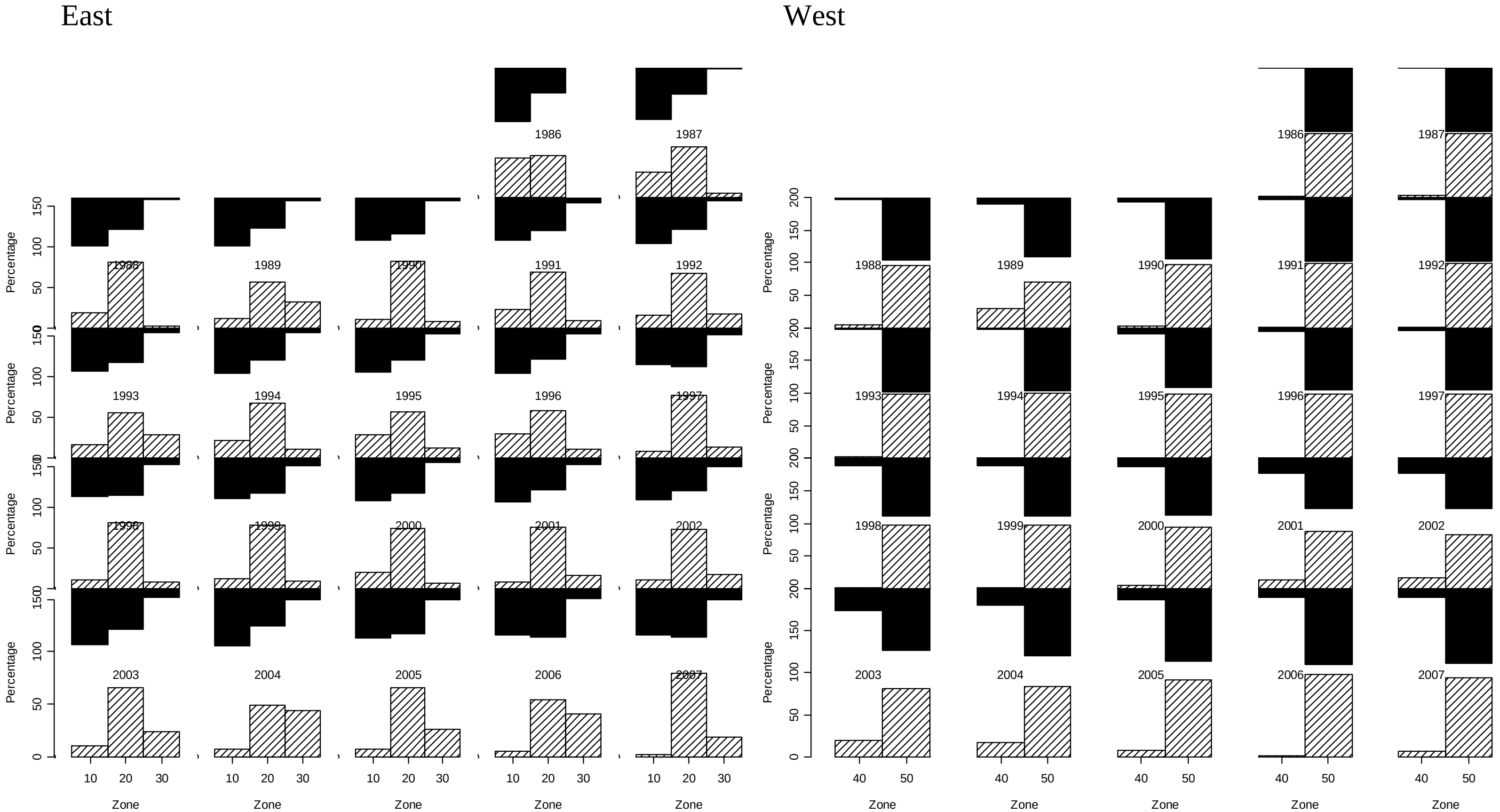


Figure 6.19. Breakdown of the catch and effort data by zone. The upper histograms (filled) show results for the zero catches and the hashed bars those for the non-zero catches. The data in this figure are restricted to records for which effort is non-zero.

