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International Council for the Exploration of the Sea

C.M.1995/Assess:2

# PART 2

# REPORT OF THE WORKING GROUP ON THE ASSESSMENT OF MACKEREL, HORSE MACKEREL, SARDINE AND ANCHOVY

ICES Headquarters, 21 June - 1 July 1994

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Table 12.1 : Length distribution ('000) of Bay of Biscay anchovy by country, gear and divisions in 1993

| | Quarter 1 | | | | Quarter 2 | | | | Quarter 3 | | | | Quarter 4 | | | | Total | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Length (cm) | France Total VIIIab | Spain Seine VIIIb | Spain Seine VIIIc | Total | France Total VIIIab | Spain Seine VIIIb | Spain Seine VIIIc | Total | France Total VIIIab | Spain Seine VIIIb | Spain Seine VIIIc | Total | France Total VIIIab | Spain Seine VIIIb | Spain Seine VIIIc | Total | France Total VIIIab | Spain Seine VIIIb | Spain Seine VIIIc | Total |
| 7 | | | | 0 | | | | 0 | | | | 0 | | | | 0 | 0 | 0 | 0 | 0 |
| 7.5 | | | | 0 | 17 | | | 17 | | | | 0 | | | | 0 | 17 | 0 | 0 | 17 |
| 8 | | 127 | | 127 | 82 | | | 82 | | | | 0 | | 101 | | 101 | 82 | 228 | 0 | 310 |
| 8.5 | | 855 | 34 | 889 | 522 | | | 522 | | | | 0 | | 663 | 72 | 735 | 522 | 1518 | 106 | 2146 |
| 9 | 358 | 3231 | 168 | 3757 | 2240 | | | 2240 | | | | 0 | | 2772 | 404 | 3176 | 2598 | 6003 | 572 | 9173 |
| 9.5 | 922 | 6920 | 1158 | 9000 | 5277 | | 150 | 5427 | | | | 0 | | 3343 | 1061 | 4404 | 6199 | 10263 | 2369 | 18831 |
| 10 | 3254 | 10717 | 5464 | 19435 | 10427 | | 1719 | 12146 | 5170 | | | 5170 | 17 | 2203 | 1764 | 3984 | 18868 | 12920 | 8947 | 40735 |
| 10.5 | 7205 | 6422 | 8953 | 22580 | 14010 | | 3341 | 17351 | 2585 | | | 2585 | 1 | 939 | 1678 | 2618 | 23801 | 7361 | 13972 | 45134 |
| 11 | 5931 | 5821 | 10960 | 22712 | 19978 | 72 | 4281 | 24331 | 20888 | | 408 | 21296 | 23 | 299 | 2374 | 2696 | 46820 | 6192 | 18023 | 71035 |
| 11.5 | 6220 | 3704 | 11495 | 21419 | 12930 | 1439 | 4598 | 18967 | 16144 | | 817 | 16961 | 126 | 36 | 3227 | 3389 | 35420 | 5179 | 20137 | 60736 |
| 12 | 11212 | 1745 | 16267 | 29224 | 12674 | 5937 | 8833 | 27444 | 23528 | 692 | 3463 | 27683 | 14087 | 68 | 6626 | 20781 | 61501 | 8442 | 35189 | 105132 |
| 12.5 | 11777 | 1829 | 20326 | 33932 | 10875 | 9501 | 23707 | 44083 | 7899 | 1166 | 6549 | 15614 | 7324 | 46 | 3714 | 11084 | 37875 | 12542 | 54296 | 104713 |
| 13 | 25420 | 1502 | 22293 | 49215 | 3652 | 13523 | 44079 | 61254 | 13499 | 1437 | 10418 | 25354 | 15047 | 31 | 4731 | 19809 | 57618 | 16493 | 81521 | 155632 |
| 13.5 | 32406 | 603 | 15182 | 48191 | 4430 | 15566 | 48648 | 68644 | 8593 | 1387 | 9235 | 19215 | 20430 | 16 | 3688 | 24134 | 65859 | 17572 | 76753 | 160184 |
| 14 | 26261 | 306 | 10419 | 36986 | 3693 | 17950 | 58609 | 80252 | 26639 | 1423 | 12742 | 40804 | 19882 | 23 | 4757 | 24662 | 76475 | 19702 | 86527 | 182704 |
| 14.5 | 39949 | 164 | 5185 | 45298 | 7615 | 16446 | 52688 | 76749 | 36832 | 661 | 7310 | 44803 | 19243 | 13 | 4780 | 24036 | 103639 | 17284 | 69963 | 190886 |
| 15 | 29862 | 112 | 2821 | 32795 | 12866 | 23672 | 55458 | 91996 | 70975 | 352 | 5299 | 76626 | 28868 | 5 | 2298 | 31171 | 142571 | 24141 | 65876 | 232588 |
| 15.5 | 18450 | 279 | 1467 | 20196 | 10312 | 23902 | 45591 | 79805 | 55384 | 296 | 4421 | 60101 | 23605 | | 573 | 24178 | 107751 | 24477 | 52052 | 184280 |
| 16 | 28710 | 106 | 591 | 29407 | 2432 | 22403 | 47257 | 72092 | 45524 | 38 | 3100 | 48662 | 34795 | | 95 | 34890 | 111461 | 22547 | 51043 | 185051 |
| 16.5 | 5382 | 24 | 195 | 5601 | 508 | 15727 | 34170 | 50405 | 28186 | 32 | 1719 | 29937 | 23198 | | 24 | 23222 | 57274 | 15783 | 36108 | 109165 |
| 17 | 3994 | 18 | 91 | 4103 | 561 | 10481 | 26500 | 37542 | 10647 | 26 | 971 | 11644 | 22441 | | 11 | 22452 | 37643 | 10525 | 27573 | 75741 |
| 17.5 | 307 | | 23 | 330 | 107 | 4573 | 12772 | 17452 | 3161 | 21 | 703 | 3885 | 4205 | | 1 | 4206 | 7780 | 4594 | 13499 | 25873 |
| 18 | 141 | | 22 | 163 | 118 | 2021 | 8609 | 10748 | 1125 | 10 | 231 | 1366 | 4583 | | | 4583 | 5967 | 2031 | 8862 | 16860 |
| 18.5 | 40 | | | 40 | 33 | 295 | 2631 | 2959 | | | 185 | 185 | 37 | | | 37 | 110 | 295 | 2816 | 3221 |
| 19 | 35 | | | 35 | 30 | 346 | 603 | 979 | | | 2 | 2 | | | | 0 | 65 | 346 | 605 | 1016 |
| 19.5 | | | | 0 | | | 105 | 105 | | | | 0 | | | | 0 | 0 | 0 | 105 | 105 |
| 20 | | | | 0 | | | | 0 | | | | 0 | | | | 0 | 0 | 0 | 0 | 0 |
| Total | 257836 | 44485 | 133114 | 435435 | 135389 | 183854 | 484349 | 803592 | 376779 | 7541 | 67573 | 451893 | 237912 | 10558 | 41878 | 290348 | 1007916 | 246438 | 726914 | 1981268 |
| Catch (t) | 4978 | 324 | 1662 | 6964 | 1873 | 4455 | 10766 | 17094 | 8010 | 118 | 839 | 8967 | 6051 | 63 | 572 | 6685 | 20912 | 4960 | 13839 | 39710 |
| Lmoy (cm) | 14.3 | 10.8 | 12.7 | 13.4 | 12.6 | 15.1 | 14.9 | 14.6 | 14.7 | 13.7 | 14.2 | 14.6 | 15.2 | 9.8 | 12.9 | 14.7 | 14.4 | 14.1 | 14.4 | 14.4 |
| Wmoy (g) | 19.3 | 7.3 | 12.5 | 16 | 13.8 | 24.2 | 22.2 | 21.3 | 21.3 | 15.6 | 12.4 | 19.8 | 25.4 | 5.9 | 13.6 | 23 | 20.7 | 20.1 | 19 | 20 |

Table 12.2 : Spanish length distribution ('000) of Bay of Cadiz anchovy from the purse seiner in Division IXa in 1993

| Length (cm) | 1st quarter | 2nd quarter | 3rd quarter | 4th quarter | Total |
|---|---|---|---|---|---|
| 4 | 0 | 0 | 0 | 0 | 0 |
| 4.5 | 16 | 0 | 0 | 0 | 16 |
| 5 | 16 | 0 | 0 | 0 | 16 |
| 5.5 | 48 | 0 | 0 | 0 | 48 |
| 6 | 130 | 0 | 0 | 0 | 130 |
| 6.5 | 441 | 0 | 0 | 0 | 441 |
| 7 | 1342 | 4 | 0 | 0 | 1346 |
| 7.5 | 2564 | 10 | 0 | 0 | 2574 |
| 8 | 2930 | 24 | 0 | 0 | 2954 |
| 8.5 | 1865 | 40 | 0 | 0 | 1905 |
| 9 | 1119 | 2011 | 46 | 29 | 3205 |
| 9.5 | 680 | 5303 | 46 | 29 | 6058 |
| 10 | 869 | 5115 | 151 | 94 | 6229 |
| 10.5 | 2687 | 4129 | 667 | 416 | 7899 |
| 11 | 2986 | 2196 | 1533 | 956 | 7671 |
| 11.5 | 2670 | 4093 | 1850 | 1153 | 9766 |
| 12 | 7818 | 8740 | 2305 | 1437 | 20300 |
| 12.5 | 11145 | 12032 | 2297 | 1432 | 26906 |
| 13 | 6494 | 13850 | 1127 | 702 | 22173 |
| 13.5 | 2654 | 7144 | 625 | 390 | 10813 |
| 14 | 968 | 3313 | 183 | 114 | 4578 |
| 14.5 | 343 | 1566 | 183 | 114 | 2206 |
| 15 | 0 | 859 | 0 | 0 | 859 |
| 15.5 | 67 | 303 | 46 | 29 | 445 |
| 16 | 0 | 51 | 0 | 0 | 51 |
| | | | | | |
| Total N | 49852 | 70783 | 11059 | 6895 | 138589 |
| Catch (t) | 554 | 839 | 146 | 91 | 1630 |
| Lmoy (cm) | 11.5 | 12.3 | 12.3 | 12.3 | 12 |
| Wmoy (g) | 11.1 | 11.9 | 13.2 | 13.2 | 11.8 |

Table 13.1: Annual catches (in tonnes) of Bay of Biscay anchovy (Subarea VIII) As estimated by the Working Group.

| YEAR | COUNTRY<br>**FRANCE**<br>VIIIab | **SPAIN**<br>VIIIbc | **INTERNATIONAL**<br>VIII |
|---|---|---|---|
| 1960 | 1085 | 57000 | 58085 |
| 1961 | 1494 | 74000 | 75494 |
| 1962 | 1123 | 58000 | 59123 |
| 1963 | 652 | 48000 | 48652 |
| 1964 | 1973 | 75000 | 76973 |
| 1965 | 2615 | 81000 | 83615 |
| 1966 | 839 | 47519 | 48358 |
| 1967 | 1812 | 39363 | 41175 |
| 1968 | 1190 | 38429 | 39619 |
| 1969 | 2991 | 33092 | 36083 |
| 1970 | 3665 | 19820 | 23485 |
| 1971 | 4825 | 23787 | 28612 |
| 1972 | 6150 | 26917 | 33067 |
| 1973 | 4395 | 23614 | 28009 |
| 1974 | 3835 | 27282 | 31117 |
| 1975 | 2913 | 23389 | 26302 |
| 1976 | 1095 | 36166 | 37261 |
| 1977 | 3807 | 44384 | 48191 |
| 1978 | 3683 | 41536 | 45219 |
| 1979 | 1349 | 25000 | 26349 |
| 1980 | 1564 | 20538 | 22102 |
| 1981 | 1021 | 9794 | 10815 |
| 1982 | 381 | 4610 | 4991 |
| 1983 | 1911 | 12242 | 14153 |
| 1984 | 1711 | 33468 | 35179 |
| 1985 | 3005 | 8481 | 11486 |
| 1986 | 2311 | 5612 | 7923 |
| 1987 | 5061 | 9863 | 14924 |
| 1988 | 6743 | 8266 | 15009 |
| 1989 | 2200 | 8174 | 10374 |
| 1990 | 10598 | 23258 | 33856 |
| 1991 | 9708 | 9573 | 19281 |
| 1992 | 15207 | 22468 | 37675 |
| 1993 | 20914 | 19173 | 40087 |
| 1994 | 6000 | 13000 | 19000 (*) |
| AVERAGE (1960-93) | 3936 | 30553 | 34490 |

(*) Preliminary data for the first half of the year

Table 13.2 Monthly catches (in tons) of the Bay of Biscay anchovy by country (Sub-area VIII)

COUNTRY: FRANCE

| YEAR\MONTH | J | F | M | A | M | J | J | O | S | O | N | D | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1987 | 0.0 | 0.0 | 0.0 | 1225.0 | 1716.0 | 283.0 | 162.0 | 643.0 | 749.0 | 273.0 | 15.0 | 1.0 | 5067.0 |
| 1988 | 0.0 | 0.4 | 14.0 | 784.0 | 1388.0 | 781.0 | 296.0 | 1154.0 | 2000.0 | 324.0 | 0.2 | 0.0 | 6741.6 |
| 1989 | 699.6 | 81.4 | 11.0 | 378.4 | 763.4 | 11.0 | 59.4 | 8.8 | 30.8 | 151.8 | 4.4 | 0.0 | 2200.0 |
| 1990 | 0.4 | 0.0 | 15.9 | 1330.0 | 1511.3 | 127.2 | 269.2 | 1904.5 | 3274.8 | 1446.3 | 635.9 | 82.7 | 10598.1 |
| 1991 | 1318.0 | 2135.4 | 603.1 | 808.0 | 1622.0 | 195.2 | 124.2 | 419.1 | 1587.3 | 556.7 | 53.7 | 285.5 | 9708.2 |
| 1992 | 2062.0 | 1480.0 | 941.0 | 783.0 | 48.0 | 10.0 | 335.0 | 1202.0 | 2786.0 | 3165.0 | 2395.0 | 0.4 | 15207.4 |
| 1993 | 1636.4 | 1805.3 | 1536.7 | 91.2 | 342.5 | 1439.2 | 1314.6 | 2639.7 | 4056.6 | 3277.3 | 2726.7 | 47.2 | 20913.4 |
| Average 87-91 | 404 | 443 | 129 | 905 | 1400 | 279 | 182 | 826 | 1528 | 550 | 142 | 74 | 6863 |
| in percentage | 5.9% | 6.5% | 1.9% | 13.2% | 20.4% | 4.1% | 2.7% | 12.0% | 22.3% | 8.0% | 2.1% | 1.1% | 100.0% |
| Average 92-93 | 1849 | 1643 | 1239 | 437 | 195 | 725 | 825 | 1921 | 3421 | 3221 | 2561 | 24 | 18060 |
| in percentage | 10.2% | 9.1% | 6.9% | 2.4% | 1.1% | 4.0% | 4.6% | 10.6% | 18 9% | 17.8% | 14.2% | 0.1% | 100.0% |

COUNTRY: SPAIN

| YEAR\MONTH | J | F | M | A | M | J | J | O | S | O | N | D | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | 202.066 | | |
| 1987 | 0 | 0 | 453.534 | 4133 | 3676.988 | 514.022 | 80.573 | 53.509 | 27.888 | 456.876 | 136.171 | 265.109 | 9797.67 |
| 1988 | 5.96 | 0.015 | 27.868 | 785.663 | 2931.356 | 3203.765 | 292.143 | 97.586 | 421.121 | 118.348 | 1609.636 | 245.945 | 9739.406 |
| 1989 | 1.854 | 2.258 | 25.056 | 257.759 | 4295.474 | 794.911 | 89.993 | 509.725 | 115.643 | 198.399 | 16.39 | 272.743 | 6580.205 |
| 1990 | 79.176 | 5.629 | 2084.678 | 1327.846 | 9947.4 | 2956.681 | 1202.426 | 3226.926 | 2278.31 | 123.239 | 184.385 | 9 545 | 23426.241 |
| 1991 | 99.587 | 39.675 | 22.957 | 1227.554 | 5290.774 | 1662.673 | 90.519 | 59.515 | 34.126 | 265.348 | 94 | 596.215 | 9482.943 |
| 1992 | 360 | 384 | 340 | 3458 | 13068 | 3437 | 384 | 286 | 505 | 63 | 545.8 | 89 | 22919.8 |
| 1993 | 101.7 | 59.1 | 1825 | 3169 | 7563.5 | 4488.2 | 794.9 | 339.7 | 197.5 | 64.9 | | 23.5 | 18627 |
| | | | | | | | | | | | 398 | | |
| Average 87-93 | 93 | 70 | 683 | 2051 | 6682 | 2437 | 419 | 653 | 511 | 184 | 2.8% | 215 | 14368 |
| in percentage | 0.6% | 0.5% | 4.8% | 14.3% | 46.5% | 17.0% | 2.9% | 4.5% | 3.6% | 1.3% | | 1.5% | 100.0% |

Table 13.3: ANCHOVY catches in the Bay of Biscay by country and divisions in 1993

| | DIVISIONS | QUARTERS 1 | 2 | 3 | 4 | CATCH ( t ) ANNUAL | % |
|---|---|---|---|---|---|---|---|
| SPAIN | VIIIb | 324.0 | 5014.7 | 117.6 | 62.6 | 5518.9 | 28.8% |
| | VIIIC | 1661.8 | 10206.1 | 1214.5 | 571.6 | 13654.0 | 71.2% |
| | TOTAL | 1985.8 | 15220.8 | 1332.1 | 634.2 | 19172.9 | |
| | % | 10.4% | 79.4% | 6.9% | 3.3% | | 100.0% |
| FRANCE | VIIIa | 1143.0 | 658.0 | 6902.0 | 5106.0 | 13809.0 | 66.0% |
| | VIIIb | 3823.0 | 1215.0 | 1110.0 | 942.0 | 7090.0 | 33.9% |
| | VIIIC | 12.0 | 0.0 | 0.0 | 3.0 | 15.0 | 0.1% |
| | TOTAL | 4978.0 | 1873.0 | 8012.0 | 6051.0 | 20914.0 | |
| | % | 23.8% | 9.0% | 38.3% | 28.9% | | 100.0% |
| INTERNATION. | VIIIa | 1143.0 | 658.0 | 6902.0 | 5106.0 | 13809.0 | 34.4% |
| | VIIIb | 4147.0 | 6229.7 | 1227.6 | 1004.6 | 12608.9 | 31.5% |
| | VIIIC | 1673.8 | 10206.1 | 1214.5 | 574.6 | 13669.0 | 34.1% |
| | TOTAL | 6963.8 | 17093.8 | 9344.1 | 6685.2 | 40086.9 | |
| | % | 17.4% | 42.6% | 23.3% | 16.7% | | 100.0% |

**Table 13.4** Bay of Biscay anchovy catches by country and EU categories in 1993.

| | | QUARTERS | | | | | |
|---|---|---|---|---|---|---|---|
| **COUNTRY** | **EU CAT.** | **1** | **2** | **3** | **4** | **ANNUAL** | **%** |
| **SPAIN** | **T1** | 0 | 1447808 | 26109 | 0 | 1473917 | 7.7% |
| | **T2** | 8095 | 9027901 | 185319 | 5410 | 9226725 | 48.1% |
| | **T3** | 1078349 | 4303604 | 1013269 | 244992 | 6640214 | 34.6% |
| | **T4** | 899267 | 441433 | 107336 | 383752 | 1831788 | 9.6% |
| | **TOTAL** | 1985711 | 15220746 | 1332034 | 634154 | 19172645 | 100.0% |
| **FRANCE** | **T1** | 30349 | 27430 | 141262 | 189791 | 388832 | 1.9% |
| | **T2** | 2884057 | 793937 | 6954601 | 5625239 | 16257834 | 77.7% |
| | **T3** | 1878139 | 389603 | 271937 | 235922 | 2775601 | 13.3% |
| | **T4** | 185791 | 661933 | 643066 | 284 | 1491074 | 7.1% |
| | **TOTAL** | 4978336 | 1872903 | 8010866 | 6051236 | 20913341 | 100.0% |
| **INTERN.** | **T1** | 30349 | 1475238 | 167371 | 189791 | 1862749 | 4.6% |
| | **T2** | 2892152 | 9821838 | 7139920 | 5630649 | 25484559 | 63.6% |
| | **T3** | 2956488 | 4693207 | 1285206 | 480914 | 9415815 | 23.5% |
| | **T4** | 1085058 | 1103366 | 750402 | 384036 | 3322862 | 8.3% |
| | **TOTAL** | 6964047 | 17093649 | 9342900 | 6685390 | 40085986 | 100.0% |

T1 : <== 30 anchovies/Kg.
T2 : between 31 and 50 per Kg.
T3 : between 51 and 83 per Kg.
T4 : more than 84 per Kg.

**Table 13.5** Evolution of the French and Spanish fleet for ANCHOVY (from Working Group members). Number of boats.

| Year | France | | | Spain | Total |
|---|---|---|---|---|---|
| | P. seiner | P. trawl | Total | P. seiner | |
| 1960[1] | 52 | 0 | 52 | 571 | 623 |
| 1972[1] | 35 | 0 | 35 | 492 | 527 |
| 1976[1] | 24 | 0 | 24 | 354 | 378 |
| 1980[1] | 14 | n/a | 14 | 293 | 307 |
| 1984[1] | n/a | 4 | 4 | 306 | 310 |
| 1987[1] | 9 | 36 | 45 | 282 | 327 |
| 1988 | 10 | 61 | 71 | 278 | 349 |
| 1989 | 2 | 51 | 53 | 215 | 268 |
| 1990 | 30 | 80[1] | 110 | 266 | 376 |
| 1991 | 30 | 115[2] | 145 | 250 | 395 |
| 1992 | 13 | 123[2] | 136 | 244 | 380 |
| 1993 | 21 | 138 | 159 | 253 | 412 |
| 1994[3] | 26 | 150 | 176[3] | 255 | 431 |

[1] Only St. Jean de Luz and Hendaya.

[2] Maximum number of potential boats; the number of mid-water trawls is roughly half of this number due to the fishing in pairs of mid-water trawlers.

[3]Provisional figure.

n/a = Not available.

Table 13.6 : Catch per Unit Effort of the Spanish spring fishery on Bay of Biscay anchovy

| Year<br>period | 1987<br>03-06 | 1988<br>03-06 | 1989<br>04-06 | 1990<br>04-06 | 1991<br>04-06 | 1992<br>04-06 | 1993<br>03-06 | 1994(*)<br>03-06 |
|---|---|---|---|---|---|---|---|---|
| CPUE (t) | 0.9 | 0.65 | 0.79 | 1.5 | 1.2 | 2.55 | 1.72 | 1.37 |
| CPUE<br>1 y-old (**) | 13.76 | 16.7 | 16.11 | 63.35 | 29.26 | 86.28 | 57.7 | 35.8 |
| CPUE<br>2 y-old and + (**) | 17.49 | 9.09 | 14.9 | 5.25 | 20.56 | 17.94 | 26.6 | 20.8 |

(*) provisional ; (**) in thousand

**Table 13.7** Daily Egg Production Method. Egg surveys on ANCHOVY - Bay of Biscay. Data revised and updated by Motos and Uriarte (WD 93).

| Year | | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|
| Period of year | | 02-07 June | 21-28 May | 10-21 May | 04-15 May | 16 May-07 Jun | 16 May-13 Jun |
| Positive area (km$^2$) | | 23,850 | 45,384 | 17,546 | 59,757 | 24,264 | 67,796 |
| Surveyed area (km$^2$) | | 34,934 | 59,840 | 37,930 | 79,759 | 84,032 | 92,782 |
| Daily total egg production Exp(-12) | | 2,198 | 5,015 | 0,730 | 5,020 | 1,240 | 5,81 |
| C.V. | | 0.390 | 0.240 | 0.400 | 0.150 | 0.060 | 0.14 |
| SSB (t) | | 29,365 | 63,500 | 11,861 | 97,239 | 19,276 | 90,720 |
| C.V. | | 0.480 | 0.310 | 0.410 | 0.222 | 0.140 | 0.20 |
| Coastal egg production Exp(-12) | | 2,319 | 5,312 | 0,328 | 3,350 | 0,524 | 2.97 |
| | | TOTAL | | | | | |
| No/age: | 1 | 656 | 2,349 | 246 | 5,613 | 647 | 5,571 |
| (millions) | 2 | 331 | 258 | 206 | 190 | 279 | 209 |
| | 3 | 76 | 66 | 18 | 40 | 4 | 17 |
| | 4 | 41 | 2 | 0 | 0 | 0 | 0 |
| | 5 | 25 | 0 | 0 | 0 | 0 | 0 |
| Regional estimates | | Oceanic | Oceanic | Remainder | Oceanic | Remainder | Remainder |
| SSB (t) | | 21,000 | 23,400 | 9,200 | 32,315 | 12,250 | 41,464 |
| No/age: | 1 | 181 | 592 | 172 | 1,230 | 283 | 1,784 |
| (millions) | 2 | 331 | 258 | 166 | 155 | 221 | 187 |
| | 3 | 76 | 66 | 16 | 35 | 4 | 17 |
| | 4 | 41 | 2 | 0 | 0 | 0 | 0 |
| | 5 | 25 | 0 | 0 | 0 | 0 | 0 |
| | | Coastal-gar. | Coastal-gar. | Garonne | Coastal-gar. | Garonne | Garonne |
| SSB (t) | | 9,500 | 39,600 | 2,800 | 64,924 | 7,026 | 49,256 |
| No/age: | 1 | 475 | 1,757 | 74 | 4,383 | 363 | 3,787 |
| (millions) | 2 | 0 | 0 | 40 | 35 | 58 | 22 |
| | 3 | 0 | 0 | 2 | 5 | 0 | 0 |
| | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 5 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 13.8** Evaluation of abundance index from French acoustic surveys.

| | 1983 | 1984 | 1989[2] | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|
| | 20/4-25/4 | 30/4-13/5 | 23/4-2/5 | 12/4-25/4 | 6/4-29/4 | 13/4-30/4 |
| Surveyed area | 3,267 | 3,743 | 5,112 | 3,418[3] | 3,388[3] | 2,440 |
| Density ($t/nm^2$) | 15.4 | 10.3 | 3.0 | 14.5-32.2[4] | 23.6 | 32.8 |
| Biomass (t) | 50,000 | 38,500 | 15,500 | 60-110,000[4] | 64,000 | 89,000 |
| Number ($10^{-6}$) | 2,600 | 2.000 | 805 | 4,300-7,900[4] | 3,173 | 9,342 |
| Number of 1-group ($10^{-6}$) | 1,800[1] | 600[1] | 400 | 4,100-7,500[4] | 1,873 | 9,072 |

[1]Rough estimation.
[2]Assumption of overestimate.
[3]Positive area.
[4]Must be revised.

**Table 13.9** Summary of egg and acoustic surveys of Bay of Biscay ANCHOVY.

| Year | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|---|---|---|
| SSB (tonnes) | - | - | - | - | 29,365 | 63,500 | 11,860 | 97,239 | 19,276 | 90,720 |
| Acoustic index (tonnes) | 50,000 | 38,500 | - | - | - | - | 15,500 | N.A. | 64,000 | 89,000 |
| Egg survey (million) (1-year-old) | - | - | - | - | 656 | 2,349 | 246 | 5,613 | 647 | 5,571 |
| Acoustic survey (1-year-old) millions | 1,800 | 600 | - | - | - | - | 440 | N.A. | 1,373 | 9,072 |
| Y.C.C.[1] | 1,444 | 352 | 177 | 267 | 340 | 542 | 302 | 1,738 | 667 | 1,961 |
| Catch | 14,153 | 35,179 | 11,486 | 7,923 | 14,924 | 15,009 | 10,374 | 33,856 | 19,281 | 37,676 |

[1]Year class cumulative in numbers $\left\{ \sum_{i=1}^{N} C_{ij} \right\}$ Cij: Catch from year class j in year i; N: Number of catch years for the year class j

Table 13.10: ANCHOVY catch at age in thousands for 1993 by country, division and quarter.

QUARTERS AND MAIN DIVISIONS

| SPAIN | 1 VIIIbc | 2 VIIIbc | 3 VIIIbc | 4 VIIIbc | Year VIIIbc |
|---|---|---|---|---|---|
| Age | | | | | |
| 0 | 0 | 0 | 8520 | 51422 | 59942 |
| 1 | 170515 | 407713 | 54644 | 1010 | 633882 |
| 2 | 7078 | 259534 | 11903 | 4 | 278519 |
| 3 | 0 | 971 | 1 | 0 | 972 |
| 4 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 177593 | 668218 | 75068 | 52436 | 973315 |
| W MED. | 11.38 | 22.48 | 17.27 | 11.43 | 19.43 |
| SOP | 2020.98 | 15019.16 | 1296.74 | 599.09 | 18911.51 |
| CATCH | 1985.80 | 15220.80 | 1332.10 | 634.20 | 19172.90 |
| VAR % | 1.77% | -1.32% | -2.65% | -5.54% | -1.36% |

| FRANCE | 1 VIIIab | 2 VIIIab | 3 VIIIab | 4 VIIIab | Year VIIIab |
|---|---|---|---|---|---|
| Age | | | | | |
| 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 86504 | 130984 | 346123 | 191272 | 754883 |
| 2 | 165582 | 4418 | 30633 | 47227 | 247860 |
| 3 | 5755 | 0 | 0 | 0 | 5755 |
| 4 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 257841 | 135402 | 376756 | 238499 | 1008498 |
| W MED. | 19.00 | 13.00 | 22.60 | 24.50 | 20.84 |
| SOP | 4898.98 | 1760.23 | 8514.69 | 5843.23 | 21017.12 |
| CATCH | 4978.34 | 1872.90 | 8010.87 | 6051.24 | 20913.34 |
| VAR % | -1.59% | -6.02% | 6.29% | -3.44% | 0.50% |

Sub-area VIII

| TOTAL | 1 VIII | 2 VIII | 3 VIII | 4 VIII | Year VIII |
|---|---|---|---|---|---|
| Age | | | | | |
| 0 | 0 | 0 | 8520 | 51422 | 59942 |
| 1 | 257019 | 538697 | 400767 | 192282 | 1388765 |
| 2 | 172660 | 263952 | 42536 | 47231 | 526379 |
| 3 | 5755 | 971 | 1 | 0 | 6727 |
| 4 | 0 | 0 | 0 | 0 | 0 |
| TOTAL | 435434 | 803620 | 451824 | 290935 | 1981813 |
| W MED. | 15.89 | 20.88 | 21.72 | 22.14 | 20.15 |
| SOP | 6919.96 | 16779.39 | 9811.42 | 6442.32 | 39928.63 |
| CATCH | 6964.14 | 17093.70 | 9342.97 | 6685.44 | 40086.24 |
| VAR % | -0.63% | -1.84% | 5.01% | -3.64% | -0.39% |

HALF YEAR and DIVISIONS

| SPAIN | 1 VIIIbc | 2 VIIIbc | VIIIbc |
|---|---|---|---|
| Age | | | |
| 0 | 0 | 59942 | 59942 |
| 1 | 578228 | 55654 | 633882 |
| 2 | 266612 | 11907 | 278519 |
| 3 | 971 | 1 | 972 |
| 4 | 0 | 0 | 0 |
| TOTAL | 845811 | 127504 | 973315 |
| W MED. | 20.15 | 14.87 | 19.46 |
| SOP | 17040.14 | 1895.83 | 18935.97 |
| CATCH | 17206.6 | 1966.3 | 19172.9 |
| VAR % | -0.97% | -3.58% | -1.24% |

| FRANCE | VIIIab | VIIIab | VIIIab |
|---|---|---|---|
| Age | | | |
| 0 | 0 | 0 | 0 |
| 1 | 217488 | 537395 | 754883 |
| 2 | 170000 | 77860 | 247860 |
| 3 | 5755 | 0 | 5755 |
| 4 | 0 | 0 | 0 |
| TOTAL | 393243 | 615255 | 1008498 |
| W MED. | 16.93 | 23.34 | 20.84 |
| SOP | 6659.21 | 14357.91 | 21017.12 |
| CATCH | 6851.239 | 14062.1 | 20913.34 |
| VAR % | -2.80% | 2.10% | 0.50% |

Sub-area VIII

| TOTAL | VIII | VIII | VIII |
|---|---|---|---|
| Age | | | |
| 0 | 0 | 59942 | 59942 |
| 1 | 795716 | 593049 | 1388765 |
| 2 | 436612 | 89767 | 526379 |
| 3 | 6726 | 1 | 6727 |
| 4 | 0 | 0 | 0 |
| TOTAL | 1239054 | 742759 | 1981813 |
| W MED. | 19.13 | 21.88 | 20.16 |
| SOP | 23699.34 | 16253.74 | 39953.08 |
| CATCH | 24057.84 | 16028.4 | 40086.24 |
| VAR % | -1.49% | 1.41% | -0.33% |

Table 13.11 : Spanish half - yearly catches of anchovy (2nd semester) by age in ('000) of Bay of Biscay anchovy from the live bait tuna boats.

| Age | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|
| 0 | 10020 | 97581 | N/A | 27993 | 6098 | 2167 | 3557 |
| 1 | 24975 | 17353 | N/A | 22238 | 13736 | 14268 | 20160 |
| 2 | 1461 | 203 | N/A | 109 | | | |
| 3 | 912 | 3 | N/A | | | | |
| | | | N/A | | | | |
| Total | 37368 | 115140 | | 50340 | 19834 | 16435 | 23717 |
| Catch (t) | 546 | 493 | | 416 | 353 | 200 | 306 |
| Wmean (g) | 14.6 | 4.3 | | 8.3 | 17.8 | 12.1 | 12.9 |

Table 13.12 : International catches of anchovy (in millions) by age from 1989 to 1993 on a half-year basis including catches of live bait anchovies for tuna fishing.

| year | 1989 (*) | | 1990 | | 1991 | | 1992 | | 1993 | |
|---|---|---|---|---|---|---|---|---|---|---|
| semester | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| age | | | | | | | | | | |
| 0 | 0 | 175 | 0 | 33 | 0 | 79 | 0 | 36 | 0 | 64 |
| 1 | 157 | 8 | 842 | 541 | 328 | 113 | 998 | 452 | 796 | 613 |
| 2 | 130 | 12 | 62 | 58 | 322 | 16 | 197 | 23 | 437 | 90 |
| 3 | 14 | 3 | 10 | 5 | 16 | 1 | 17 | 1 | 7 | 0 |
| Total | 301 | 198 | 914 | 637 | 666 | 209 | 1212 | 512 | 1240 | 766.8 |
| Catch (t) | 7321 | 3052 | 19385 | 14887 | 15025 | 4610 | 26381 | 11504 | 24057 | 16334 |

(*) live bait catches not available

Table 13.13 : Catch at age in numbers (millions) of Anchovy in the Bay of Biscay

| age | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 776 | 0 | 156 | 31 | 0 | 1 | 14 | 3 | 0 | 388 |
| 2 | 602 | 861 | 1322 | 1687 | 1307 | 405 | 688 | 0 | 25 | 166 |
| 3 | 0 | 77 | 262 | 435 | 574 | 535 | 267 | 330 | 133 | 69 |
| 4 | 0 | 0 | 0 | 0 | 7 | 7 | 0 | 0 | 0 | 10 |
| 5+ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total** | 1378 | 938 | 1740 | 2153 | 1888 | 948 | 969 | 333 | 158 | 633 |

| age | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 31 | 128 | 175 | 33 | 79 | 36 | 64 |
| 1 | 161 | 53 | 52 | 220 | 385 | 164 | 1383 | 441 | 1450 | 1409 |
| 2 | 813 | 105 | 80 | 187 | 128 | 142 | 120 | 338 | 220 | 527 |
| 3 | 309 | 177 | 63 | 42 | 29 | 18 | 15 | 18 | 18 | 7 |
| 4 | 46 | 4 | 54 | 22 | 3 | 0 | 0 | 0 | 0 | 0 |
| 5+ | 0 | 0 | 0 | 12 | 1 | 0 | 0 | 0 | 0 | 0 |
| **Total** | 1329 | 339 | 249 | 514 | 674 | 499 | 1551 | 876 | 1724 | 2007 |

Table 13.14 : Half - year mean weight at age in the catches of the Bay of Biscay anchovy in 1993.

| Country | Spain | France | Spain | France | INTERNATIONAL | | |
|---|---|---|---|---|---|---|---|
| Semester | 1 | 1 | 2 | 2 | 1 | 2 | Annual |
| Area | VIII CB | VIII AB | VIII CB | VIII AB | VIII | VIII | VIII |
| Age | | | | | | | |
| 1 | | | 11.72 | | | 11.72 | 11.72 |
| 2 | 16.28 | 12.93 | 16.80 | 21.62 | 15.36 | 21.17 | 17.84 |
| 3 | 29.25 | 21.94 | 27.09 | 30.02 | 26.40 | 29.63 | 26.95 |
| 4 | 43.38 | 28.24 | 39.35 | | 30.43 | 39.35 | 30.43 |
| Total | 20.40 | 16.93 | 15.37 | 23.34 | 19.30 | 21.97 | 20.30 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Table 13.15 : Fishing and natural mortality (F/M) estimates for the Bay of Biscay anchovy | | | | | | | |
| | from the DEPM SSB estimates and catches between surveys. | | | | | | |
| | | | | | | | |
| | | | | | | | |
| Years | 1987/88 | 1989/89[1] | 1989[1]/90 | 1990/91 | 1991/92 | | |
| Age group | | | | | | | |
| 1+ | 0.39/0.96 | 0.44/1.74 | 0.4/0.72 | 0.89/2.13 | 1.08/0.36 | | |
| 2+ | | 0.45/1.96 | 0.43/1.74 | 1.26/1.0 | 1.1/1.72 | | |
| | | | | | | | |
| 1 1989 SSB estimate raised up to 1 standard deviation because of the presumption | | | | | | | |
| of underestimation, according Motos & Santiago (1990) | | | | | | | |

Table 14.1 Portuguese and Spanish annual landings (tonnes) of ANCHOVY in Division IXa. (From Pestana, 1989 and Working Group members).

| Year | Portugal | Spain | TOTAL |
|---|---|---|---|
| 1943 | 9975 | --- | |
| 1944 | 6651 | --- | |
| 1945 | 992 | --- | |
| 1946 | 6520 | --- | |
| 1947 | 3392 | --- | |
| 1948 | 4938 | --- | |
| 1949 | 2684 | --- | |
| 1950 | 3377 | --- | |
| 1951 | 3594 | --- | |
| 1952 | 4415 | --- | |
| 1953 | 1033 | --- | |
| 1954 | 3919 | --- | |
| 1955 | 4523 | --- | |
| 1956 | 7898 | --- | |
| 1957 | 12610 | --- | |
| 1958 | 3030 | --- | |
| 1959 | 3788 | --- | |
| 1960 | 9503 | --- | |
| 1961 | 2492 | --- | |
| 1962 | 4446 | --- | |
| 1963 | 5714 | --- | |
| 1964 | 4118 | --- | |
| 1965 | 4460 | --- | |
| 1966 | 4460 | --- | |
| 1967 | 3818 | --- | |
| 1968 | 970 | --- | |
| 1969 | 1243 | --- | |
| 1970 | 1172 | --- | |
| 1971 | 326 | --- | |
| 1972 | 207 | --- | |
| 1973 | 126 | --- | |
| 1974 | 238 | --- | |
| 1975 | 372 | --- | |
| 1976 | 88 | --- | |
| 1977 | 3261 | --- | |
| 1978 | 1011 | --- | |
| 1979 | 655 | --- | |
| 1980 | 980 | --- | |
| 1981 | 978 | --- | |
| 1982 | 656 | --- | |
| 1983 | 673 | --- | |
| 1984 | 392 | --- | |
| 1985 | 2122 | --- | |
| 1986 | 2153 | --- | |
| 1987 | 1622 | --- | |
| 1988 | 442 | 4263 | 4705 |
| 1989 | 823 | 5336 | 6159 |
| 1990 | 541 | 5911 | 6452 |
| 1991 | 210 | 5711 | 5921 |
| 1992 | 138 | 3028 | 3166 |
| 1993 | 23 | 1961 | 1984 |

--- No data

Table 14.2 ANCHOVY IXa. Quartely catches (t) by gear and by country in 1993.

| Country/Quarter | 1st | 2nd | 3rd | 4th | Year |
|---|---|---|---|---|---|
| Spain | 768 | 921 | 167 | 105 | 1961 |
| Purse seine | 555 | 839 | 146 | 91 | 1630 |
| trawl | 213 | 82 | 21 | 14 | 331 |
| Portugal | 3 | 6 | 0 | 13 | 23 |
| Purse seine | 0 | 0 | 0 | 13 | 13 |
| Artisanal | 1 | 0 | 0 | 0 | 1 |
| Trawl | 2 | 6 | 0 | 0 | 9 |
| Total | 771 | 927 | 167 | 117 | 1984 |

**Table 14.3** Distribution of ANCHOVY landings (t) by half year in Division IXa.

| Year | Country | 1st half year[1] | | 2nd half year[2] | |
|---|---|---|---|---|---|
| 1988 | Spain | 2,534 | (60%) | 1,708 | (40%) |
| 1989 | Spain | 3,876 | (74%) | 1,394 | (27%) |
| 1990 | Spain | 3,806 | (67%) | 1,860 | (33%) |
| 1991 | Spain | 4,736 | (83%) | 975 | (17%) |
| 1992 | Spain | 2,492 | (82%) | 536 | (18%) |
| 1993 | Spain | 1,689 | (86%) | 272 | (14%) |
| 1991 | Portugal | 39 | (18%) | 172 | (82%) |
| 1992 | Portugal | 38 | (28%) | 100 | (72%) |
| 1993 | Portugal | 9 | (41%) | 13 | (59%) |

[1]Corresponds to the spring fishery in Division IXa.
[2]Corresponds to the summer and autumn Spanish fisheries and autumn Portuguese fisheries in Division IXa.

