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catch of hake (*Merluccius australis*) on the west coast of the South
Island for 1990 to 1999**

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EXECUTIVE SUMMARY

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Ministry of Fisheries scientific observers collect a range of data on hake within HAK 7 under the observer sampling programme. These data constitute the only information currently available on the age and length structure of the commercial catch of west coast South Island hake. The age distribution for the commercial catch is derived by multiplying the length frequency of the sampled catch by an age-length key. The age-length key is constructed from age samples taken from the catch throughout each year.

The length and age sampling of hake since 1990 has been inconsistent. Individual samples have been taken from a non-random sample of vessel trips and vessel tows. This may have resulted in different subsets of the catch being sampled more intensively in different years. Better, or at least less biased, estimates may be obtained by calculating stratified estimates of the age distribution, where the strata weights are determined from the distribution of the commercial catch. We calculate stratified age distributions from the original length frequency data, employing weights derived from the distribution of the commercial catch as recorded by TCEPR data. We use a randomisation test with a Kolmogorov-Smirnov type statistic to investigate the statistical evidence of difference between estimates of the age distribution resulting from stratified and unstratified analyses of the data. We find some evidence of difference in the stratified and unstratified age distributions when we stratify by season. No strong evidence was found for difference when we used strata based on gear type, region, target species, vessel speed, bottom depth, or time of fishing. However, the power of these tests may be poor, due to the very low sample sizes in some strata.

In addition, we find strong evidence of non-random sampling by scientific observer sampling of hake in HAK 7. The coverage of some fundamental strata is poor (for example, the coverage of midwater versus bottom tows, coverage outside the main hoki fishing season, and coverage of non-hoki target tows), particularly in earlier years.

Moreover, the documentation of methods used to determine age distributions in previous years was poor, with age data for the 1990, 1991, 1994, and 1995 years not recorded on any Ministry of Fisheries databases.

This report fulfils the requirements of Objective 3 of Project HAK1999/02 "To analyse the age and length samples collected from HAK 7 by scientific observers to determine whether the catch-at-age data estimated for this fishery each year is representative of the commercial catch".

1. INTRODUCTION

Ministry of Fisheries scientific observers collect a range of data from Quota Management System (QMS) species of fish sampled on commercial fishing vessels. Within the HAK 7 Quota Management Area (QMA) (Figure 1), data collected by the scientific observers constitute the only information currently available on the age and length structure of the commercial catch of hake.

Typically, scientific observers collect sex, length, weight, and otolith samples from a subset of fish from selected vessel trips. From these data, a subsample of otoliths is chosen for ageing (typically by choosing all fish at the extremes of the overall length frequency, combined with a random sample of fish at lengths in-between — although different regimes have been used at different times). The ages and lengths of the individual samples are used to derive an age-length key by sex for each year. The age-length key, multiplied by the length frequency, gives the proportion of fish by age in the commercial catch.

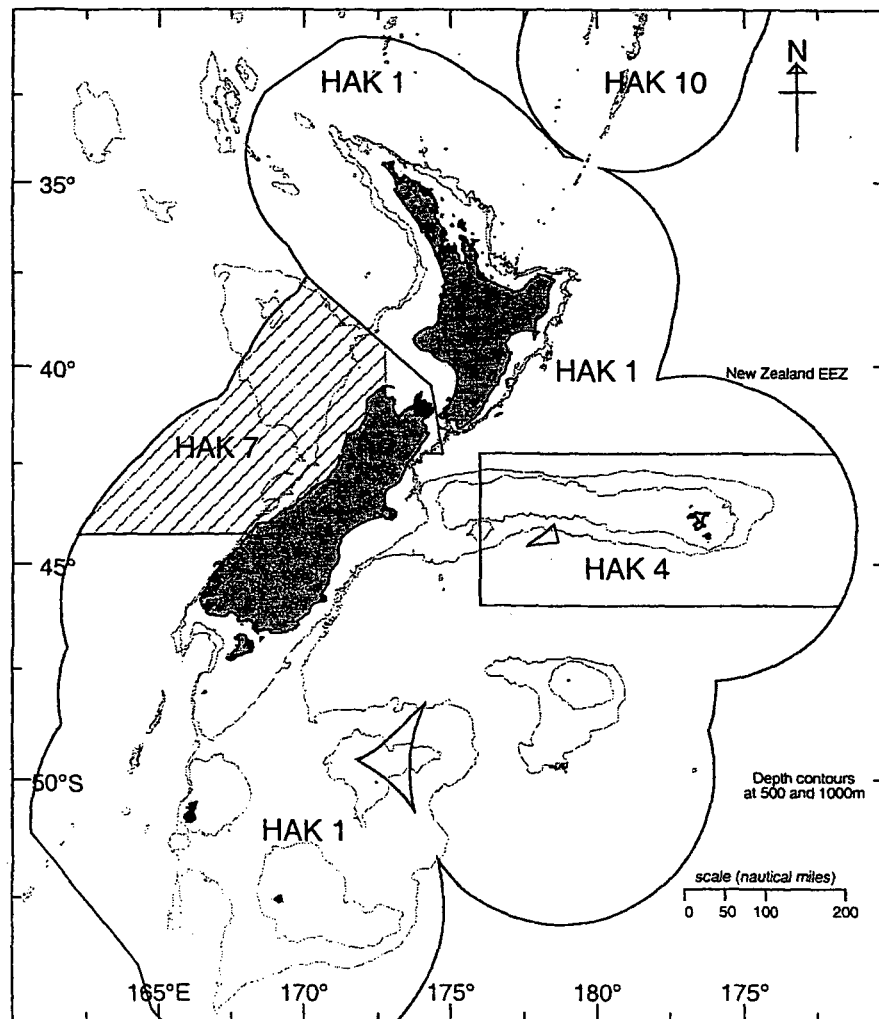


Figure 1: The Quota Management Areas (QMAs) for hake in the New Zealand EEZ. The hashed region shows the region of HAK 7 that is west of longitude 172°45'E.

Scientific observers usually join a vessel for an entire fishing trip. Each trip may incorporate any number of tows, over a period of days or weeks, with the fish samples taken from some subset of tows. The fishing vessels and trips observed by scientific observers are determined by the Ministry of Fisheries Scientific Observer Programme, and constitute a non-random sample of all

fishing trips. Scientific observers have previously been allocated to vessels in HAK 7 in such a manner as to allow the calculation of the age structure of spawning hoki on the west coast of the South Island, with lesser emphasis on hake.

Changes in coverage may have resulted in different subsets of the hake catch being sampled more intensively at different times, locations, or years, and hence may lead to bias in the estimates of the catch-at-age distribution.

We update the previously published estimates of the catch-at-age distribution for hake in HAK 7 (Colman et al. 1991, Colman & Vignaux 1992, Colman 1995, 1997, 1998, Dunn 1998, Horn 1998, Dunn et al. 2000, Dunn 2001), and investigate whether the currently estimated catch-at-age distribution is "representative" of the total commercial catch. We compare the overall catch-at-age distribution derived using subsets of scientific observer data combined with relative weightings derived from Trawl Catch Effort Processing Return (TCEPR) data. We use a Kolmogorov-Smirnov type statistic with a randomisation test to investigate evidence of significant difference between the resulting catch-at-age distribution estimates. Where the estimates of the catch-at-age distribution are inadequate, we suggest methods for improved estimates.

This report fulfils the requirements of Objective 3 of Project HAK1999/02 "To analyse the age and length samples collected from HAK 7 by scientific observers to determine whether the catch-at-age data estimated for this fishery each year is representative of the commercial catch".

2. METHODS

The scientific observer data provide information on the age and measurements of length (total length) of hake sampled in HAK 7. The age distribution for the commercial catch can be derived by multiplying the length frequency of the sampled catch with an age-length key. However, individual fish are sampled from a non-random sample of vessel trips and vessel tows. If the age or length structure of the hake in HAK 7 varies between subsets within the commercial catch, then these unstratified estimates may be biased. By subsetting the data into strata, and computing a stratified weighted age frequency across subsets, a better estimate may be calculated.

2.1 Determining the age-length key, length frequency, and age distribution

The HAK 7 age distribution is estimated from the length distribution by means of an age-length key. The age-length key for each sex, is the matrix $\{P_{al}\}$, made up of the proportions by age of fish of each length, i.e., amongst l centimetre fish, P_{al} is the proportion that is of age a .

$$\text{Hence, } \sum_a P_{al} = 1$$

Estimates of P_{al} can be obtained from aged samples that are non-random by length, provided it can be assumed that within a length class sampling with respect to age is random.

As catch of hake is recorded by weight (kg), not numbers, we estimate the number of fish caught in a tow, t , from the catch weight, H_t , and the length weight relationship, $w = \alpha_s l^{\beta_s}$, where w is fish weight, l is length and α_s and β_s are the coefficients for sex s . If P_{sl} is the estimate of the proportion of fish of sex s and length l in the catch, then an estimate of the mean fish weight is,

$$\bar{h}_t = \sum_{st} P_{st} \alpha_s l^{\beta_s}.$$

Then we calculate the number of fish of sex s , and length l , in tow t , as

$$F_{st} = P_{st} \frac{H_t}{\bar{h}_t}$$

and hence calculate the weighted length frequency for a stratum as,

$$X_{st} = \sum_t F_{st} \frac{W}{\sum_t H_t}$$

where W is the total stratum catch. The estimated number of fish of sex s and age a ,

$$Y_{sa} = \sum_t X_{st} P_{at}$$

For cases where no fish of length, l , are aged for the age-length key, we employ an imputation algorithm. We replace P_{al} by $P_{al'}$, where l' was the nearest length to l for which fish were aged. We break ties by choosing the lower of the nearest lengths.

2.2 Determining the stratified age distribution

The age distribution for any arbitrary subset (stratum) of the scientific observer data can be calculated by simply applying the methods detailed above to that stratum, i.e., we estimate the age-length key and associated length frequency for each stratum, and multiply up to estimate the stratum age distribution. The stratum catch-at-age distribution is then estimated from summing the weighted individual distributions up to the total stratum catch.

In a few instances, no samples were taken from a stratum. Where this occurred we have simply omitted that stratum from the analysis. The omitted strata usually contained very low catch and we consider that that omission will not undermine the test for variation between strata.