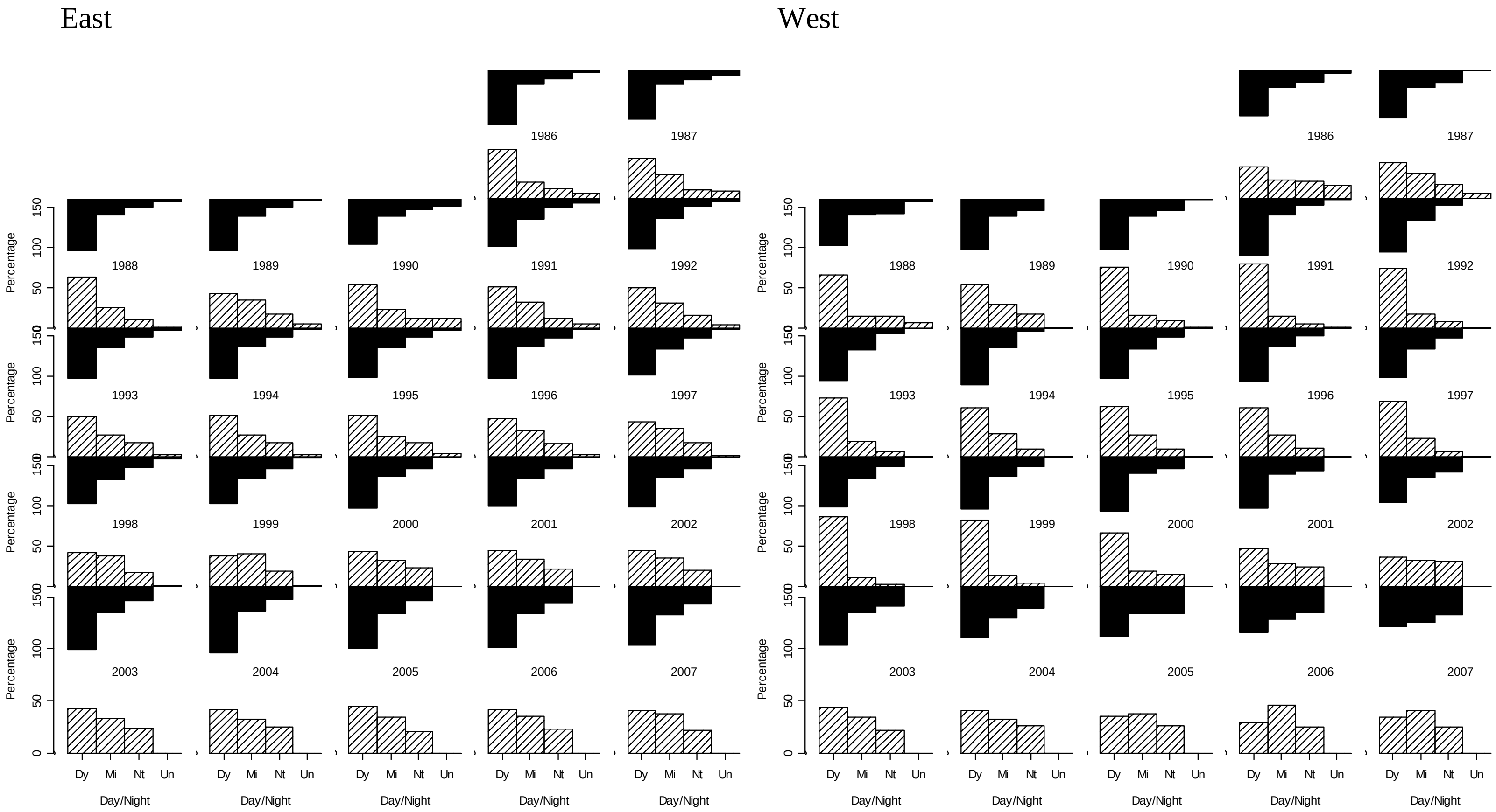