Table 14.4: ANCHOVY catches (t) in Division IXa by country and Sub-division in 1993

| COUNTRY | SUB-DIVISIONS | QUARTERS | | | | |
|---|---|---|---|---|---|---|
| | | Q1 | Q2 | Q3 | Q4 | ANUAL |
| SPAIN | IXa North | 1 | 0 | 0 | 0 | 1 |
| | IXa South | 767 | 921 | 167 | 105 | 1960 |
| | TOTAL | 768 | 921 | 167 | 105 | 1961 |
| | % | 39.2 | 47.0 | 8.5 | 5.4 | |
| PORTUGAL | IXa Central North | 3 | 6 | 0 | 13 | 22 |
| | IXa Central South | 0 | 0 | 0 | 1 | 1 |
| | IXa South | 0 | 0 | 0 | 0 | 0 |
| | TOTAL | 3 | 6 | 0 | 14 | 23 |
| | % | 11.9 | 27.9 | 0.7 | 59.6 | |
| INTERNACIONAL | IXa North | 1 | 0 | 0 | 0 | 1 |
| | IXa Central North | 3 | 6 | 0 | 13 | 22 |
| | IXa Central South | 0 | 0 | 0 | 1 | 1 |
| | IXa South | 767 | 921 | 167 | 105 | 1960 |
| | TOTAL | 771 | 927 | 167 | 119 | 1984 |
| | % | 38.8 | 46.7 | 8.4 | 6.0 | |

Table 14.5 . ANCHOVY in Division IXa. Effort data: Spain IXa (Bay of Cadiz) number of fishing trips.

SPAIN IXa (Bay of Cadiz)

| YEAR | PURSE SEINE BARBATE Single purpose | BARBATE Multi purpose | SAN LUCAR Multi purpose |
|---|---|---|---|
| | No. fishing trip | | |
| 1988 | 3958 | 17 | 210 |
| 1989 | 4415 | 39 | 234 |
| 1990 | 4622 | 92 | 660 |
| 1991 | 3981 | 40 | 919 |
| 1992 | 3450 | 116 | 583 |
| 1993 | 2152 | 5 | 225 |

Table 14.6. ANCHOVY in Division IXa. Spain IXa (Bay of Cadiz) CPUE series in commercial fisheries.

SPAIN IXa (Bay of Cadiz)

| YEAR | PURSE SEINE BARBATE Single purpose | BARBATE Multi purpose | SAN LUCAR Multi purpose |
|---|---|---|---|
| | Kg/No.Fishing trip | | |
| 1988 | 1047 | 461 | 420 |
| 1989 | 1139 | 534 | 943 |
| 1990 | 1128 | 287 | 643 |
| 1991 | 1312 | 339 | 456 |
| 1992 | 819 | 173 | 300 |
| 1993 | 641 | 268 | 225 |

**Table 14.7. Evaluation of abundance index from Spanish acoustic survey in 1993.**

| | Total | Western Sector | Central Sector | Eastern Sector |
|---|---|---|---|---|
| Period of year | 5-10 Jun 1993 | | | |
| Surveyed area (mn2) | 2865.64 | 798.1 | 1232.2 | 835.4 |
| Biomass (t) | 6569 | 1878 | 3325 | 1366 |
| Number (millions) | 462 | 124 | 253 | 86 |

Table 16.1. Summary results of integrated model fit using inverse-variance reweighting and fitting a stock-recruit relationship.

PARAMETER ESTIMATES +/- SD

Separable Model: Reference F by year

| | | | | |
|---|---|---|---|---|
| 1 | 1986 | .1986 | .1626 | .2426 |
| 2 | 1987 | .1733 | .1426 | .2105 |
| 3 | 1988 | .1729 | .1426 | .2095 |
| 4 | 1989 | .1593 | .1317 | .1926 |
| 5 | 1990 | .1611 | .1341 | .1937 |
| 6 | 1991 | .1033 | .0865 | .1234 |
| 7 | 1992 | .0987 | .0829 | .1175 |
| 8 | 1993 | .1122 | .0943 | .1335 |

Separable Model: Selection (S) by age

| | | | | |
|---|---|---|---|---|
| 9 | 0 | .2753 | .1975 | .3837 |
| 10 | 1 | .6488 | .5620 | .7489 |
| | 2 | 1.0000 | Fixed : Reference age | |
| 11 | 3 | 1.3343 | 1.1732 | 1.5174 |
| 12 | 4 | 1.3181 | 1.1616 | 1.4957 |
| | 5 | 1.2500 | Fixed : last true age | |

Separable Model: Populations in year 1993

| | | | | |
|---|---|---|---|---|
| 13 | 0 | 12600822. | 10874594. | 14601071. |
| 14 | 1 | 10489189. | 9378081. | 11731941. |
| 15 | 2 | 8346475. | 7364680. | 9459153. |
| 16 | 3 | 3657363. | 3208442. | 4169096. |
| 17 | 4 | 2109980. | 1838531. | 2421507. |
| 18 | 5 | 1167445. | 1006214. | 1354510. |

Separable Model: Populations at age 5

| | | | | |
|---|---|---|---|---|
| 19 | 1986 | 1095692.3654 | 791454.6812 | 1516879.9782 |
| 20 | 1987 | 905297.6957 | 700101.0118 | 1170636.6710 |
| 21 | 1988 | 1653366.7980 | 1320126.1014 | 2070727.7629 |
| 22 | 1989 | 1078095.4826 | 867722.1890 | 1339472.3385 |
| 23 | 1990 | 797251.8868 | 656717.8560 | 967859.4320 |
| 24 | 1991 | 910987.6318 | 780970.2631 | 1062650.5317 |
| 25 | 1992 | 1395693.3810 | 1206613.7065 | 1614402.3587 |

Age-structured index catchabilities

Age-Structured Index 1 ( Spanish Survey )

Linear model fitted. Slopes at age:

| | | | | |
|---|---|---|---|---|
| 26 | 1 Q | .11260E-04 | .77677E-05 | .16321E-04 |
| 27 | 2 Q | .15649E-04 | .10596E-04 | .23113E-04 |
| 28 | 3 Q | .55302E-04 | .35055E-04 | .87244E-04 |
| 29 | 4 Q | .65946E-04 | .41566E-04 | .10463E-03 |
| 30 | 5 Q | .15914E-03 | .10062E-03 | .25170E-03 |
| 31 | 6 Q | .89225E-03 | .61020E-03 | .13047E-02 |

Age-Structured Index 2 ( Portuguese Survey )

Linear model fitted. Slopes at age:

| | | | | |
|---|---|---|---|---|
| 32 | 0 Q | .35497E-03 | .32698E-03 | .38535E-03 |
| 33 | 1 Q | .50550E-03 | .43978E-03 | .58103E-03 |
| 34 | 2 Q | .47606E-03 | .37514E-03 | .60413E-03 |
| 35 | 3 Q | .41029E-03 | .31011E-03 | .54283E-03 |
| 36 | 4 Q | .47733E-03 | .31886E-03 | .71455E-03 |
| 37 | 5 Q | .20497E-03 | .95806E-04 | .43850E-03 |
| 38 | 6 Q | .83738E-04 | .29620E-04 | .23673E-03 |

Parameters of the B.-H. stock-recruit relationship

| | | | | |
|---|---|---|---|---|
| 39 | a | .1301105E+08 | .1247188E+08 | .1357352E+08 |
| 40 | b | .2018195E-10 | .2018195E-10 | .2018195E-10 |

PARAMETERS OF THE DISTRIBUTION OF ln CATCHES AT AGE

Separable model fitted from 1986 to 1993

Variance : .2810

Skewness test statistic : .1215

(continued)

**Table 16.1** (continued)

| | | |
|---|---|---|
| Kurtosis test statistic | : | 7.6362 |
| Partial chi-square | : | .5021 |
| Probability of chi-square | : | 1.0000 |
| Degrees of freedom | : | 25 |

PARAMETERS OF THE DISTRIBUTION OF THE AGE-STRUCTURED INDICES

DISTRIBUTION STATISTICS FOR ln AGED INDEX 1

Linear catchability relationship assumed.

| Age | : | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Variance | : | .5231 | .5734 | .6654 | .7780 | .7343 | .4966 |
| Skewness test stat. | : | -.3583 | -.2755 | 1.0053 | -.1176 | .6811 | -.0960 |
| Kurtosis test stat. | : | -.4143 | -.2999 | -.1866 | -.7765 | -.6054 | -.2228 |
| Partial chi-square | : | .6975 | .7791 | .6243 | .9858 | .8548 | .5009 |
| Prob. of chi-square | : | .9945 | .9926 | .9869 | .9861 | .9905 | .9978 |
| Number of data | : | 7 | 7 | 6 | 7 | 7 | 7 |
| Degrees of freedom | : | 6 | 6 | 5 | 6 | 6 | 6 |
| Weight in analysis | : | .5336 | .4876 | .4179 | .3579 | .3791 | .5580 |

DISTRIBUTION STATISTICS FOR ln AGED INDEX 2

Linear catchability relationship assumed.

| Age | : | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|
| Variance | : | .0125 | .0428 | .1255 | .1729 | .3715 | 1.3490 | 2.5557 |
| Skewness test stat. | : | .6680 | .1499 | .3545 | -.7198 | .3677 | -.1797 | -.2384 |
| Kurtosis test stat. | : | -.2816 | -.3407 | -.3947 | -.3051 | -.6162 | -.4857 | -.2317 |
| Partial chi-square | : | .0062 | .0213 | .0653 | .0996 | .2530 | 1.2261 | 4.6703 |
| Prob. of chi-square | : | 1.0000 | .9999 | .9995 | .9988 | .9926 | .8738 | .3228 |
| Number of data | : | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Degrees of freedom | : | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Weight in analysis | : | 23.0469 | 6.8524 | 2.2094 | 1.6084 | .7579 | .2066 | .1089 |

Weight of stock-recruit model in analysis = 2.54

**Table 18.1** Estimated catch in numbers ('000) of North Sea mackerel stock in 1988-1993 by quarter.

| Year | 1988 | | | | | 1989 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Quarter | 1 | 2 | 3 | 4 | Sum | 1 | 2 | 3 | 4 | Sum |
| Age % | 2.8 | 0.4 | 25.5 | 71.3 | | 5.5 | 0.6 | 36.4 | 57.5 | |
| 1 | 81 | 12 | 741 | 2,072 | 2,906 | 115 | 13 | 746 | 1,206 | 2,098 |
| 2 | 87 | 12 | 795 | 2,224 | 3,118 | 449 | 49 | 2,969 | 4,689 | 8,156 |
| 3 | 94 | 13 | 859 | 2,402 | 3,368 | 445 | 49 | 2,947 | 4,654 | 8,095 |
| 4 | 53 | 8 | 486 | 1,358 | 1,905 | 129 | 14 | 854 | 1,349 | 2,346 |
| 5 | 11 | 2 | 99 | 276 | 388 | 73 | 8 | 482 | 760 | 1,323 |
| 6 | 45 | 6 | 414 | 1,158 | 1,623 | 16 | 1 | 103 | 162 | 282 |
| 7 | 27 | 4 | 243 | 678 | 952 | 62 | 7 | 411 | 649 | 1,129 |
| 8 | 30 | 4 | 274 | 768 | 1,076 | 37 | 4 | 245 | 387 | 673 |
| 9 | 1 | + | 9 | 25 | 35 | 41 | 4 | 270 | 426 | 741 |
| 10 | 15 | 2 | 139 | 391 | 547 | 2 | + | 13 | 20 | 35 |
| 11 | 3 | + | 31 | 88 | 123 | 21 | 2 | 142 | 223 | 388 |
| 12 | 1 | + | 5 | 12 | 18 | 5 | 1 | 32 | 51 | 88 |
| 13 | 4 | 1 | 36 | 101 | 142 | 1 | + | 7 | 10 | 18 |
| 14 | 2 | + | 22 | 61 | 85 | 3 | + | 21 | 36 | 59 |
| 15 | 16 | 2 | 146 | 403 | 567 | 27 | 3 | 178 | 280 | 488 |

| Year | 1990 | | | | | 1991 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Quarter | 1 | 2 | 3 | 4 | Sum | 1 | 2 | 3 | 4 | Sum |
| Age % | 13.2 | 0.6 | 22.8 | 63.4 | | 31.2 | 0.3 | 25.2 | 45.3 | |
| 1 | 172 | 8 | 297 | 825 | 1,302 | 153 | 1 | 114 | 222 | 489 |
| 2 | 571 | 26 | 986 | 2,740 | 4,323 | 3,841 | 37 | 2,856 | 5,077 | 12,311 |
| 3 | 2,795 | 127 | 4,829 | 13,429 | 21,180 | 4,112 | 40 | 3,058 | 5,871 | 13,180 |
| 4 | 744 | 34 | 1,286 | 3,576 | 5,640 | 1,995 | 19 | 1,485 | 2,896 | 6,393 |
| 5 | 216 | 10 | 374 | 1,040 | 1,640 | 443 | 4 | 330 | 644 | 1,421 |
| 6 | 121 | 6 | 209 | 581 | 917 | 172 | 2 | 128 | 250 | 552 |
| 7 | 26 | 1 | 44 | 123 | 194 | 394 | 4 | 293 | 572 | 1,263 |
| 8 | 105 | 5 | 181 | 503 | 794 | + | + | + | + | + |
| 9 | 60 | 3 | 104 | 291 | 458 | 148 | 1 | 110 | 215 | 494 |
| 10 | 70 | 3 | 121 | 335 | 529 | 172 | 2 | 128 | 250 | 552 |
| 11 | 2 | + | 4 | 12 | 18 | 123 | 1 | 92 | 179 | 395 |
| 12 | 35 | 2 | 60 | 168 | 265 | 49 | + | 37 | 72 | 158 |
| 13 | 7 | + | 12 | 34 | 53 | 49 | + | 37 | 72 | 158 |
| 14 | + | + | + | 1 | 1 | 25 | + | 18 | 36 | 79 |
| 15 | 51 | 2 | 89 | 246 | 388 | 98 | 1 | 93 | 143 | 316 |

| Year | 1992 | | | | | 1993 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Quarter | 1 | 2 | 3 | 4 | Sum | 1 | 2 | 3 | 4 | Sum | % |
| Age % | 19.8 | 0.4 | 16.1 | 63.7 | | 17.5 | 0.3 | 16.5 | 65.7 | | |
| 1 | 747 | 15 | 608 | 2,404 | 3,775 | 331 | 6 | 312 | 1,242 | 1,870 | 5 |
| 2 | 3,005 | 61 | 3,443 | 9,667 | 15,176 | 1,323 | 23 | 1,247 | 4,960 | 7,554 | 20 |
| 3 | 2,444 | 49 | 1,987 | 7,863 | 12,344 | 2,315 | 40 | 2,183 | 8,681 | 13,219 | 35 |
| 4 | 573 | 12 | 480 | 1,890 | 2,982 | 1,693 | 29 | 1,596 | 6,149 | 9,669 | 25 |
| 5 | 359 | 7 | 292 | 1,154 | 1,812 | 562 | 10 | 530 | 2,108 | 3,210 | 8.5 |
| 6 | 112 | 2 | 91 | 361 | 566 | 132 | 2 | 125 | 496 | 755 | 2.0 |
| 7 | 45 | 1 | 37 | 145 | 227 | 40 | 1 | 37 | 149 | 227 | 0.6 |
| 8 | 22 | + | 18 | 72 | 113 | 26 | + | 25 | 99 | 151 | 0.4 |
| 9 | + | + | + | + | + | 20 | + | 19 | 74 | 113 | 0.3 |
| 10 | + | + | + | + | + | + | + | + | + | + | + |
| 11 | 15 | + | 12 | 48 | 76 | + | + | + | + | + | 0.1 |
| 12 | 37 | 1 | 30 | 120 | 189 | 7 | + | 6 | 25 | 38 | 0.2 |
| 13 | 15 | + | 12 | 48 | 76 | 26 | + | 25 | 99 | 151 | 0.5 |
| 14 | + | + | + | + | + | 13 | + | 12 | 50 | 96 | 0.3 |
| 15+ | 82 | 2 | 67 | 264 | 415 | 126 | 2 | 119 | 471 | 718 | 2.0 |

**Table 18.2** Mean weight at age (g) by quarter in the North Sea mackerel stock and mean weight in the catch.

| Age | Quarter | | | | Mean weight in catch |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| 1 | 180 | 140 | 180 | 180 | 180 |
| 2 | 210 | 255 | 240 | 210 | 215 |
| 3 | 240 | 330 | 280 | 240 | 250 |
| 4 | 260 | 395 | 330 | 260 | 275 |
| 5 | 300 | 450 | 375 | 300 | 320 |
| 6 | 325 | 500 | 420 | 325 | 350 |
| 7 | 355 | 540 | 465 | 355 | 380 |
| 8 | 380 | 570 | 510 | 380 | 410 |
| 9 | 410 | 605 | 550 | 410 | 445 |
| 10 | 435 | 635 | 585 | 435 | 470 |
| 11 | 465 | 670 | 620 | 465 | 500 |
| 12 | 500 | 700 | 650 | 500 | 535 |
| 13 | 530 | 730 | 680 | 530 | 565 |
| 14 | 560 | 765 | 705 | 560 | 595 |
| 15+ | 590 | 790 | 720 | 590 | 620 |

**Table 18.3** Percentage of each mackerel stock assumed to be present in the North Sea by quarter in 1993.

| Age | North Sea Stock | | | | Western Stock | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| 1 | 100 | 100 | 100 | 100 | - | 20 | 30 | 30 |
| 2 | 80 | 100 | 100 | 80 | 10 | 10 | 50 | 70 |
| >2 | 80 | 100 | 50 | 70 | 10 | + | 50 | 70 |

**Table 18.4** Mean weight at age (g) by quarter in the catches of North Sea horse mackerel in 1993. The numbers of fish analyzed per age group are given in ( ).

| Age | Quarter | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| 1 | **NO DATA** | | 56 (6) | |
| 2 | | 73 (15) | 94 (2) | 104 (1) |
| 3 | | 115 (20) | 123 (4) | |
| 4 | | 136 (39) | 157 (11) | 186 (1) |
| 5 | | 152 (5) | 195 (4) | 194 (2) |
| 6 | | 157 (4) | 182 (5) | 193 (3) |
| 7 | | 187 (4) | 198 (6) | 232 (5) |
| 8 | | 179 (2) | 241 (5) | 188 (3) |
| 9 | | | 263 (2) | 224 (2) |
| 10 | | 207 (1) | 248 (3) | 269 (5) |
| 11 | | 239 (11) | 266 (25) | 323 (26) |
| 12 | | | 315 (3) | 272 (3) |
| 13 | | | 255 (4) | 266 (5) |
| 14 | | 299 (3) | 265 (14) | 318 (11) |
| 15+ | | 343 (7) | 328 (31) | 364 (35) |

**Table 18.5** Percentage of each horse mackerel stock assumed to be present in the North Sea by quarter in 1993.

| Age | North Sea Stock | | | | Western Stock | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| 1-4 | 100 | 100 | 100 | 100 | 0 | 0 | 0 | 0 |
| 5+ | 100 | 100 | 100 | 100 | 0 | 0 | 5 | 65 |

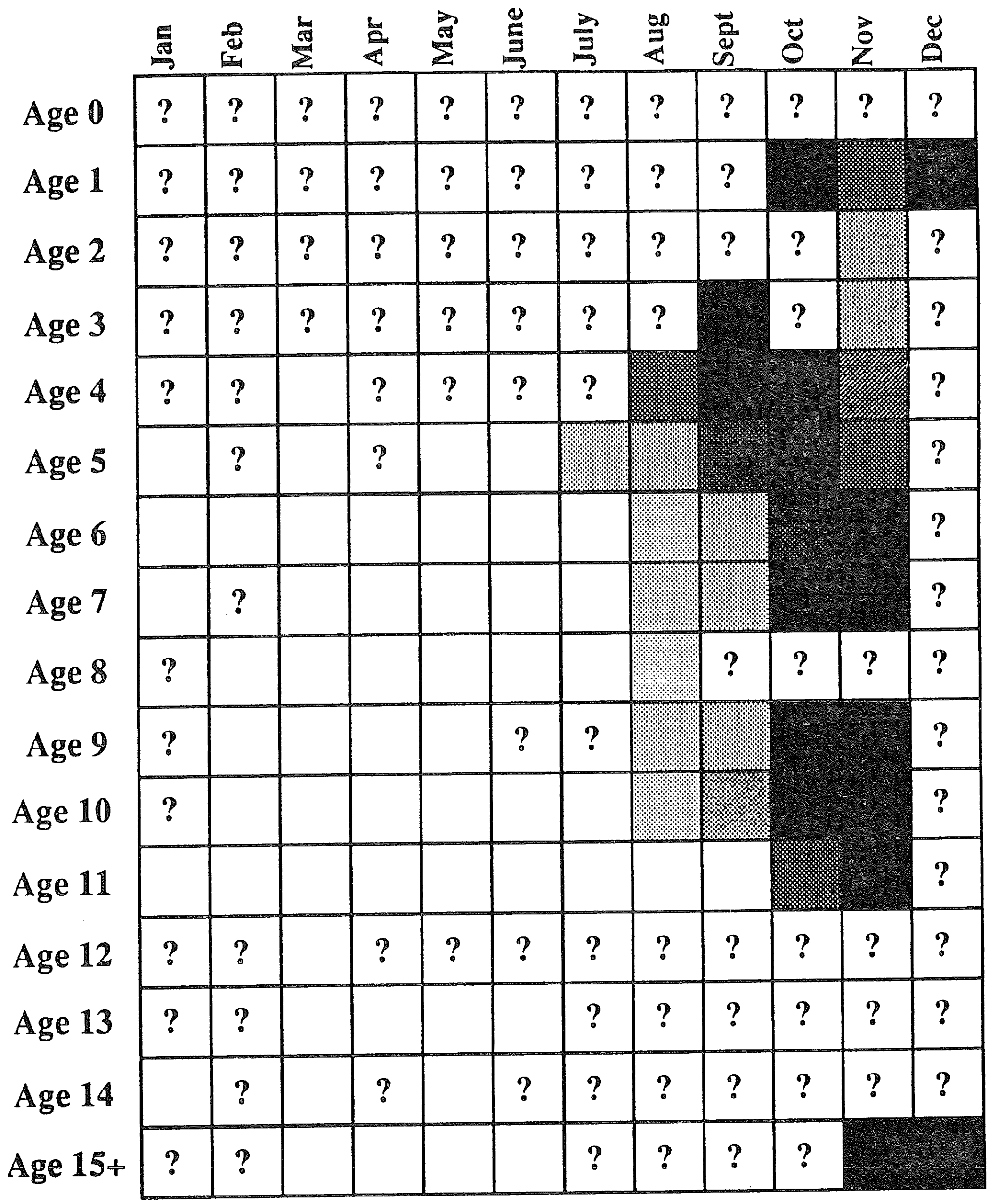



Figure 2.1 The proportion of horse mackerel having otoliths with an opaque edge given by age group and by month of catch for ICES **Divisions VIIa-c,e-k**. A '?' is shown if less than 10 otoliths were available. A white square indicates that all otoliths have a hyaline edge. Based on Dutch otolith edge interpretation on otoliths from fish samples collected during 1990 - 1993.

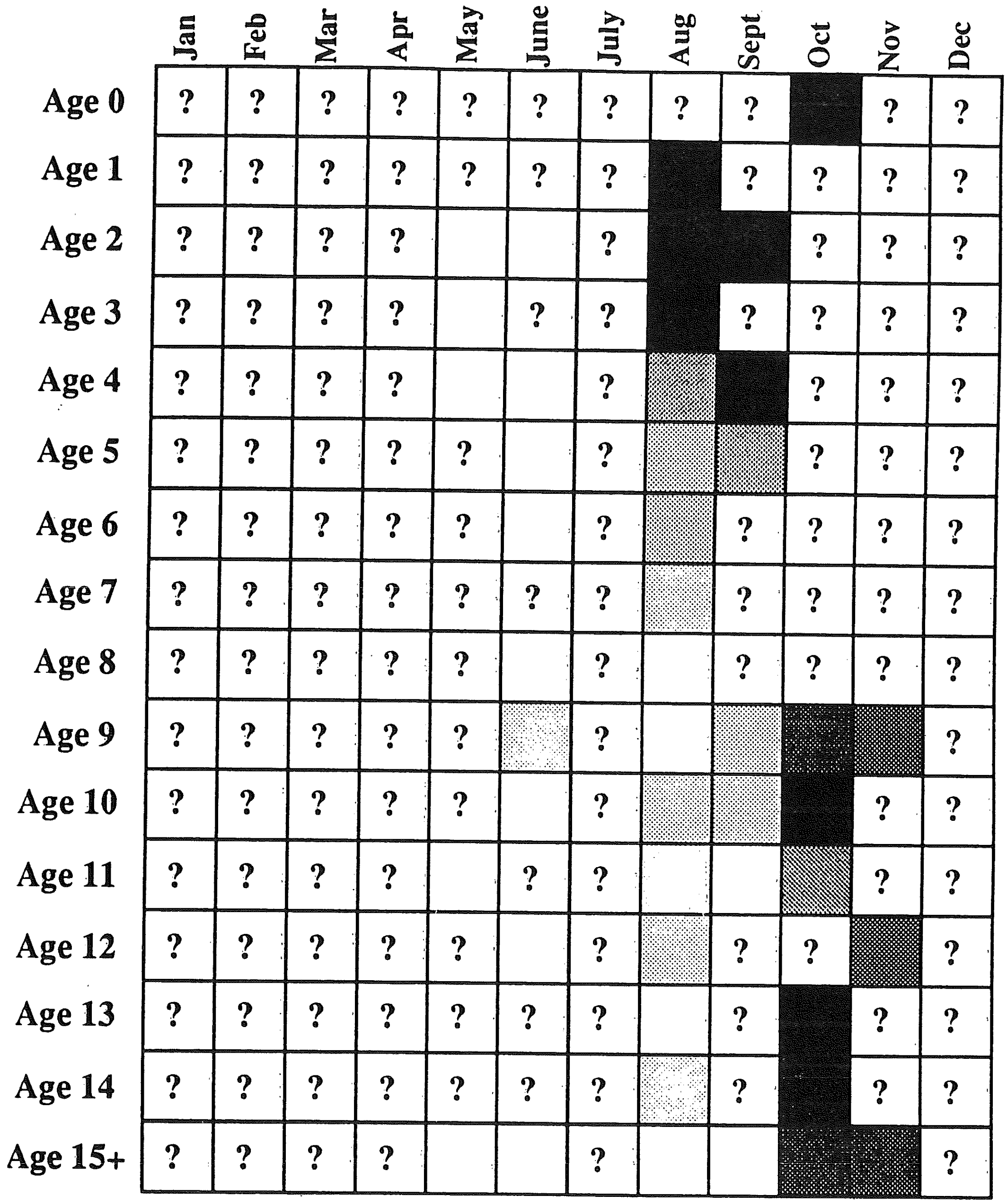



Figure 2.2 The proportion of horse mackerel having otoliths with an opaque edge given by age group and by month of catch for ICES Divisions IVb+c. A '?' is shown if less than 10 otoliths were available. A white square indicates that all otoliths have a hyaline edge. Based on Dutch otolith edge interpretation on otoliths from fish samples collected during 1990 - 1993.

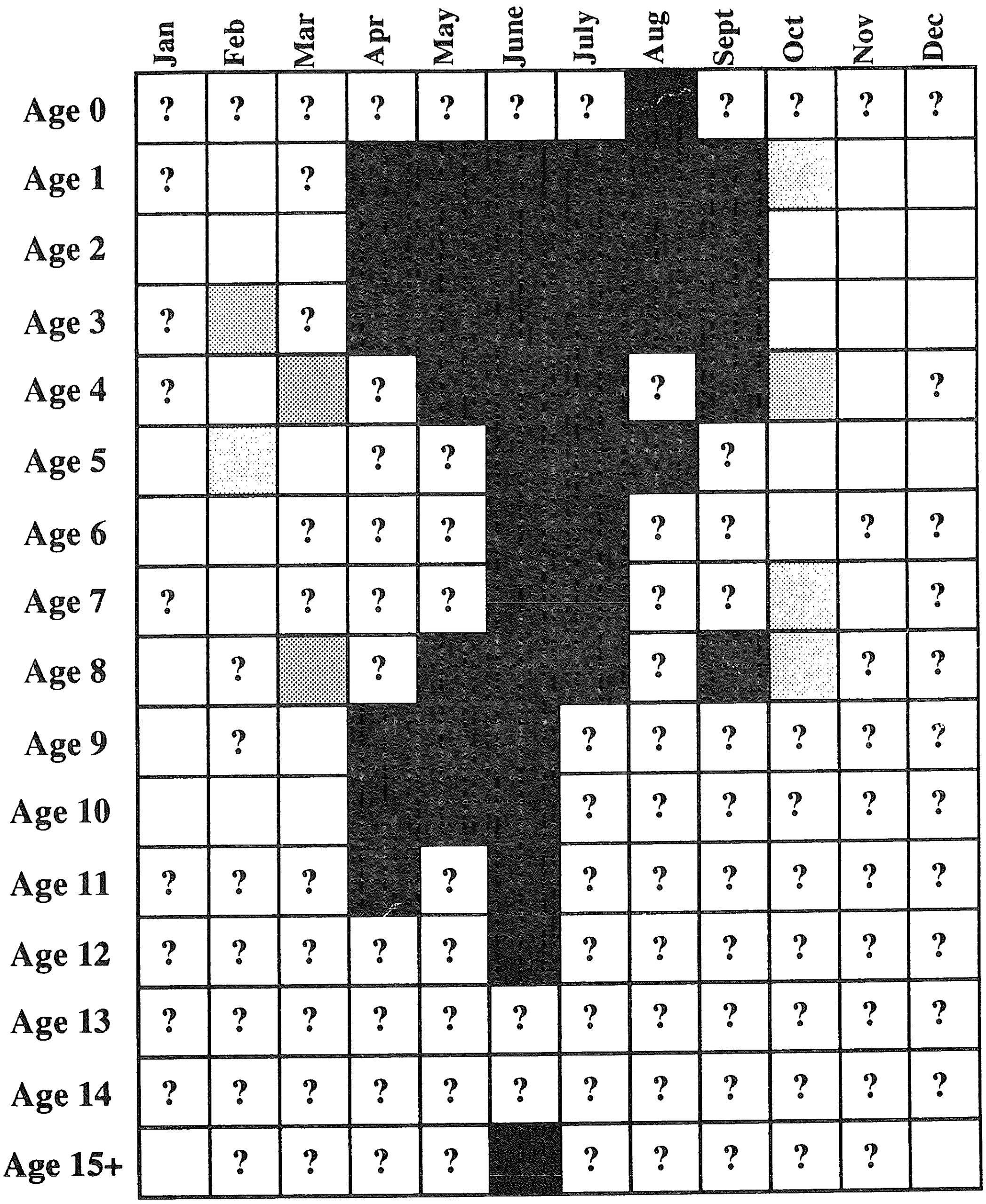



Figure 2.3 The proportion of horse mackerel having otoliths with an opaque edge given by age group and by month of catch for ICES **Division IXa**. A '?' is shown if less than 10 otoliths were available. A white square indicates that all otoliths have a hyaline edge. Based on Portuguese otolith edge interpretation on otoliths from fish samples collected during 1990 - 1993.

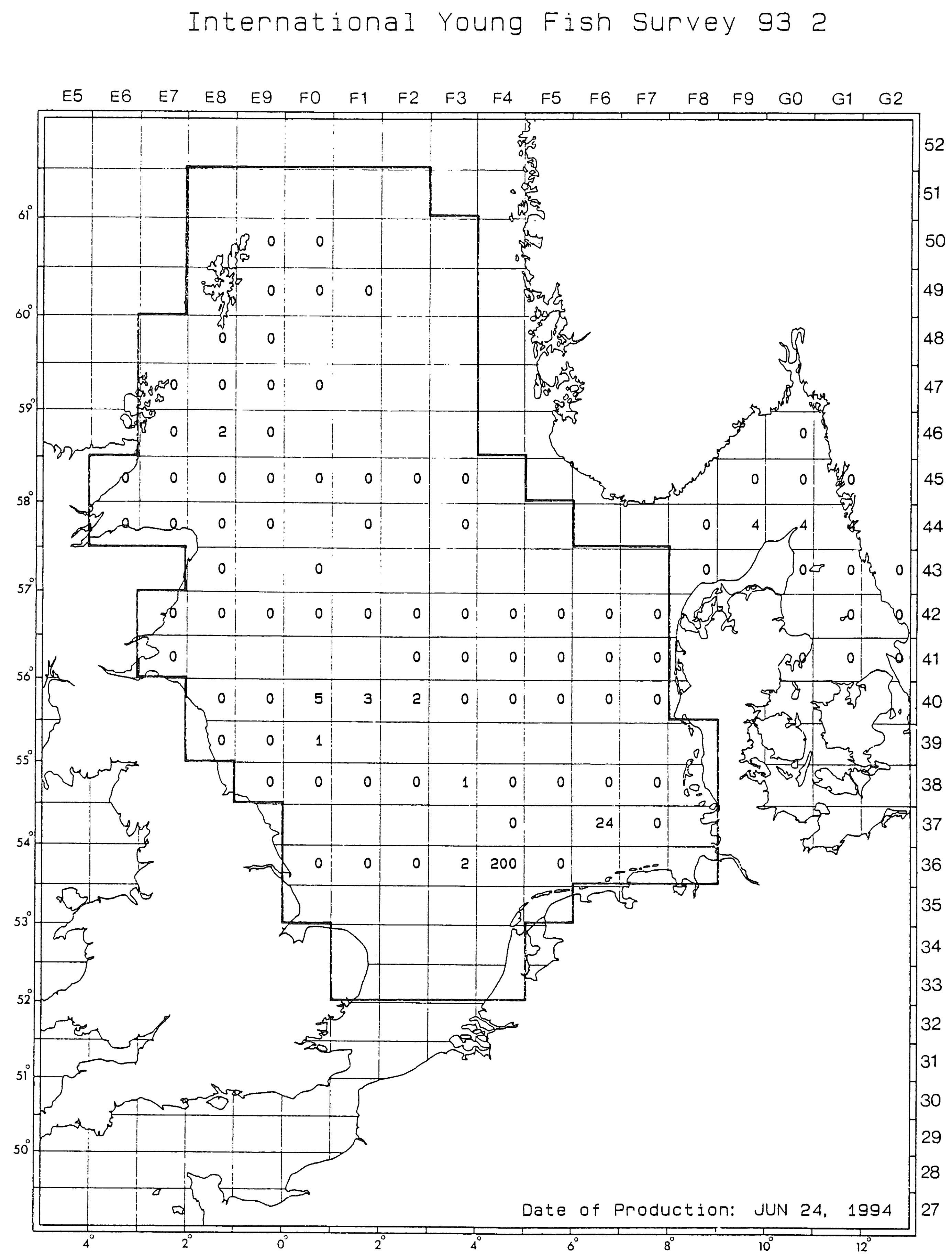



**Figure 4.1** **The distribution of age 1 group mackerel, as numbers per hour, from the International Bottom Trawl Surveys of the North Sea in the second quater of 1993. (Provisional)**

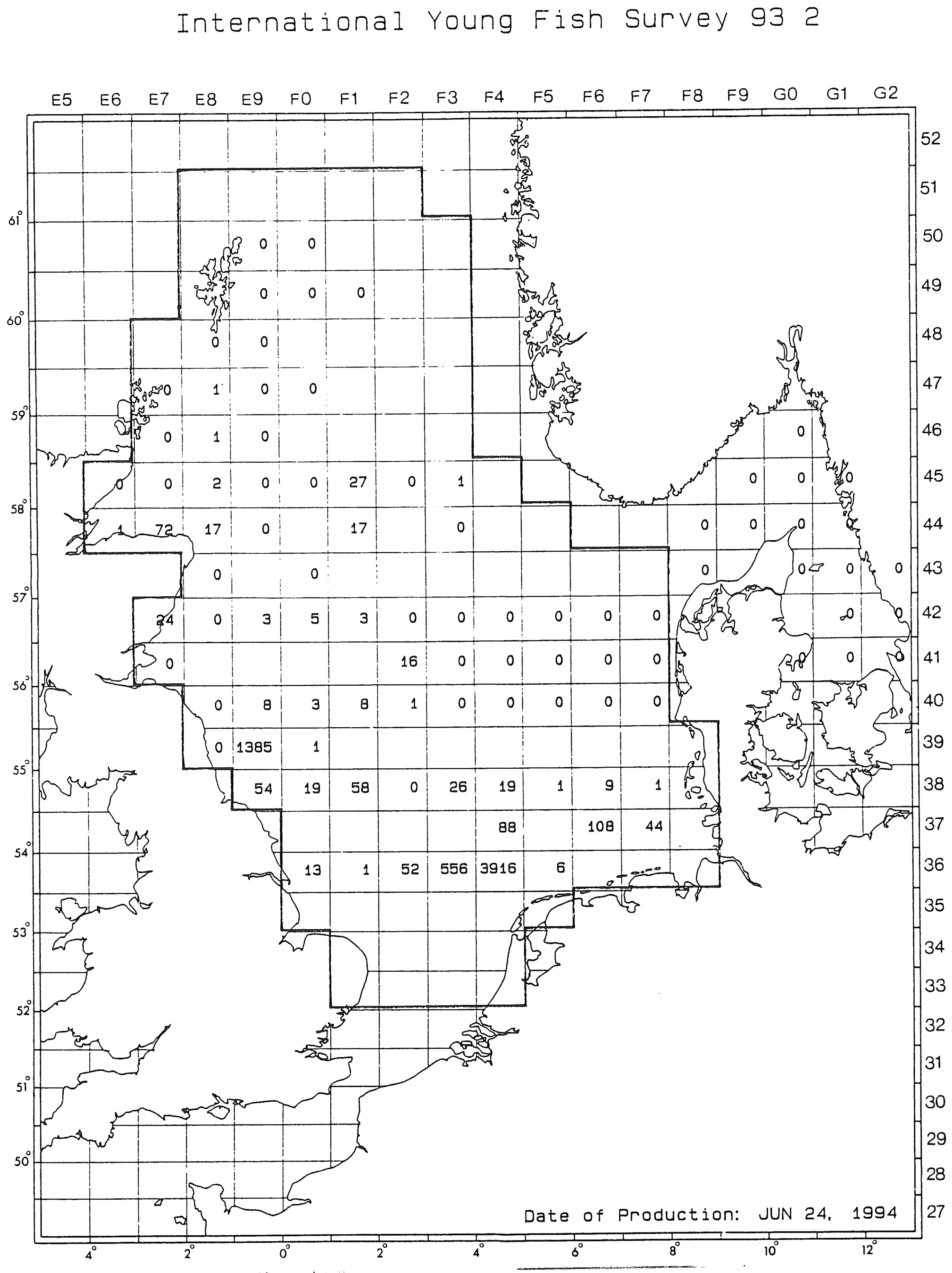



**Figure 4.2** **The distribution of age 2+ group mackerel, as numbers per hour, from the International Bottom Trawl Surveys of the North Sea in the second quater of 1993. (Provisional)**