Estimating the age-length key for some strata may, however, result in a sparsely populated matrix with a truncated length range when numbers of aged fish are small. The associated bias resulting from imputation may unduly influence the estimated age frequencies. Typically the number of fish aged for hake in any one year is low, and hence for most strata may be too low to allow a reasonable estimate of the associated age-length key. Hence, we assume a constant age-length key and use it to estimate the age frequency for all strata.

We assume that data given in the TCEPR records represent the true distribution of hake catch in each year, and use the catch of hake within each stratum to estimate a stratified weighted age distribution.

2.3 Kolmogorov-Smirnov type statistics for comparing empirical distributions

Test for differences between distributions used a randomisation test with a Kolmogorov-Smirnov type statistic (Birbaum & Hall 1960, Conover 1980). We define the test statistic S as the maximum absolute deviation between two cumulative distributions, θ_1 and θ_2 ,

$$S = \max|\theta_1 - \theta_2|$$

The null distribution of the test statistic was estimated by resampling the tows that had been sampled for length. The age-length key remained constant. We randomised the sampled tows amongst the strata, i.e., we resampled the set of stratum codes without replacement. For each tow we also resampled the lengths within the sample, with replacement. This latter step properly took account of the variability resulting from small sample sizes.

A simple rank based p-value for the test statistic was calculated as

$$\text{p-value} = 1 - \text{rank}(S)/(N + 1) \quad (\text{Cox \& Hinkley 1974})$$

where N is the number of randomisation samples.

Hence, we calculate a p-value to determine if significant differences exist between the age frequency distributions from stratified and from unstratified analyses. For all comparisons, 999 randomisation samples were generated using S-Plus (MathSoft 1997).

2.4 Available data

Scientific observer data from commercial vessels are recorded in the Ministry of Fisheries databases *obs_lfs* and *age*. An extract of data from these databases was taken on 1 May 2000. The data extracted were all tows where hake were sampled, the recorded ages and lengths, and associated tow characteristics between 1 January 1990 and 31 December 1999 in HAK 7. All TCEPR records that recorded a catch of hake (at least 0.01 t) in HAK 7 between 1 January 1990 and 31 December 1999 were extracted from the Ministry of Fisheries catch effort database in March 2000.

No individual records of age data collected from scientific observers were found for the years 1990, 1991, 1994, or 1995 on the *age* database. Individual paper records for the 1990 and 1991 years were located, and these data were key-punched (and added to the *age* database). No individual records for the 1994 or 1995 data could be located. Hence, data for 1994 and 1995 were not subjected to the comparative analysis.

Numbers of hake measured and aged from the scientific observer data are shown in Table 1. Discrepancies between the numbers of fish measured (total length), aged, and the number of tows that were sampled are apparent between the data used in this analysis and in previously published data. Most of these differences are due to the definition of the year as the calendar year (rather than the fishing year), and the choice of region that is defined as HAK 7. However, other differences (though minor) cannot be reconciled.

Data from TCEPR records typically contain a number of recording errors. Raw TCEPR data was extracted from the Ministry of Fisheries catch effort database, where the recorded FMA was HAK 7. Records with a start of tow longitude and start of tow latitude outside of HAK 7 or east of longitude 172°45'E were excluded. The remaining variables of interest were range checked only, with recorded values outside the valid range set to missing. Details of variables extracted and subsequent range checks are given in Table 2.

The QMA for hake on the west coast of the South Island (HAK 7) includes the west coast of the South Island, Farewell Spit, southern Cook Strait, and the eastern corner of the northern tip of the South Island (see Figure 1). However, the HAK 7 fish stock is usually defined as that on the west coast of the South Island (Horn 1998). Hence, we exclude all TCEPR records and scientific observer samples taken from east of Farewell Spit, and define HAK 7 as the

region within the QMA to the west of longitude 172°45'E. Excluding the data from east of longitude 172°45'E resulted in the removal of about 0.9% all TCEPR records and about 0.8% of all scientific observer samples. We note that previously published catch-at-age estimates for west coast South Island (HAK 7) hake have included all scientific observer data within the entire QMA.

Table 1: Numbers of measured and aged fish by sex and the corresponding number of trips and tows from Dunn (2001) (Pub.) and numbers obtained from data extracts from the Ministry of Fisheries databases (Avail.). The revised year and areal definitions of HAK 7 used for this analysis have resulted in minor discrepancies between previously published data and data available for this analysis.

Year	Measured								Aged							
	Male		Female		Tows		Trips		Male		Female		Tows		Trips	
	Pub.	Avail.	Pub.	Avail.	Pub.	Avail.	Pub.	Avail.	Pub.	Avail.	Pub.	Avail.	Avail.	Avail.	Avail.	Avail.
1990 ¹	587	587	586	586	70	70	5	205	84	255	80	77	4			
1991	2 316	2 316	1 679	1 679	166	168	11	280	281	346	345	146	12			
1992	2 620	2 620	1 228	1 228	144	147	12	176	176	237	234	99	9			
1993	2 520	2 592	1 212	1 249	125	124	12	160	160	133	135	60	3			
1994 ²	1 631	1 631	1 724	1 724	223	227	16	135	–	258	–	–	–			
1995 ²	2 543	2 543	2 805	2 805	171	170	10	254	–	322	–	–	–			
1996	2 874	2 874	1 774	1 774	205	209	13	271	271	310	310	144	12			
1997	3 359	3 359	1 784	1 784	279	284	12	240	240	180	180	190	12			
1998 ³	2 354	2 373	1 539	1 538	268	266	15	240	232	228	224	186	10			
1999 ³	4 227	4 218	3 797	3 789	345	340	16	247	243	225	222	219	14			

1. The published data for 1990 included age (but not length) data collected from the research voyage GIL9001. These data has been excluded from this analysis
2. No age data are available for the years 1994 and 1995 in a form that allow them to be matched with recorded length data, and hence have been excluded from this analysis.
3. Published data for 1998 and 1999 defined the year as 1 October to 31 September. Previous years' definitions were not recorded.

Table 2: TCEPR variable, description, and valid range.

Variable	Description	Valid range
Date of tow	Start date of tow	From 01/01/1990 to 31/12/1999
Time of tow	Start time of tow	From 0000 hours to 2359 hours
Longitude	Start longitude of tow	Within the defined region ¹
Latitude	Start latitude of tow	Within the defined region ¹
Gear type	Trawl gear type	Midwater or bottom trawl gear
Bottom depth	Depth of bottom at start of tow	Between 200 m and 2 000 m
Target species	Target species	Hoki, hake, other
Tow speed	Vessel speed at start of tow	Between 1.5 and 6.5 knots
Hake catch	Total estimated catch of hake (t)	Between 0.01 and 15 000 t

1. The HAK 7 region is defined as inside HAK 7 QMA and west of longitude 172°45'E

We ignore the usual definition of fishing year and instead analyse the data by calendar year, as almost all fishing that recorded a catch of hake on the west coast of the South Island occurs during the hoki spawning season (June–September); less than 1% of the hake catch was recorded as caught from 1 October to 31 December (see later). Previously published catch-at-age estimates appear to have used both definitions over different years; however, the choice of year in the previously published data is poorly documented.

Values of variables from the scientific observer data were left unchecked. Previously published data for 1990 included age (but not length) data collected from the research voyage GIL9001 — a research voyage on the commercial vessel F.V. *Giljanas*, chartered by the

Ministry of Fisheries and Agriculture from 7 to 21 July 1990. We exclude these data from this analysis.

Estimates of the length-weight relationship are used to derive weighting factors for the analysis. We use the length-weight relationship from Colman et al. (1991), which was based on data collected on a research voyage by F.V. *Shinkai Maru* on the west coast of the South Island in 1976. No newer length-weight analyses are available for hake in HAK 7 (Horn 1998). The length-weight parameters are shown in Table 3.

Table 3: Length-weight relationships for hake in HAK 7.

Parameter	Male	Female
α	0.00275	0.00133
β	3.23	3.41

1. α and β are defined such that $w = \alpha l^\beta$, w = weight in grams and l = length in centimetres

2.5 Stratification

The choice of strata for comparison was determined by the available data. Common data between the scientific observer data and the TCEPR data are restricted to; vessel speed, location, gear type, bottom depth, time of tow, date of tow, and target species. Vessel characteristics were not available for this analysis (although could be analysed using the same methodology). The stratification and definitions of strata are shown in Table 4. The proportions of catches from scientific observer and from TCEPR data, by stratum, are shown in Appendix A, Tables A1–A7.

Table 4: Stratifications and definitions of strata.

Stratification	Number of strata	Definition
Gear type	2	Midwater or bottom trawl gear
Season	4	Before July, July, August, or after August
Location	4	Region A, B, C, or N&S (see Figure 2)
Target species	3	Hoki, hake, or other
Vessel speed	2	≤ 4 or > 4 knots
Bottom depth	6	≤ 400 m, 401–500 m, 501–600 m, 601–700 m, 701–800 m, or > 800 m
Time of day	4	0000–0600, 0601–1200, 1201–1800, or 1801–2359 hours

3. RESULTS

Locations of TCEPR tow data and scientific observer length and age samples are shown in Figures 2 and 3. Figure 4 shows the total catch of hake recorded on TCEPR records by year, total catch of hake recorded on tows that were sampled by scientific observers, and the total recorded landings for HAK 7 (from catch landing returns, CLR) for the years from 1990 to 1999. Note that some discrepancy between the CLR landings and the total catch from TCEPR data is usual, as the TCEPR forms record estimated catches for the top five species (by weight) from each tow.

Most hake catch is concentrated on or around the Hokitika Canyon (Phillips 2001). However, the seasonal distribution of catch varies between years considerably (Table 5). Although almost all of the recorded catch of hake occurs during the hoki spawning season, there can be large differences between years in the timing of the hake catch.

The distribution of the number of fish measured by tow and trip is shown in Figure 5. The number of hake length samples in each year, and across tows, is highly variable. In particular, in some years, the data appear dominated by a few very large samples.

Tables A1–A7 show the proportion of the catch by strata in each year for both the TCEPR data and the scientific observer data. The distribution of catch from observer samples would be expected, if scientific observer sampling was random, to follow the distribution of catch recorded on the TCEPR records. For most of the stratifications, the distributions of sampled catch from scientific observer data are highly variable between years, and differ markedly from the expected distribution from the TCEPR recorded catch. In particular, the catch of hake recorded from TCEPR records suggests that there are often occasions when a large proportion of the catch has not been sampled at all by scientific observers (see Tables A1–A7).