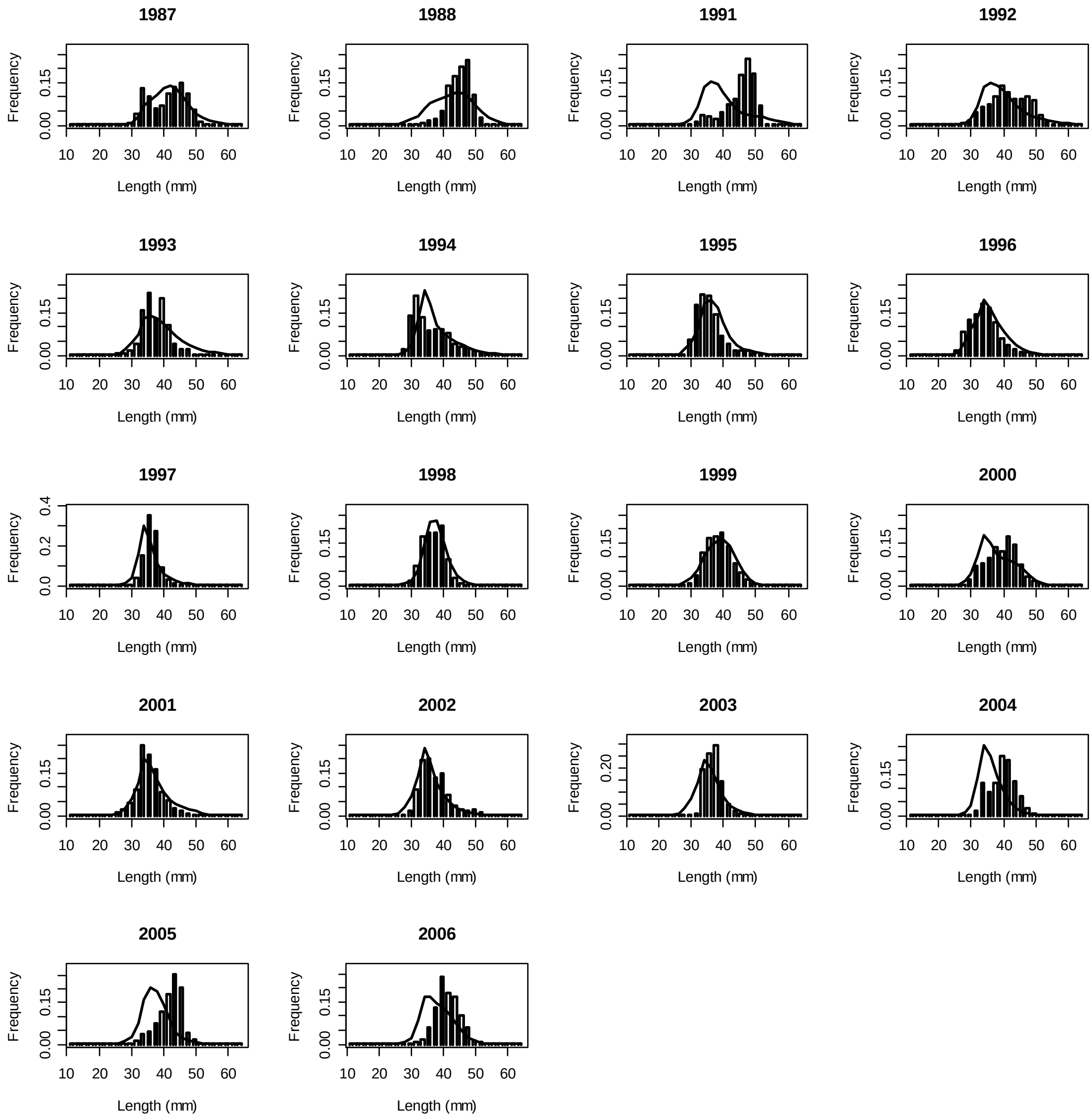