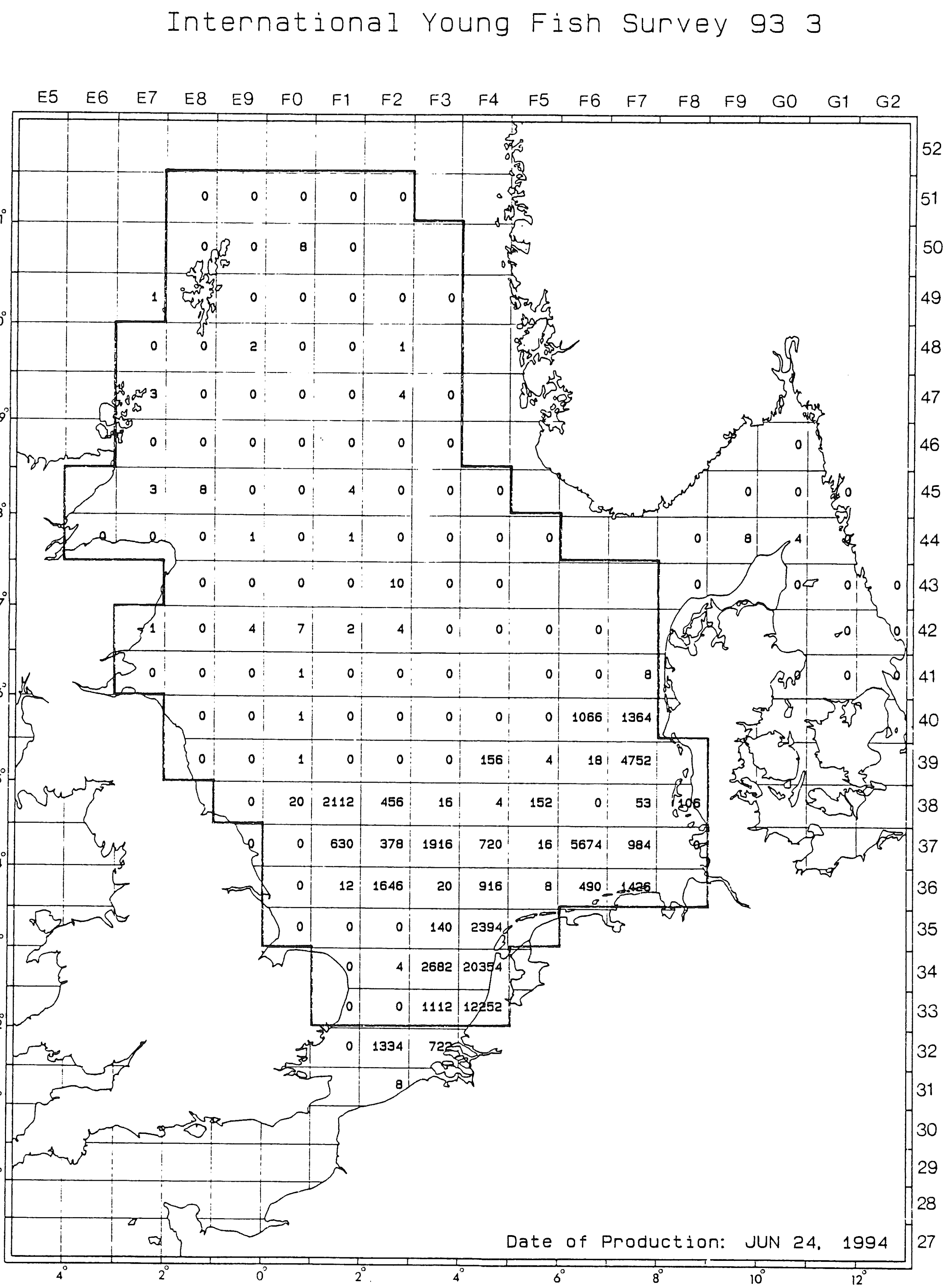



**Figure 4.3** **The distribution of age 1 group mackerel, as numbers per hour, from the International Bottom Trawl Surveys of the North Sea in the third quater of 1993. (Provisional)**

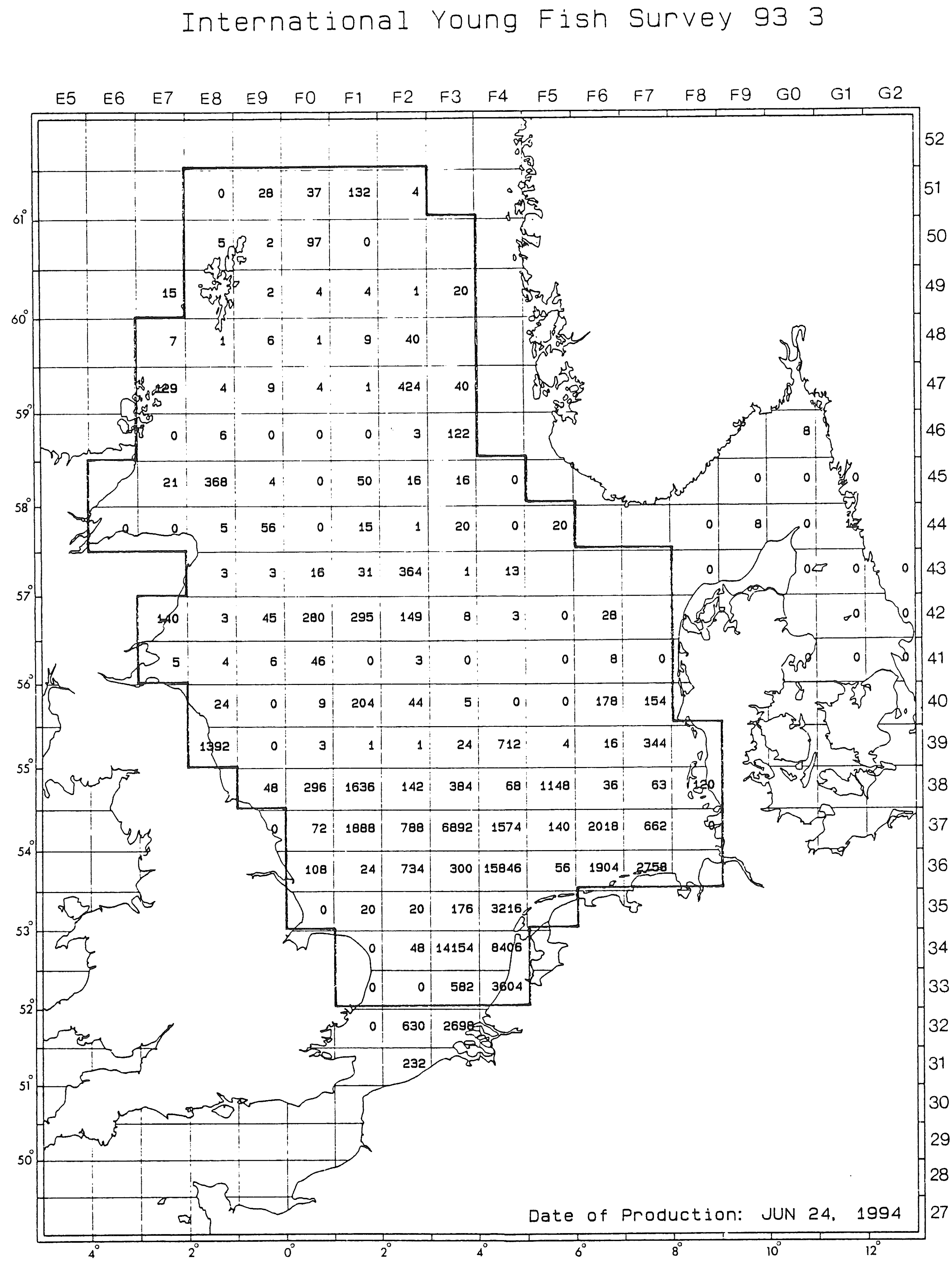



**Figure 4.4** The distribution of age 2+ group mackerel, as numbers per hour, from the International Bottom Trawl Surveys of the North Sea in the third quater of 1993. (Provisional)

M Donald

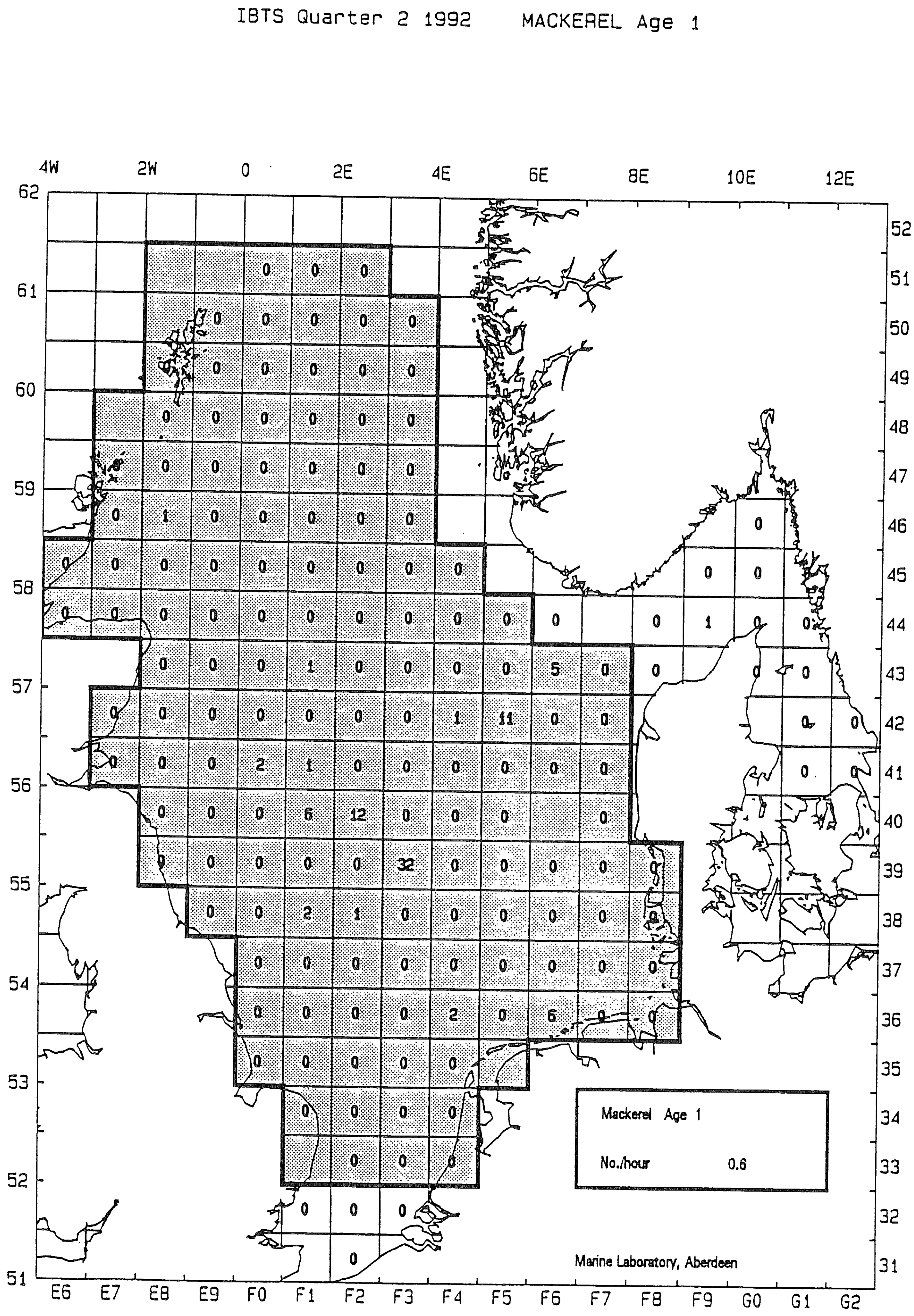



**Figure 4.5** The distribution of age 1 group mackerel, as numbers per hour, from the International Bottom Trawl Surveys of the North Sea in the second quater of 1992. (Provisional)

M Donald

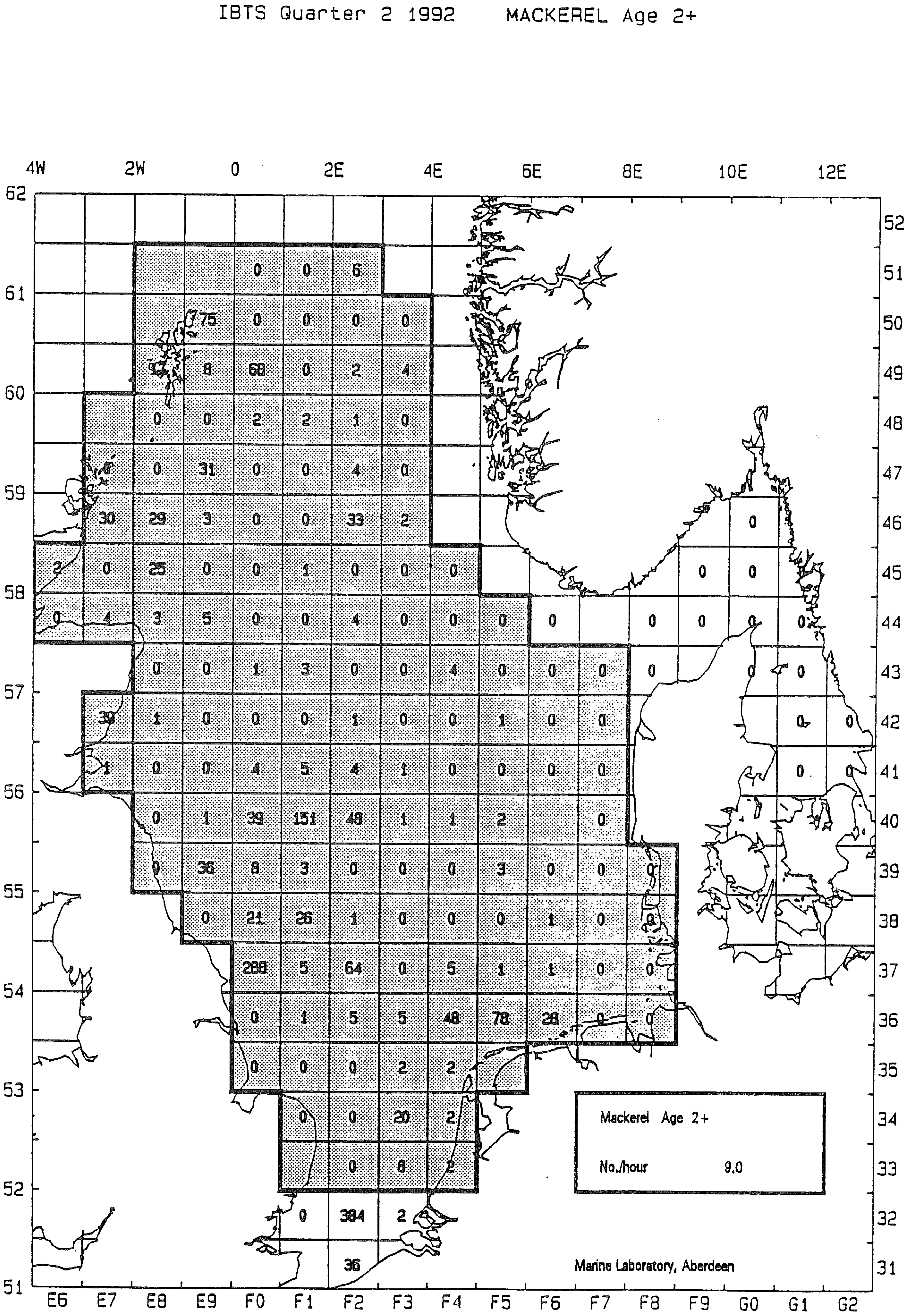



**Figure 4.6** **The distribution of age 2+ group mackerel, as numbers per hour, from the International Bottom Trawl Surveys of the North Sea in the second quater of 1992. (Provisional)**

IBTS Quarter 3 1992 MACKEREL Age 1

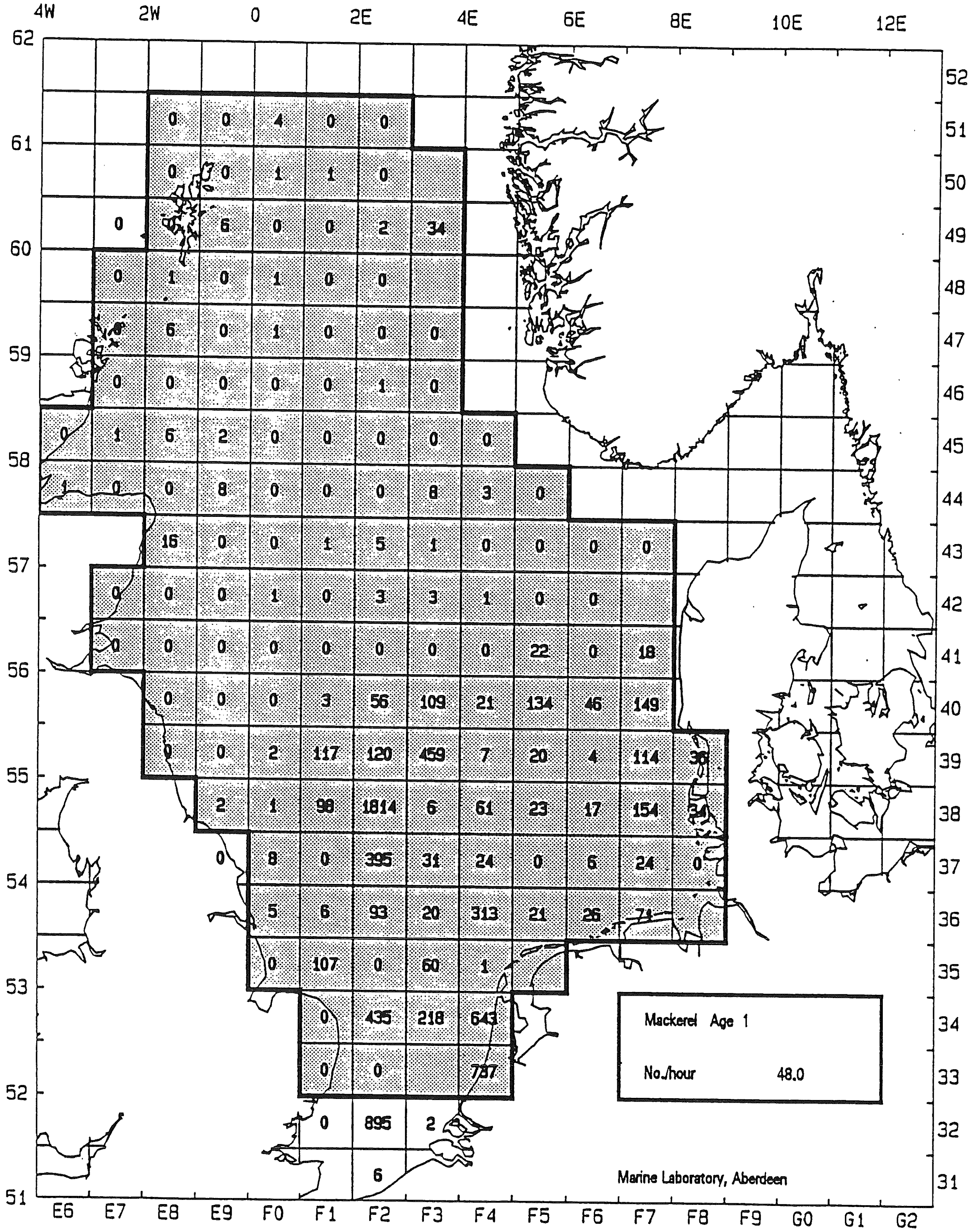



Figure 4.7 The distribution of age 1 group mackerel, as numbers per hour, from the International Bottom Trawl Surveys of the North Sea in the third quater of 1992. (Provisional)

IBTS Quarter 3 1992 MACKEREL Age 2+

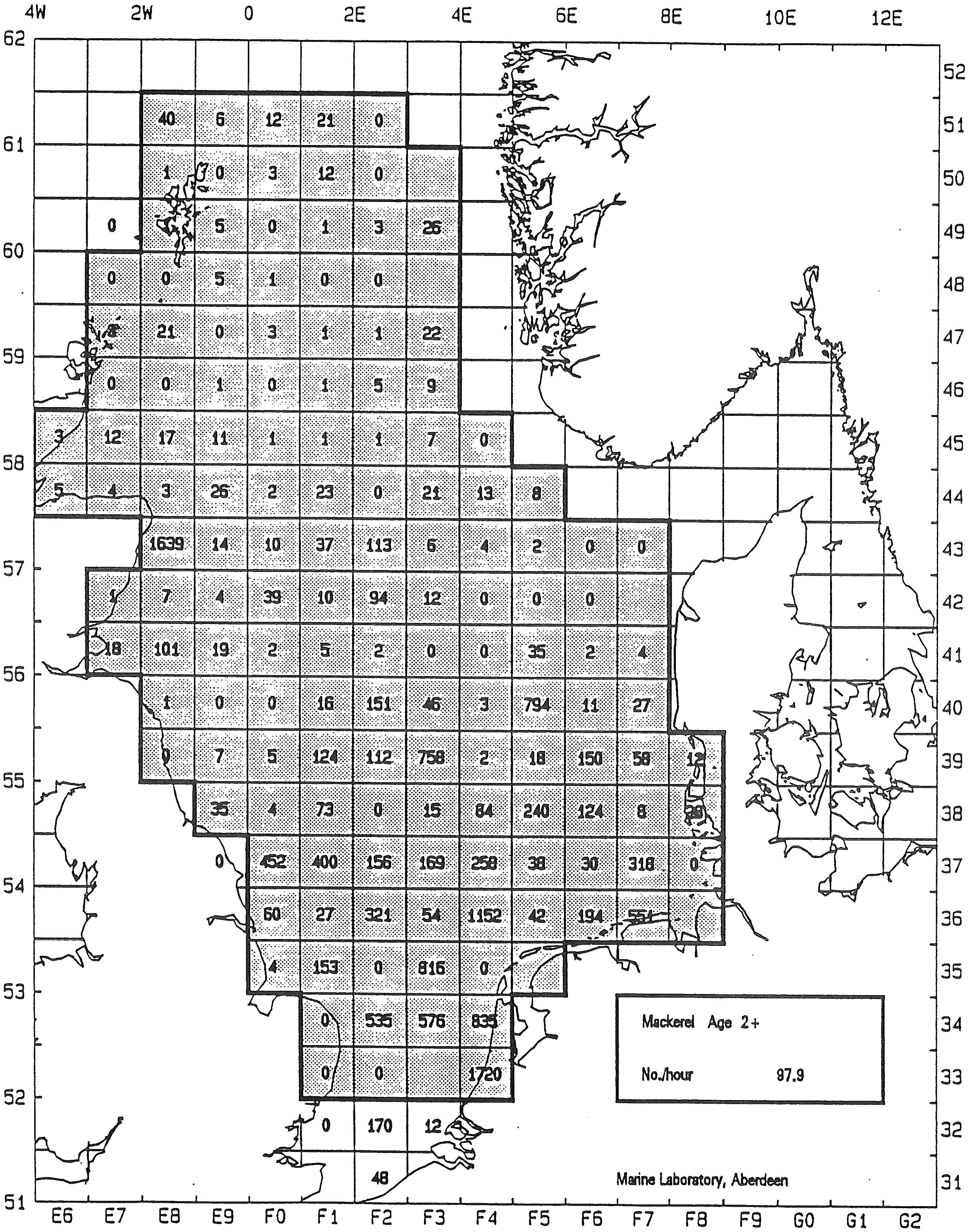



**Figure 4.8** The distribution of age 2+ group mackerel, as numbers per hour, from the International Bottom Trawl Surveys of the North Sea in the third quater of 1992. (Provisional)

# IBTS QUARTER 4 1992
## Mackerel Age 1

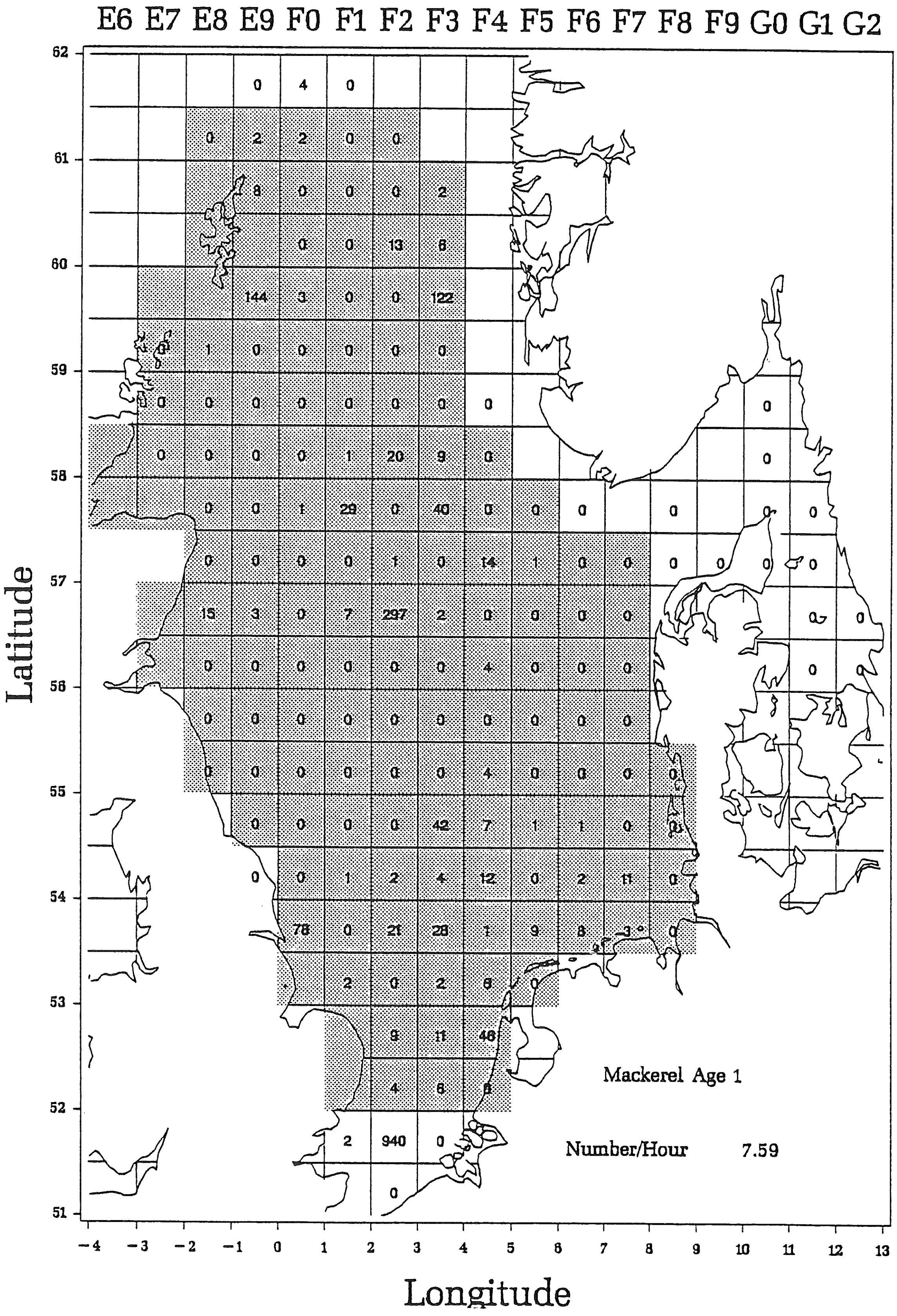



**Figure 4.9** **The distribution of age 1 group mackerel, as numbers per hour, from the International Bottom Trawl Surveys of the North Sea in the fourth quater of 1992. (Provisional)**

# IBTS QUARTER 4 1992
## Mackerel Age 2+

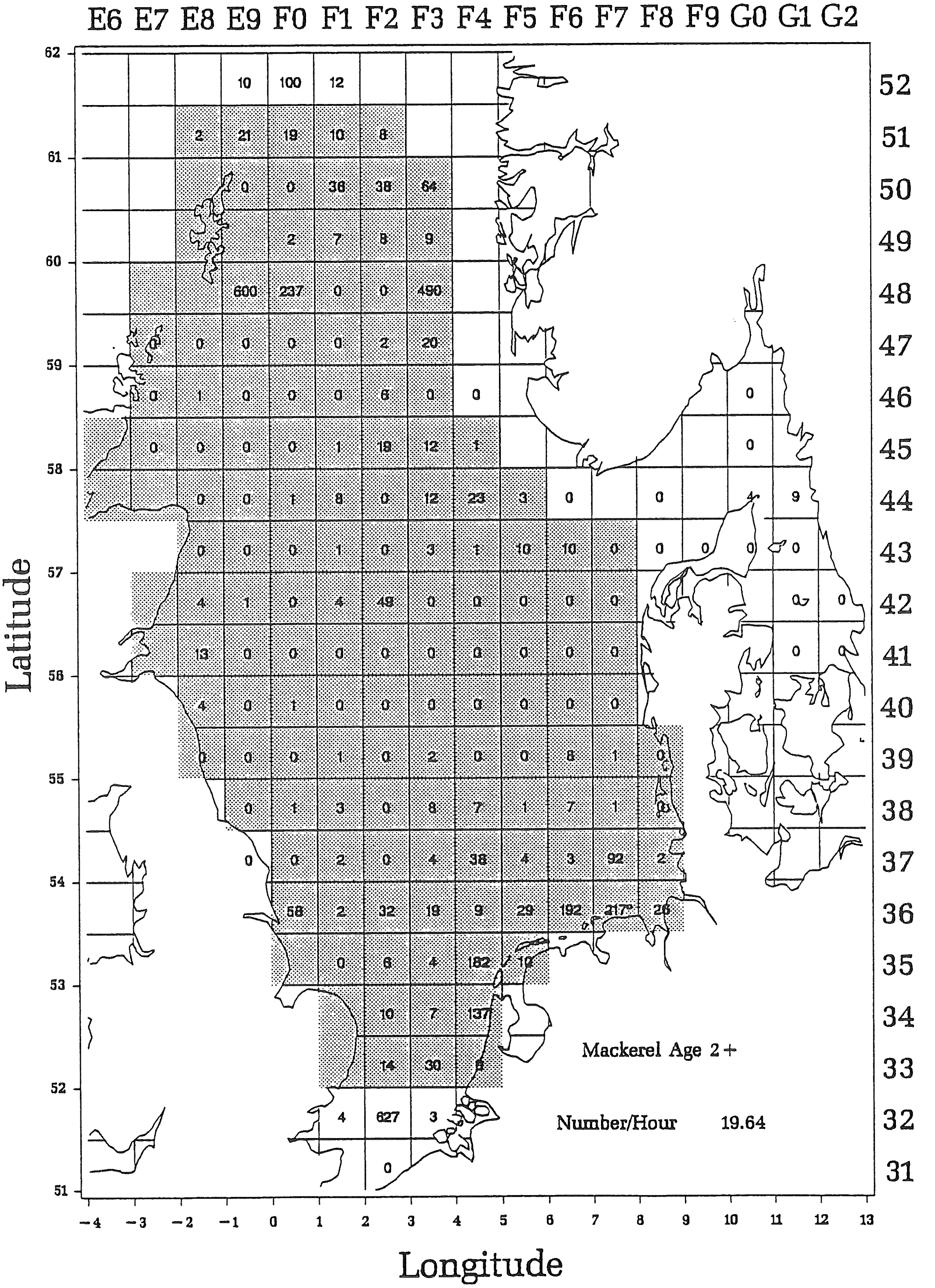



**Figure 4.10** **The distribution of age 2+ group mackerel, as numbers per hour, from the International Bottom Trawl Surveys of the North Sea in the fourth quater of 1992. (Provisional)**

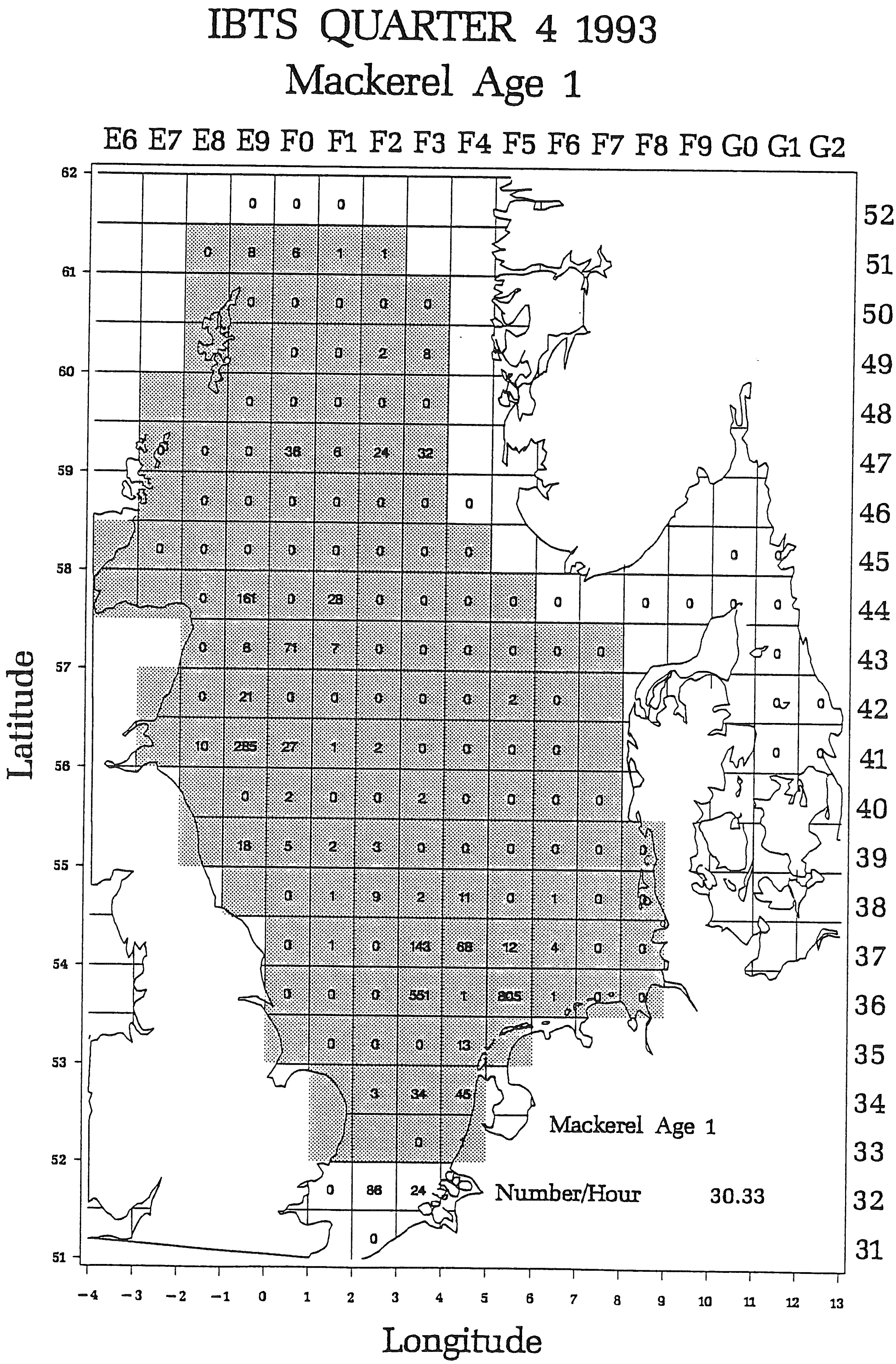



**Figure 4.11** The distribution of age 1 group mackerel, as numbers per hour, from the International Bottom Trawl Surveys of the North Sea in the fourth quater of 1993. (Provisional)

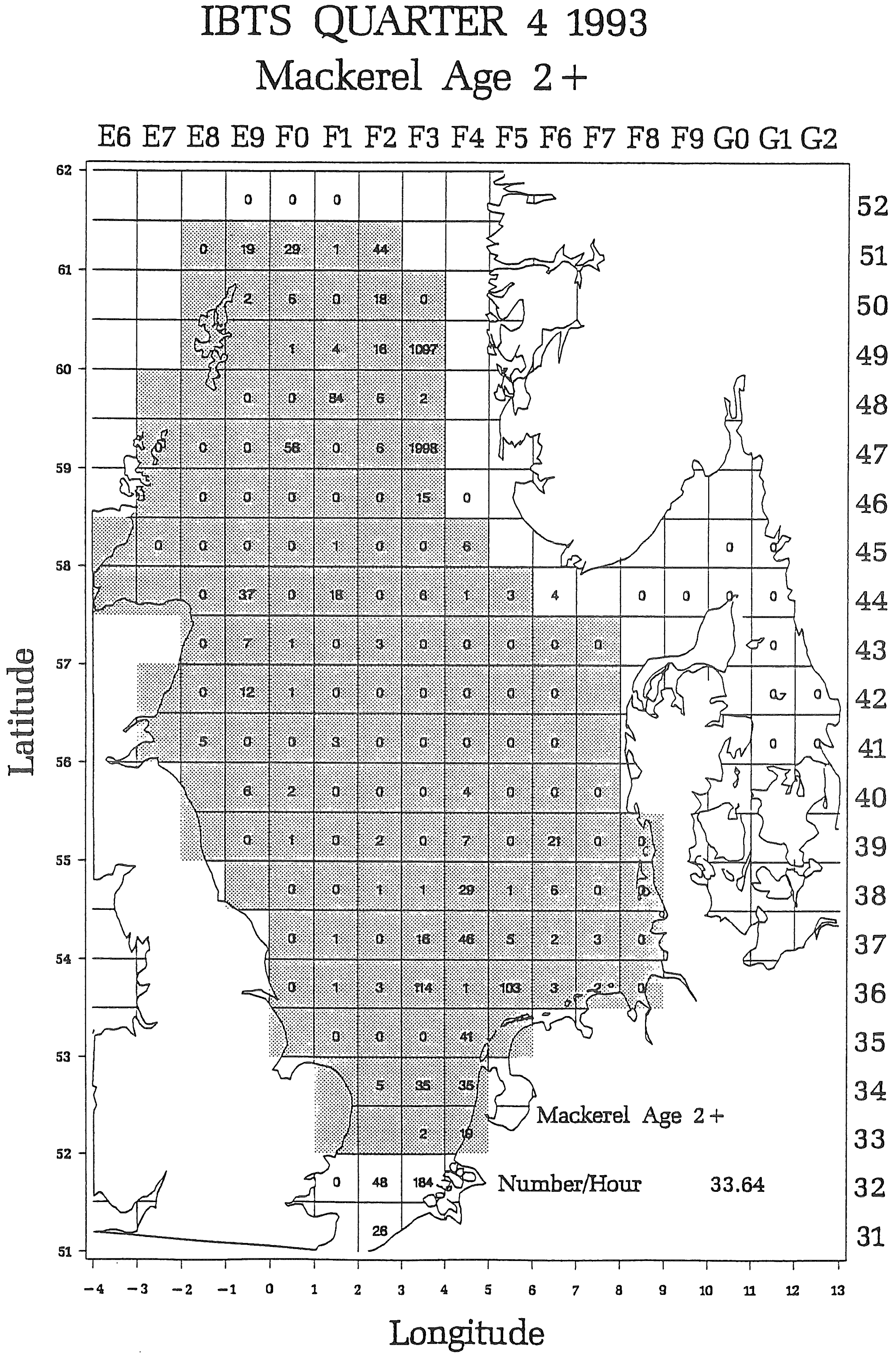



**Figure 4.12** The distribution of age 2+ group mackerel, as numbers per hour, from the International Bottom Trawl Surveys of the North Sea in the fourth quater of 1993. (Provisional)