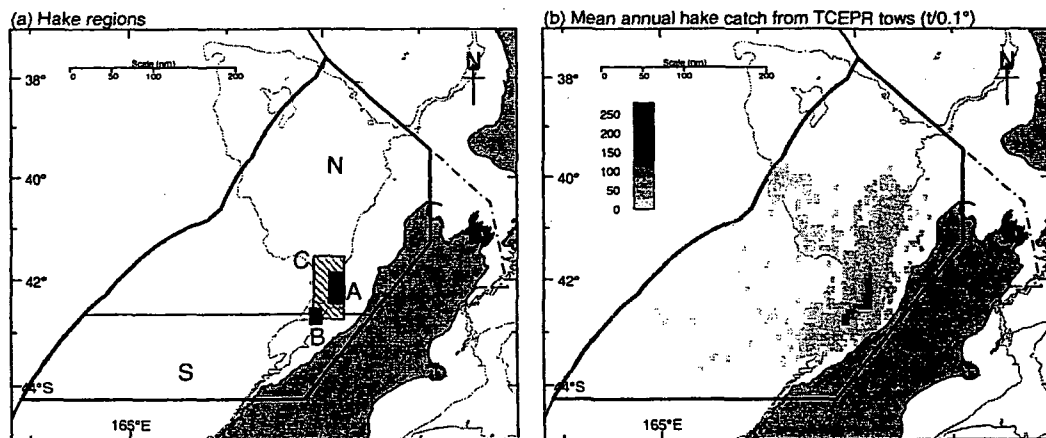


Figure 2: (a) Definitions of spawning regions for hake, and (b) relative density of hake catch from TCEPR recorded tows (all years combined).

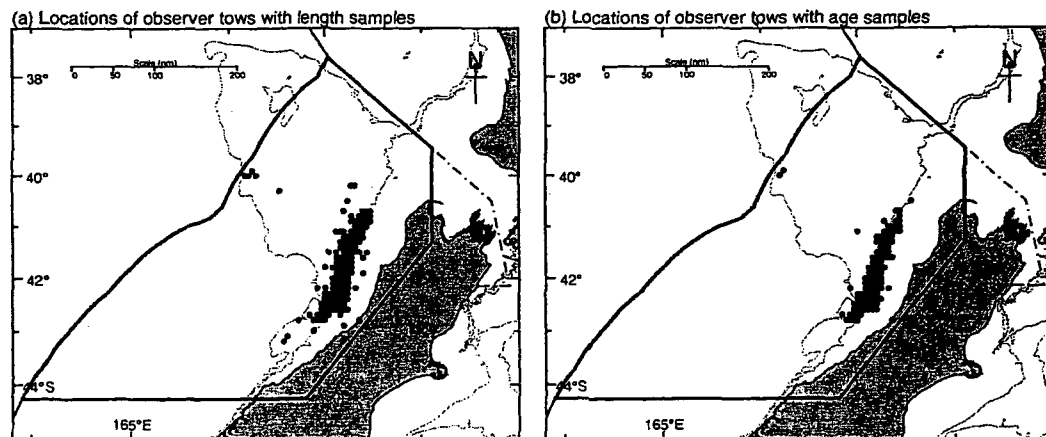


Figure 3: Locations of all hake observer tows (a) length samples, and (b) age samples.

Figure 6 shows the estimated proportions at age from previously published data and the unstratified estimates from this analysis. Discrepancies between the two estimates are large, and may be more than would be expected as a result of the difference in data definitions alone. The discrepancy for the 1990 data can be partially explained by the choice to exclude the age data from hake sampled by *F.V. Giljanos*. The rationale for the inclusion of this data in determining the age-length key for 1990 is not documented, but is likely to be that the data for the age-length key were otherwise sparse. Data for 1991, 1993, 1996, and 1997 appear to

have been truncated so as to remove shorter (and hence younger) fish from the length distribution before applying the age-length key. The rationale for this has not been documented.

Estimated p-values from the Kolmogorov-Smirnov type statistics are shown in Table 6 for males and females. Lower p-values indicate evidence for statistically significant differences between the stratified (by either gear type, season, region, target species, vessel speed, bottom depth, or time of tow) and unstratified estimates of the proportions at age. Plots of the age distributions resulting from stratification by each of the key variables are shown as Figures A1 to A7 in Appendix A.

For the stratification by season, (before July, July, August, or after August), significant differences (assuming a critical value of 0.05) were found only for male hake in 1993 and 1998. Of the remaining tests across males and females, four were significant at the $p = 0.10$ level. For the stratification by gear type (either midwater or bottom trawl), significant differences were found only for the 1997 males. The test suggested a borderline significance for 1990 male hake comparison. Of all the remaining tests, only two were significant; target species (either hoki, hake, or other) for 1992 males ($p = 0.01$) and region (area A, B, C, or N&S) for 1992 males ($p = 0.08$).

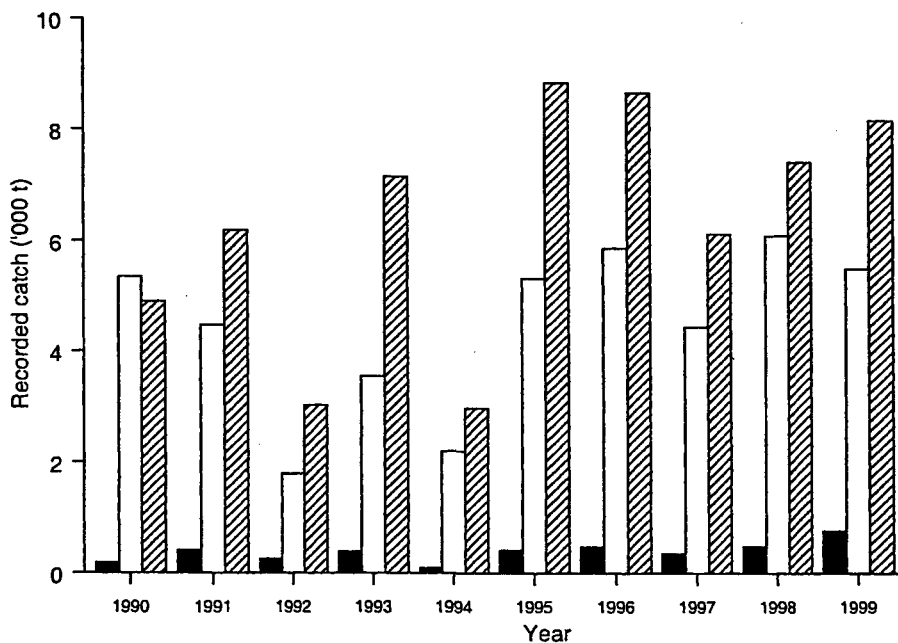


Figure 4: Total recorded hake catch from observer tows (black bars), TCEPR records (white bars), and CLR landings (fishing year, hashed bars) in HAK 7 for the years 1990 to 1999.

Table 5: Total estimated catch¹ of hake (t) by month from TCEPR records² and total landings (CLR) of hake³ by year.

Year	Month												CLR landings	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		Total
1990	-	-	0	-	-	1 069	3 596	858	31	0	-	-	5 554	4 903
1991	-	-	-	-	0	540	3 977	293	19	-	-	0	4 829	6 189
1992	-	-	1	0	0	180	723	112	1 201	2	-	-	2 219	3 027
1993	-	-	3	-	0	425	1 028	908	1 674	-	-	-	2 404	7 154
1994	0	-	0	-	0	666	969	341	421	12	0	2	2 411	2 973
1995	0	0	2	1	22	2 079	1 527	2 222	189	53	-	-	6 095	8 840
1996	0	-	1	0	1	1 566	2 275	1 949	776	13	-	0	6 581	8 660
1997	0	-	0	-	0	524	1 515	1 601	897	28	30	-	4 595	6 118
1998	0	0	-	1	13	1 189	2 811	1 612	423	42	266	13	6 370	7 416
1999	0	0	3	1	14	2 121	2 835	889	309	-	-	-	6 172	8 165

1. Total estimated catches from TCEPR records are given for calendar years
2. 0 records a value of less than 0.5 t and - denotes that no catch was recorded.
3. Totals of CLR landings are given for fishing years

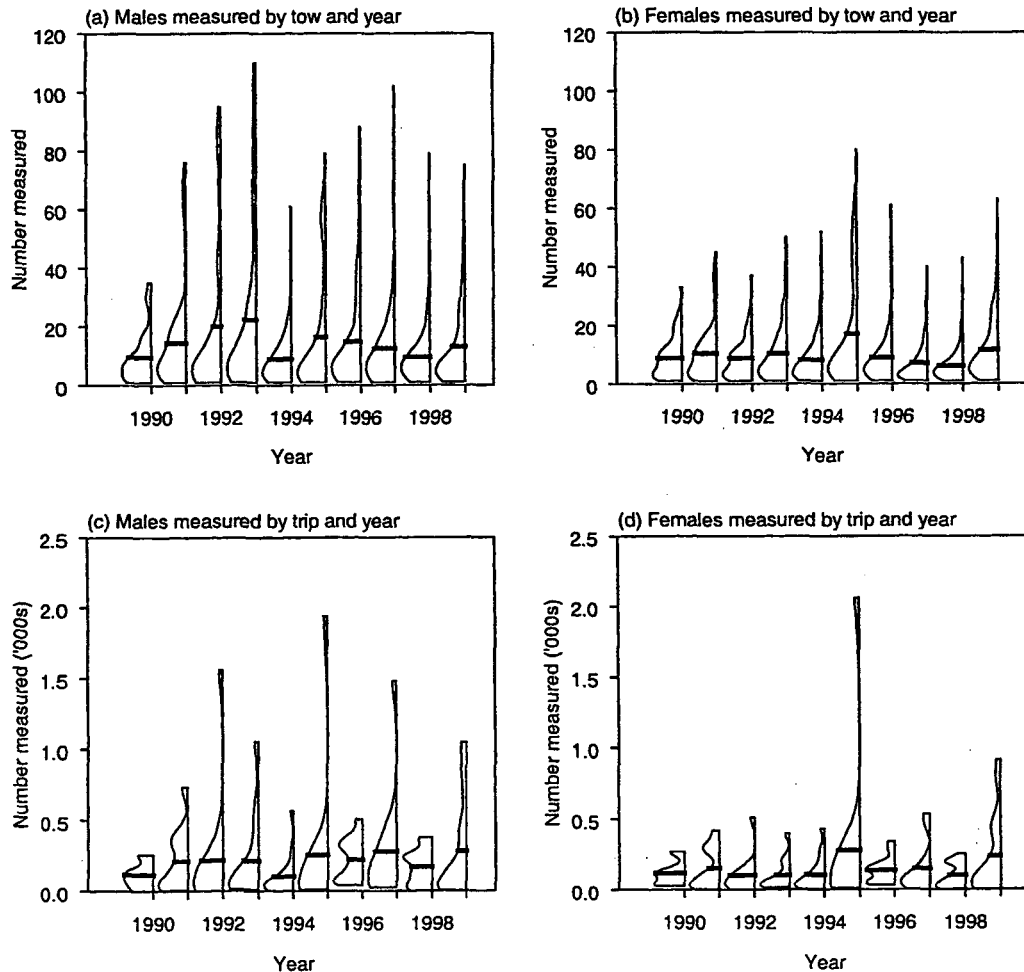


Figure 5: Density distribution of the numbers of (a) male and (b) female hake measured in each year by tow, and density distribution of the numbers of male (c) and female (d) hake measured in each year by trip. Means are shown as horizontal lines. Vertical limits indicate the range.