Figure 6.20. Breakdown of the catch and effort data by the when the shot took place (day, mixed, night, and unknown). The upper histograms (filled) show results for the zero catches and the hashed bars those for the non-zero catches. The data in this figure are restricted to records for which effort is non-zero.

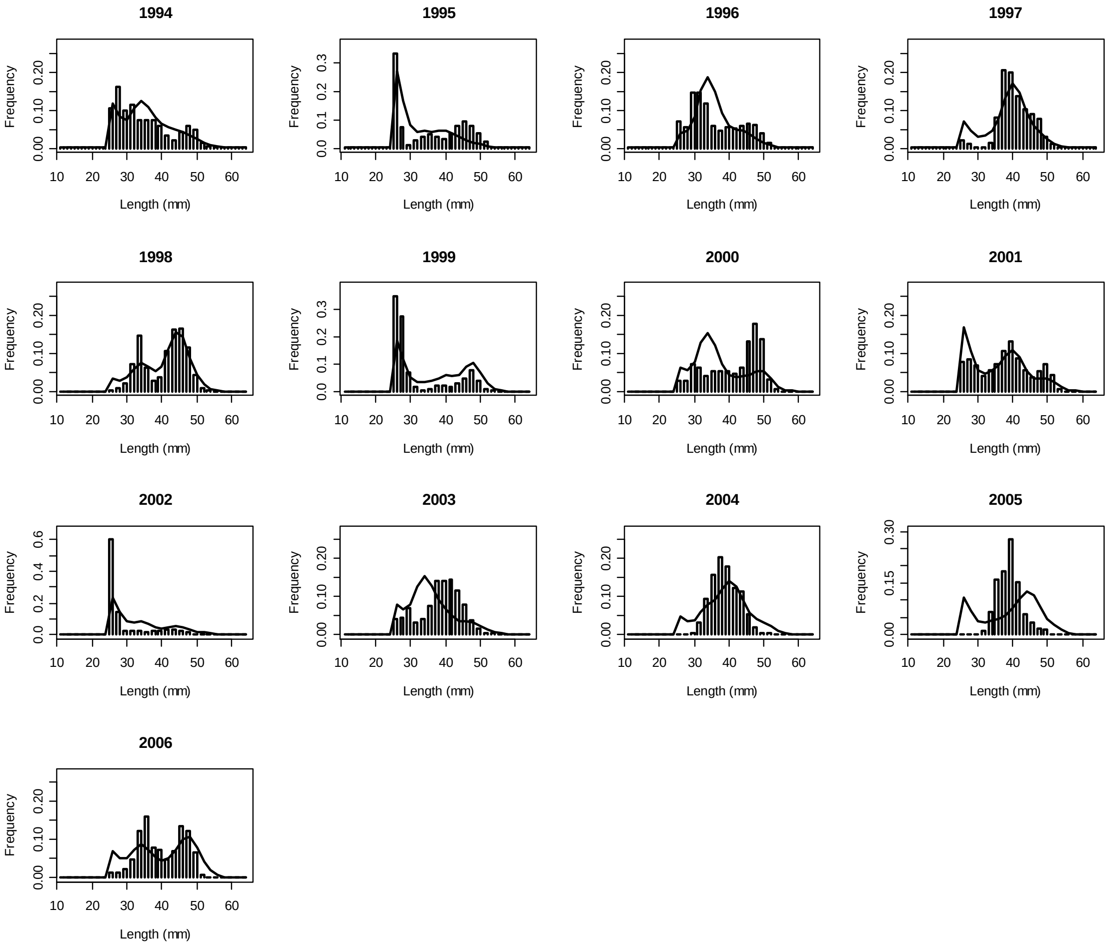
6.10 Appendix B: Fits to the length-frequency data