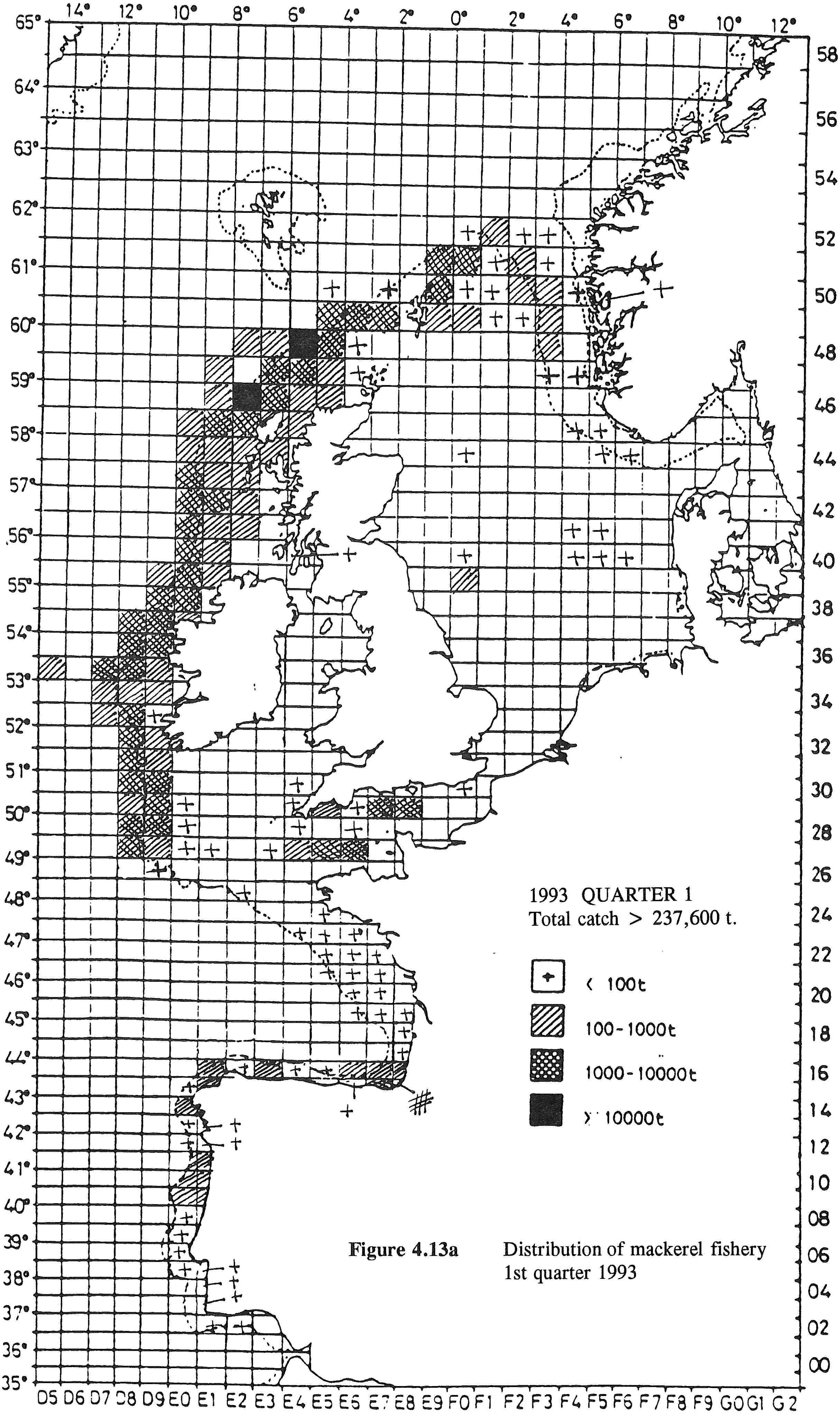



**Figure 4.13a** Distribution of mackerel fishery 1st quarter 1993

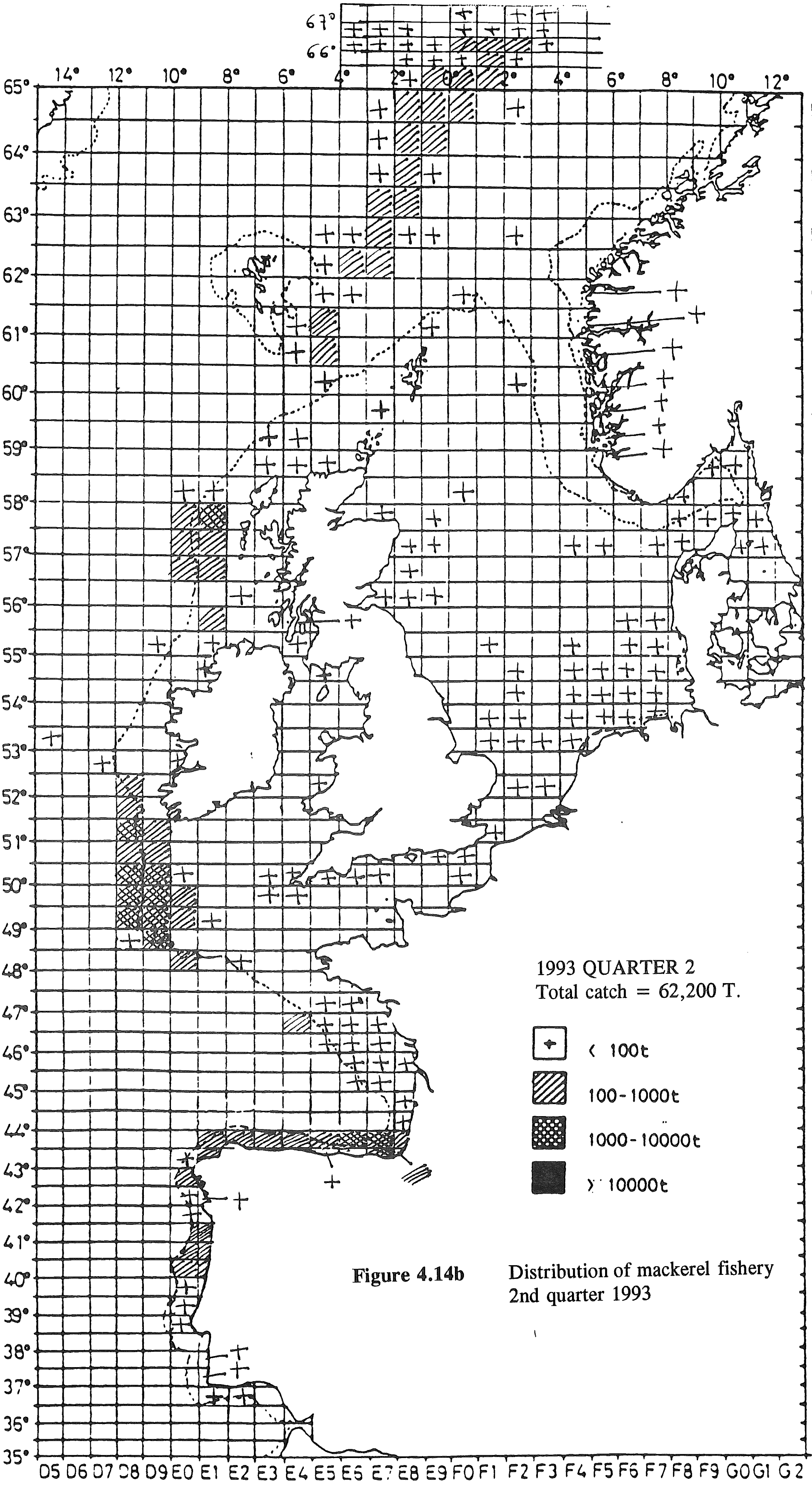



**Figure 4.14b** Distribution of mackerel fishery 2nd quarter 1993

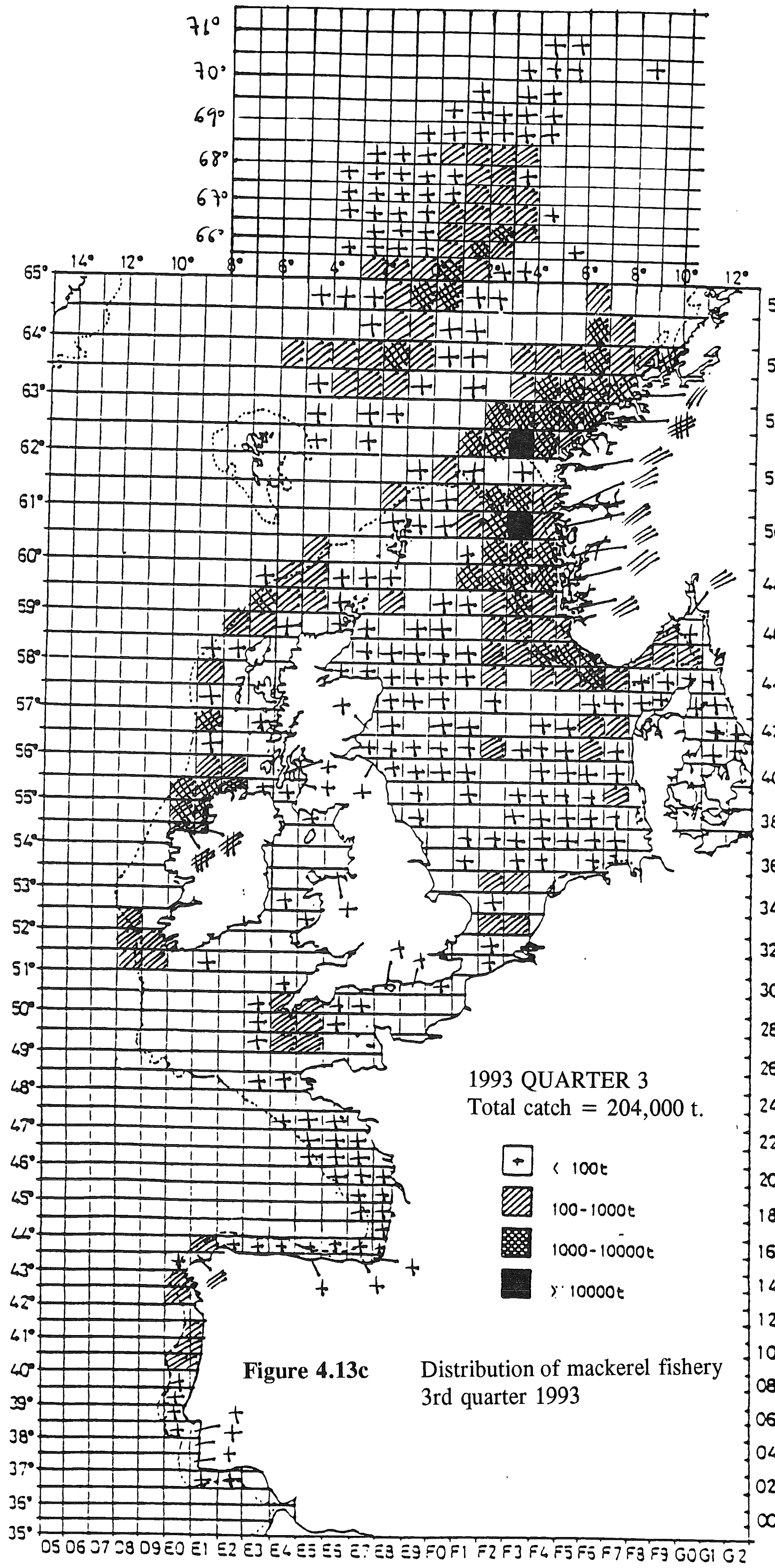



**Figure 4.13c** Distribution of mackerel fishery 3rd quarter 1993

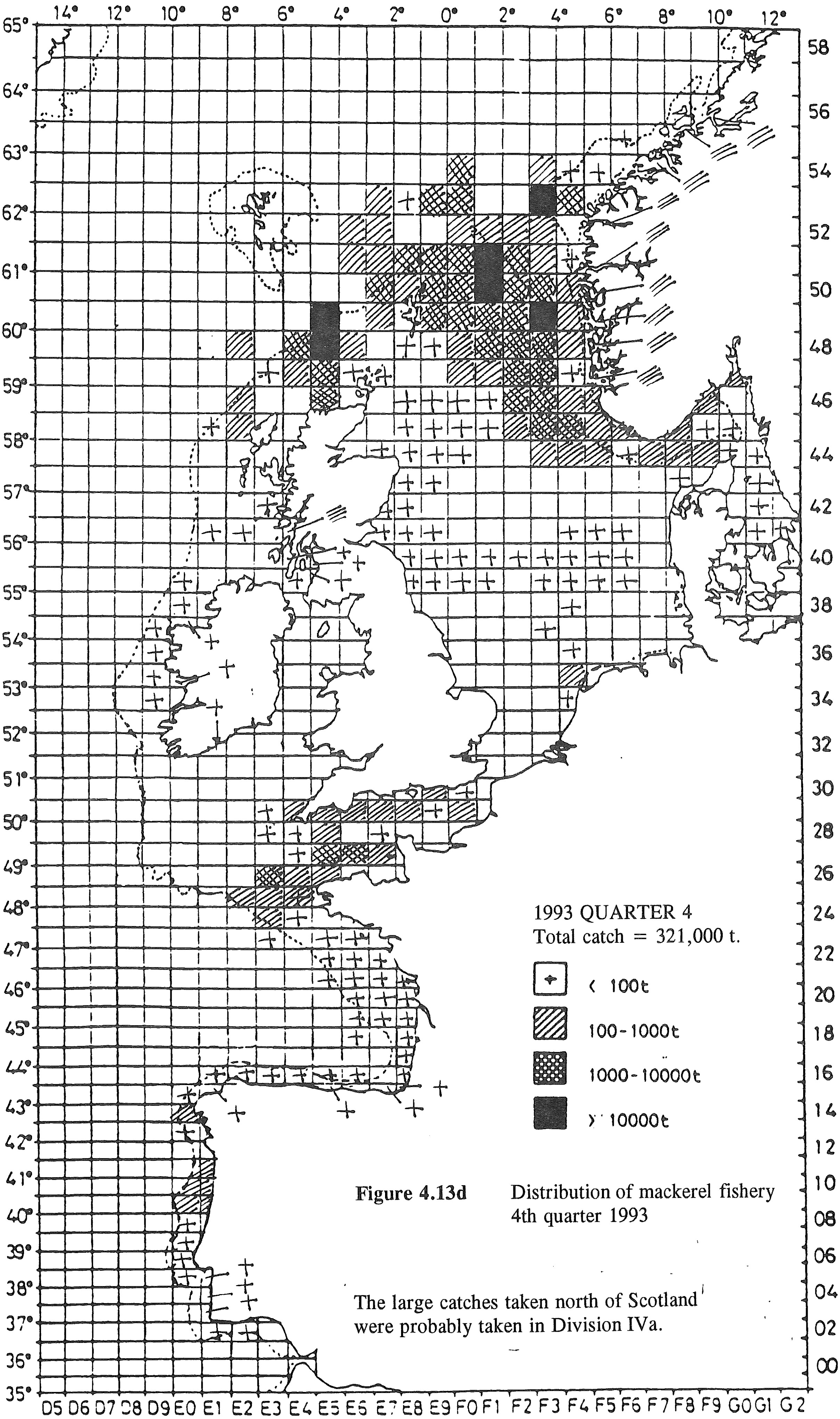



**Figure 4.13d** Distribution of mackerel fishery 4th quarter 1993

The large catches taken north of Scotland were probably taken in Division IVa.

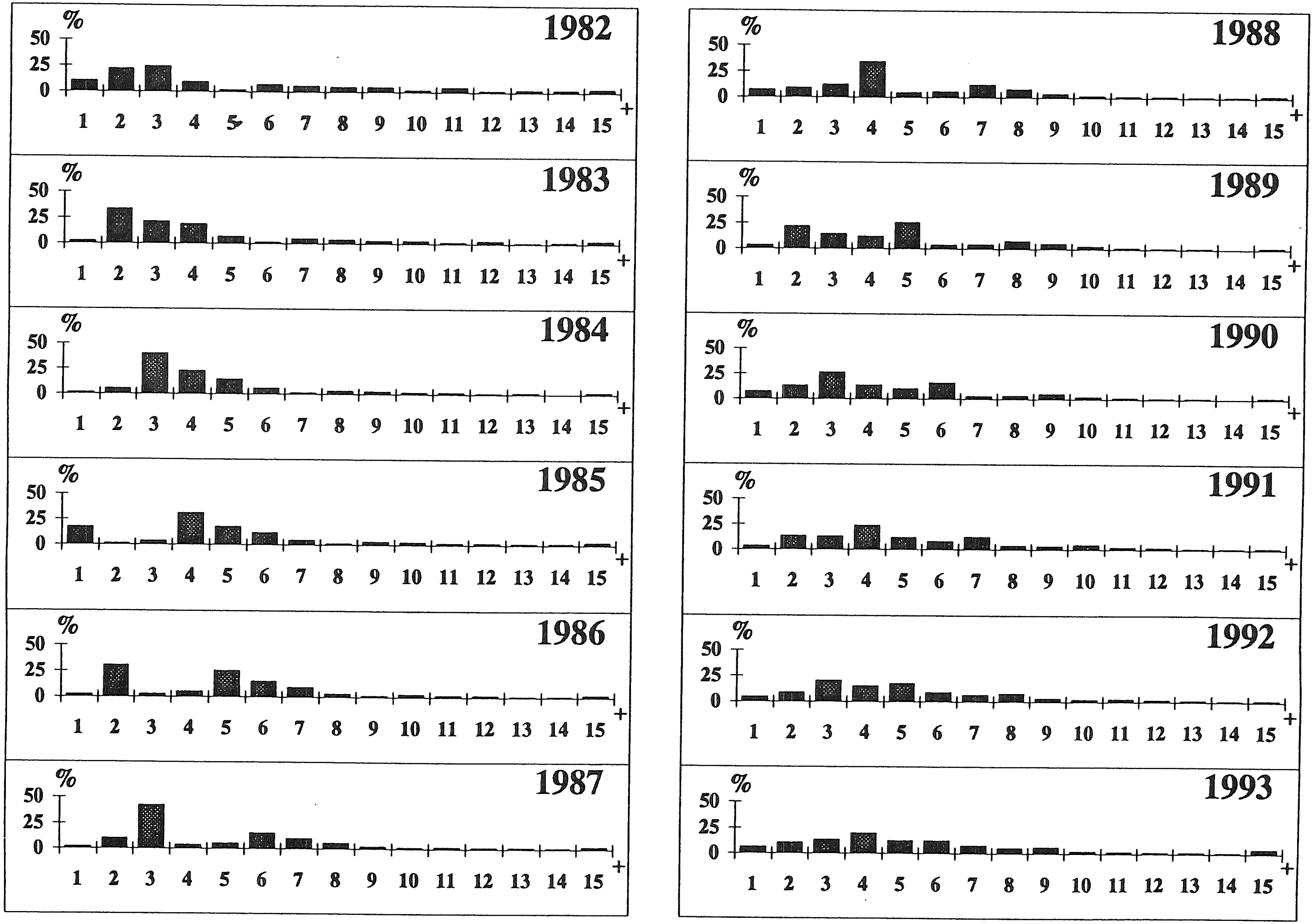



**Figure 5.1** The age composition of the western mackerel in the international catches from 1982-1993.

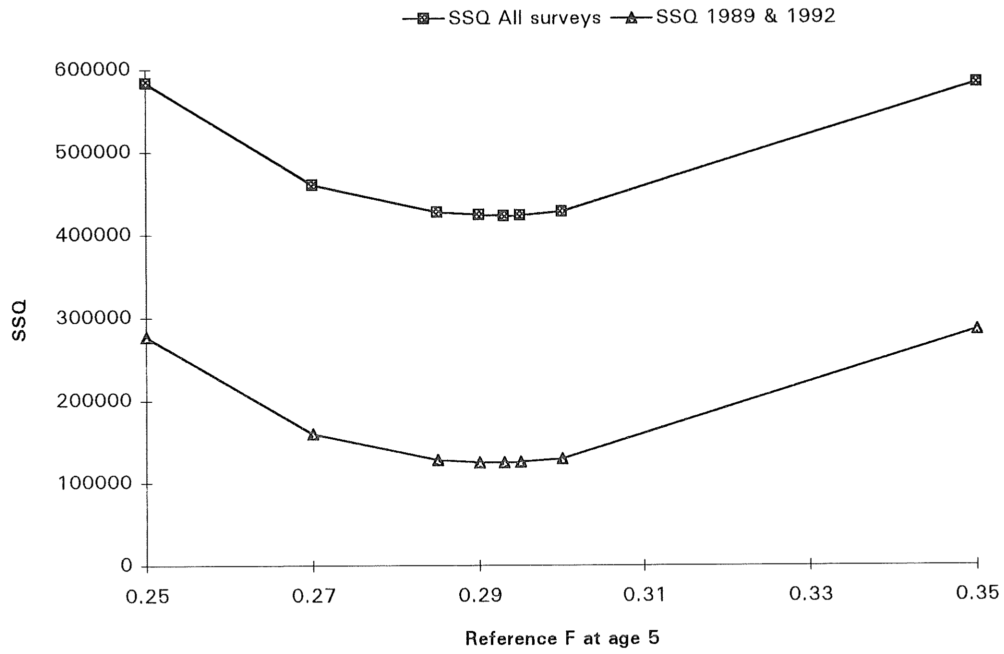



Figure 5.2 The SSQ surface produced by tuning the Western Mackerel, Separable VPA assessments to two time periods of the egg production spawning stock biomass estimates.

FISH STOCK SUMMARY
STOCK : Western mackerel

Figure 5.3

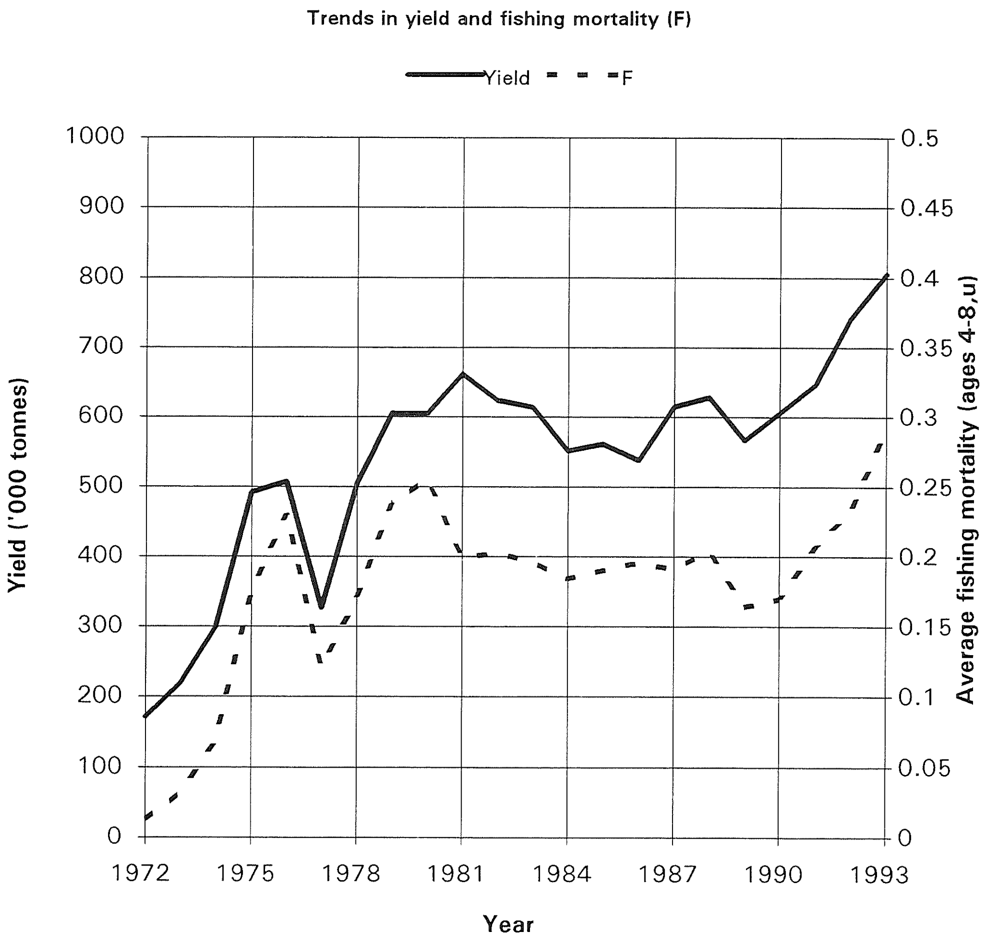
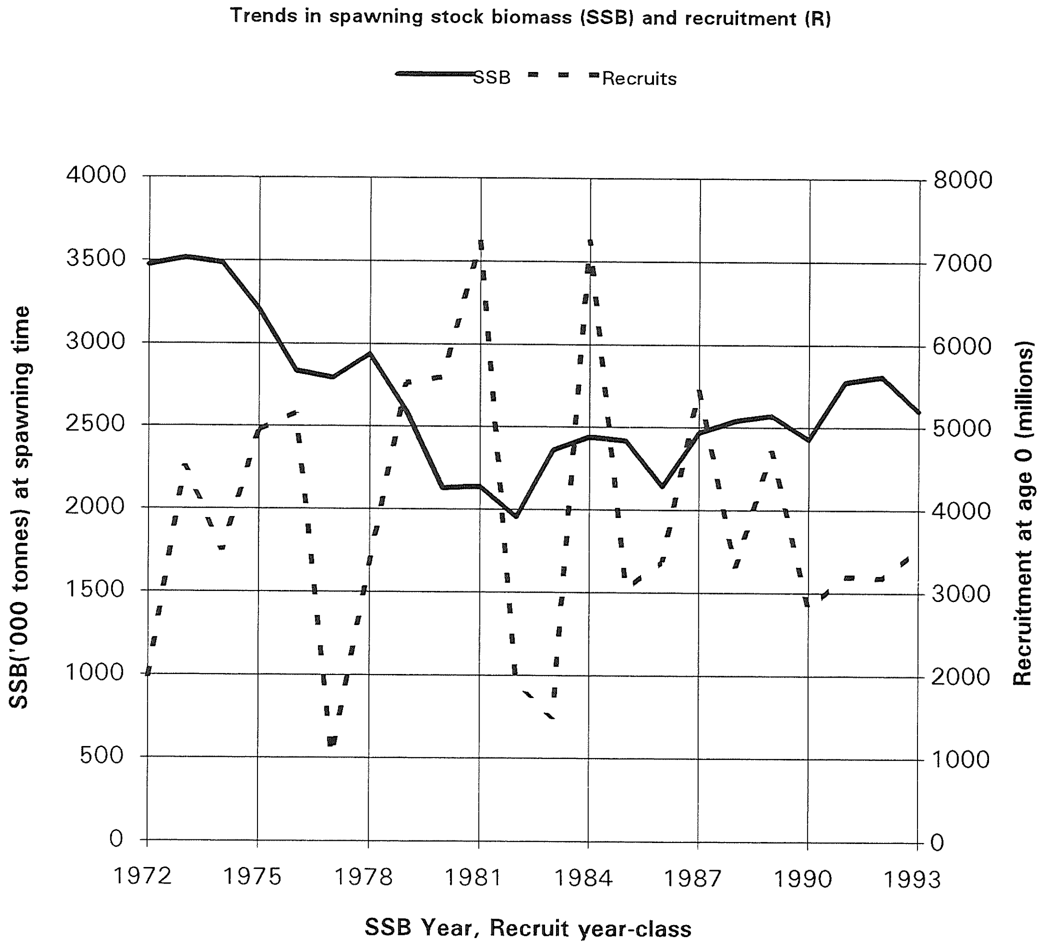


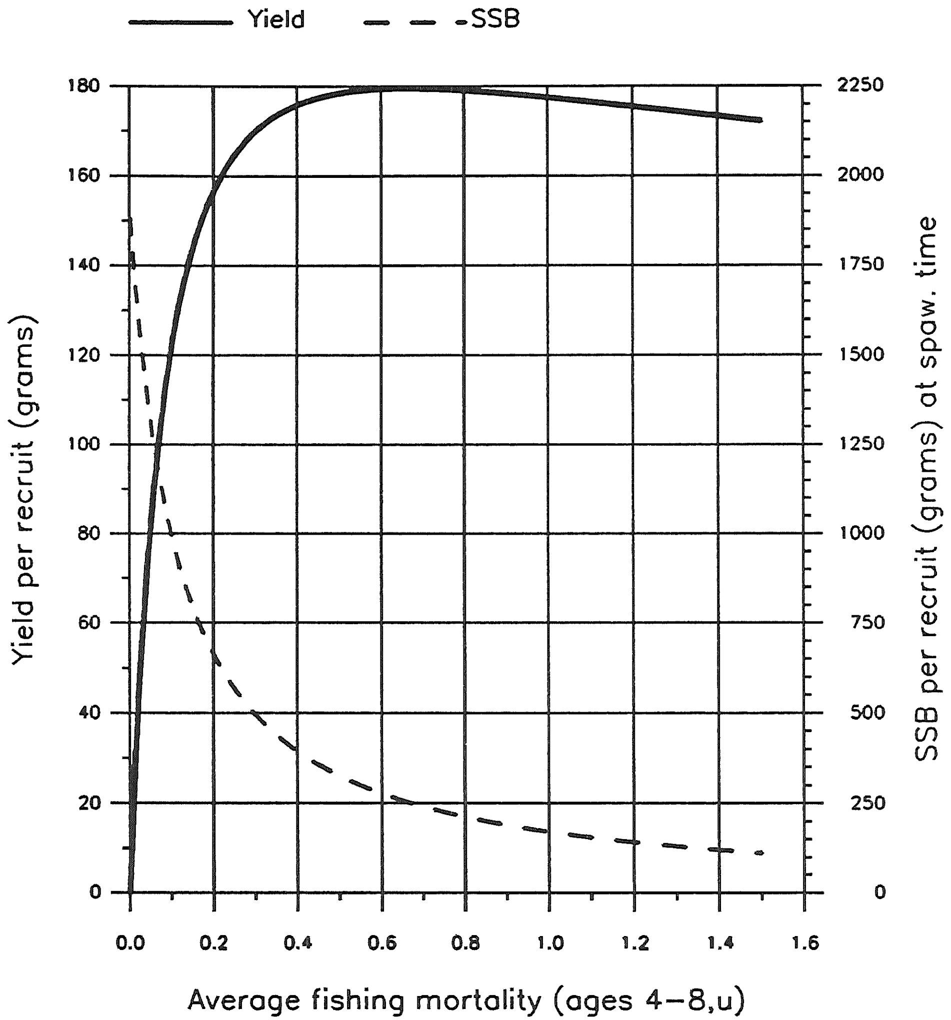

Figure 5.4



# FISH STOCK SUMMARY
## STOCK: Mackerel in the Western Area (Fishing Areas VI, VII and VIII)
## 8–9–1994

**Figure 5.5**

Long term yield and spawning stock biomass

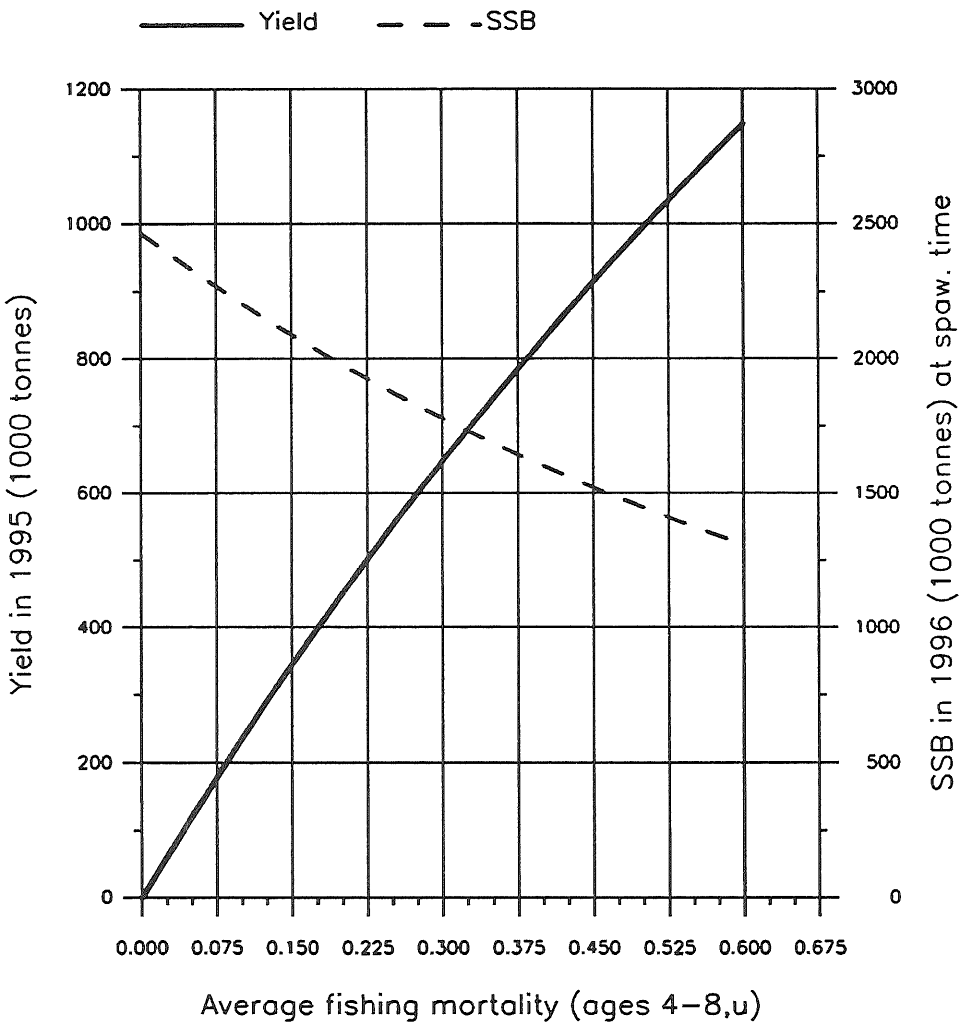



(run: H1YR)

**C**

**Figure 5.6**

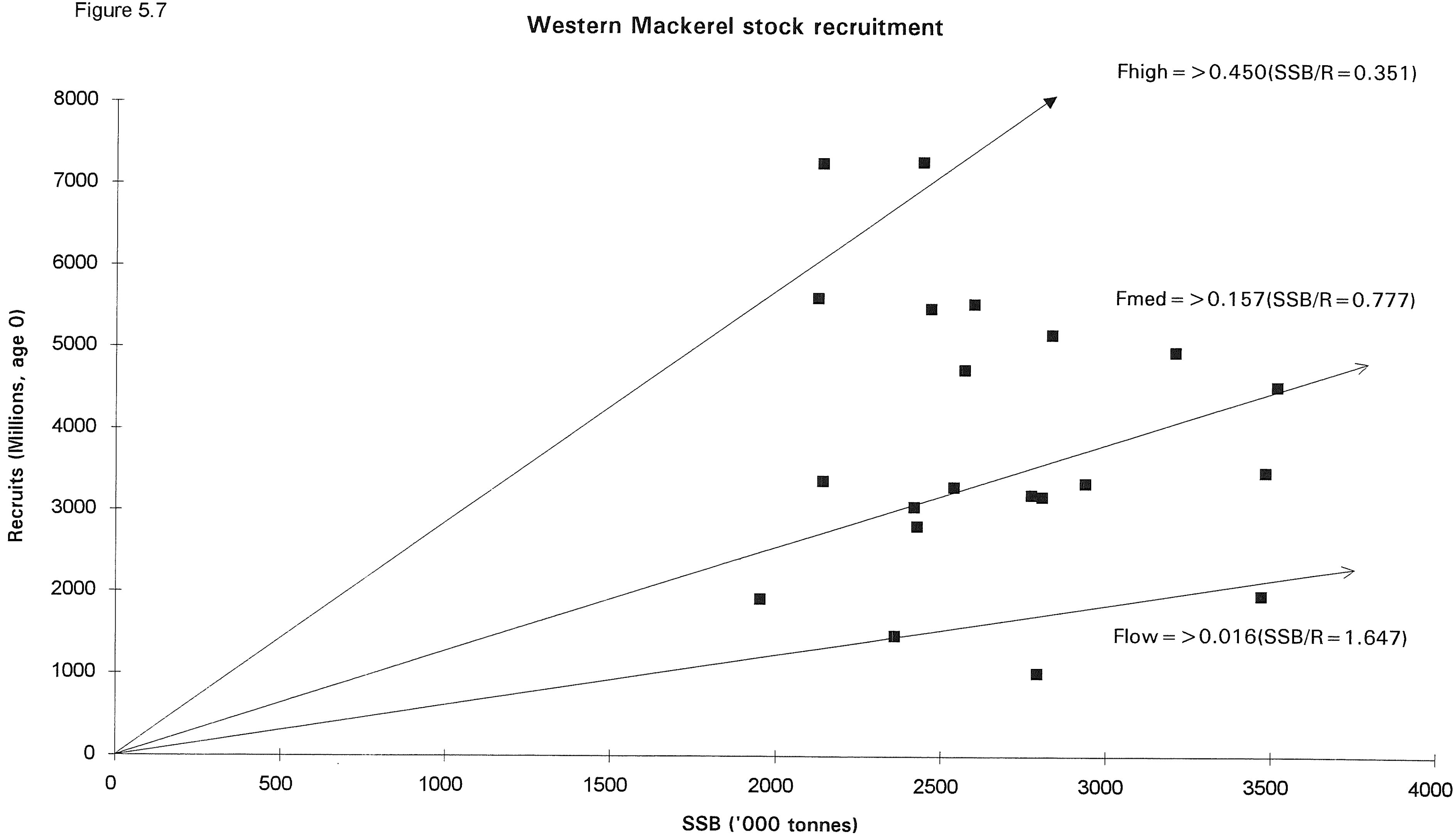
Short–term yield and spawning stock biomass




(run: H1)

**D**

Figure 5.7


Western Mackerel stock recruitment
Fhigh=>0.450(SSB/R=0.351)
Fmed=>0.157(SSB/R=0.777)
Flow=>0.016(SSB/R=1.647)
Recruits (Millions, age 0)
8000
7000
6000
5000
4000
3000
2000
1000
0
500
1000
1500
2000
2500
3000
3500
4000
SSB ('000 tonnes)

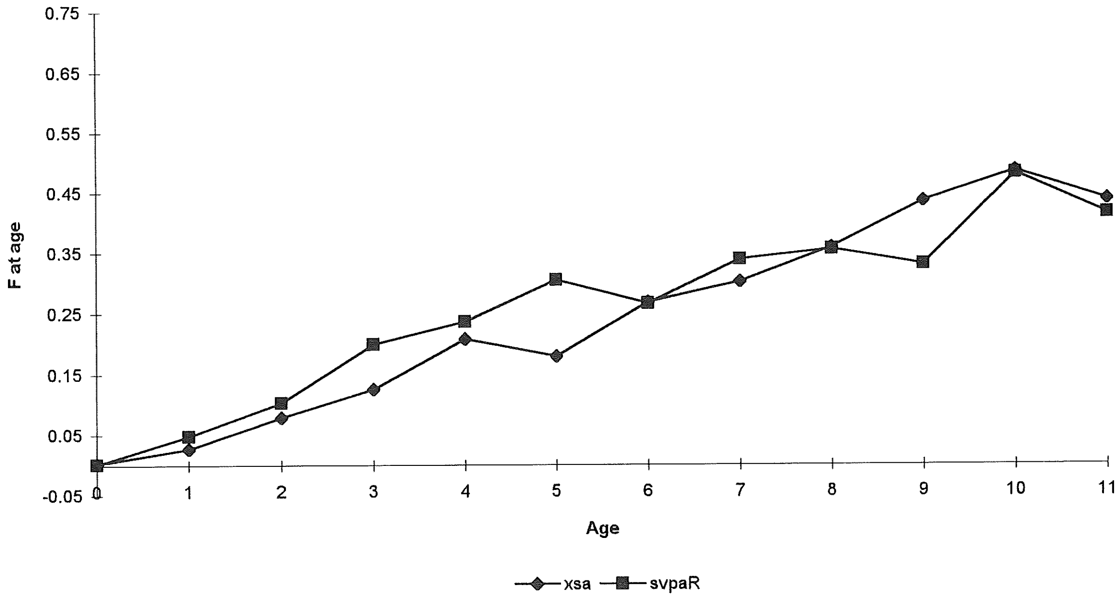



Figure 5.8 The F at age estimates estimated by an XSA assessment and a VPA initialised with terminal F estimates generated by a tuned Separable VPA

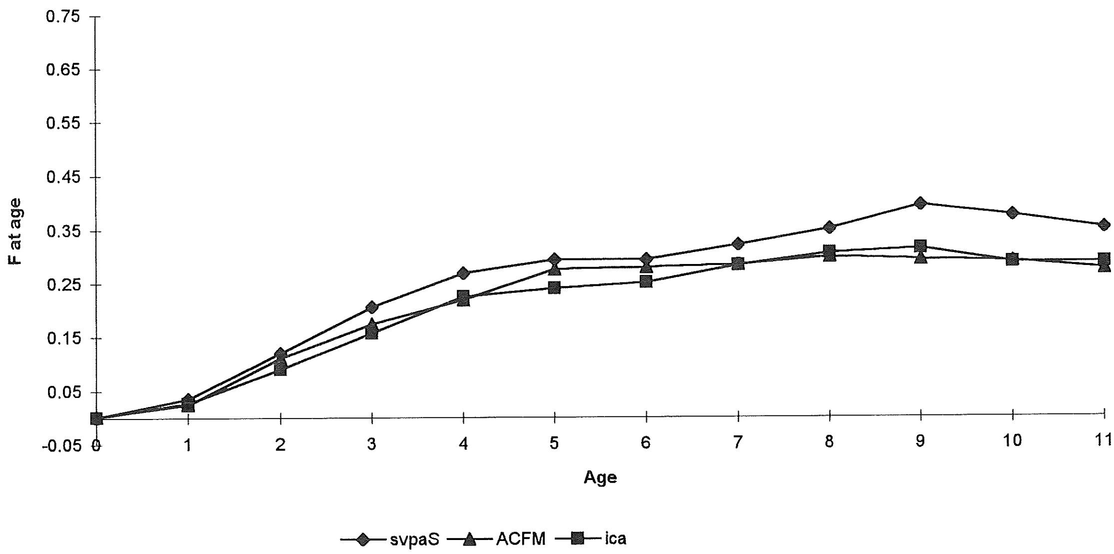



Figure 5.9 The "smooth" F's at age estimated by the 1994 Separable VPA and ICA assessments and the status quo values used for the the 1994 forcast by ACFM in 1993

NEWMAC.XLW

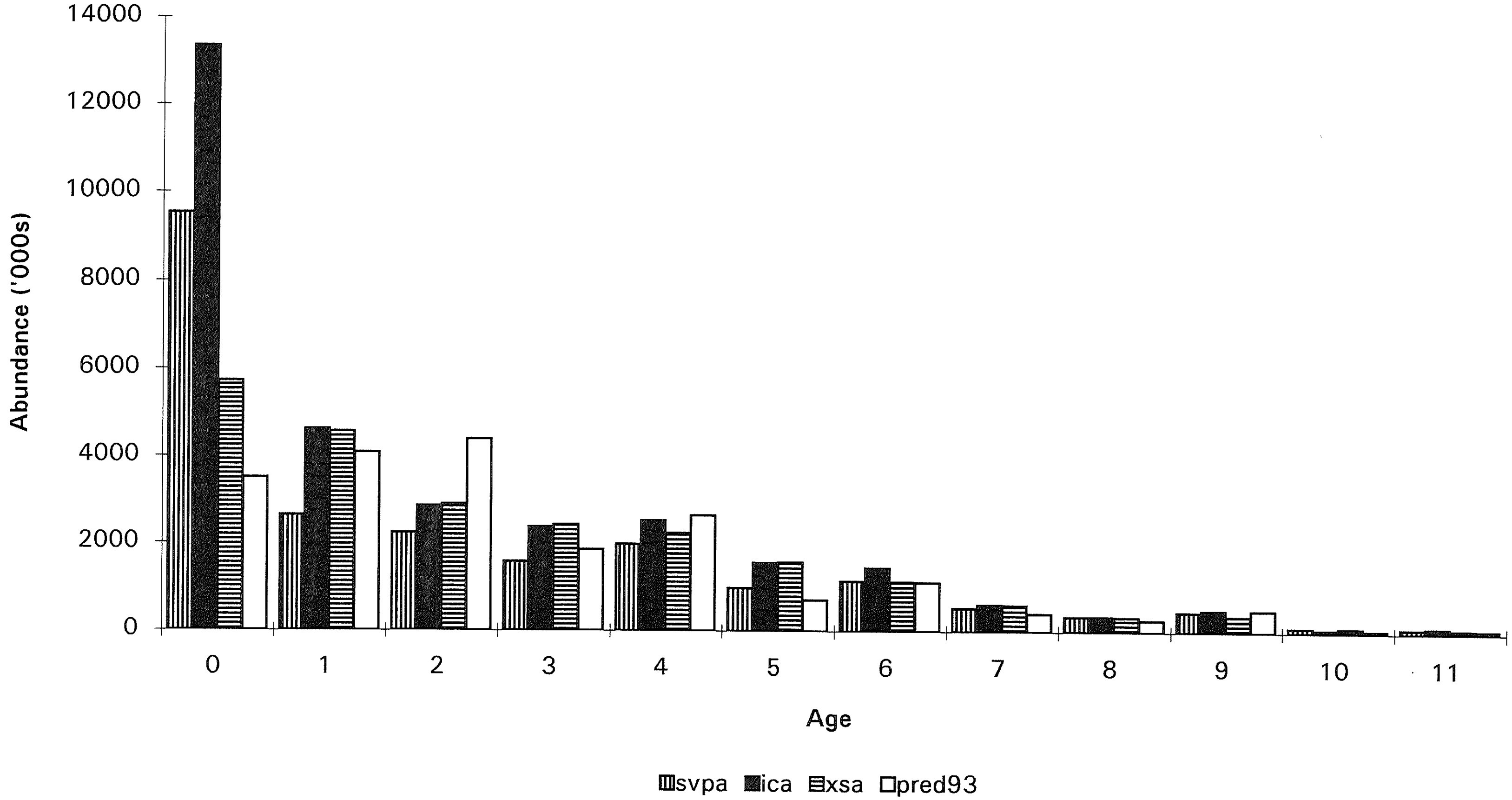



Figure 5.10 Population abundance at age estimated by three analysis methods compared with the values used for the 1993 stock projections