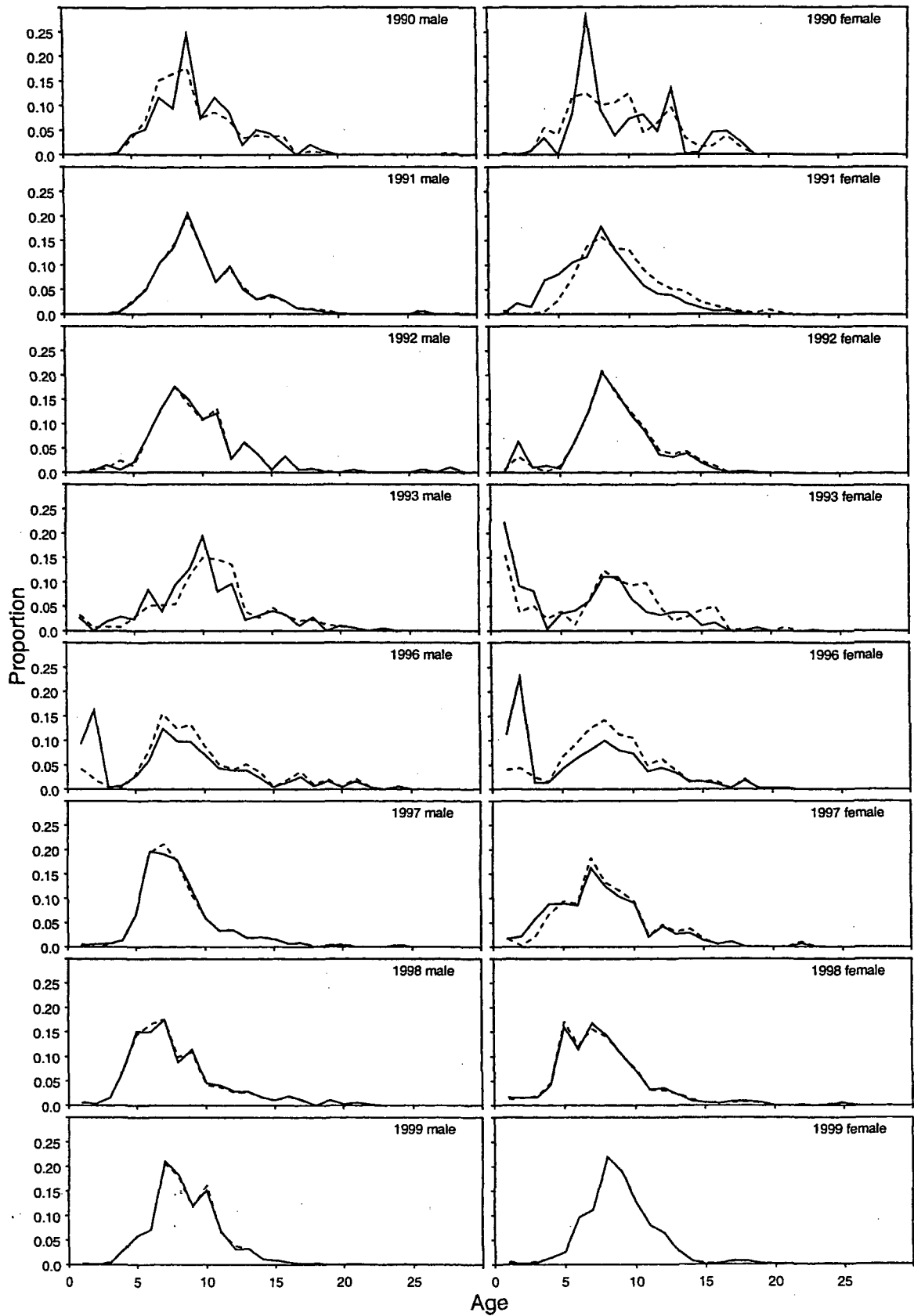


Figure 6: Previously published (Dunn 2001) (dashed line) and revised (unstratified) estimates (solid line) of proportions at age for commercially caught hake in HAK 7.

Table 6: Estimated p-values for (a) male and (b) female hake, for evidence of difference between estimated proportions at age for unstratified and stratified subsets (gear type, season, region, target species, vessel speed, bottom depth, and time) of observer length data.

(a) Male

Year	Gear	Season	Region	Target ²	Speed	Depth	Time
1990	0.08	0.95	0.92	—	0.99	1.00	1.00
1991	0.99	0.88	1.00	—	1.00	0.97	0.98
1992	0.80	0.08	0.08	0.01	0.94	0.27	0.66
1993	0.79	0.04	0.64	0.74	0.66	0.12	1.00
1994 ¹	—	—	—	—	—	—	—
1995 ¹	—	—	—	—	—	—	—
1996	0.99	0.09	0.66	0.98	0.11	0.81	0.86
1997	0.03	1.00	1.00	1.00	0.76	1.00	1.00
1998	0.96	0.00	0.20	0.34	0.94	0.89	0.84
1999	0.90	0.87	0.37	0.10	1.00	0.93	0.93

(b) Female

Year	Gear	Season	Region	Target ²	Speed	Depth	Time
1990	0.67	0.47	0.99	—	0.84	0.92	0.91
1991	1.00	0.79	1.00	—	1.00	0.98	0.92
1992	0.79	0.94	0.90	0.31	0.87	1.00	1.00
1993	0.96	0.97	0.96	0.36	0.87	1.00	1.00
1994 ¹	—	—	—	—	—	—	—
1995 ¹	—	—	—	—	—	—	—
1996	0.86	0.08	0.13	1.00	0.68	0.87	0.50
1997	0.58	0.98	0.85	1.00	1.00	1.00	0.98
1998	1.00	0.09	0.76	0.57	0.24	0.74	0.98
1999	0.98	0.69	0.33	0.11	1.00	1.00	0.99

1. No age data were available for the years 1994 and 1995.
2. Only one target species (HOK) was recorded on observer tows in 1990 and 1991.

4. DISCUSSION

In general, better, or at least less biased, estimates may be obtained by calculating stratified estimates of the age distribution. We have calculated stratified age distributions from the original length frequency data, using sampling weights derived from the distribution of the commercial catch as recorded by TCEPR data.

The Kolmogorov-Smirnov type statistics suggest some evidence of difference in the stratified and unstratified age distributions when we stratify by season. No evidence was found for difference when we used strata based on gear type, region, target species, vessel speed, bottom depth, or time of fishing. However, the power of these tests may be low, due to the very low sample sizes obtained for some strata.

In addition, we find evidence of non-random sampling by scientific observer sampling of hake in HAK 7. The coverage of some fundamental strata is poor (for example, the coverage of midwater versus bottom tows, coverage outside the main hoki fishing season, and coverage of non-hoki target tows), particularly in earlier years. Scientific observers have previously been allocated to vessels in HAK 7 in such a manner as to optimise the estimates of the age structure of spawning hoki on the west coast of the South Island. A range of factors (e.g., the temporal and geographical distribution of hake, gear type, or target species) can influence the data recorded for hake. These factors may result in different subsets of the hake catch being sampled more intensively in different years, and hence may lead to bias in the estimates of age.

The changing pattern of the scientific observer coverage is of concern. Coverage of important components of the hake catch is patchy, suggesting that the estimated age distributions for hake may be inadequate irrespective of the stratifications used.

We have assumed a constant age-length key for each year in this analysis. This was a pragmatic choice and a consequence of the low number of age samples available for each year. However, this is a potentially important factor when comparing between stratified and unstratified estimates of the age distribution. This choice could be reconsidered if more age data become available.

The methods used to derive age distributions in previous years have been poorly documented. This has resulted in different practices being employed in different years, for example, fishing years and calendar years for the analysis at different times. In addition, discrepancies between the previously published estimates of the age distribution and the revised (unstratified) estimates presented here are large, and are more than would be expected as a result of the minor difference in data definitions alone. The apparent truncation of data for 1991, 1993, 1996, and 1997 to remove shorter (and hence younger) fish from the length distribution is difficult to justify.

Some data (namely, age data for the years 1990, 1991, 1994, and 1995) were not recorded on any Ministry of Fisheries databases. Paper records for the 1990 and 1991 years were located and the data entered onto the Ministry of Fisheries *age* database. However, one possible explanation for the discrepancy between the previously published and revised estimates of the 1991 female age distribution, is that not all the data were found (although the number of samples is similar) or that the data found were incorrect. The loss of the 1994 and 1995 data makes the calculation of any revised (stratified) estimates of the age distribution for these years impossible.

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APPENDIX A

Table A1: Percent¹ hake catch by gear type for tows recorded by observers and from TCEPR records, 1990 to 1999.