(a) Western stock

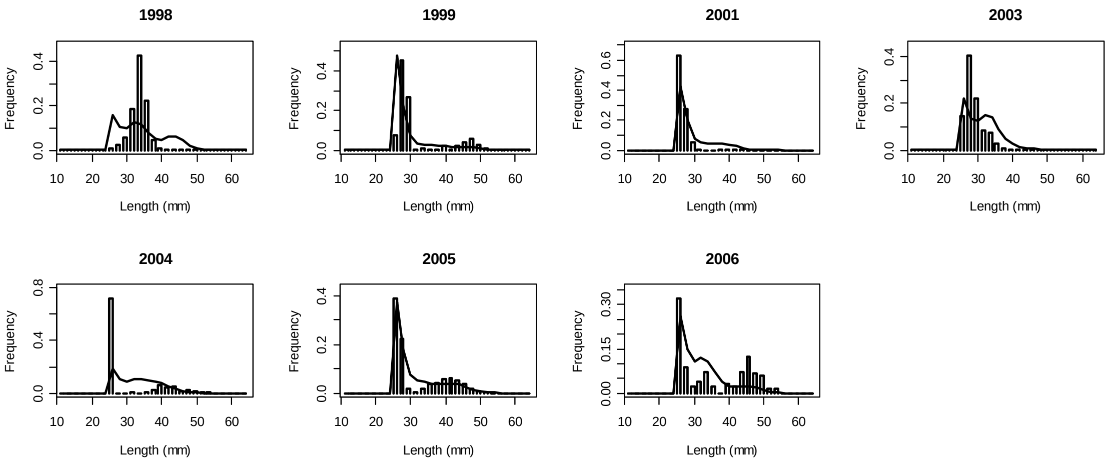


(b) Eastern stock

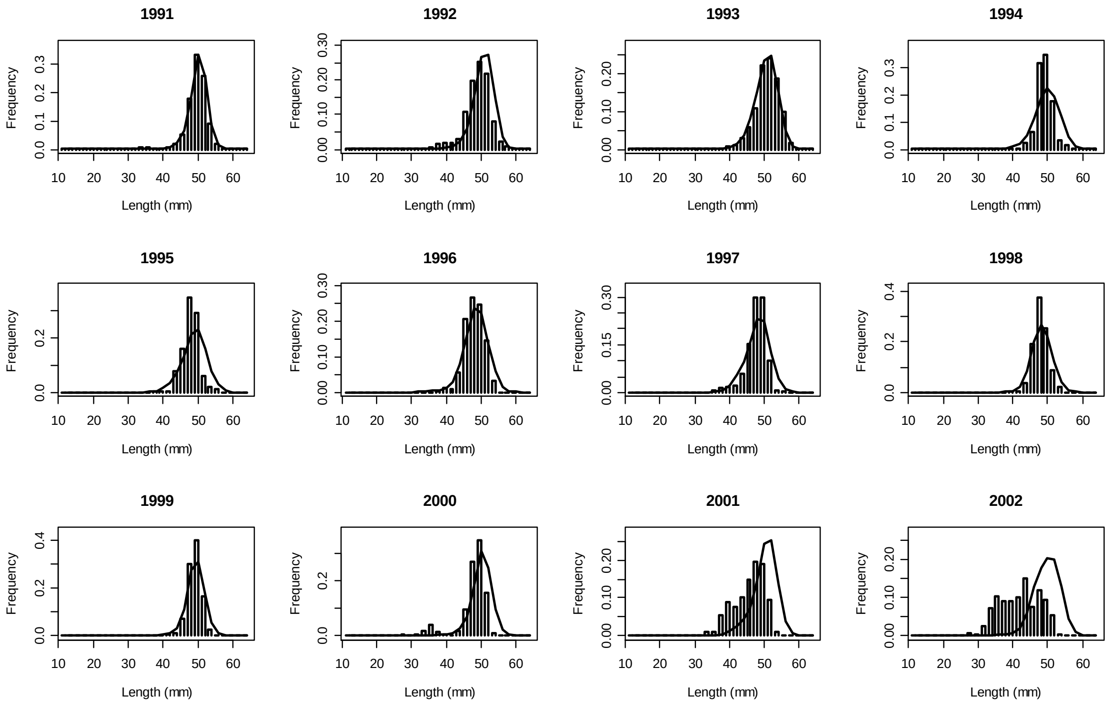
(b-i) East trawl (landed)



(b-ii) East trawl (discarded)



(b-iii) Non-trawl



(b-iv) Tasmanian meshnet