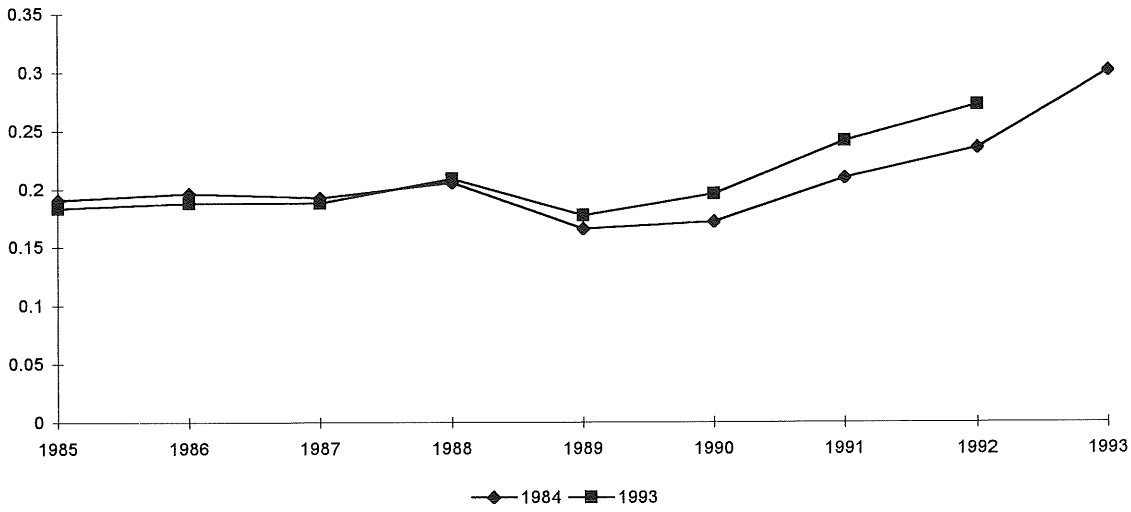



Figure 5.11 The time series of reference F's estimated by the 1993 and 1994 separable VPA assessments

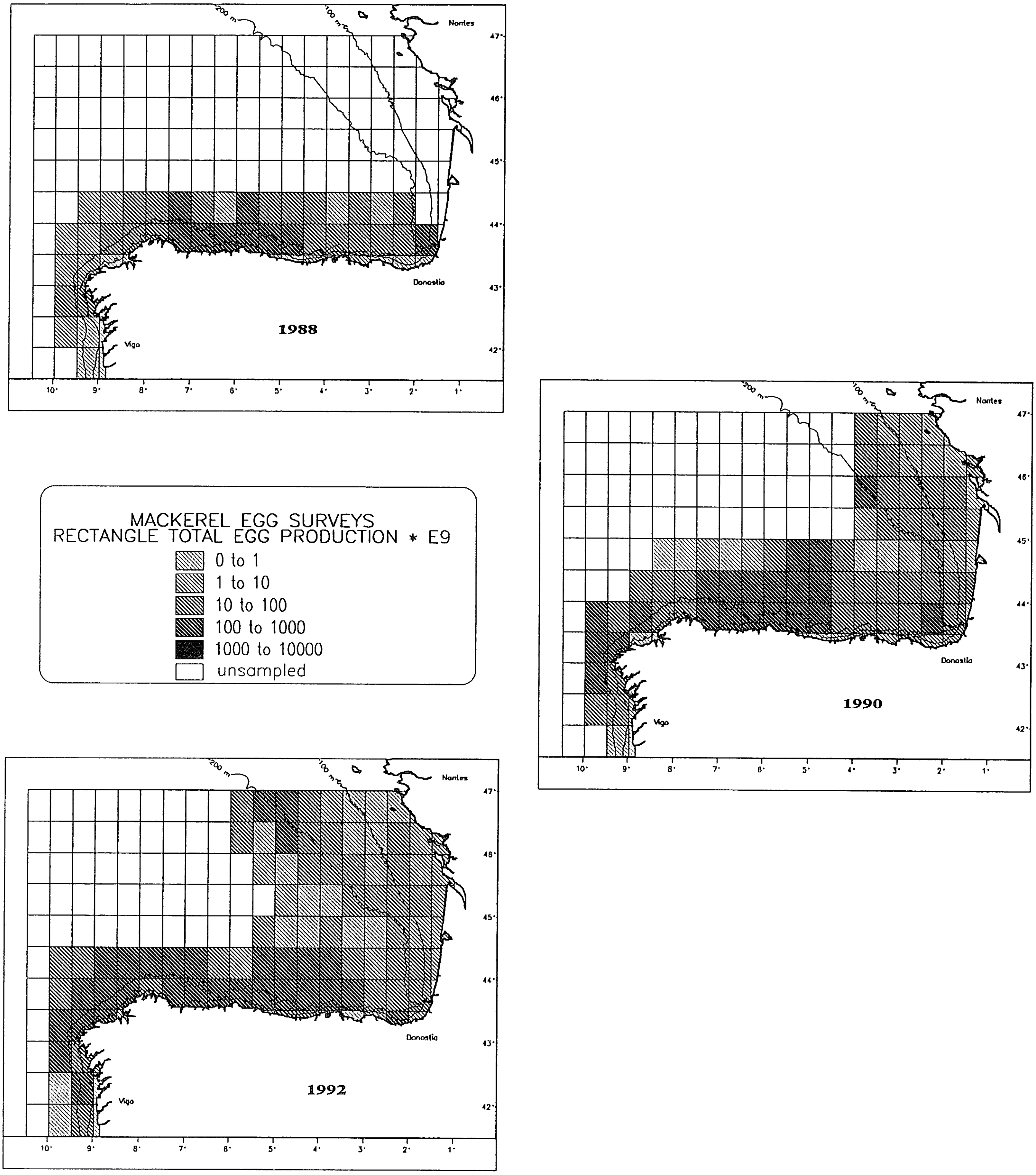



Figure 6.1: Rectangle daily (stage I) egg production of mackerel in numbers per 10exp( 9) in 1988, 1990 and 1992 (from Lago de Lanzos et al., 1993).

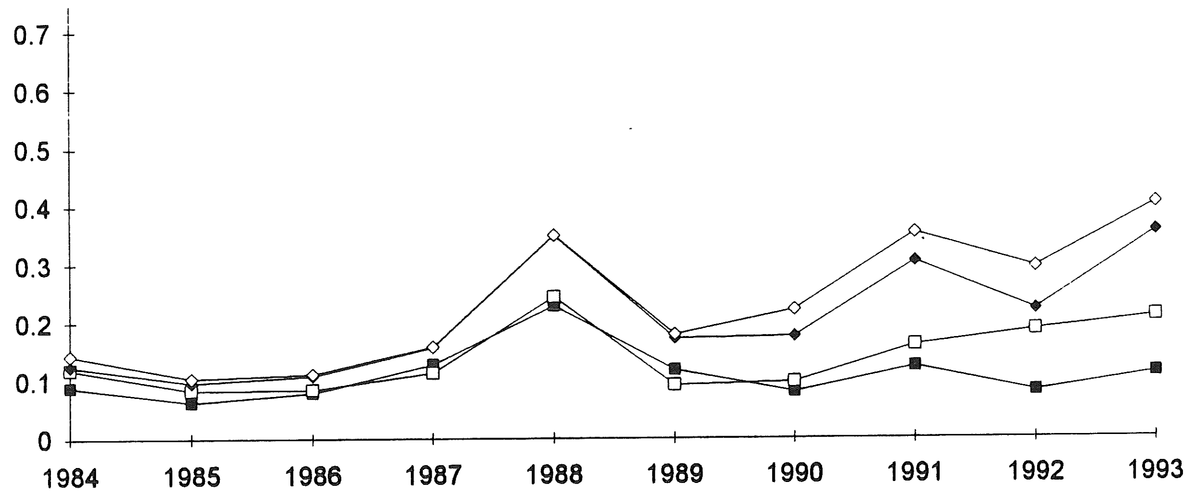



**Figure 6.2** Fbar (2-7)estimated using an XSA assessment tuned independently to 4 fleet data sets.

Shrinkage s.l. = 1.5

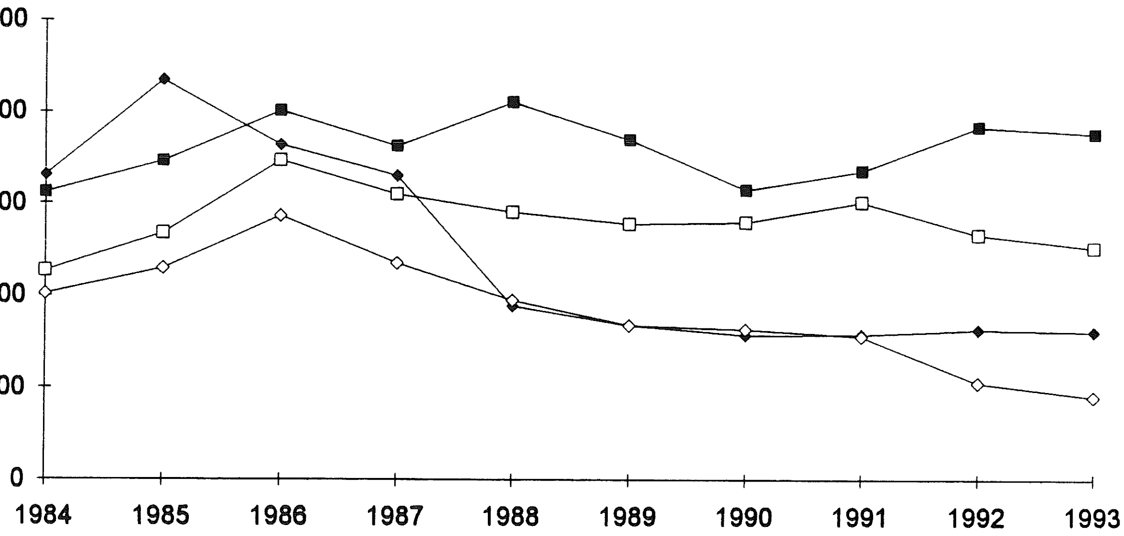
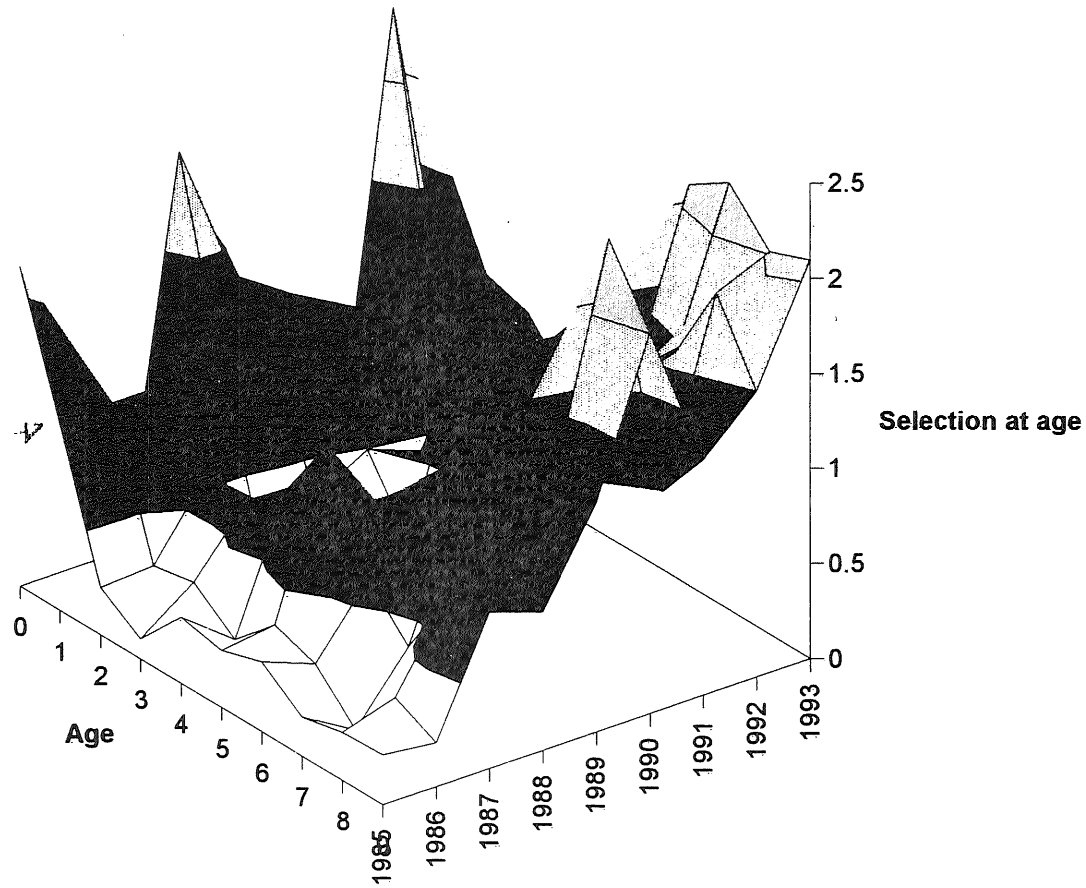



**Figure 6.3** The SSB estimated using an XSA assessment tuned independently to 4 fleet data sets.

F shrinkage s.l. = 1.5

**Figure 6.4** Selectivity at age of fishery for southern mackerel relative to age 1.

S = 1 age 1



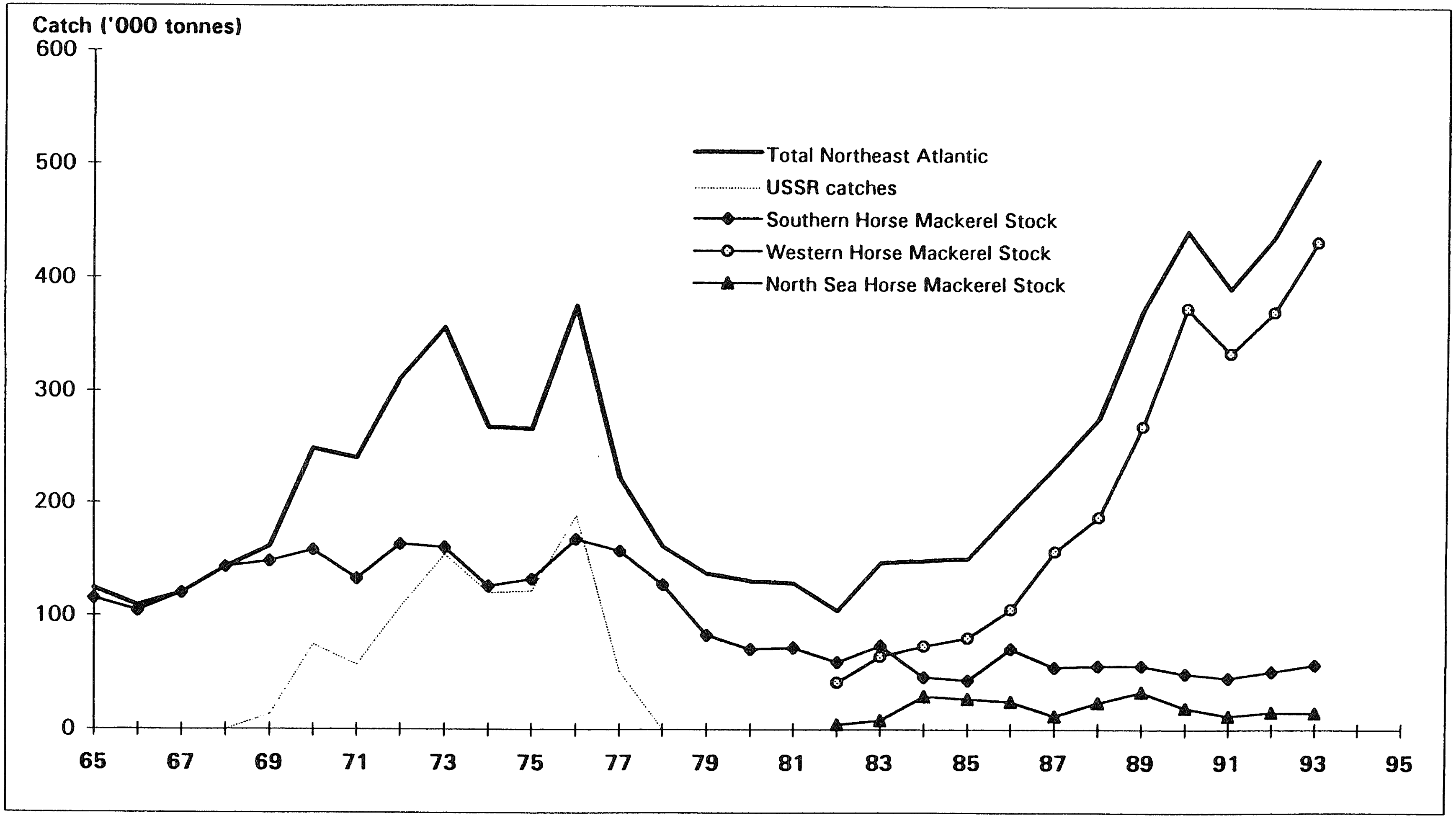



Figure 7.1 Total catches of horse mackerel in the northeast Atlantic during the period 1965 - 1993. The catches taken by the USSR and catches taken from the southern, western and North Sea horse mackerel stocks are shown in relation to the total catches in the northeast Atlantic.

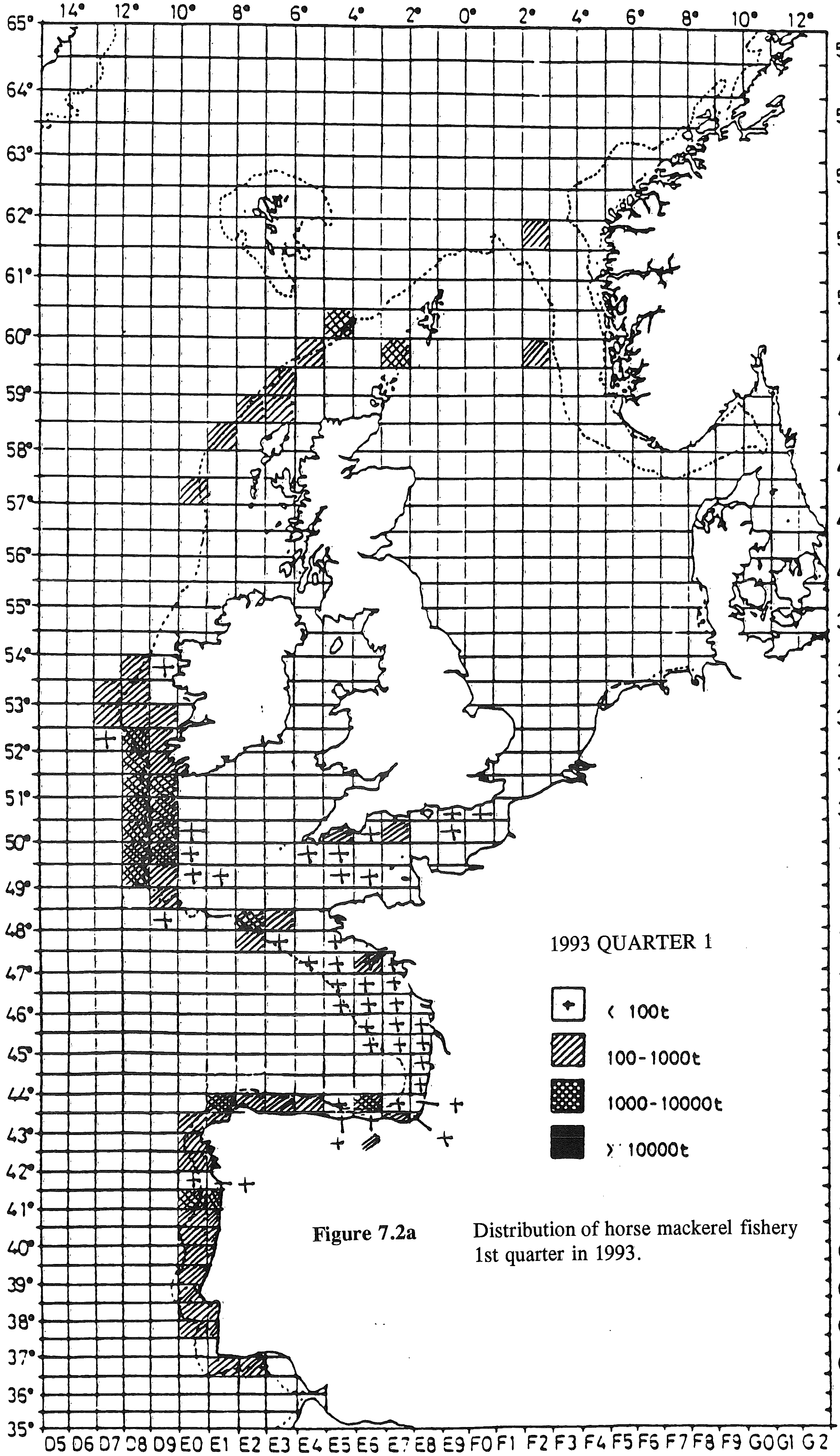



**Figure 7.2a** Distribution of horse mackerel fishery 1st quarter in 1993.

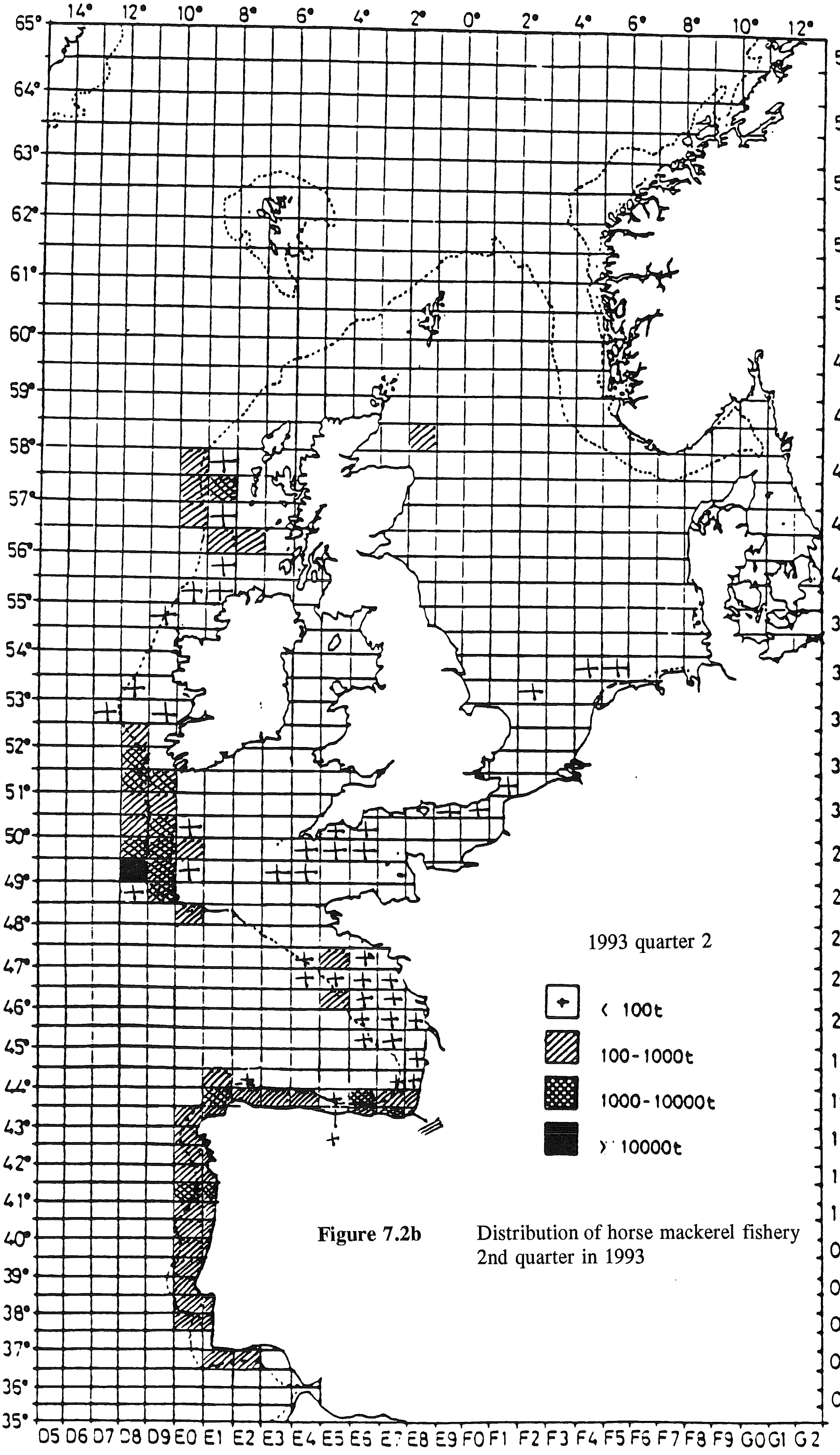



**Figure 7.2b** Distribution of horse mackerel fishery 2nd quarter in 1993

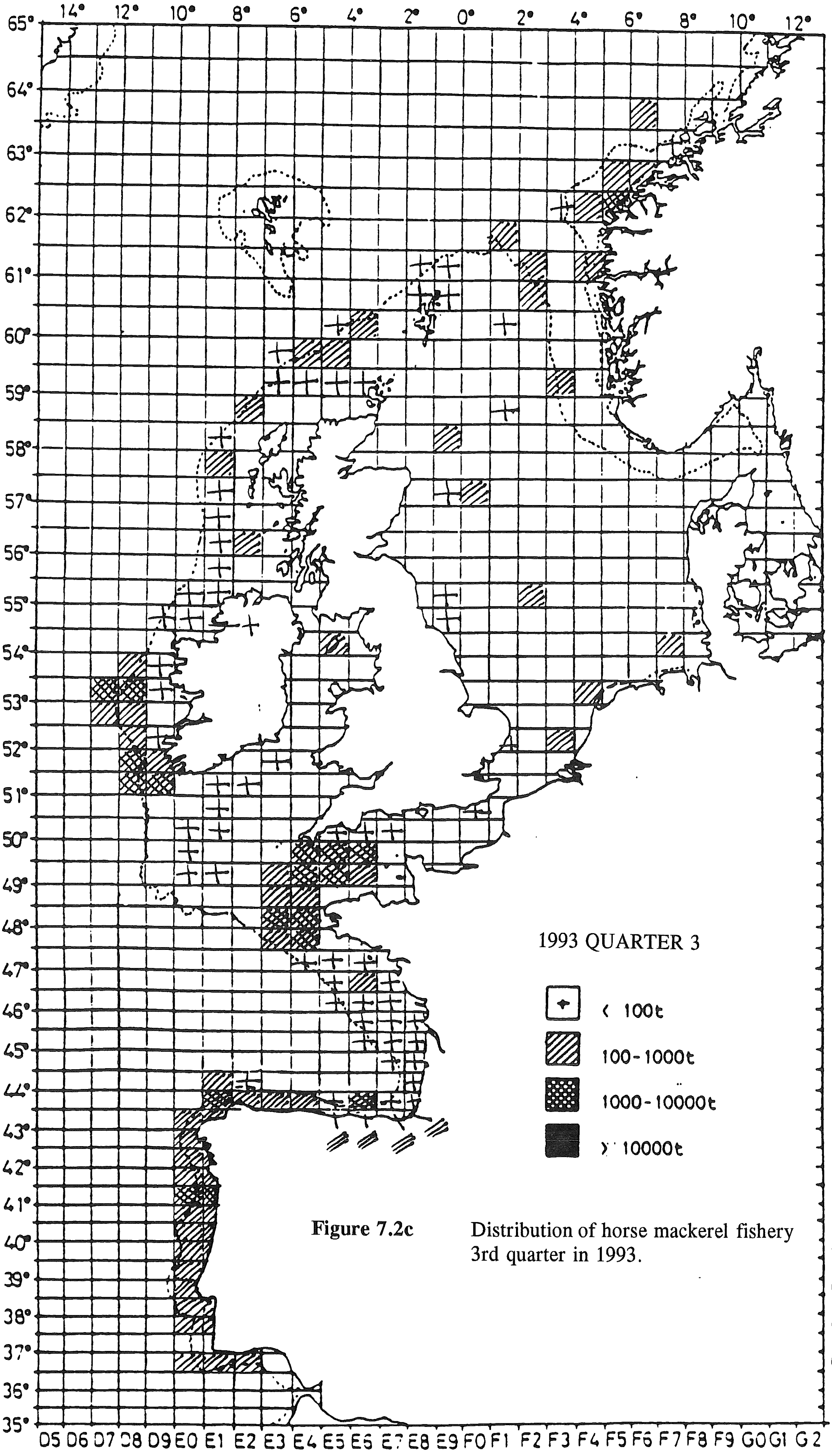



**Figure 7.2c** Distribution of horse mackerel fishery 3rd quarter in 1993.

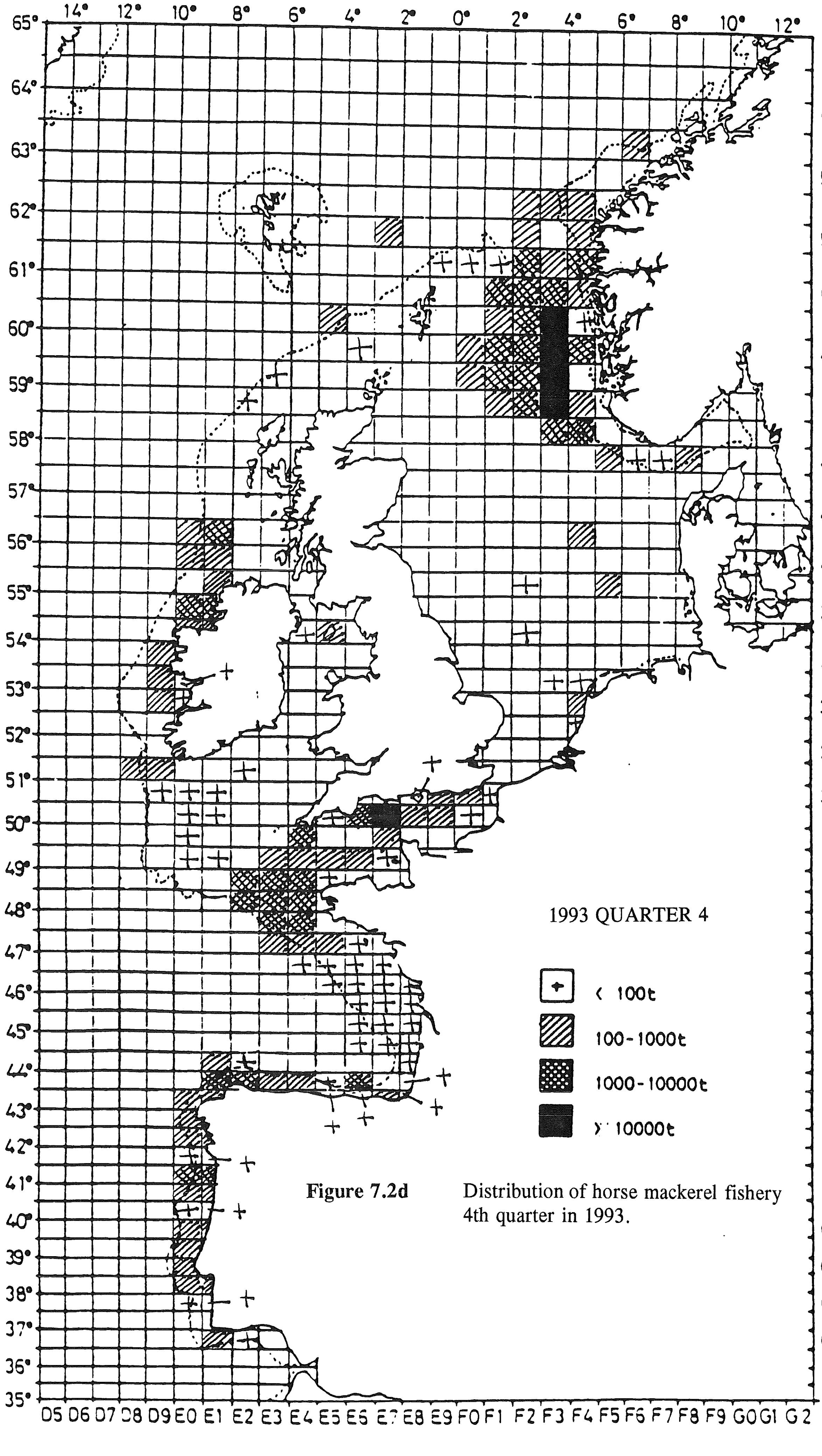



**Figure 7.2d** Distribution of horse mackerel fishery 4th quarter in 1993.

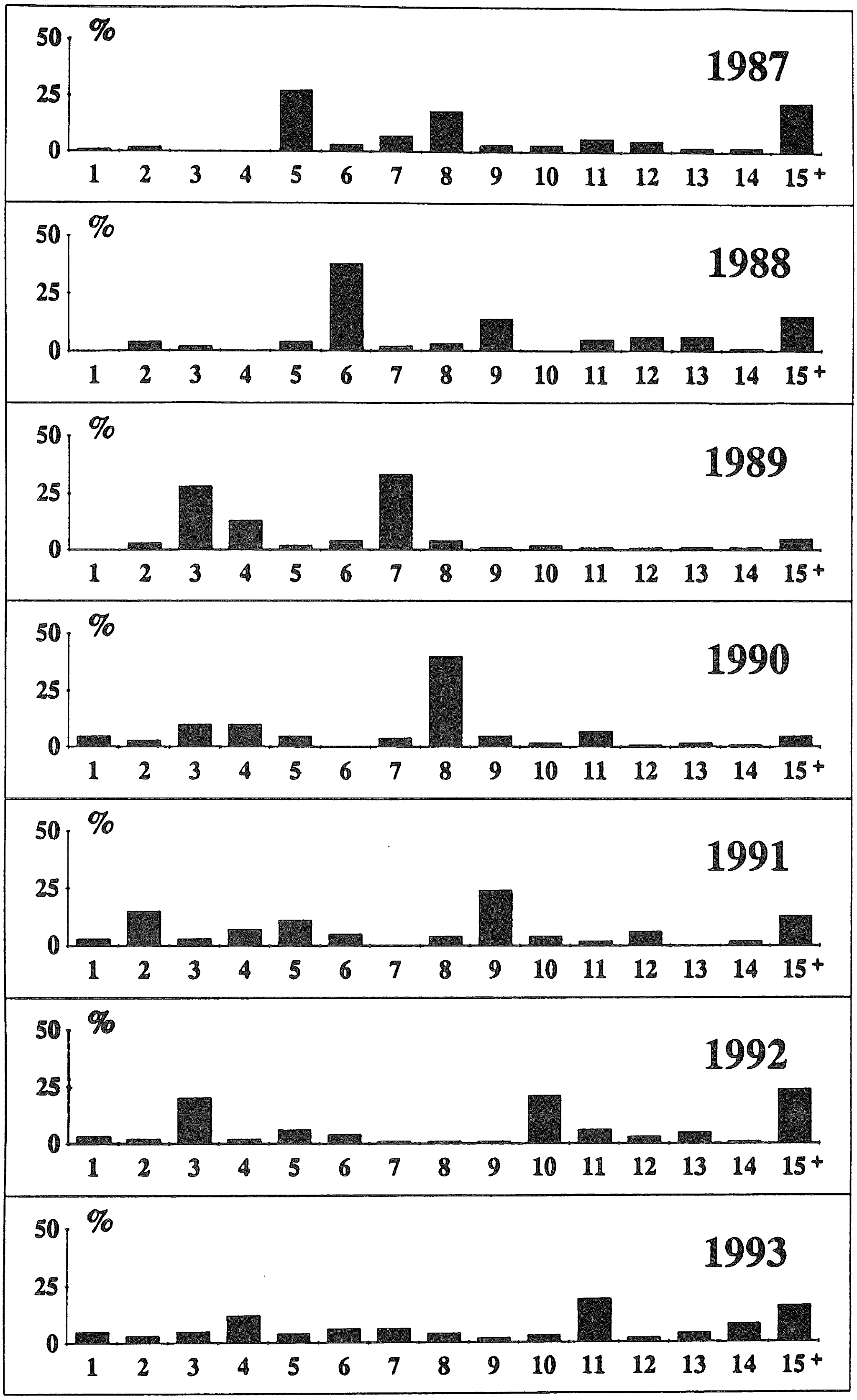



**Figure 8.1** The age composition of the North Sea horse mackerel based on commercial and research vessel samples from 1987-1993.