Year	Observer tows (%)				TCEPR tows (%)			
	Midwater	Bottom	Unknown	Total	Midwater	Bottom	Unknown	Total
1990	98.8	1.2	–	100.0	86.9	13.1	–	100.0
1991	98.7	1.3	–	100.0	95.1	4.9	–	100.0
1992	74.5	25.5	–	100.0	54.9	45.1	–	100.0
1993	67.0	33.0	–	100.0	82.2	17.8	–	100.0
1994	93.0	7.0	–	100.0	71.8	28.2	–	100.0
1995	99.0	1.0	–	100.0	89.5	10.5	–	100.0
1996	84.8	15.2	–	100.0	80.2	19.8	–	100.0
1997	100.0	0.0	–	100.0	80.8	19.1	0.0	100.0
1998	94.6	5.4	–	100.0	84.8	15.0	0.2	100.0
1999	90.4	9.6	–	100.0	81.1	18.6	0.2	100.0

1. 0 records a value of less than 0.05 and – denotes that no catch was recorded.

Table A2: Percent¹ hake catch by season for tows recorded by observers and from TCEPR records, 1990 to 1999.

Year	Observer tows (%)					TCEPR tows (%)				
	Before		After			Before		After		
	July	July	August	August	Total	July	July	August	August	Total
1990	33.8	59.4	6.8	–	100.0	18.3	65.1	16.0	0.6	100.0
1991	1.5	92.7	5.8	–	100.0	11.3	82.2	6.1	0.4	100.0
1992	0.6	20.5	2.9	76.0	100.0	10.1	40.4	5.4	44.0	100.0
1993	–	8.5	32.6	58.9	100.0	11.1	28.5	20.9	39.5	100.0
1994	–	73.8	18.3	7.9	100.0	24.8	40.7	15.5	18.9	100.0
1995	10.2	64.3	24.9	0.6	100.0	32.8	27.1	36.2	3.9	100.0
1996	11.7	12.1	33.0	43.2	100.0	21.2	37.8	28.4	12.6	100.0
1997	9.1	36.2	44.7	10.0	100.0	11.4	33.4	35.2	20.0	100.0
1998	0.0	57.3	38.7	3.9	100.0	17.2	45.0	26.5	11.4	100.0
1999	15.4	67.5	17.0	0.0	100.0	32.0	46.6	15.8	5.6	100.0

1. 0 records a value of less than 0.05 and – denotes that no catch was recorded.

Table A3: Percent¹ hake catch by region for tows recorded by observers and from TCEPR records, 1990 to 1999. (see Figure 2 for regional definitions.)

Year	Observer tows (%)					TCEPR tows (%)				
	A	B	C	N & S	Total	A	B	C	N & S	Total
1990	22.7	2.2	73.9	1.2	100.0	44.9	4.7	49.0	1.5	100.0
1991	25.0	6.7	66.8	1.5	100.0	29.1	5.6	62.9	2.4	100.0
1992	73.0	2.4	24.2	0.3	100.0	48.1	17.7	27.8	6.4	100.0
1993	79.8	1.6	14.8	3.7	100.0	61.7	17.0	17.0	4.3	100.0
1994	21.3	1.7	58.7	18.2	100.0	27.0	28.2	33.3	11.5	100.0
1995	15.9	58.7	21.8	3.6	100.0	30.6	39.6	19.5	10.4	100.0
1996	39.1	13.7	44.1	3.1	100.0	38.5	23.4	30.5	7.6	100.0
1997	19.9	8.7	49.7	21.7	100.0	34.8	8.5	30.8	25.9	100.0
1998	38.3	0.2	51.6	9.9	100.0	35.5	13.1	41.9	9.5	100.0
1999	19.8	16.6	61.2	2.3	100.0	21.3	27.5	41.4	9.8	100.0

1. 0 records a value of less than 0.05 and – denotes that no catch was recorded.

Table A4: Percent¹ hake catch by target species for tows recorded by observers and from TCEPR records, 1990 to 1999.

Year	Observer tows (%)				TCEPR tows (%)			
	Hoki	Hake	Other	Total	Hoki	Hake	Other	Total
1990	100.0	–	–	100.0	99.7	0.2	0.1	100.0
1991	100.0	–	–	100.0	99.0	0.1	0.9	100.0
1992	22.0	75.6	2.3	100.0	62.6	33.2	4.2	100.0
1993	23.7	76.3	0.0	100.0	54.1	45.2	0.7	100.0
1994	97.9	1.7	0.4	100.0	75.5	23.4	1.1	100.0
1995	60.3	39.7	0.0	100.0	71.7	28.0	0.3	100.0
1996	87.5	12.5	0.0	100.0	89.0	10.9	0.1	100.0
1997	92.6	7.4	0.0	100.0	92.1	7.5	0.4	100.0
1998	100.0	–	0.0	100.0	90.3	9.3	0.4	100.0
1999	84.6	15.4	0.0	100.0	75.3	24.2	0.5	100.0

1. 0 records a value of less than 0.05 and – denotes that no catch was recorded.

Table A5: Percent¹ hake catch by speed for tows recorded by observers and from TCEPR records, 1990 to 1999.

Year	Observer tows (%)			TCEPR tows (%)		
	≤ 4 knots	> 4 knots	Total	≤ 4 knots	> 4 knots	Total
1990	53.8	46.2	100.0	38.0	62.0	100.0
1991	42.0	58.0	100.0	42.7	57.3	100.0
1992	16.3	83.7	100.0	30.1	69.9	100.0
1993	66.3	33.7	100.0	36.7	63.3	100.0
1994	20.3	79.7	100.0	43.8	56.2	100.0
1995	60.7	39.3	100.0	52.9	47.1	100.0
1996	29.3	70.7	100.0	50.7	49.3	100.0
1997	54.2	45.8	100.0	33.9	66.1	100.0
1998	15.8	84.2	100.0	46.1	53.9	100.0
1999	54.4	45.6	100.0	51.9	48.1	100.0

1. 0 records a value of less than 0.05 and – denotes that no catch was recorded.

Table A6: Percent¹ hake catch by depth of bottom for tows recorded by (a) observers and from (b) TCEPR records, 1990 to 1999.

(a) Observer tows (%)

Year	< 400 m	400-499 m	500-599 m	600-699 m	700-799 m	≥ 800 m	Total
1990	2.9	13.3	16.0	22.6	17.1	28.1	100.0
1991	0.4	5.8	20.0	48.2	18.4	7.2	100.0
1992	3.3	7.2	11.1	73.5	4.4	0.3	100.0
1993	0.2	4.9	20.8	69.3	4.6	0.1	100.0
1994	10.9	30.0	29.9	22.0	6.9	0.3	100.0
1995	13.3	21.4	15.3	24.6	25.4	-	100.0
1996	11.1	17.3	53.1	8.1	10.4	-	100.0
1997	10.7	33.2	29.5	21.8	4.8	-	100.0
1998	8.8	39.3	26.9	22.4	2.2	0.4	100.0
1999	5.1	23.0	29.3	19.1	22.6	1.0	100.0

(b) TCEPR tows (%)

1990	4.8	17.3	26.9	24.9	20.4	5.8	100.0
1991	3.7	12.0	25.6	30.5	21.8	6.4	100.0
1992	3.6	13.1	26.2	52.1	4.1	0.8	100.0
1993	3.6	6.6	18.2	57.7	12.8	1.2	100.0
1994	5.5	14.1	26.3	48.2	5.3	0.5	100.0
1995	8.8	16.1	33.2	30.6	11.2	0.1	100.0
1996	7.0	23.7	37.5	12.7	16.8	2.3	100.0
1997	10.1	32.2	41.8	8.8	6.4	0.7	100.0
1998	6.2	29.5	31.7	15.6	16.2	0.8	100.0
1999	6.0	14.8	26.8	20.8	30.3	1.4	100.0

1. 0 records a value of less than 0.05 and - denotes that no catch was recorded.

Table A7: Percent¹ hake catch by time of day (hours) for tows recorded by observers and from TCEPR records, 1990 to 1999.

Year	Observer tows (%)					TCEPR tows (%)				
	0000-0600	0601-1200	1201-1800	1801-2359	Total	0000-0600	0601-1200	1201-1800	1801-2359	Total
1990	13.2	37.7	23.9	25.2	100.0	16.5	38.5	27.0	18.0	100.0
1991	7.6	46.3	40.2	6.0	100.0	15.2	42.8	28.6	13.5	100.0
1992	26.2	47.7	19.3	6.8	100.0	16.4	38.9	33.7	11.0	100.0
1993	9.8	45.8	41.5	2.9	100.0	14.1	41.2	34.8	9.9	100.0
1994	7.3	36.3	31.6	24.9	100.0	16.2	33.4	32.2	18.1	100.0
1995	15.3	39.1	21.8	23.8	100.0	14.4	37.8	27.8	20.0	100.0
1996	6.7	28.1	49.1	16.1	100.0	13.1	37.0	32.1	17.8	100.0
1997	12.2	48.2	21.6	17.9	100.0	12.1	44.6	29.6	13.7	100.0
1998	7.5	41.8	35.7	14.9	100.0	11.7	44.2	27.0	17.1	100.0
1999	13.4	40.8	32.5	13.4	100.0	18.2	35.3	27.7	18.7	100.0

1. 0 records a value of less than 0.05 and - denotes that no catch was recorded.