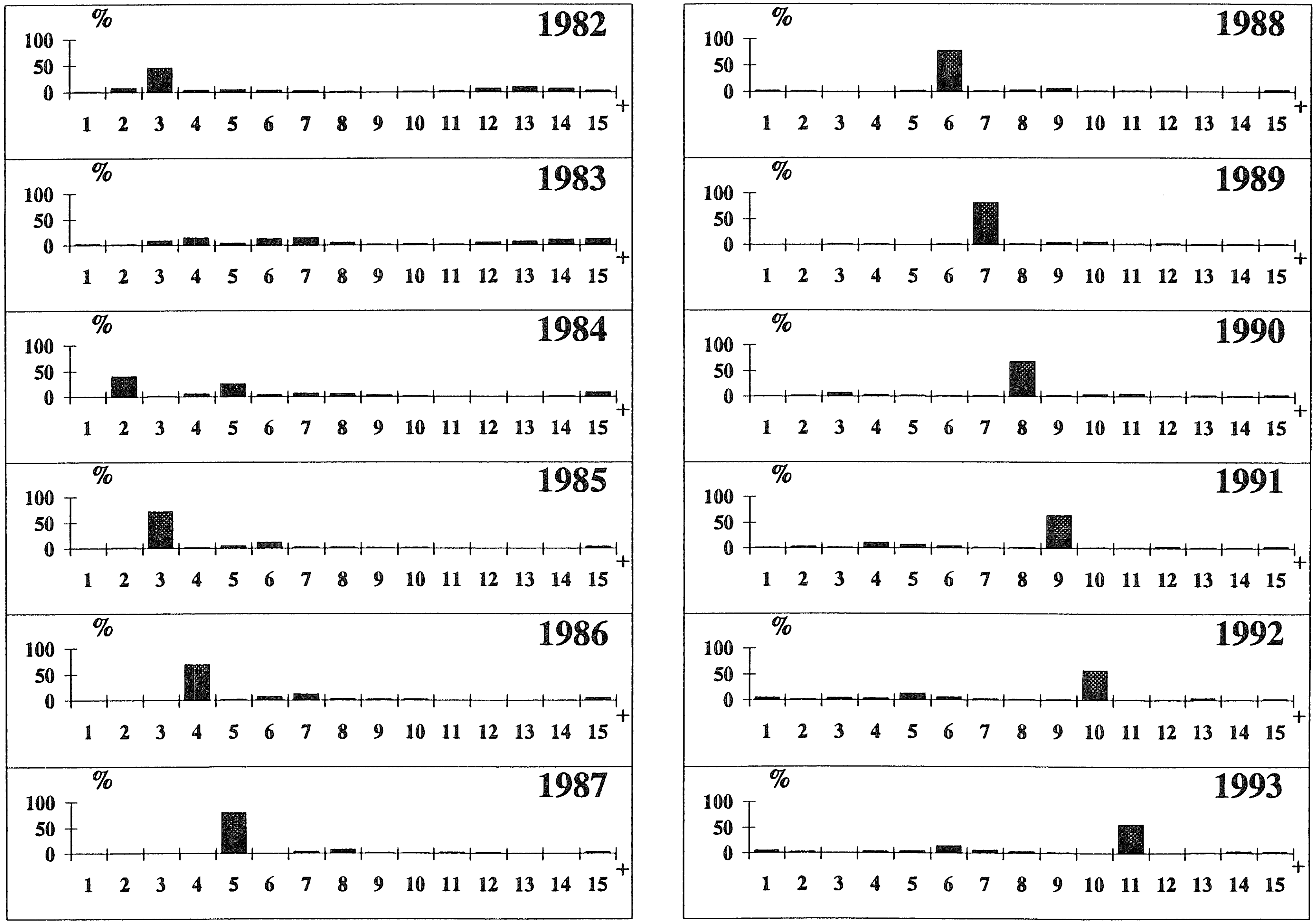



**Figure 9.1** The age composition of the western horse mackerel in the international catches from 1982-1993.

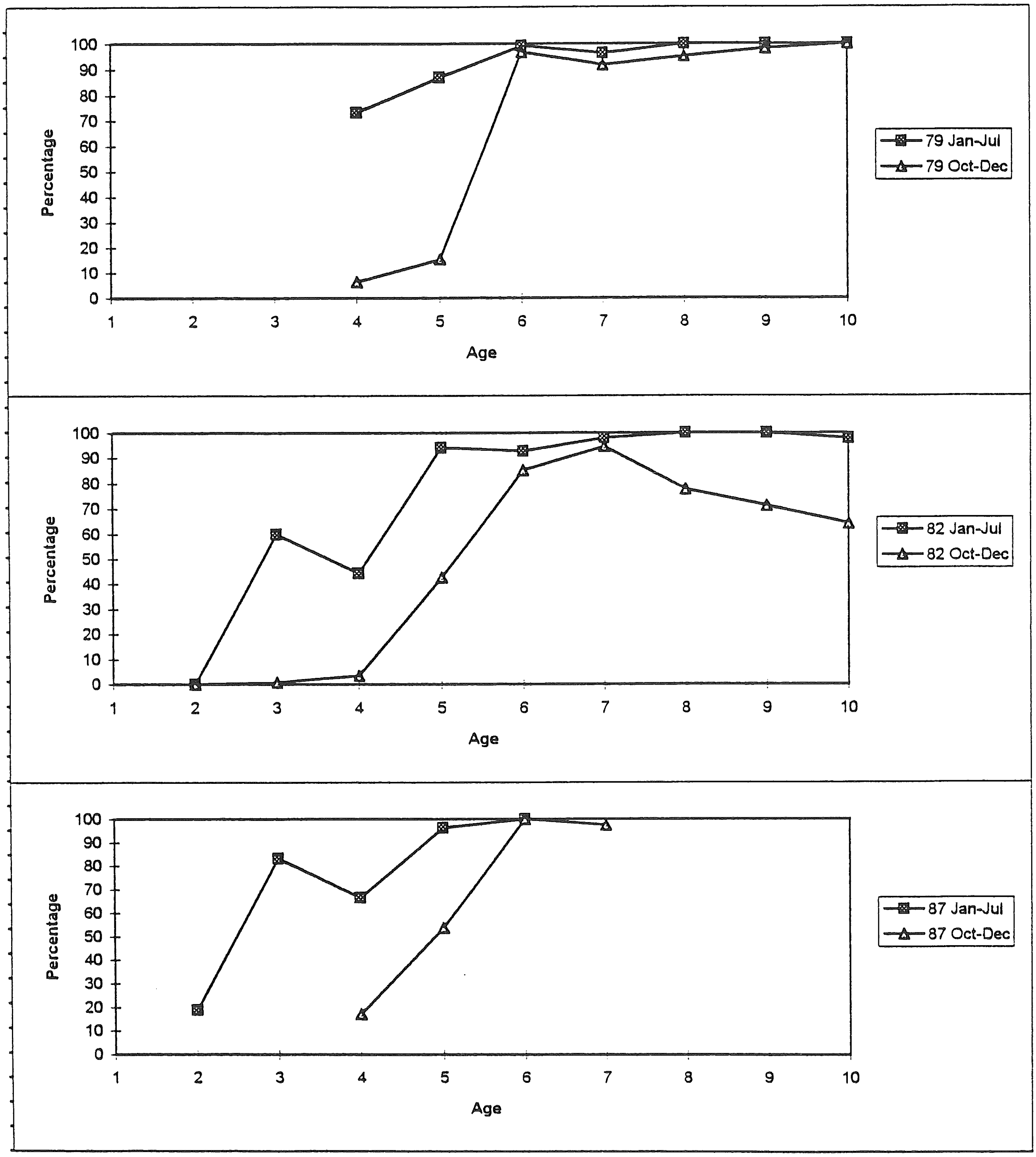



**Figure 9.2** The maturity ogives from western horse mackerel of the year classes 1979, 1982 and 1987 for the periods January-July (spawning area) and for October-December (nursery area). The ages for the period October-December have been increased with one year, because these fish will be spawning in the next year. Based on data from 1982-1993.

Figure 9.3 The sum of squared residuals between estimated SSB and egg production estimates generated by variation of terminal F on the 1982 and 1987 cohorts.

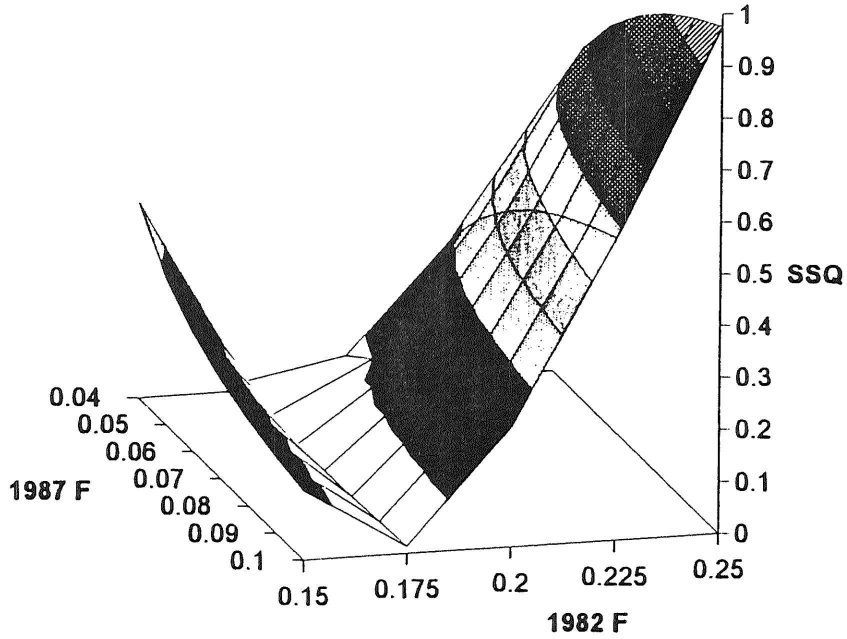
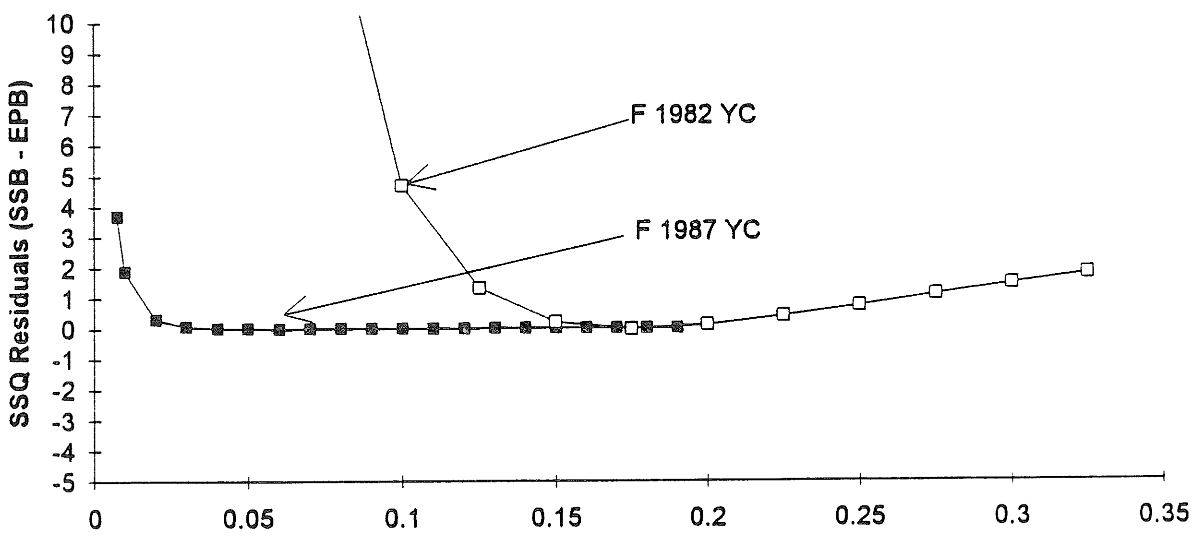


**Figure 9.4** Sections through the SSB SSQ response surface for variation in terminal F on two Western horse mackerel cohorts



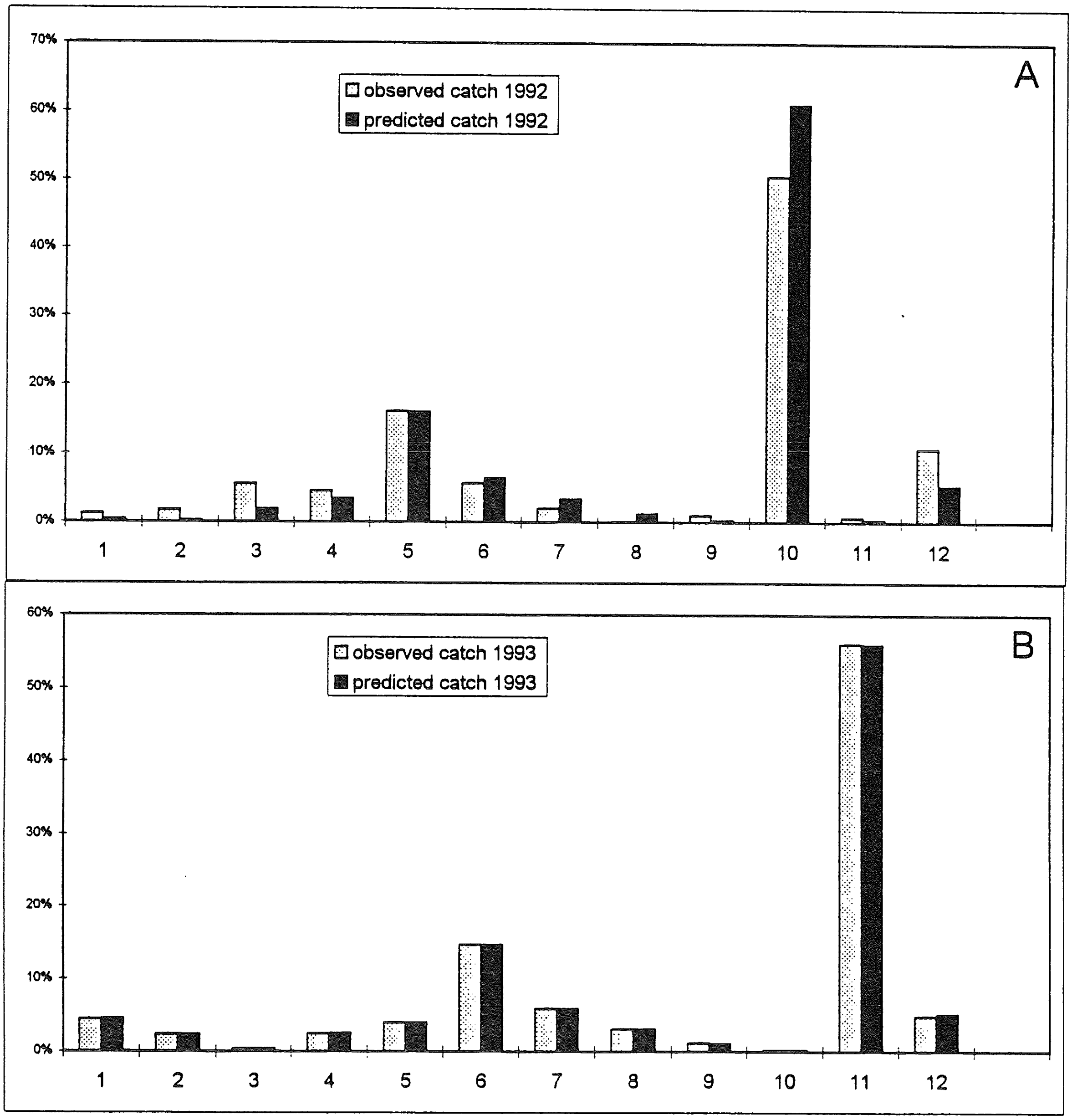



**Figure 9.5** Observed age composition in the catch in 1992 (A) and in 1993 (B). In the predictions was tuned to the age composition of the catch in 1993 (therefore same age compositions observed and predicted in (B)). After this tuning the observed age composition of the catch in 1992 can be compared with the predicted age composition in 1992 (A).

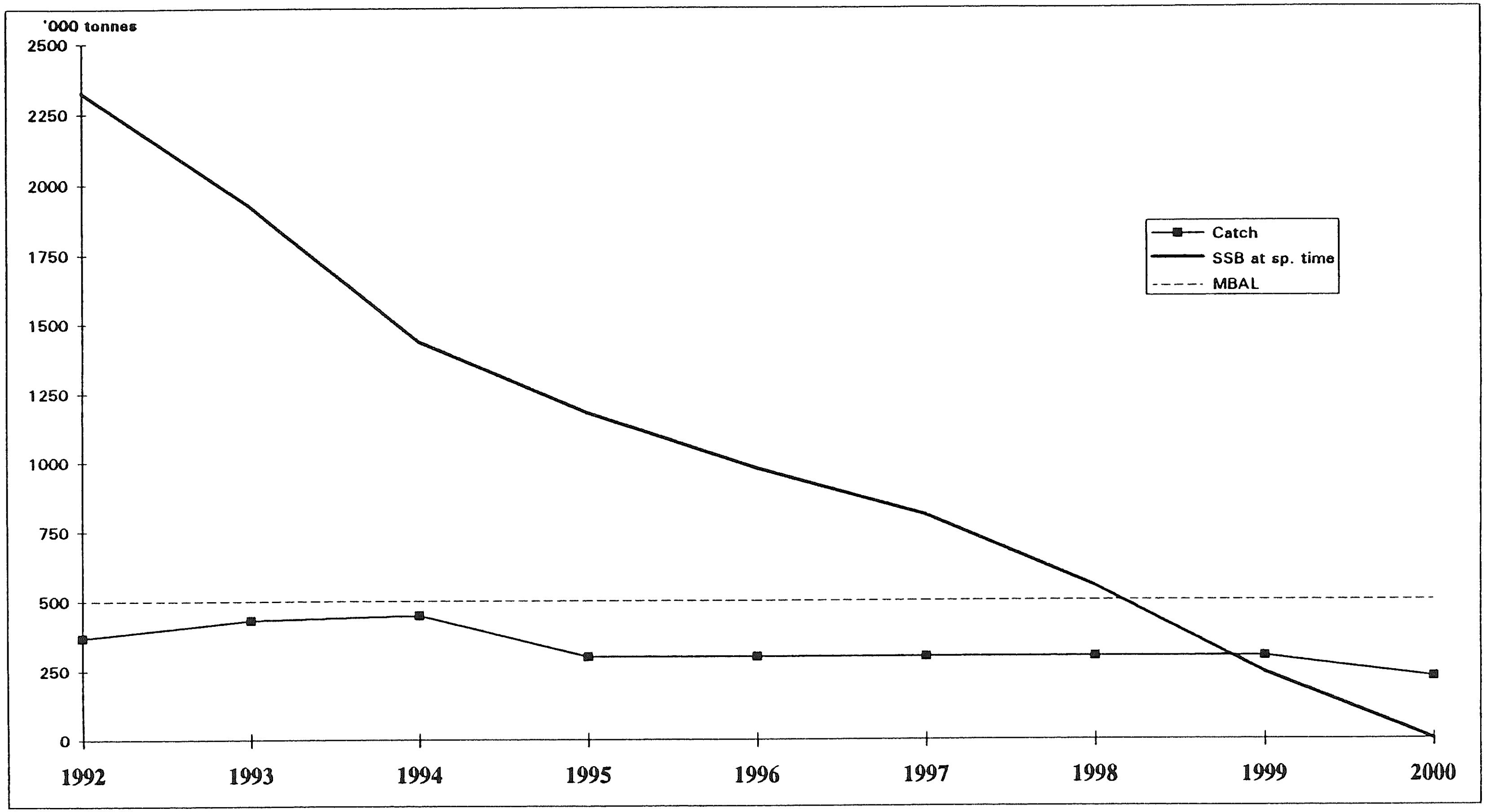



**Figure 9.6** The predicted decrease in spawning stock biomass of western horse mackerel if a TAC of 300,000 t is respected from 1995 onwards and assuming weak recruitment at age 1 from 1994 onwards.

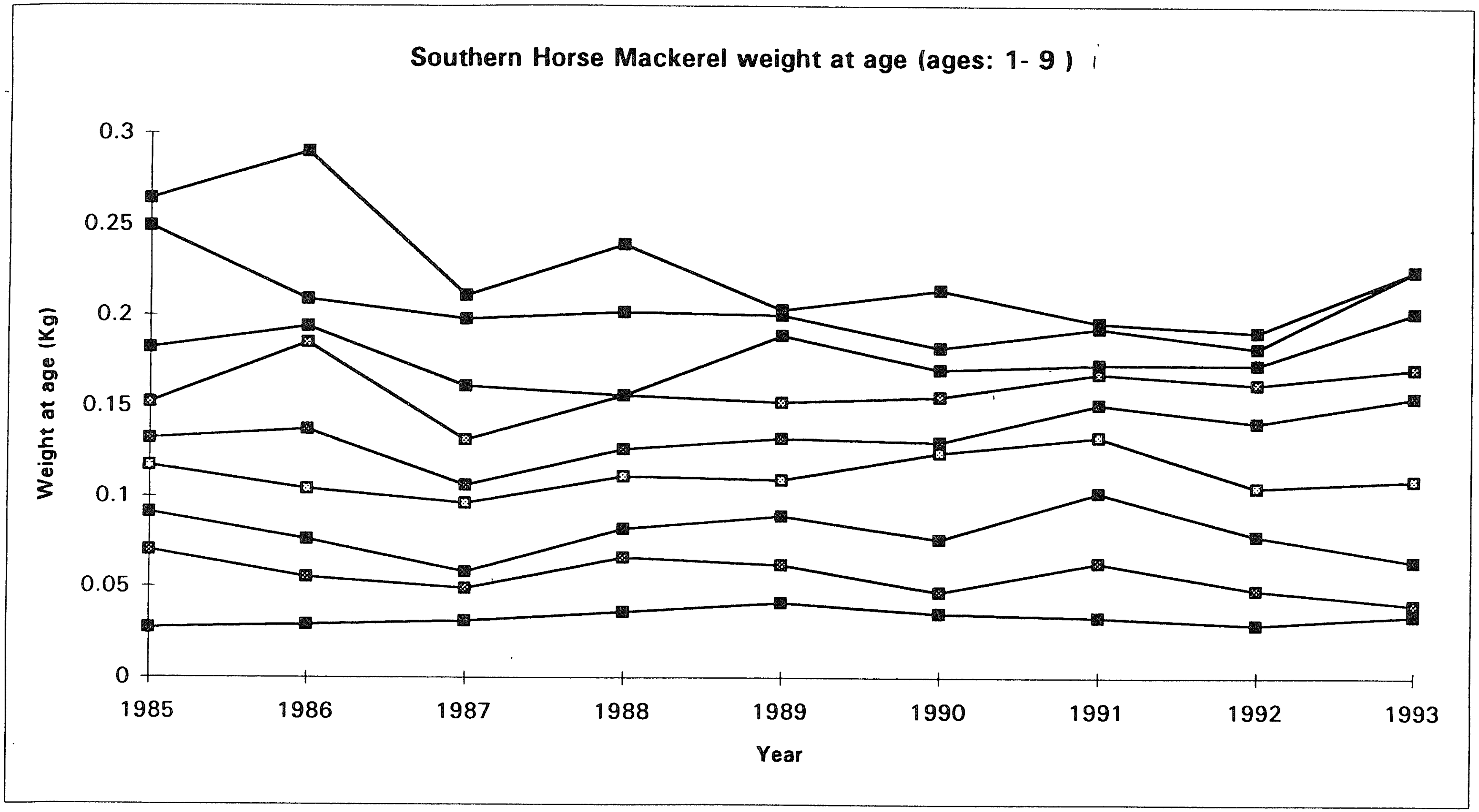



Fig. 10.1.- Mean weight at age in the catch (ages: 1 - 9 )

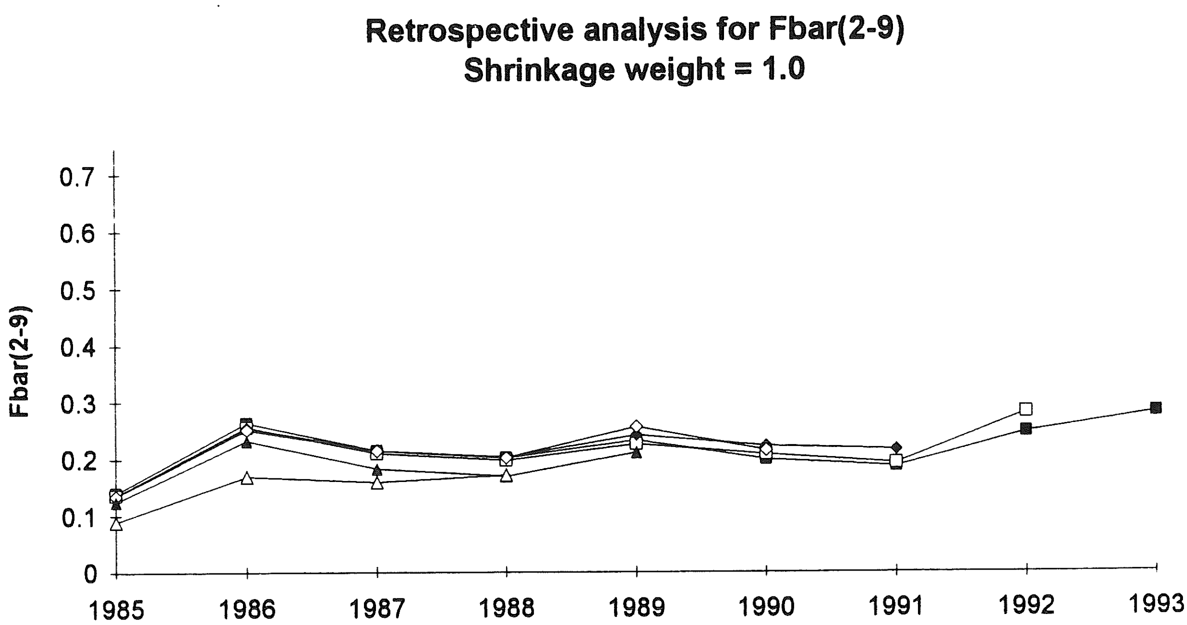



Fig. 10.2.- Southern Horse Mackerel Retrospective Analysis

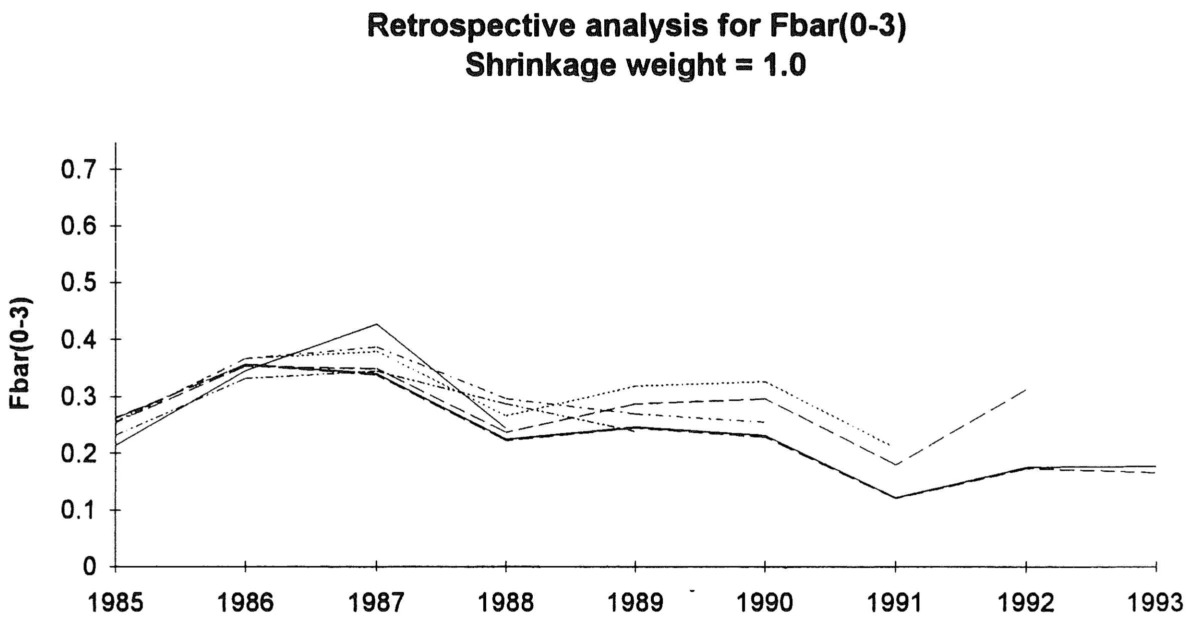



Fig. 10.3.- Southern Horse Mackerel Retrospective analysis

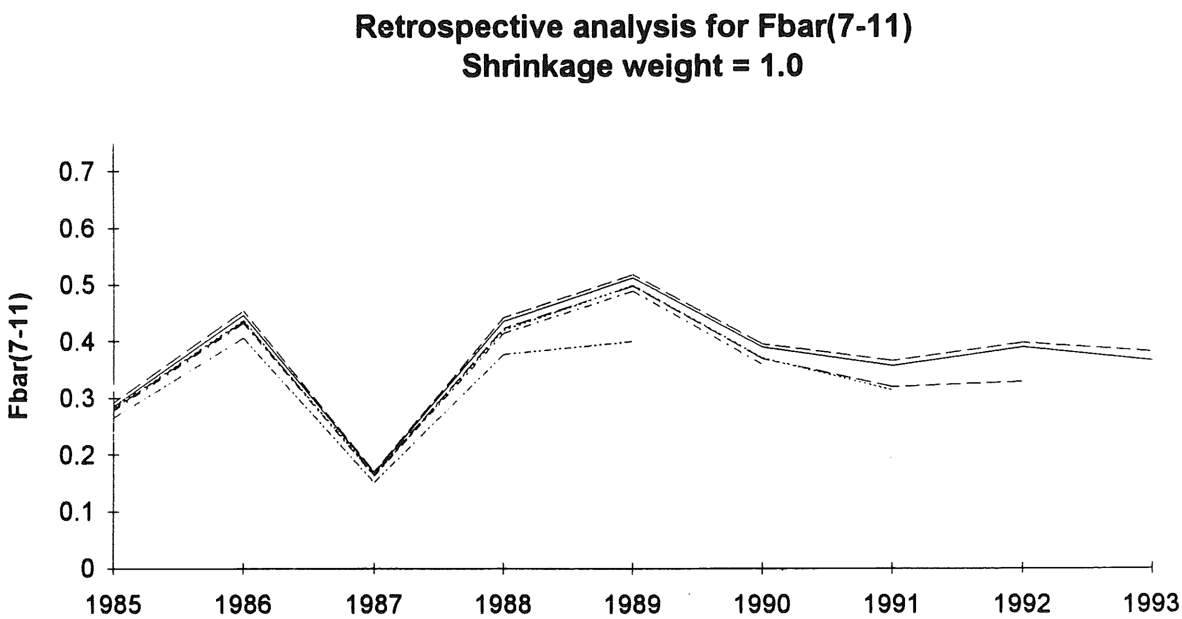
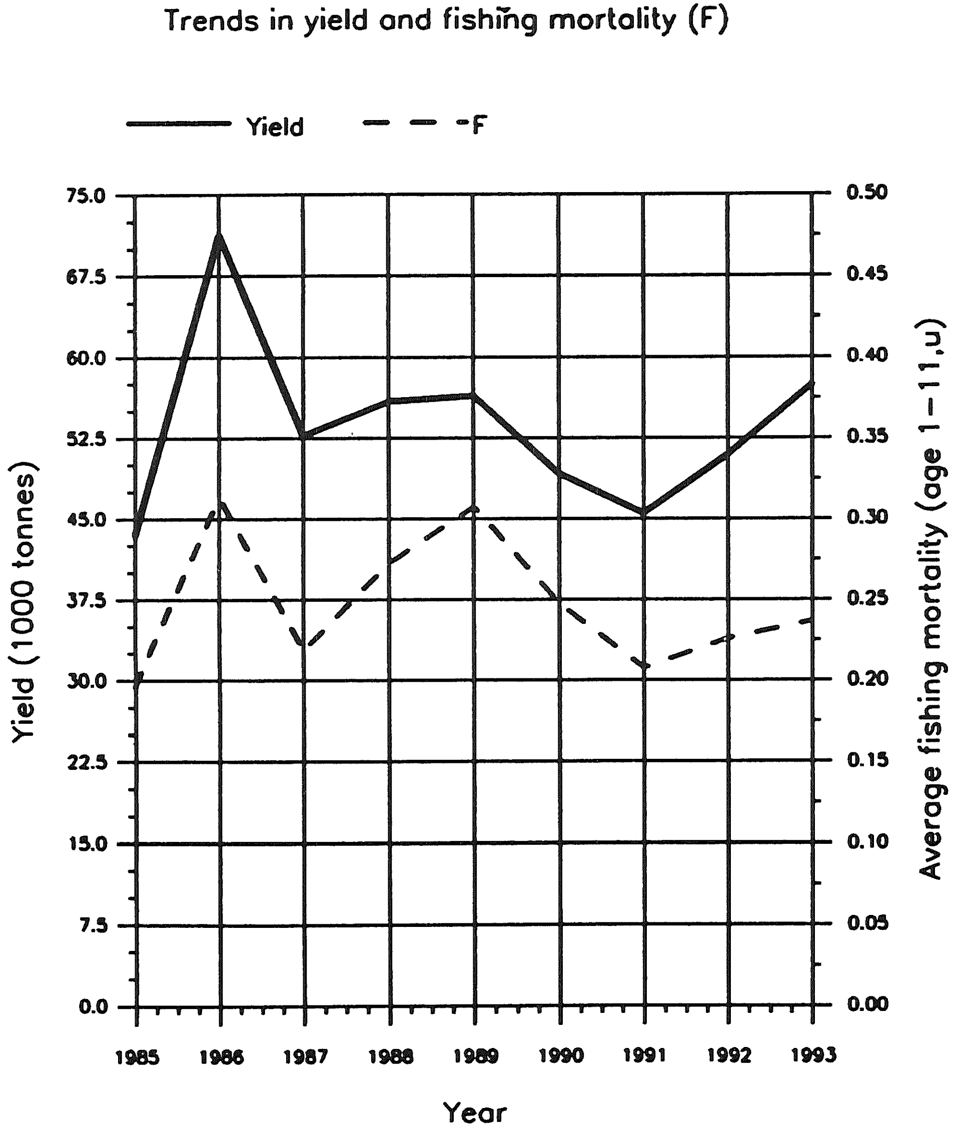



Fig. 10.4.- Southern Horse Mackerel Retrospective Analysis

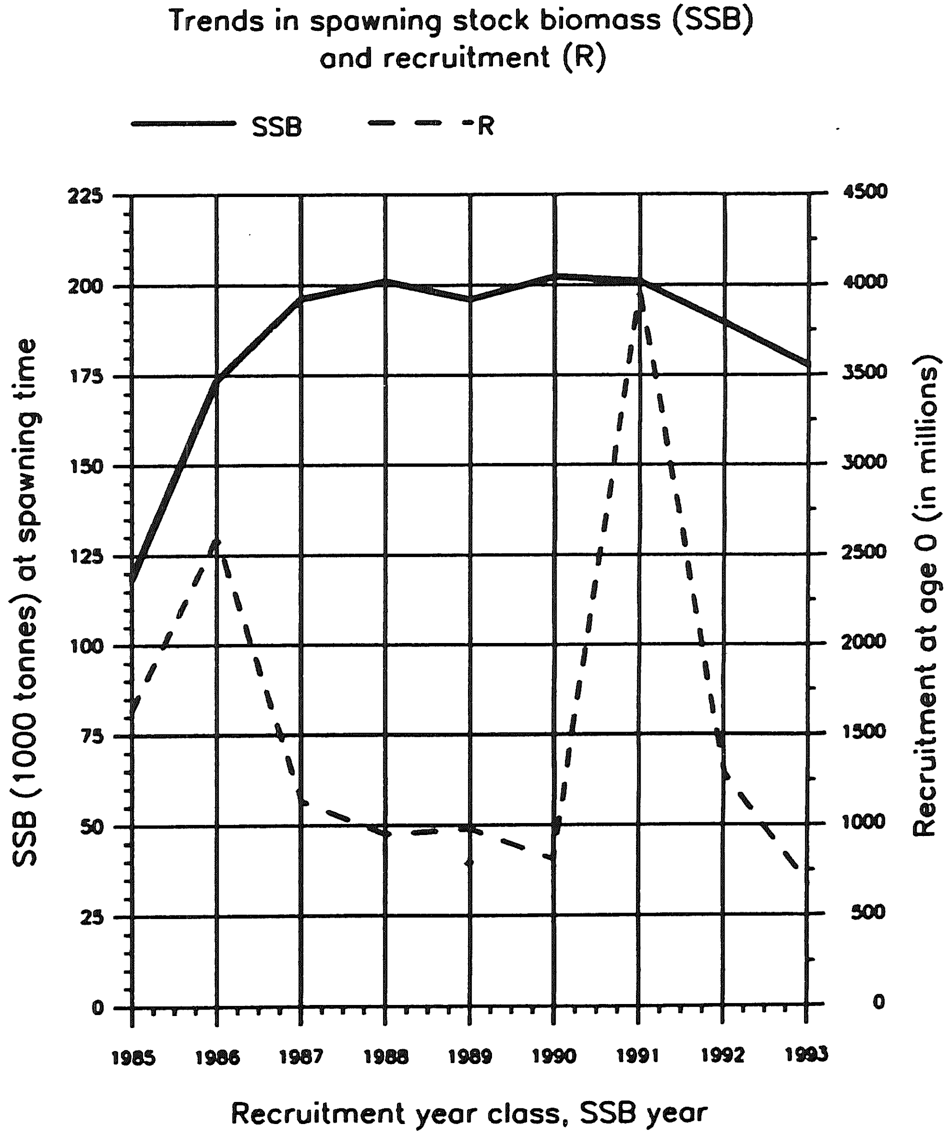
# FISH STOCK SUMMARY

Fig. 10.5.- **STOCK: Horse mackerel in Fishing Areas VIIIc and IXa**

**30–6–1994**




(run: JUREL35) **A**




(run: JUREL35) **B**

# FISH STOCK SUMMARY
# STOCK: Horse mackerel in Fishing Areas VIIIc and IXa
# 1-7-1994

Fig 10.6.-

Long term yield and spawning stock biomass

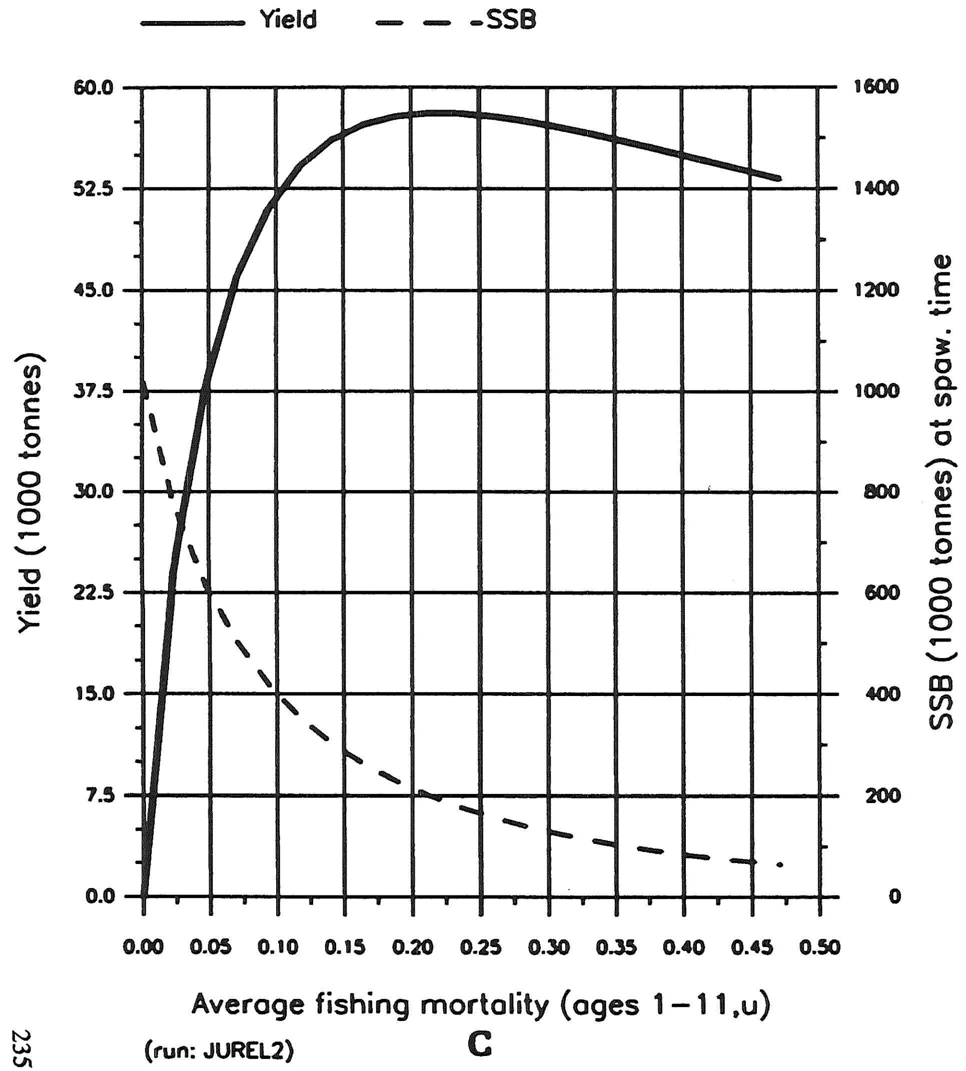



Fig 10.7.- Short-term yield and spawning stock biomass

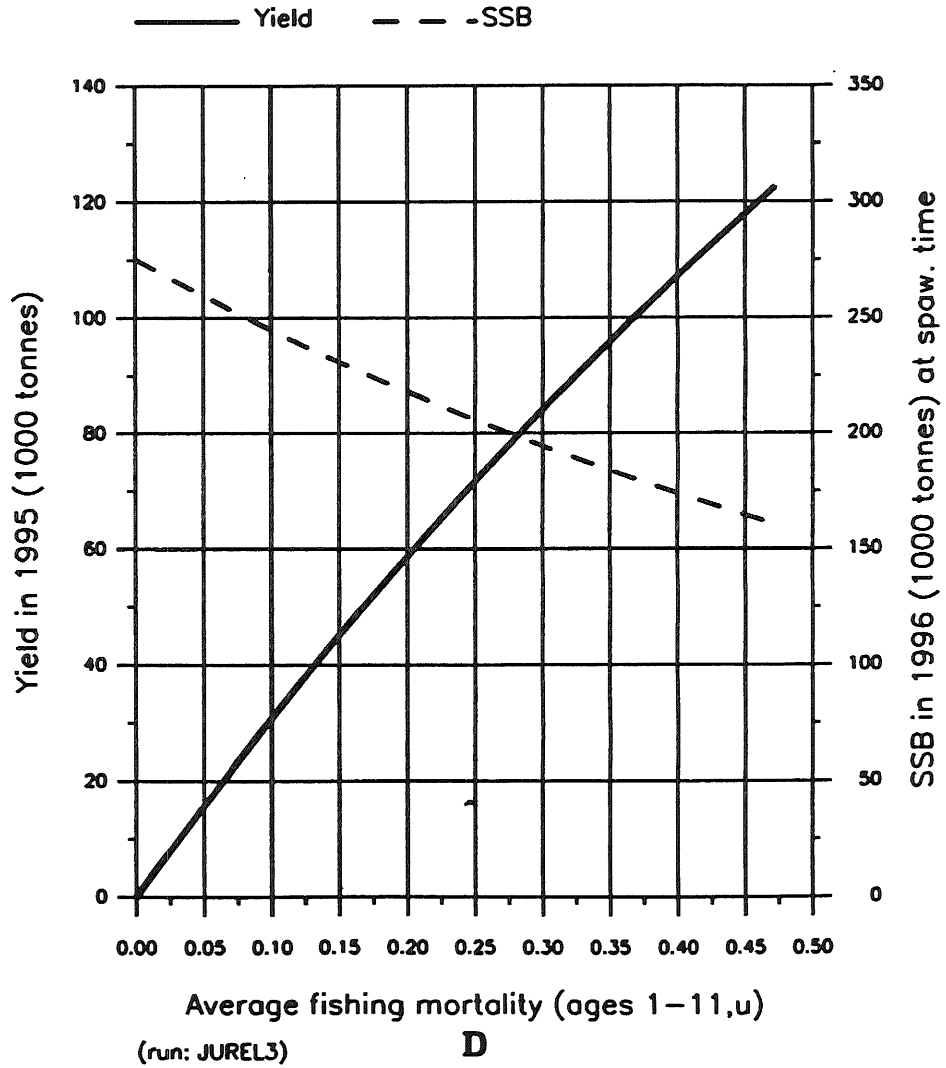
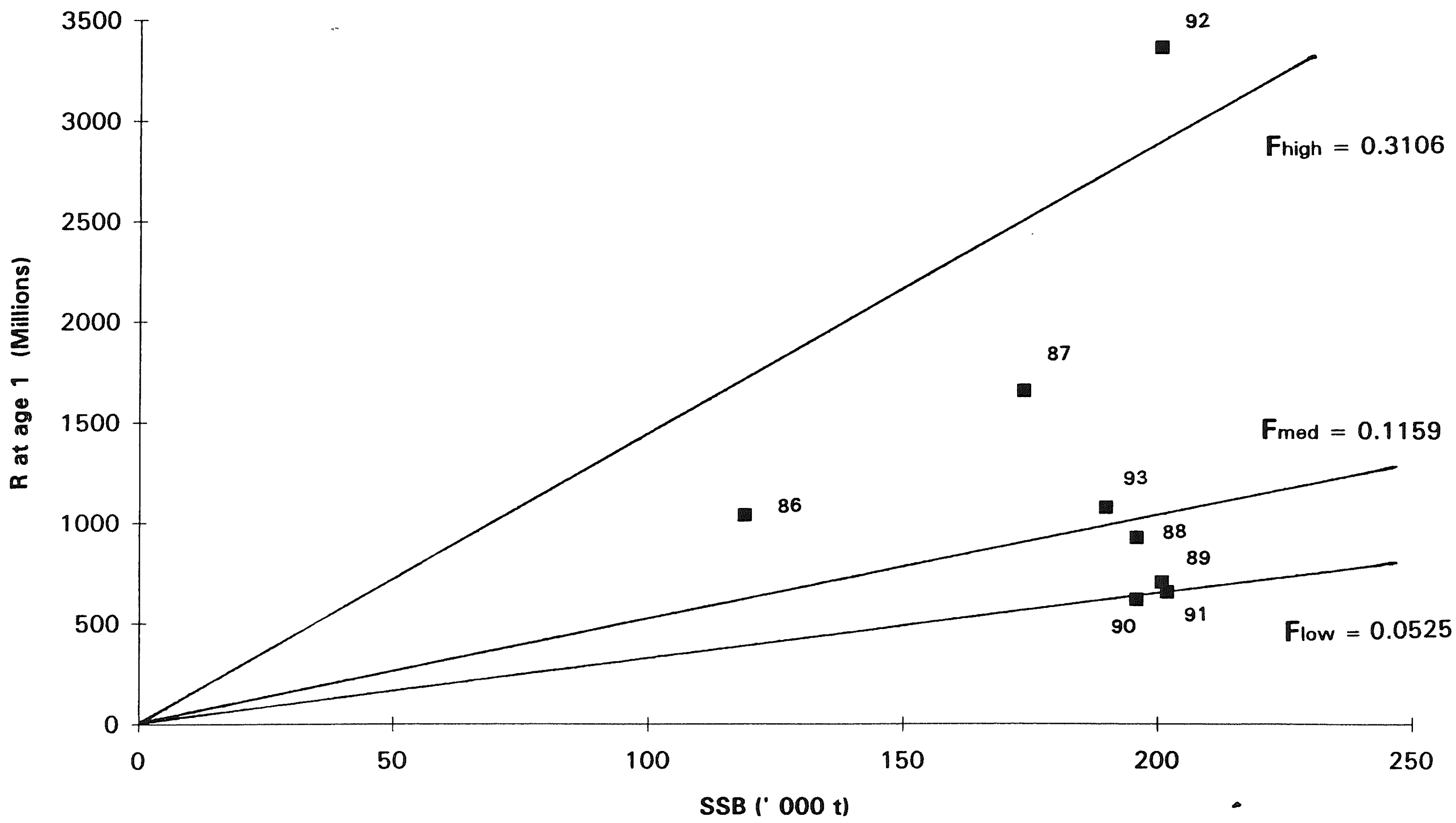


Fig 10.8 Southern horse mackerel. R1 versus SSB in previous year



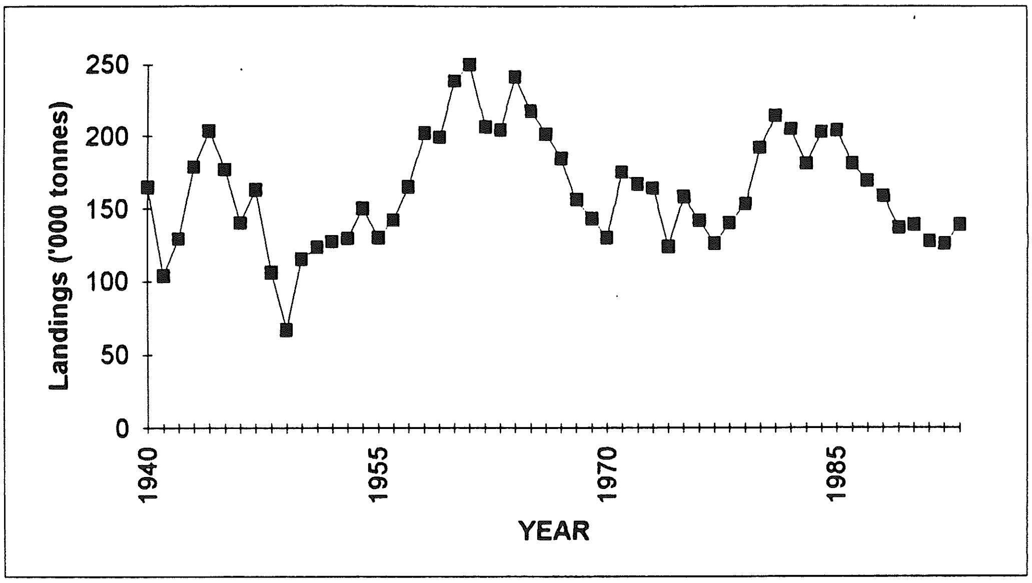



Figure 11.1 Total landings of sardine in Divisions VIIIc and IXa from 1940-1993.

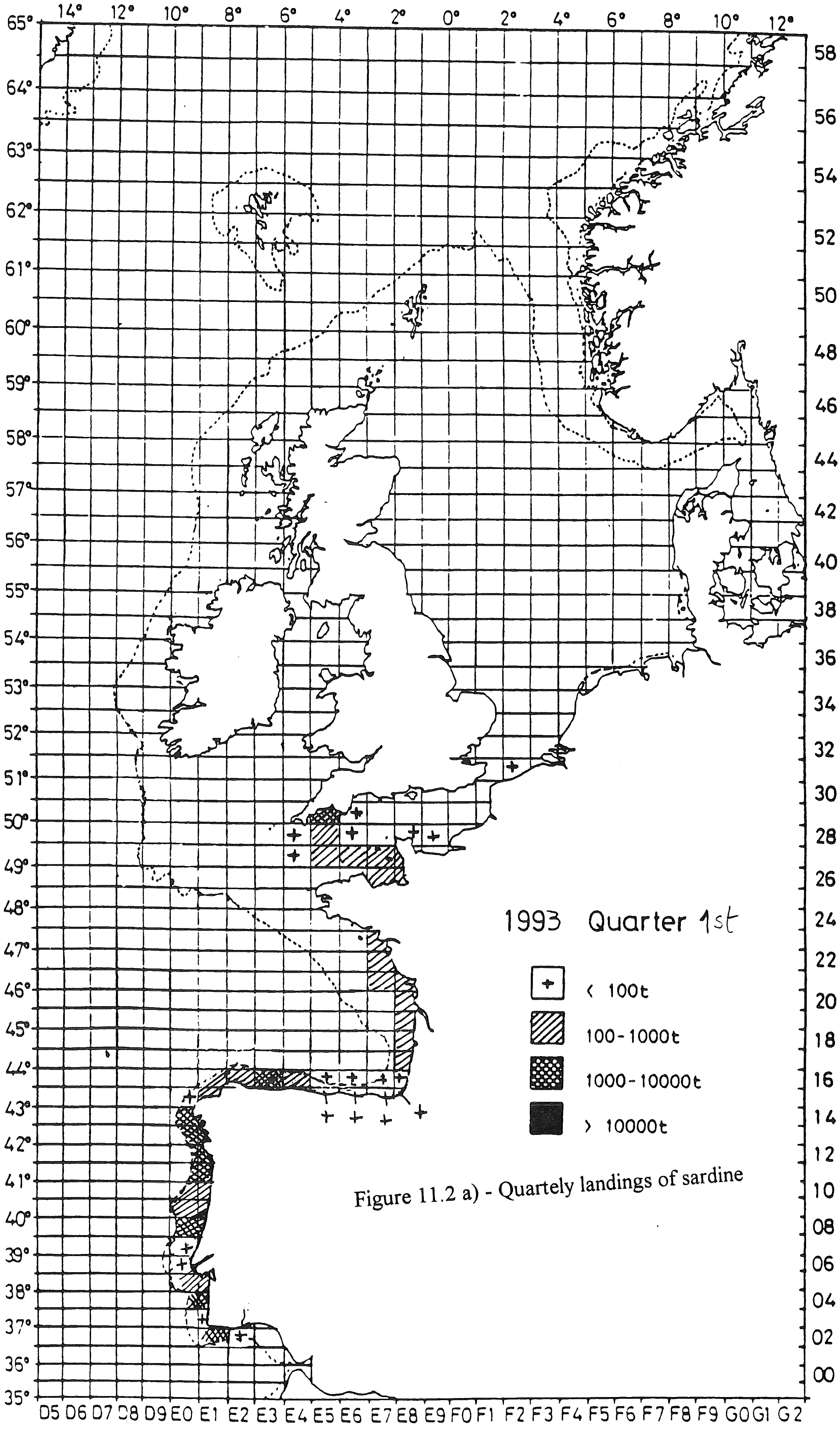



Figure 11.2 a) - Quartely landings of sardine

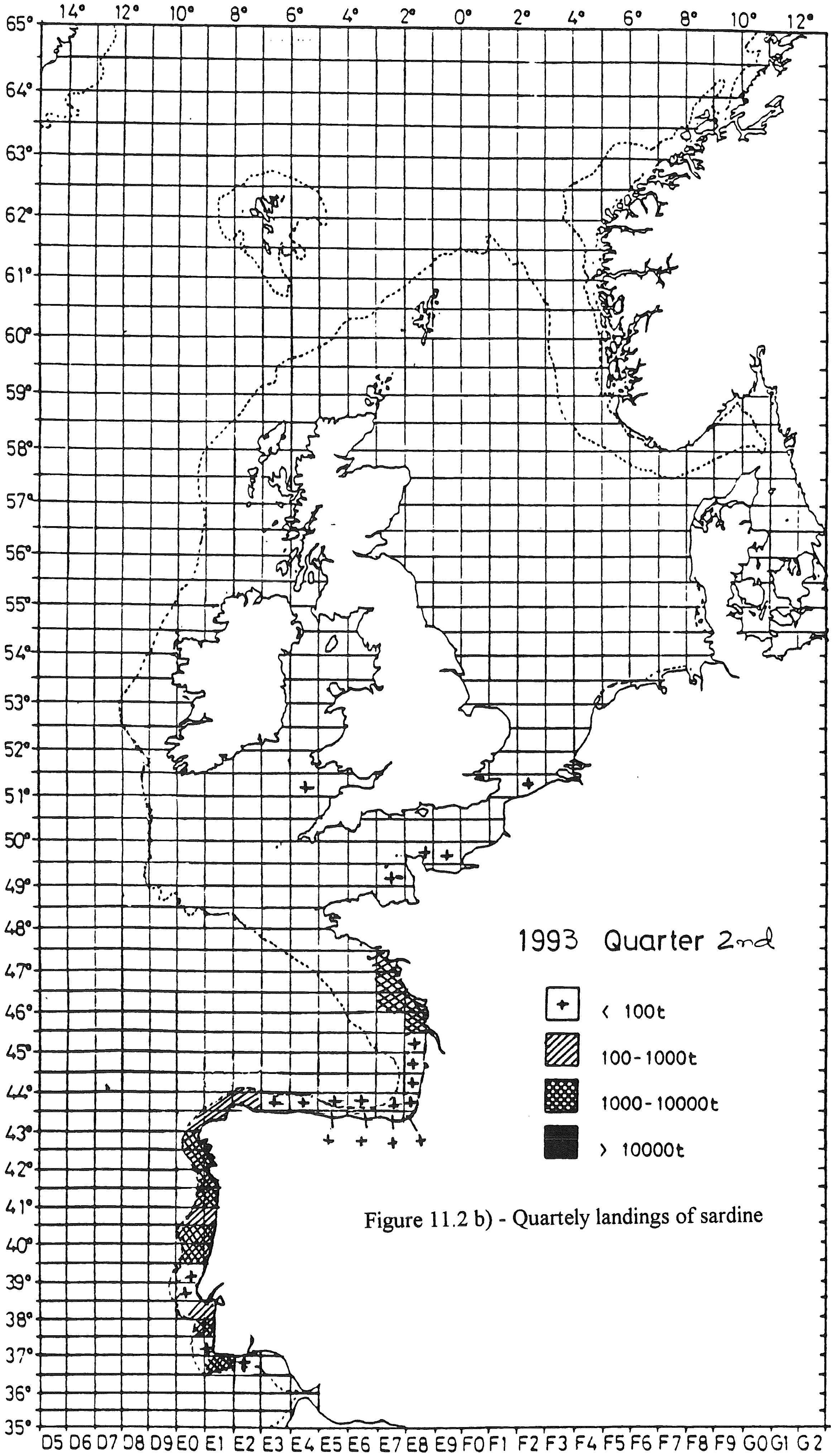



Figure 11.2 b) - Quartely landings of sardine

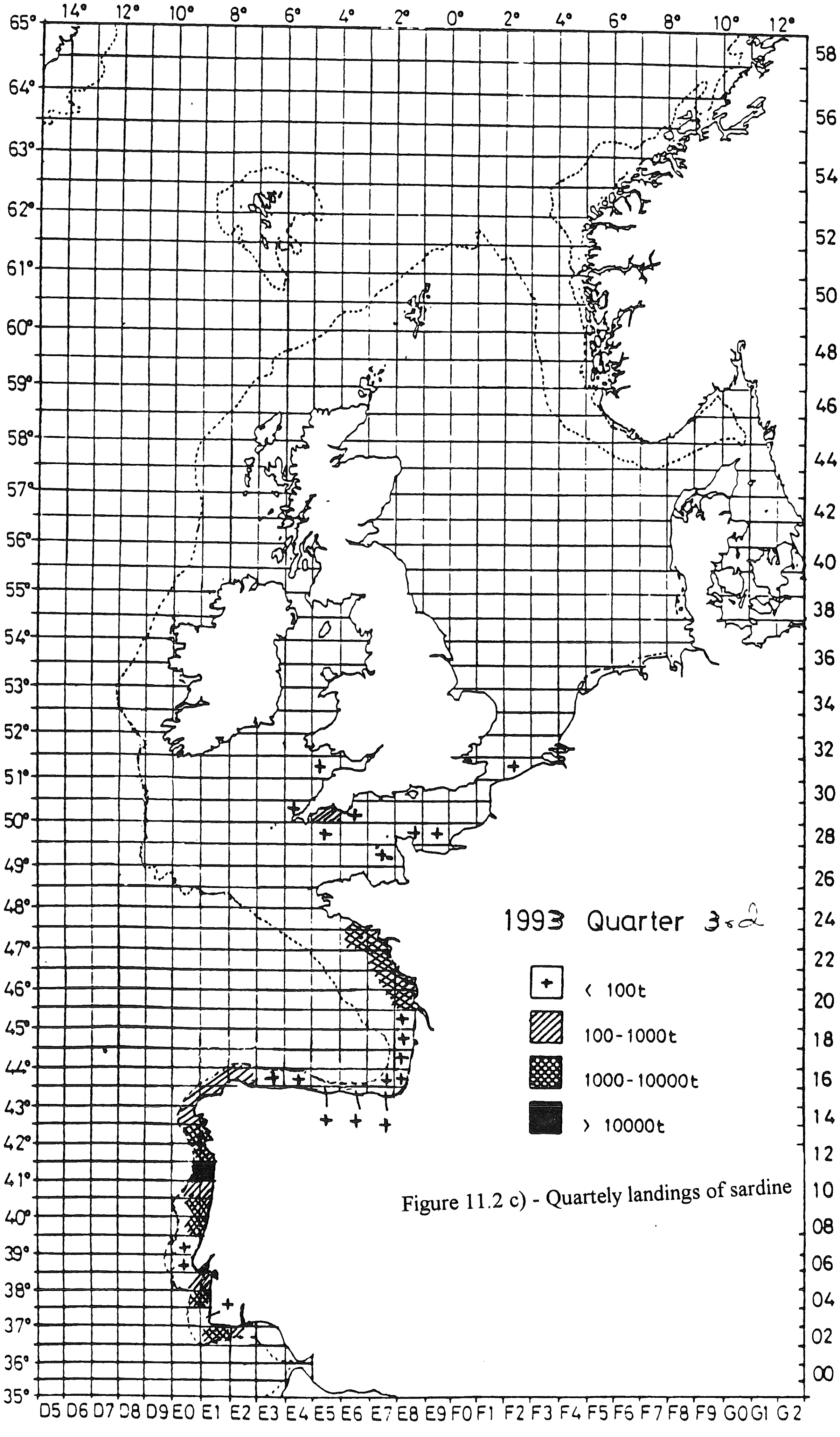



Figure 11.2 c) - Quartely landings of sardine

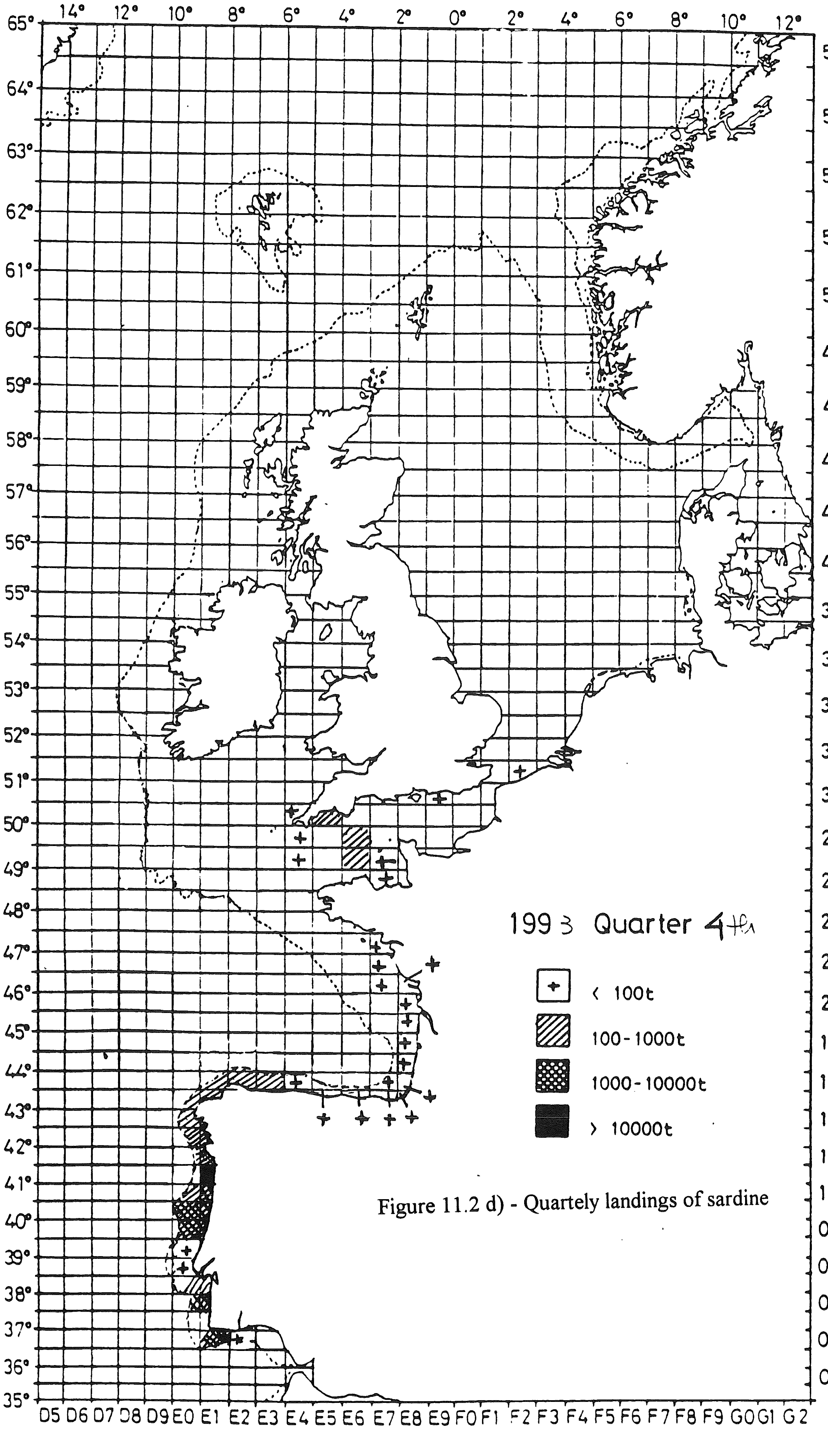



Figure 11.2 d) - Quartely landings of sardine

**Figure 11.3** ,SARDINE-CPUE data
from Purse seine fleets (DIV. VIIIc+IXa)

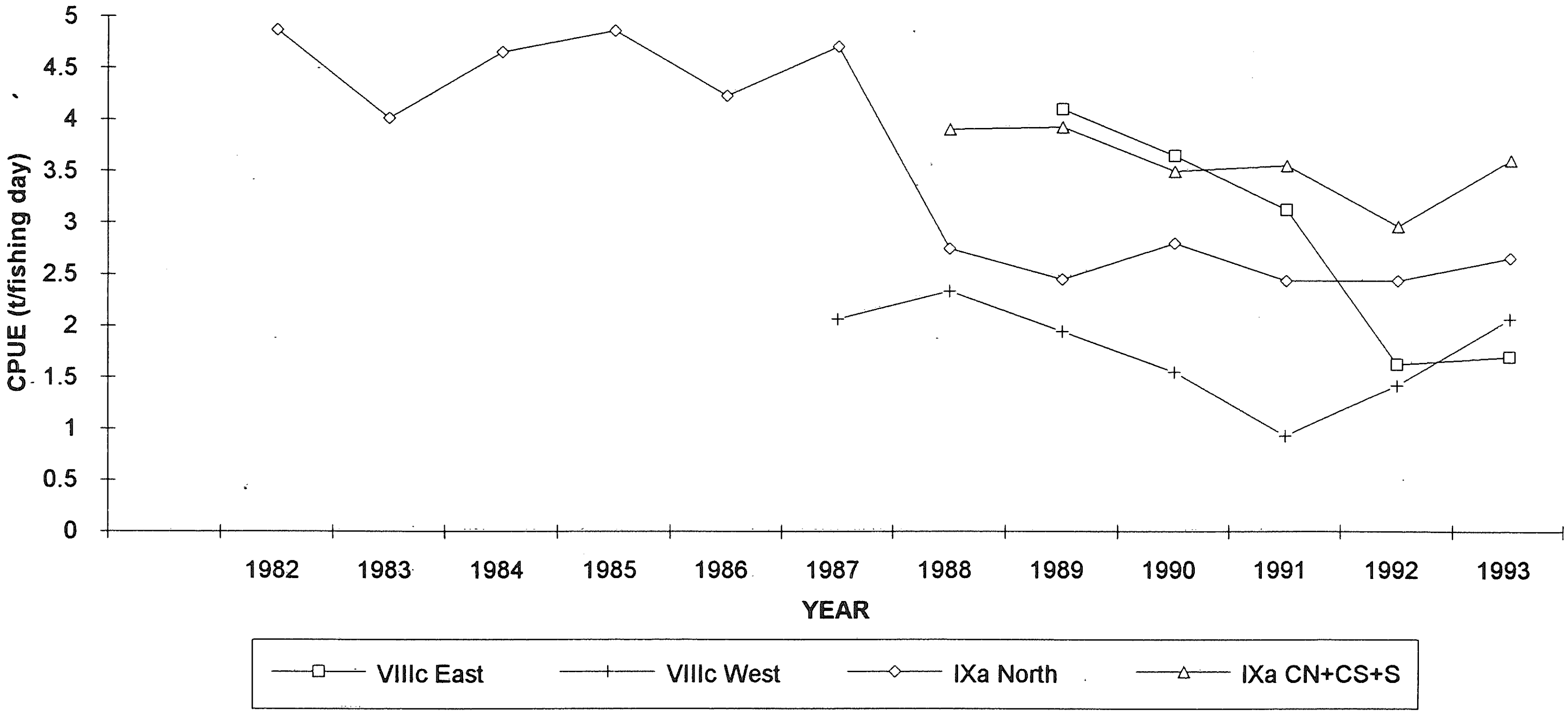


**Figure 11.4a** Stock summary and separable model diagnostics (Terminal S=1.0 relative to age 3 without plus-group in the fitting)

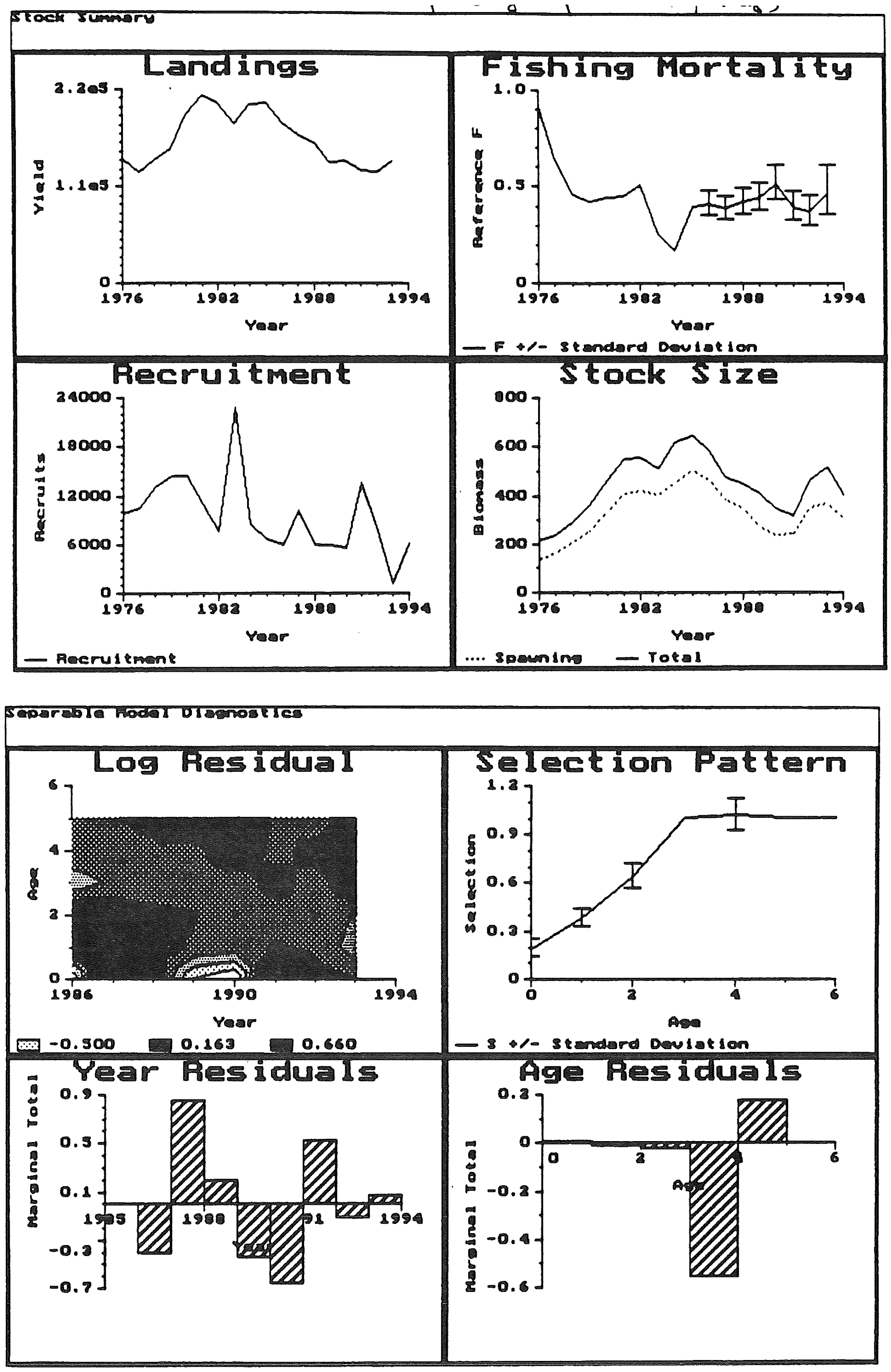


**Figure 11.4b** Tuning diagnostics: aged index 1 at ages 1, 2, 3 and 4.

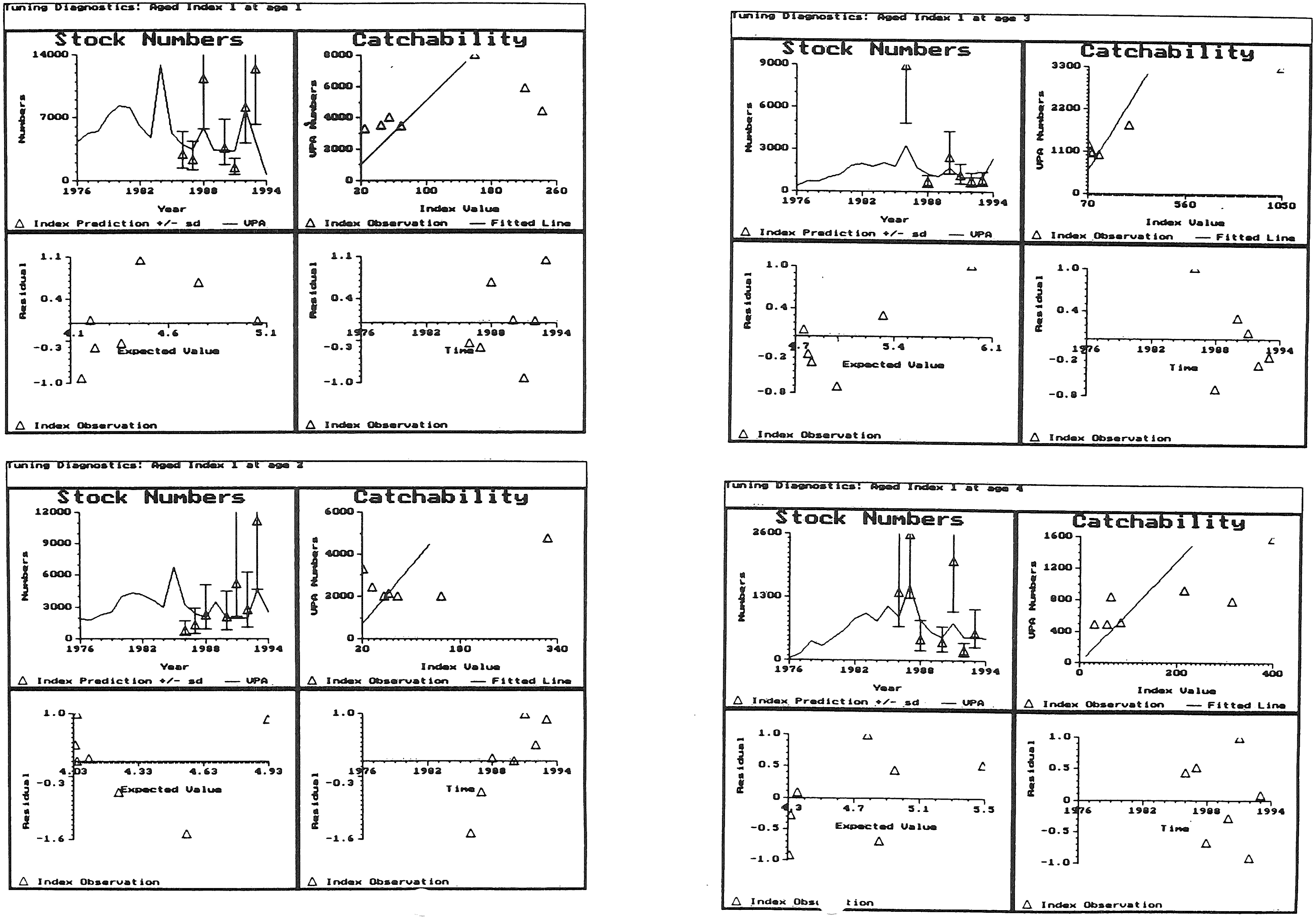


**Figure 11.4c** Tuning diagnostics: aged index 1 at ages 5 and 6.

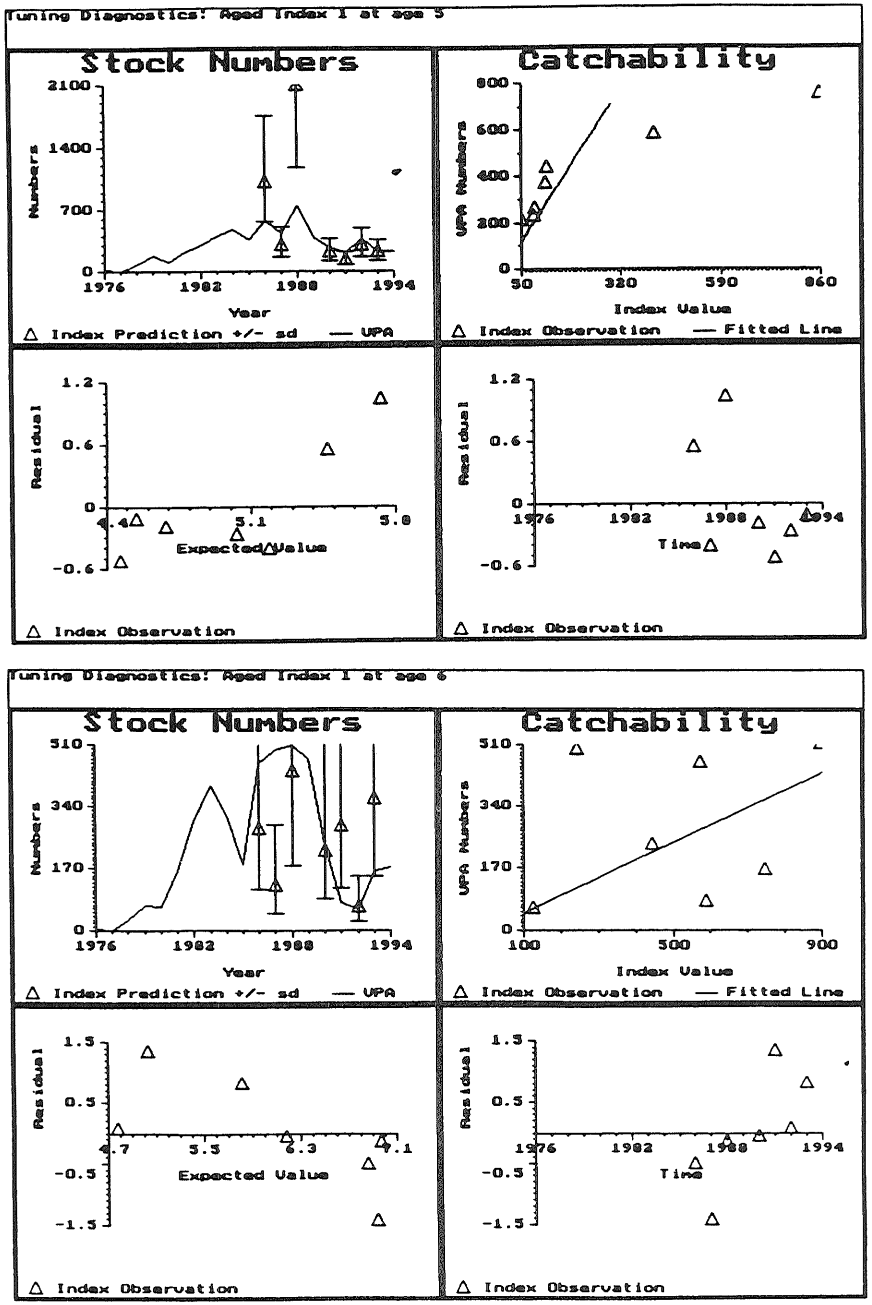


**Figure 11.4d** Tuning diagnostics: aged index 1 at ages 0, 1, 2 and 3.

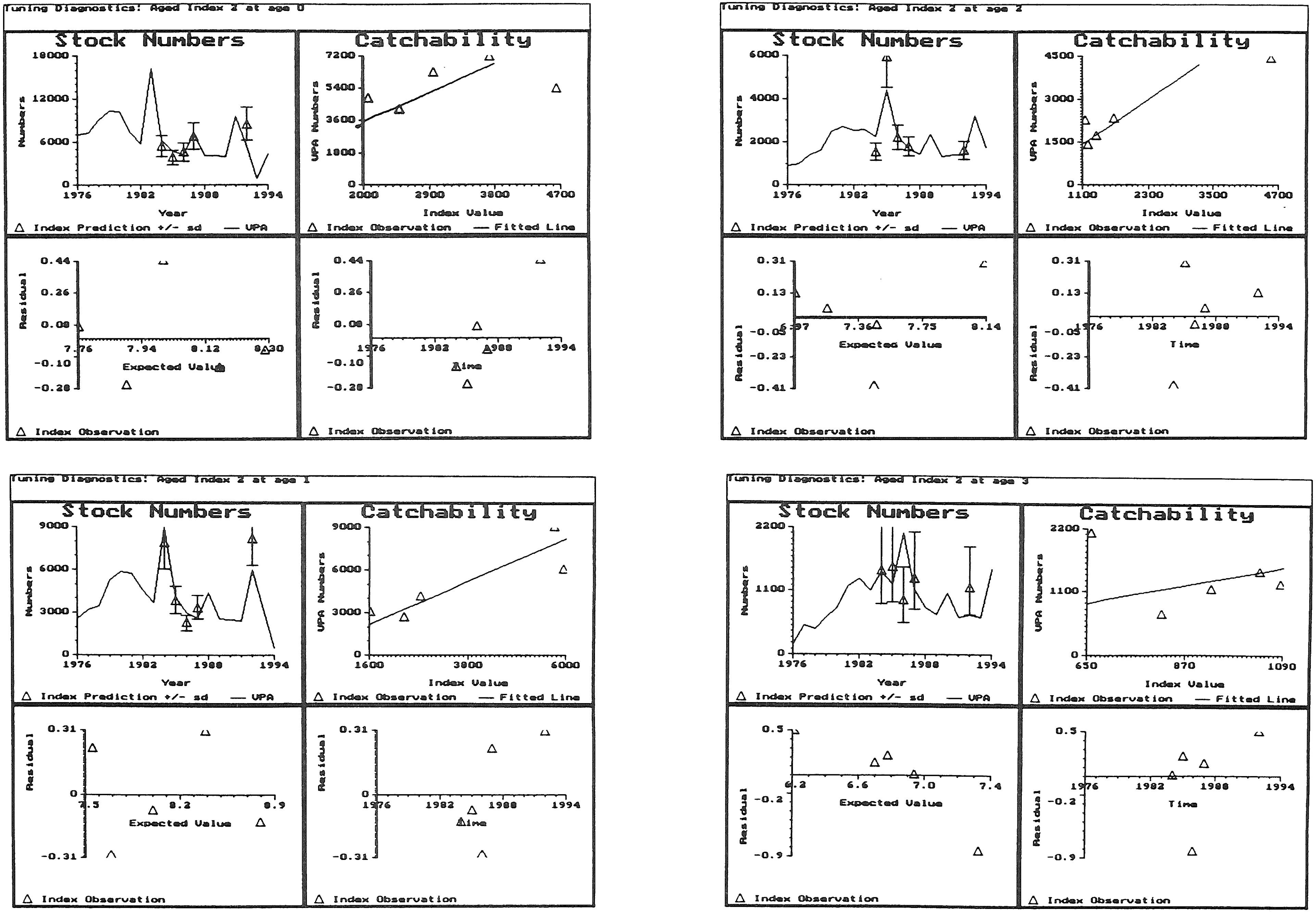
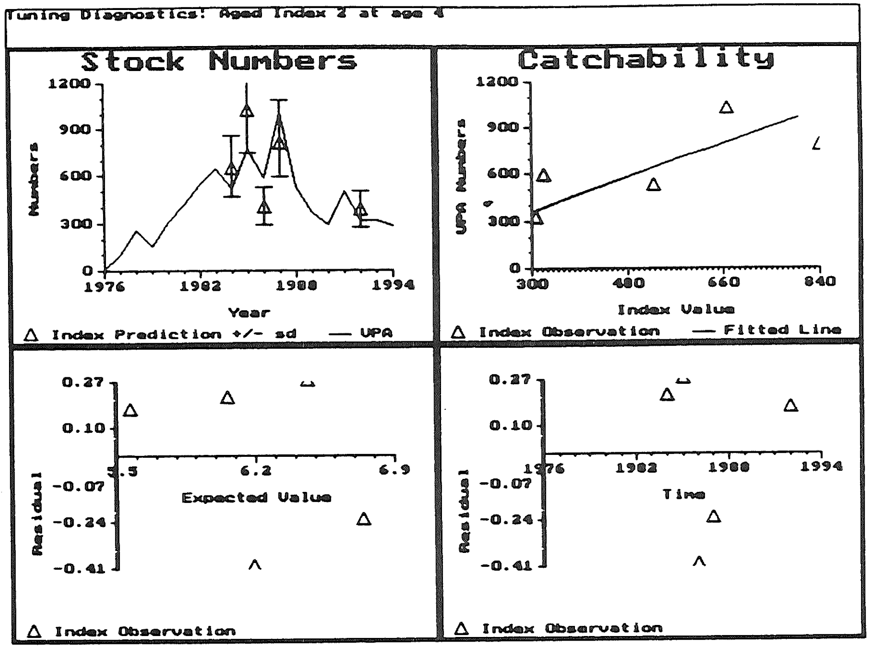
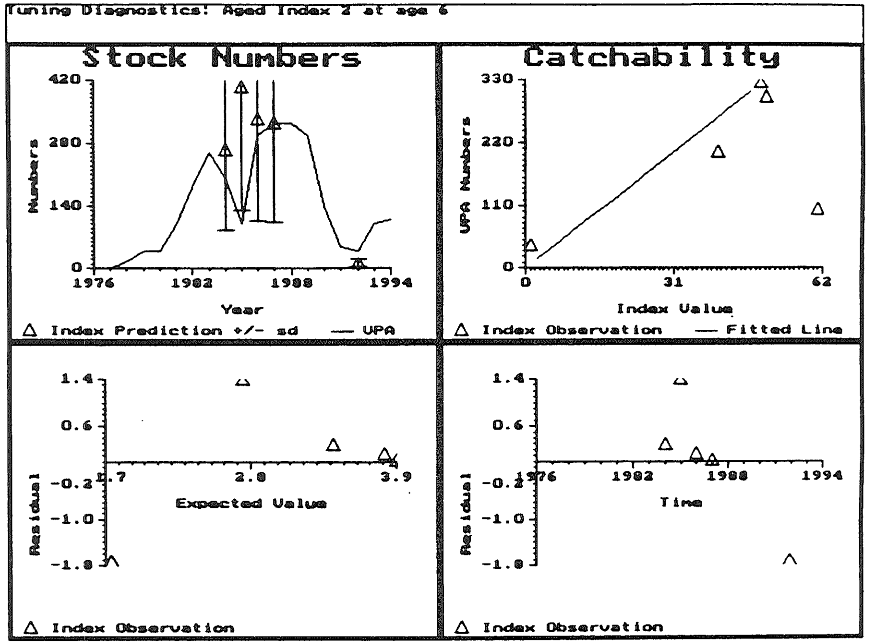