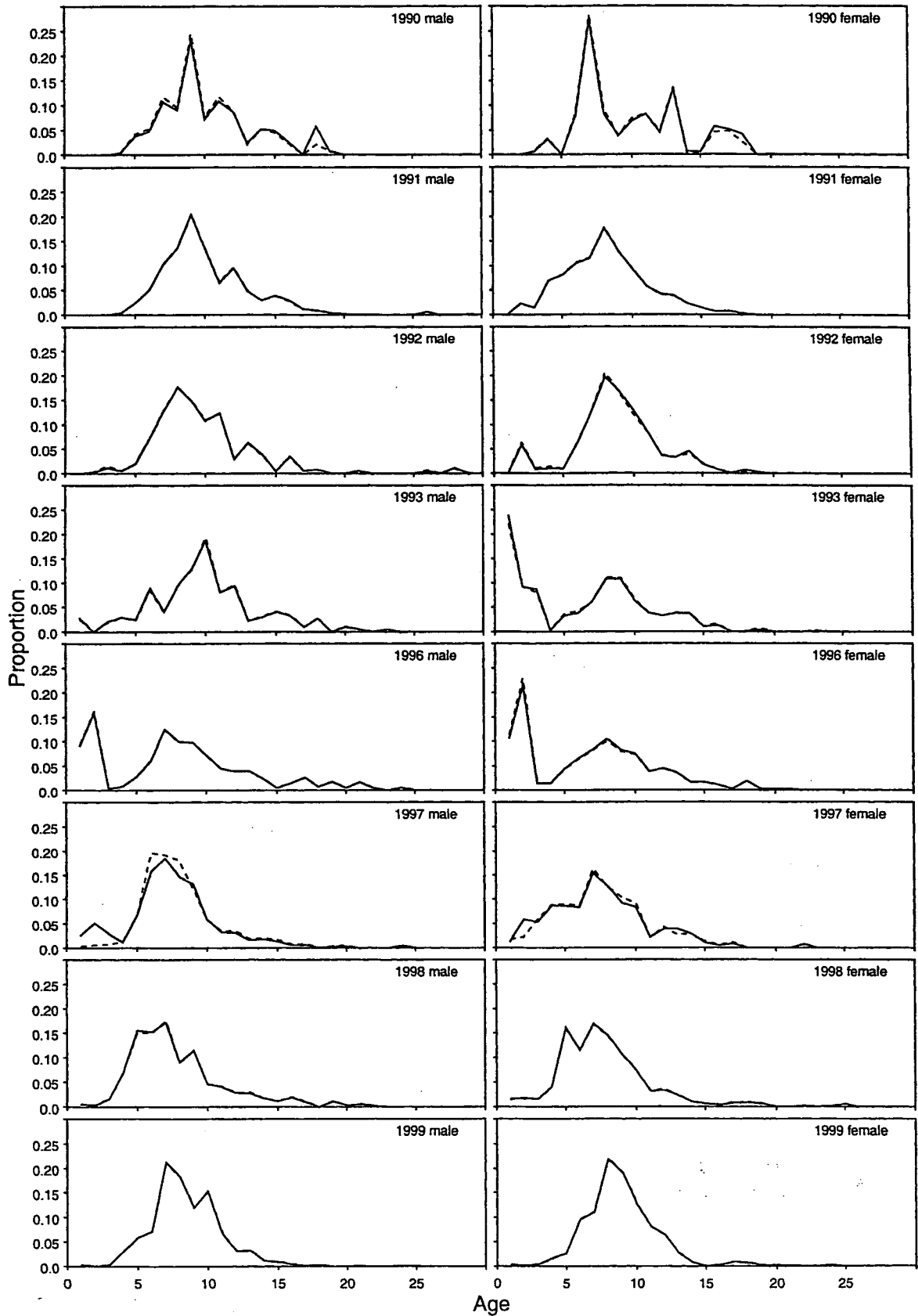


Figure A1: Stratified by gear type (solid line) and unstratified (dashed line) estimates of proportions at age for commercially caught hake in HAK 7, 1990 to 1993 and 1996 to 1999.

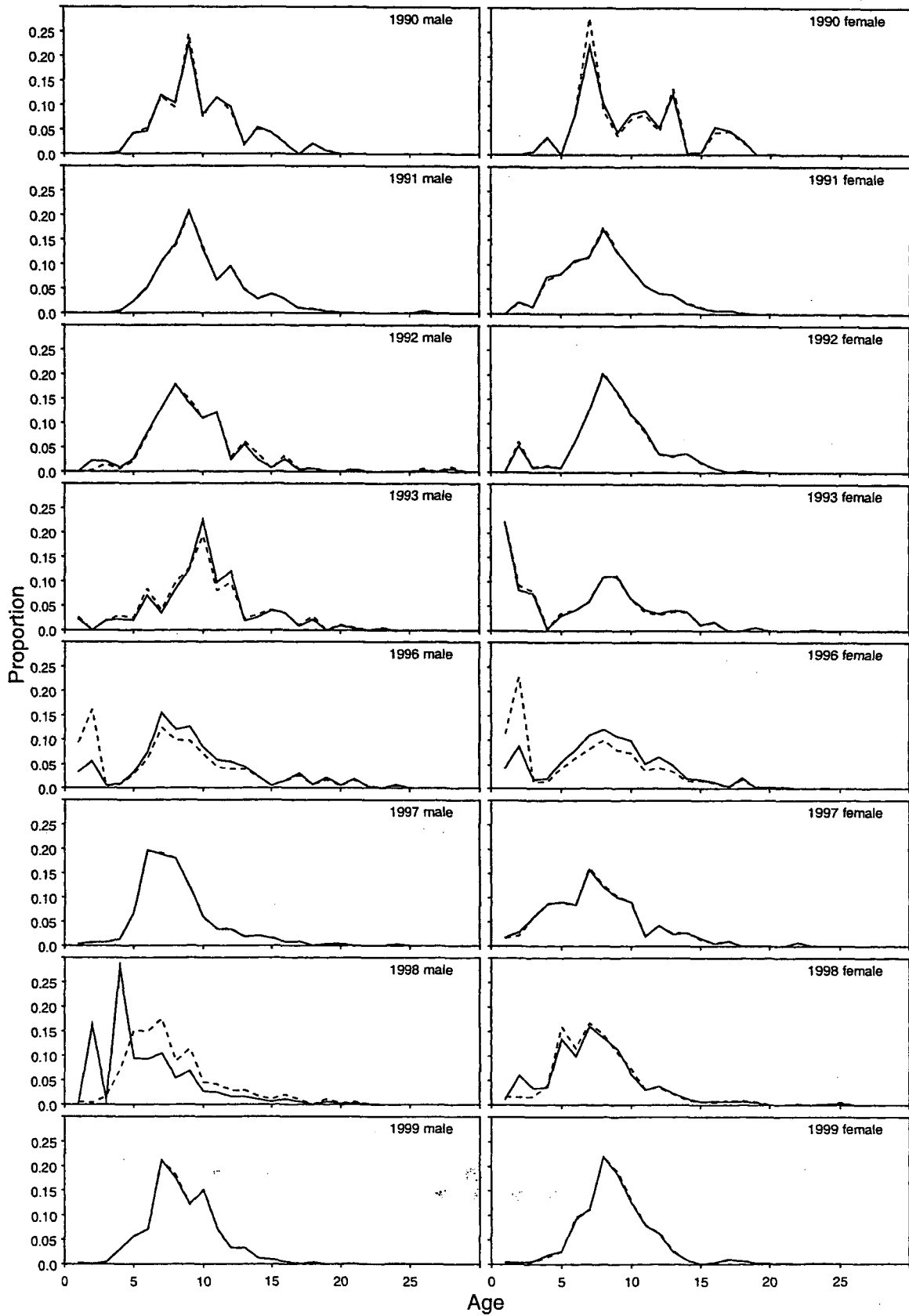


Figure A2: Stratified by season (solid line) and unstratified (dashed line) estimates of proportions at age for commercially caught hake in HAK 7, 1990 to 1993 and 1996 to 1999.

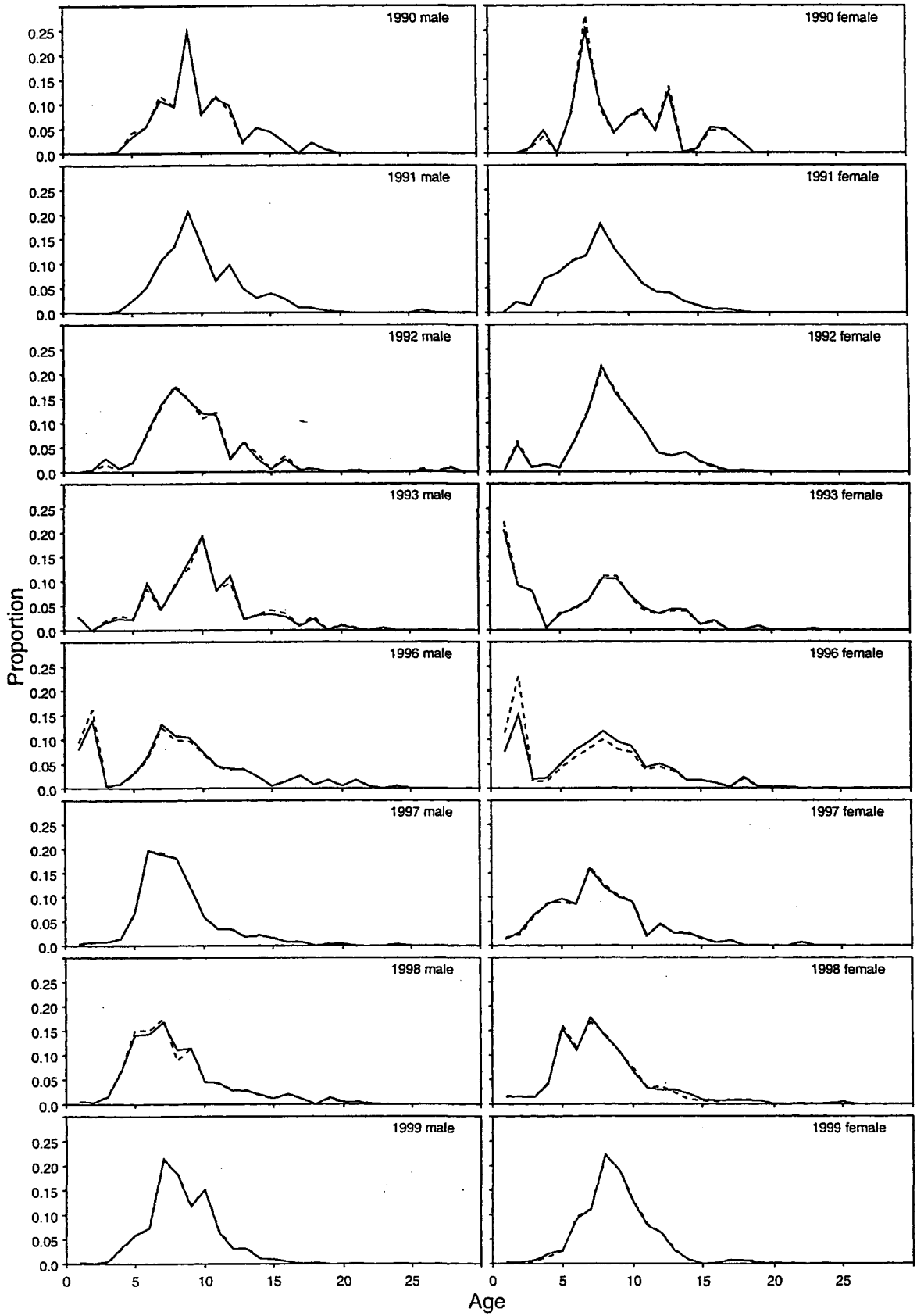


Figure A3: Stratified by region (solid line) and unstratified (dashed line) estimates of proportions at age for commercially caught hake in HAK 7, 1990 to 1993 and 1996 to 1999.

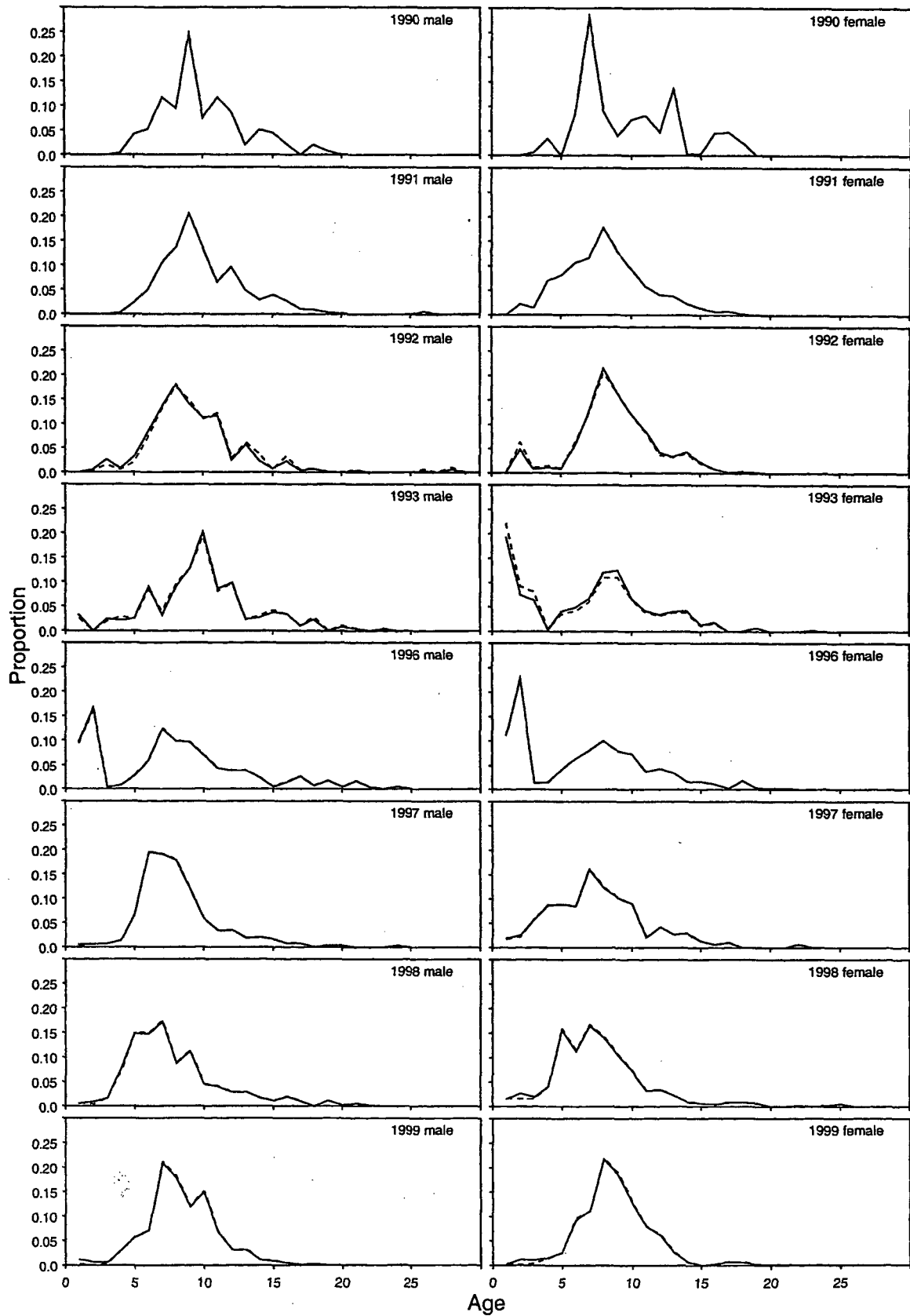


Figure A4: Stratified by target species (solid line) and unstratified (dashed line) estimates of proportions at age for commercially caught hake in HAK 7, 1990 to 1993 and 1996 to 1999.

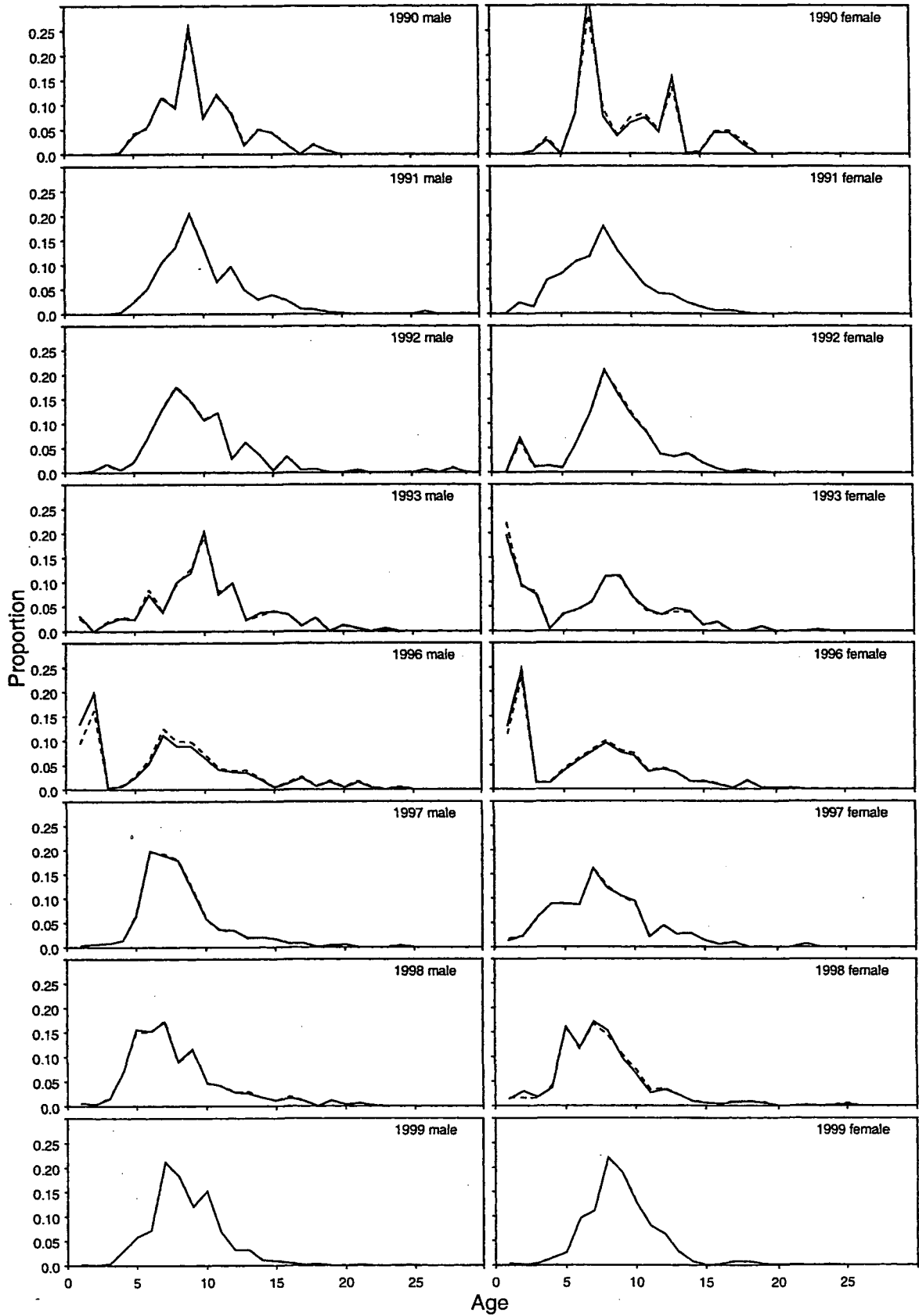


Figure A5: Stratified by vessel speed (solid line) and unstratified (dashed line) estimates of proportions at age for commercially caught hake in HAK 7, 1990 to 1993 and 1996 to 1999.

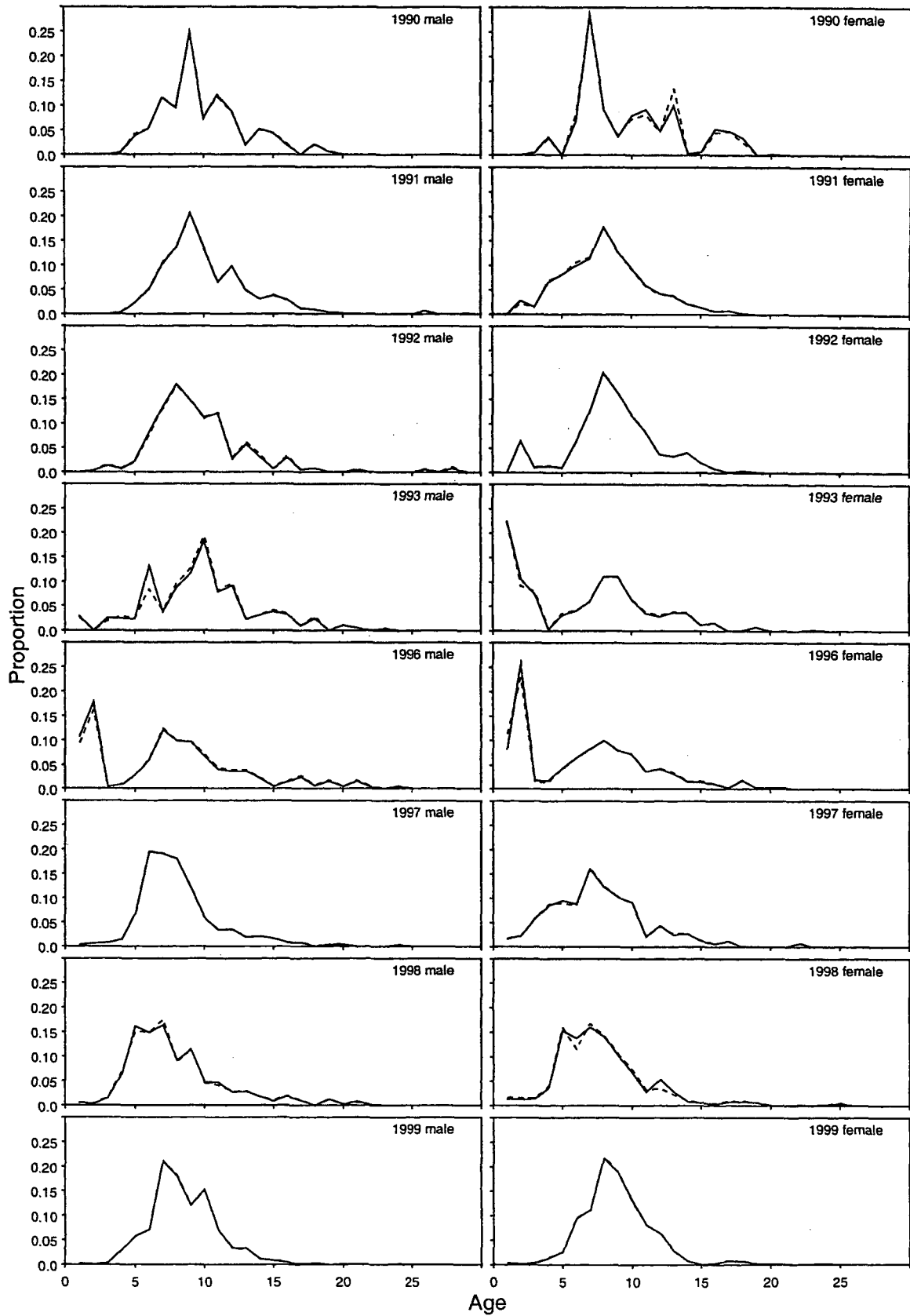


Figure A6: Stratified by bottom depth (solid line) and unstratified (dashed line) estimates of proportions at age for commercially caught hake in HAK 7, 1990 to 1993 and 1996 to 1999.

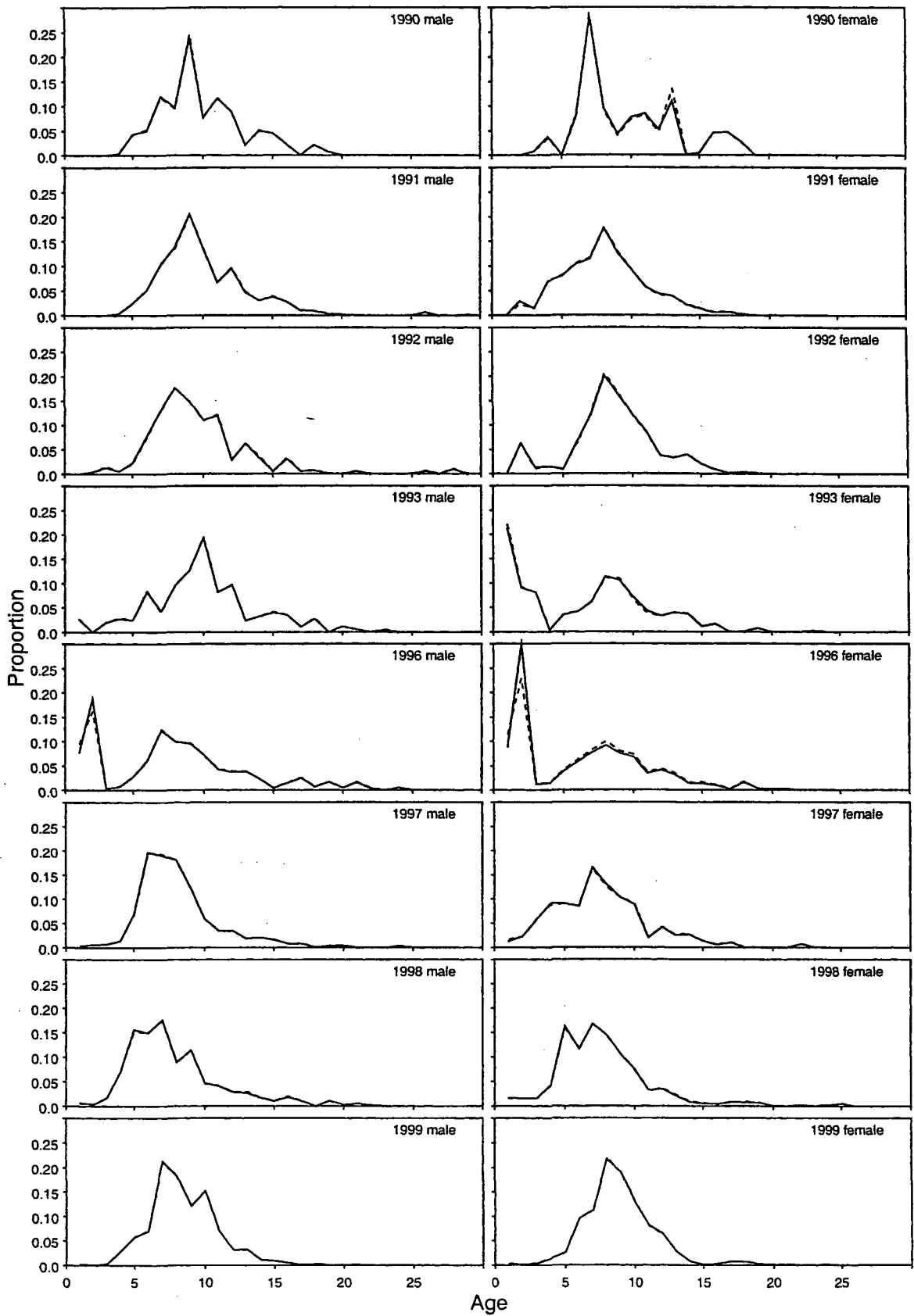


Figure A7: Stratified by time of day (solid line) and unstratified (dashed line) estimates of proportions at age for commercially caught hake in HAK 7, 1990 to 1993 and 1996 to 1999.

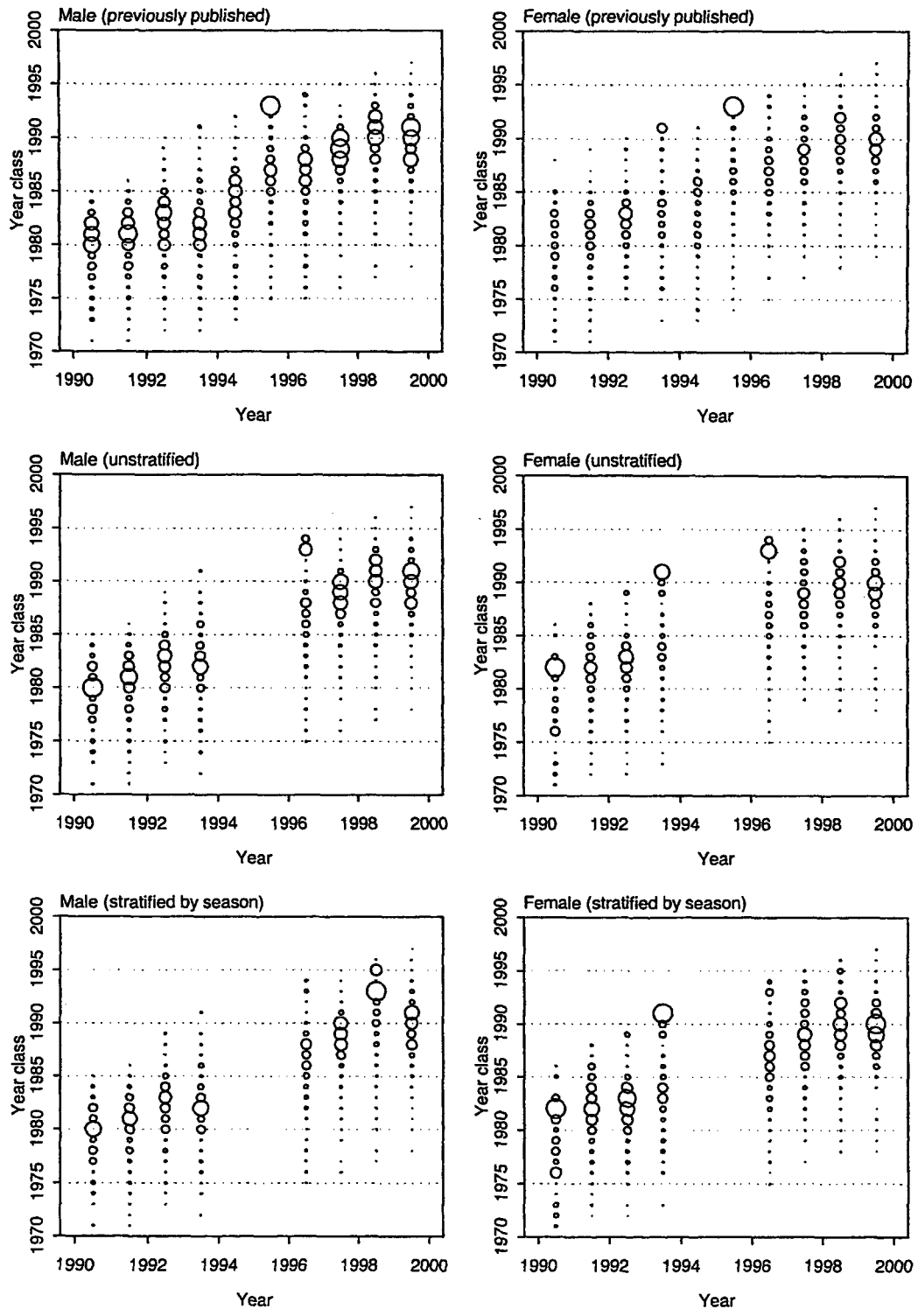


Figure A8: Age frequencies (ages 1 to 20) by year class and year (symbol diameter proportional to the proportions at age within sampling event) for males and females in the HAK 7 commercial catch-at-age data 1990 to 1999, for the (top row) previously published (Dunn 2001) estimates, (middle row) the revised unstratified estimates, and (bottom row) the stratified by season estimates.