**Figure 11.4e** Tuning diagnostics: aged index 1 at ages 4, 5 and 6.



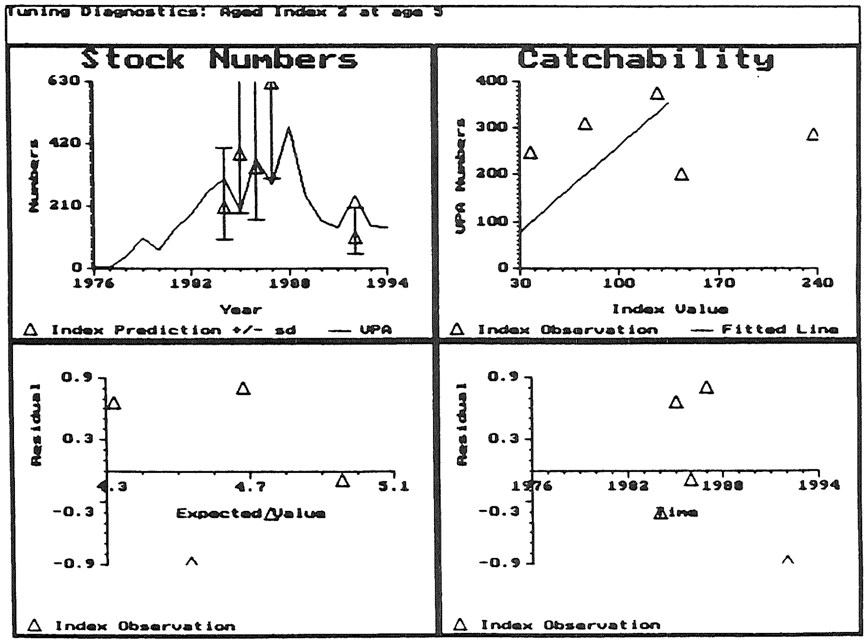
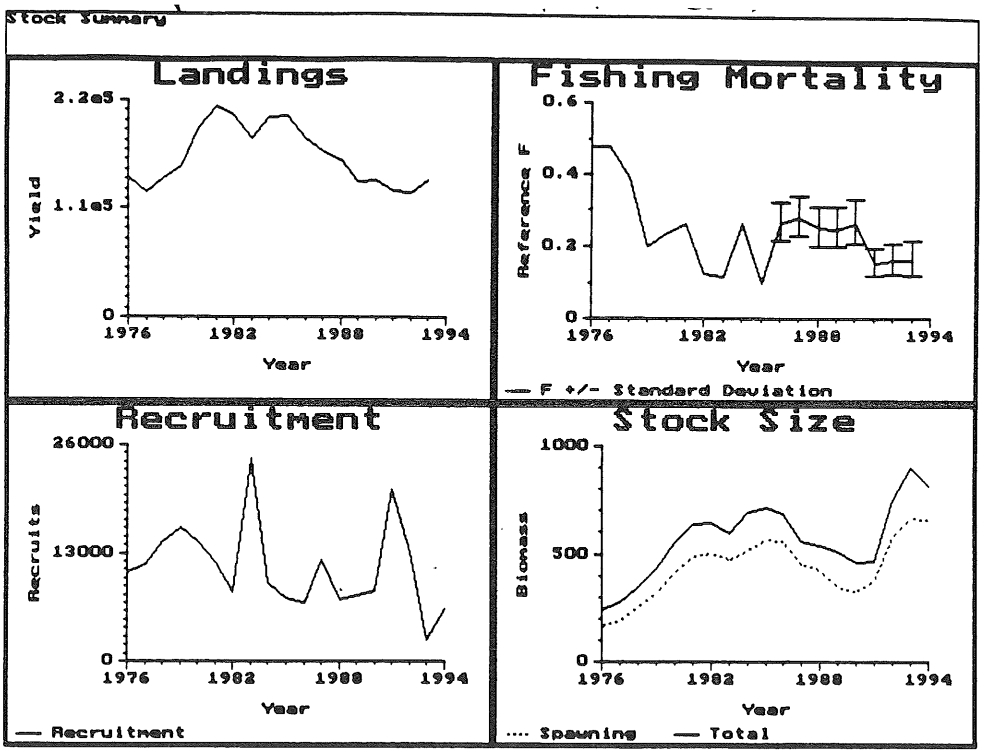



**Figure 11.5a** Stock summary and separable model diagnostics (terminal S = 1.25 relative to age 2, older fish in the Spanish acoustic surveys included).



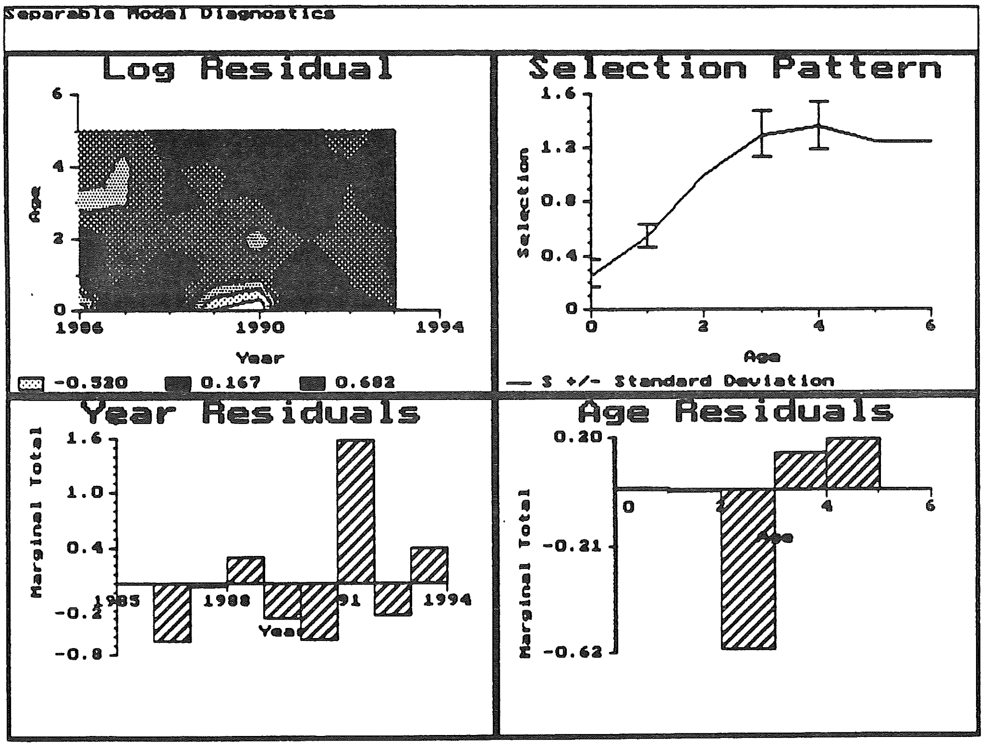



**Figure 11.5b** Tuning diagnostics: aged index 1 at age 1, 2, 3 and 4.

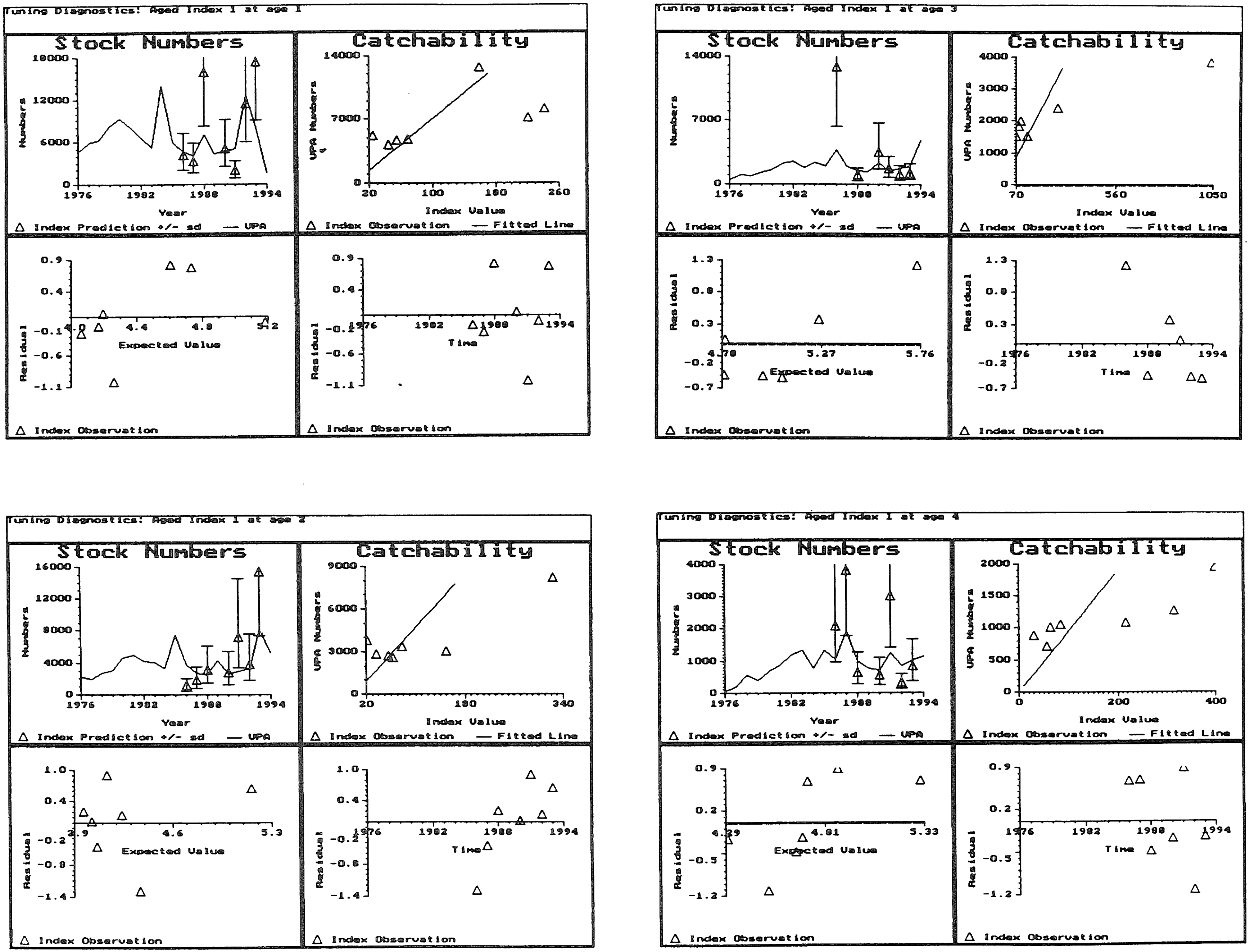
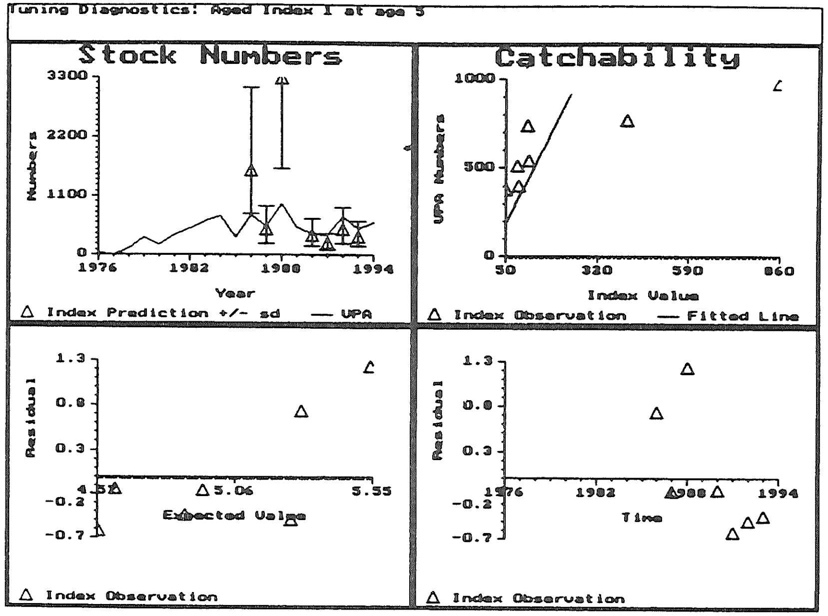


Figure 11.5b Tuning diagnostics: aged index 1 at age 5 and 6.



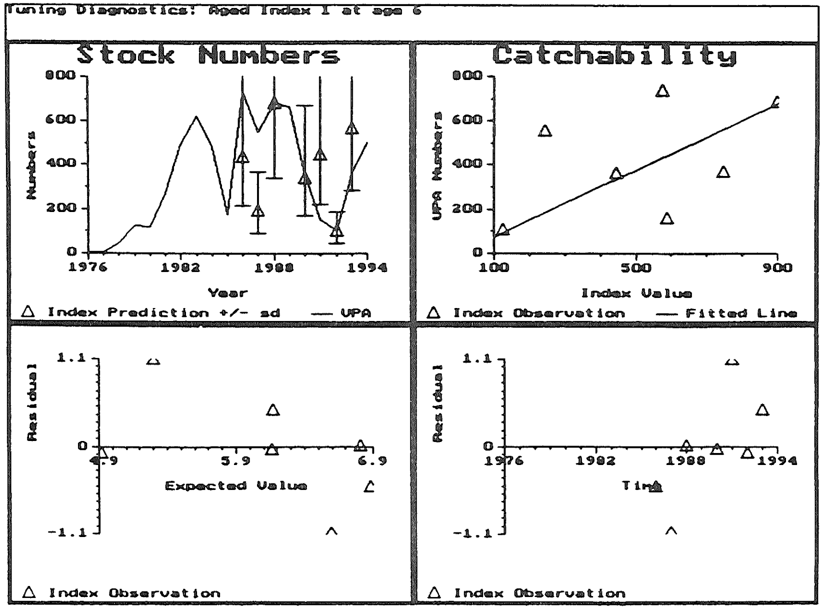



Figure 11.5d Tuning diagnostics: aged index 2 at age 0, 1 and 2.

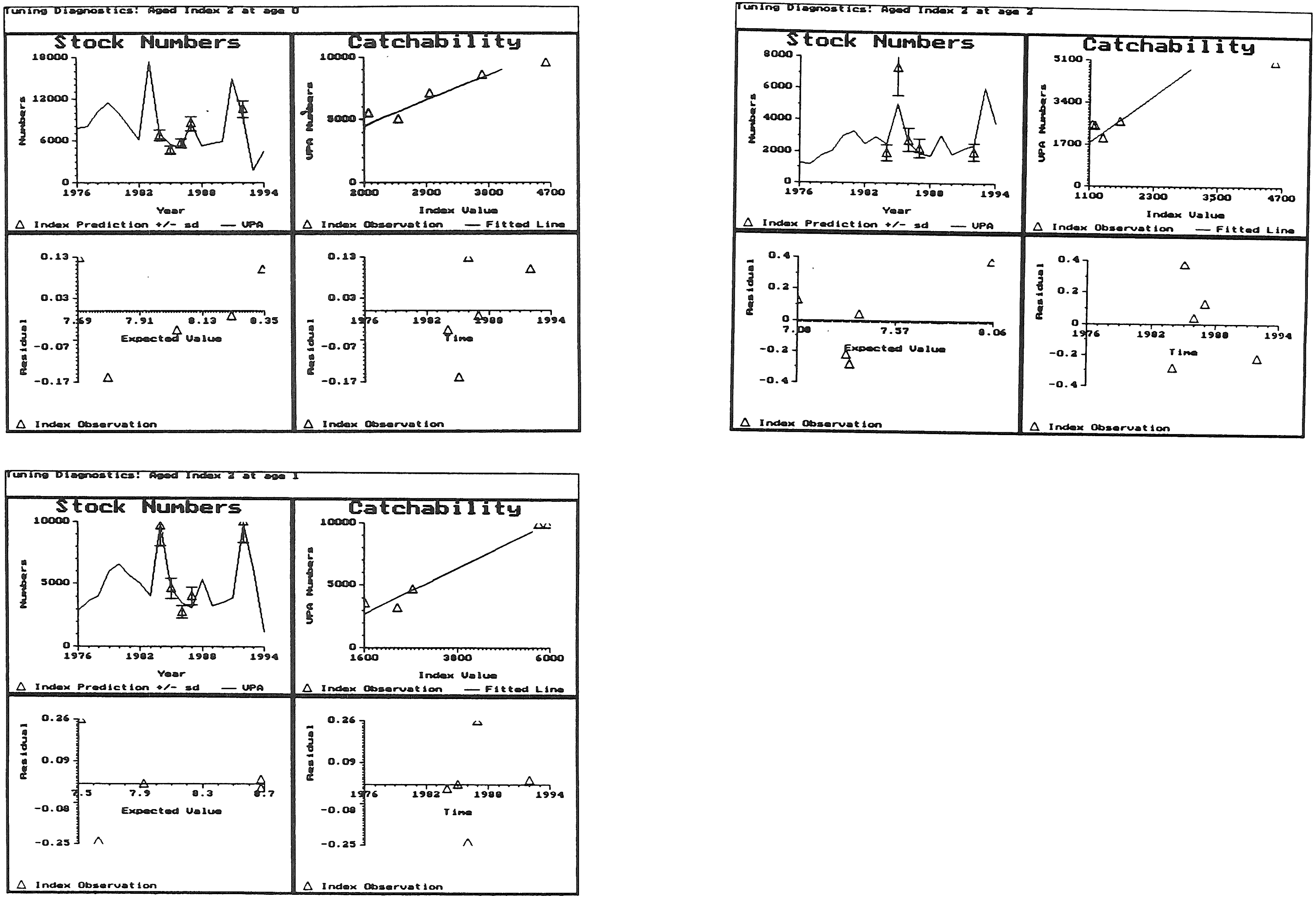
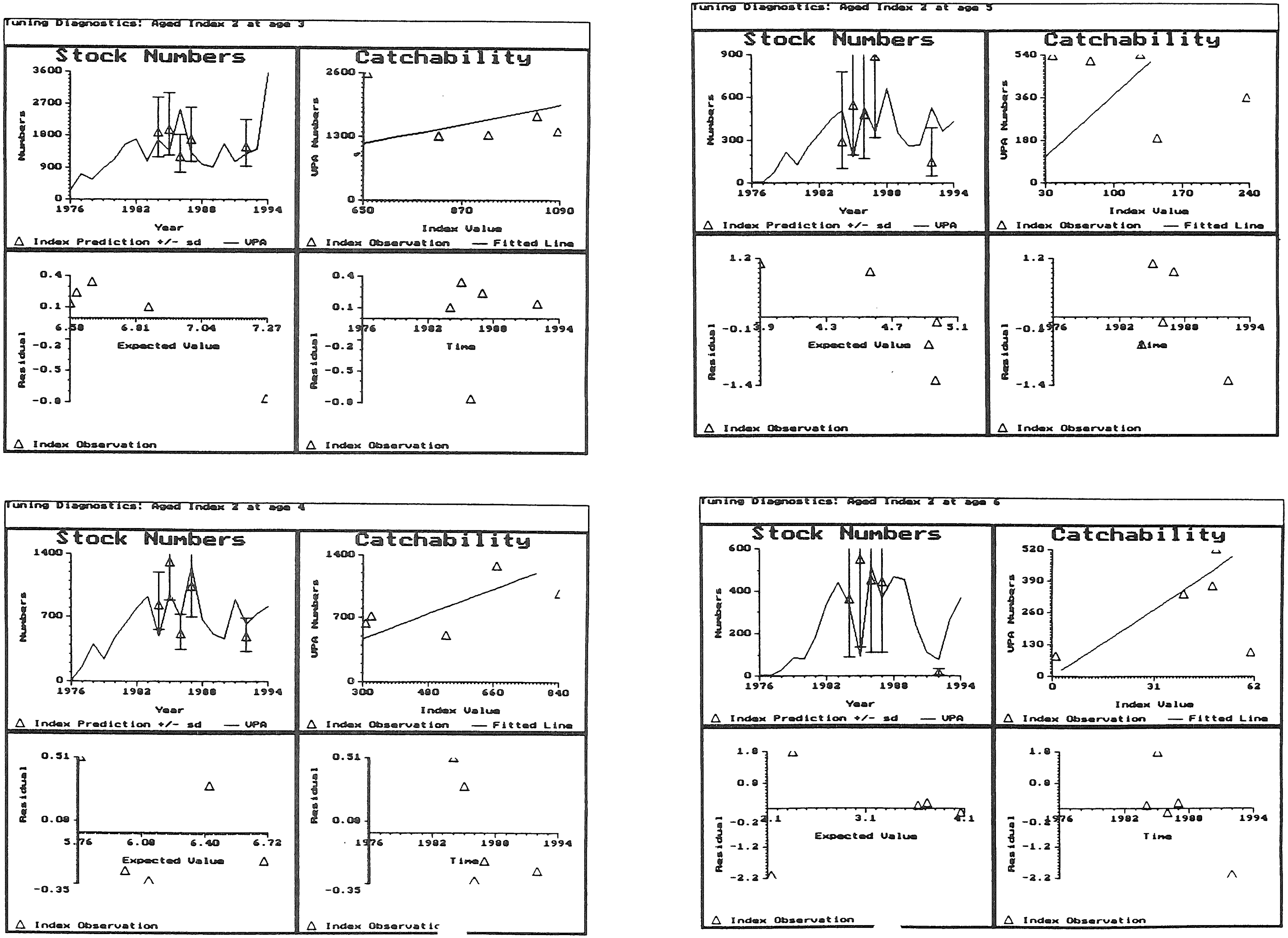


**Figure 11.5e** Tuning diagnostics: aged index 2 at age 3, 4, 5 and 6.



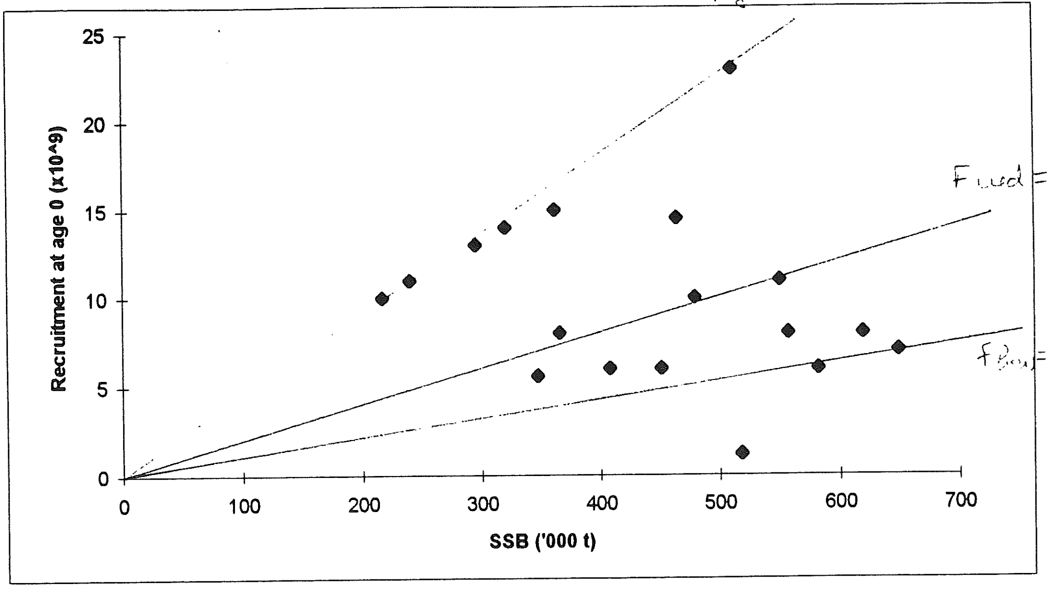



Figure 11.6. Sardine Recruitment ploited against spawning stock biomass at spawning time (Assessment, S = 1.0) $(F_{1991-1993} = 0.306)$

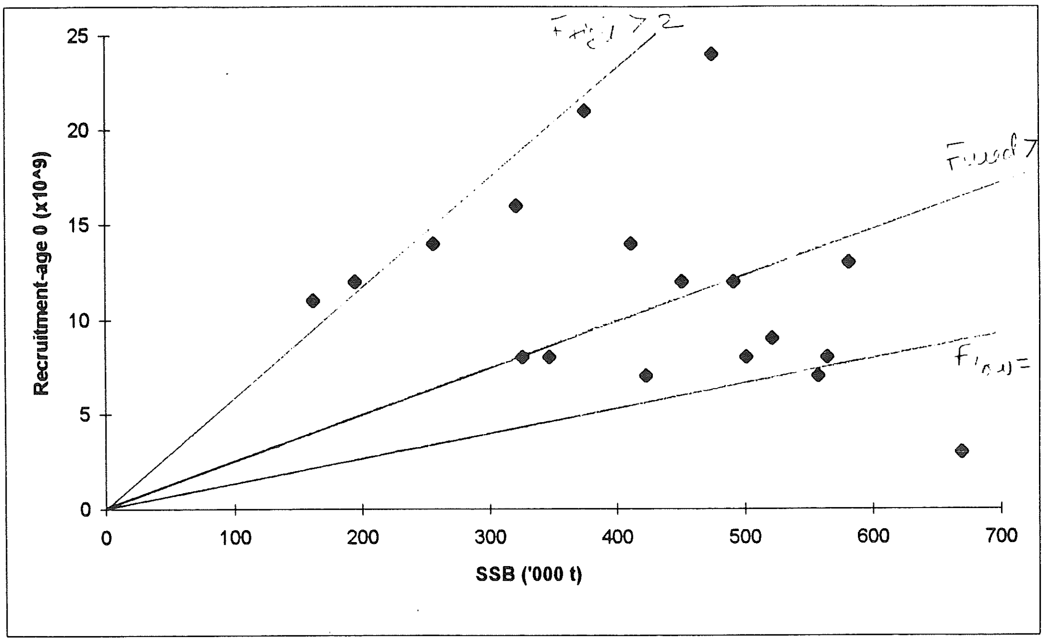


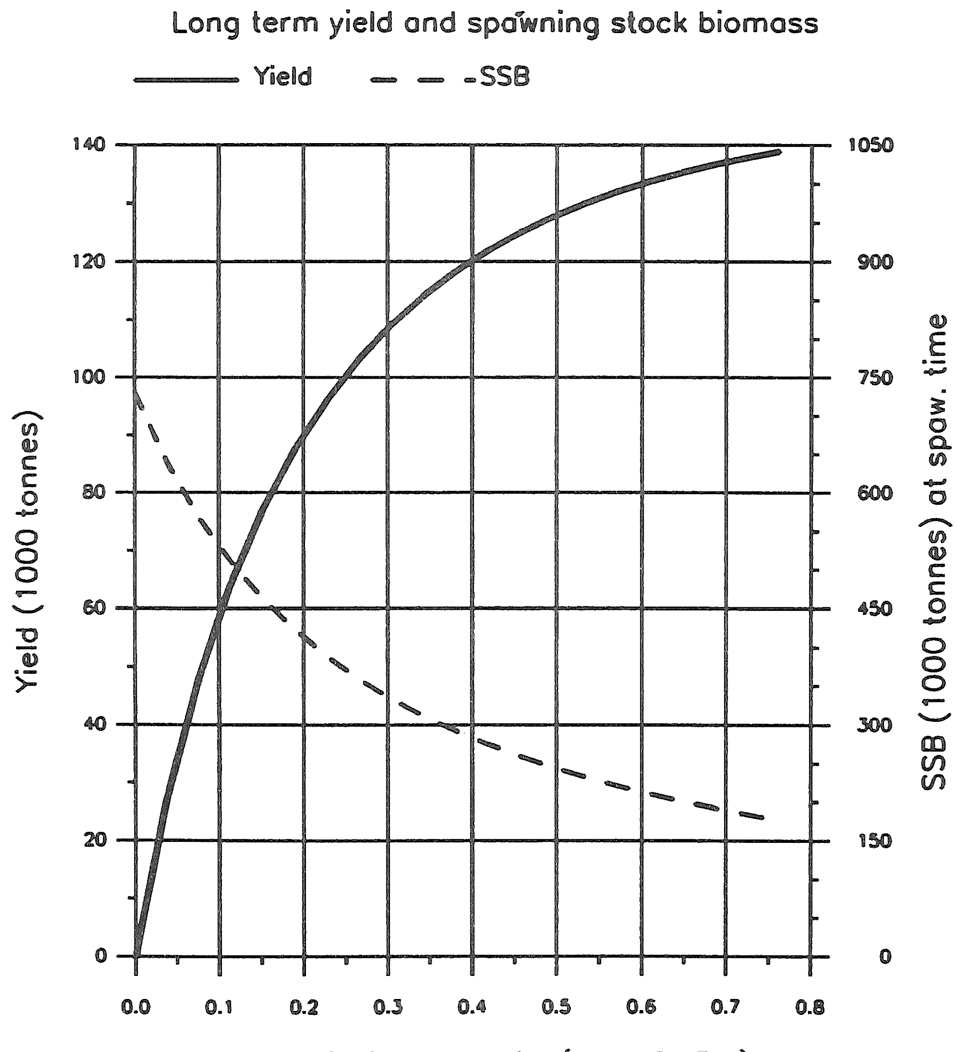

Figure 11.7. Sardine recruitment ploited against spawning stock biomass at spawning time (Assessment, S = 1.25) $(F_{1991-93} = 0.159)$

# FISH STOCK SUMMARY

Figure 11.8

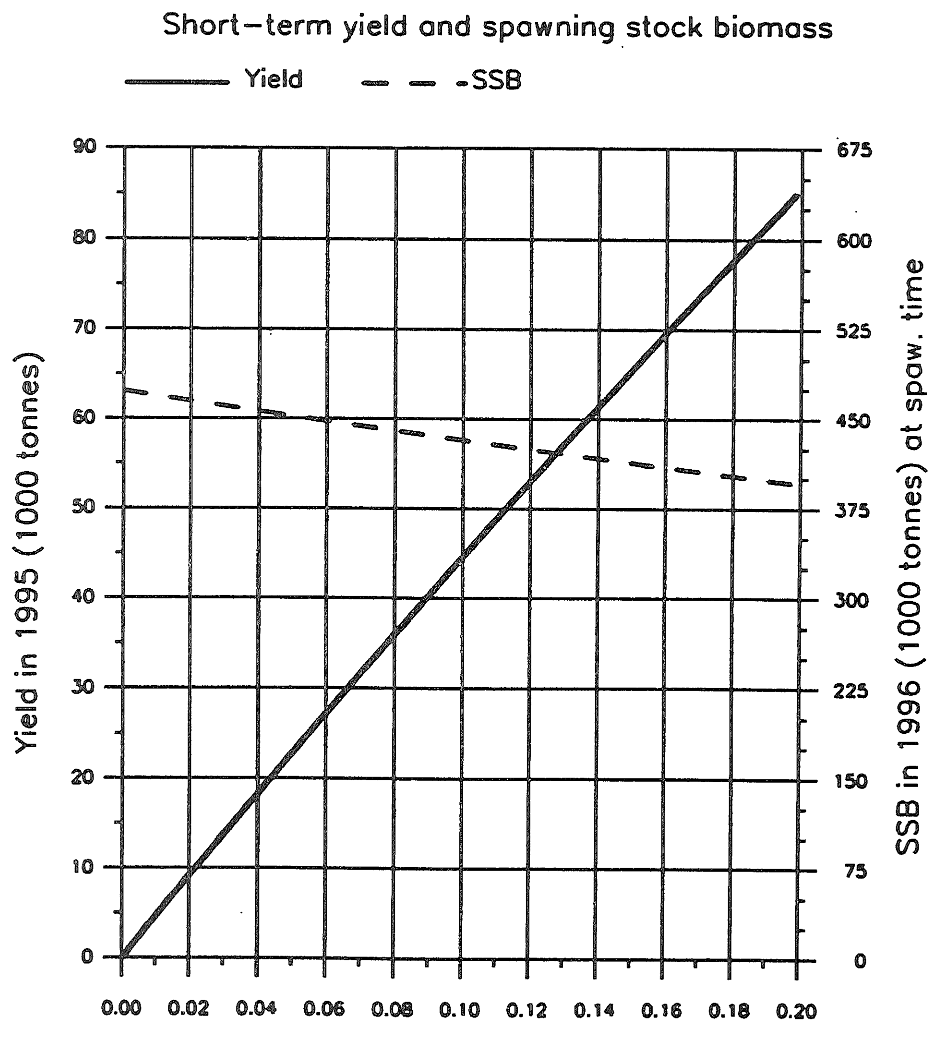
## STOCK: Sardine in Fishing Areas VIIIc and IXa

## 30–6–1994




(run: YPR)

C



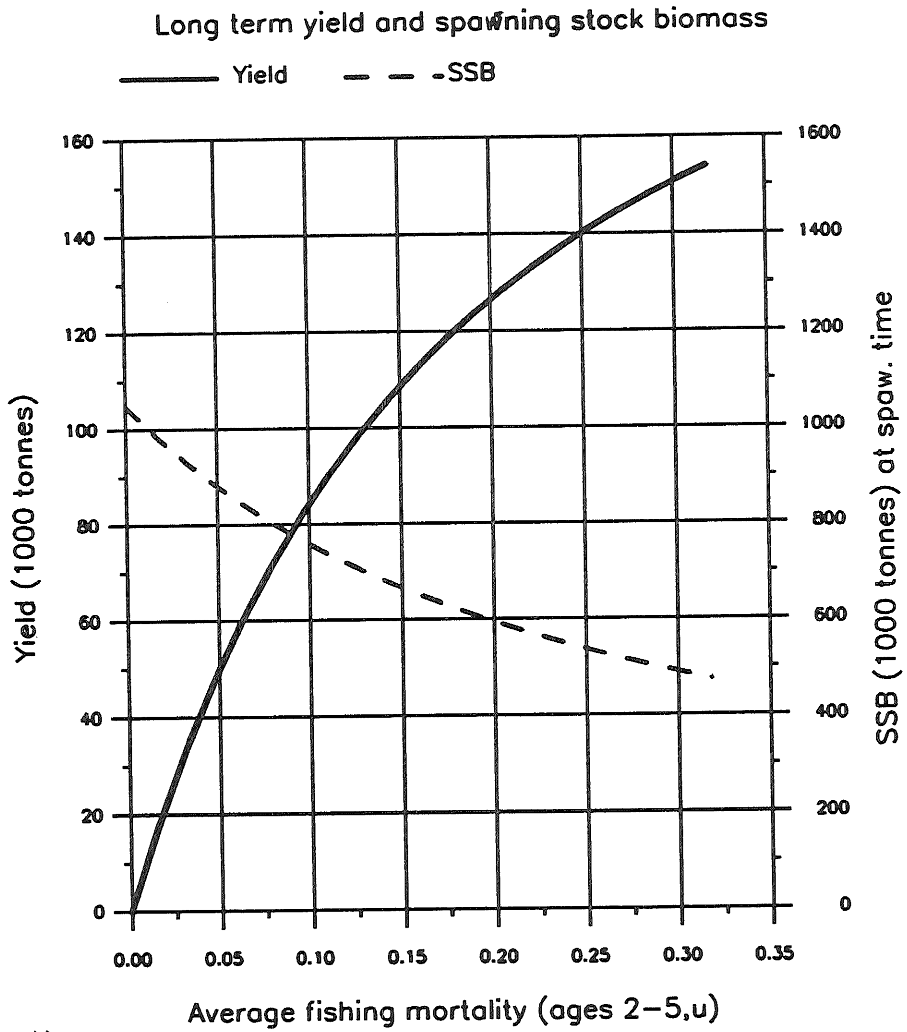

(run: FLAT)

D

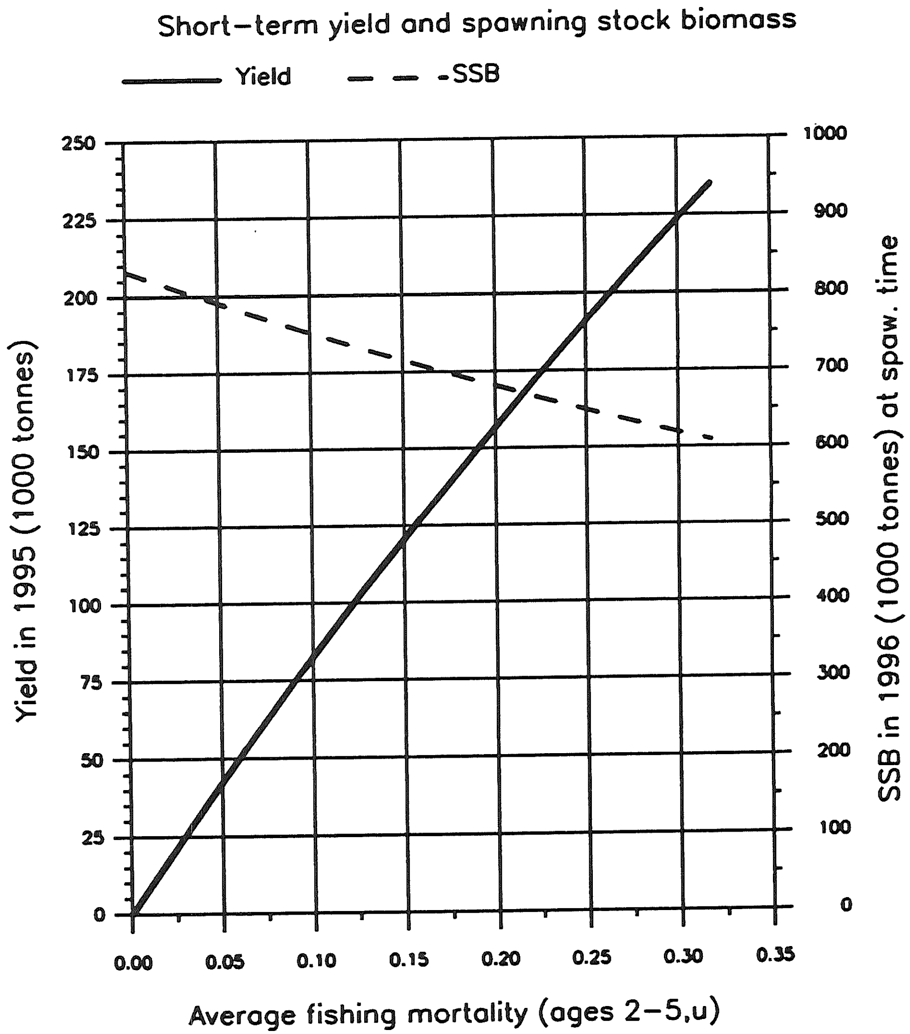
(S=1,25)

Figure 11.9

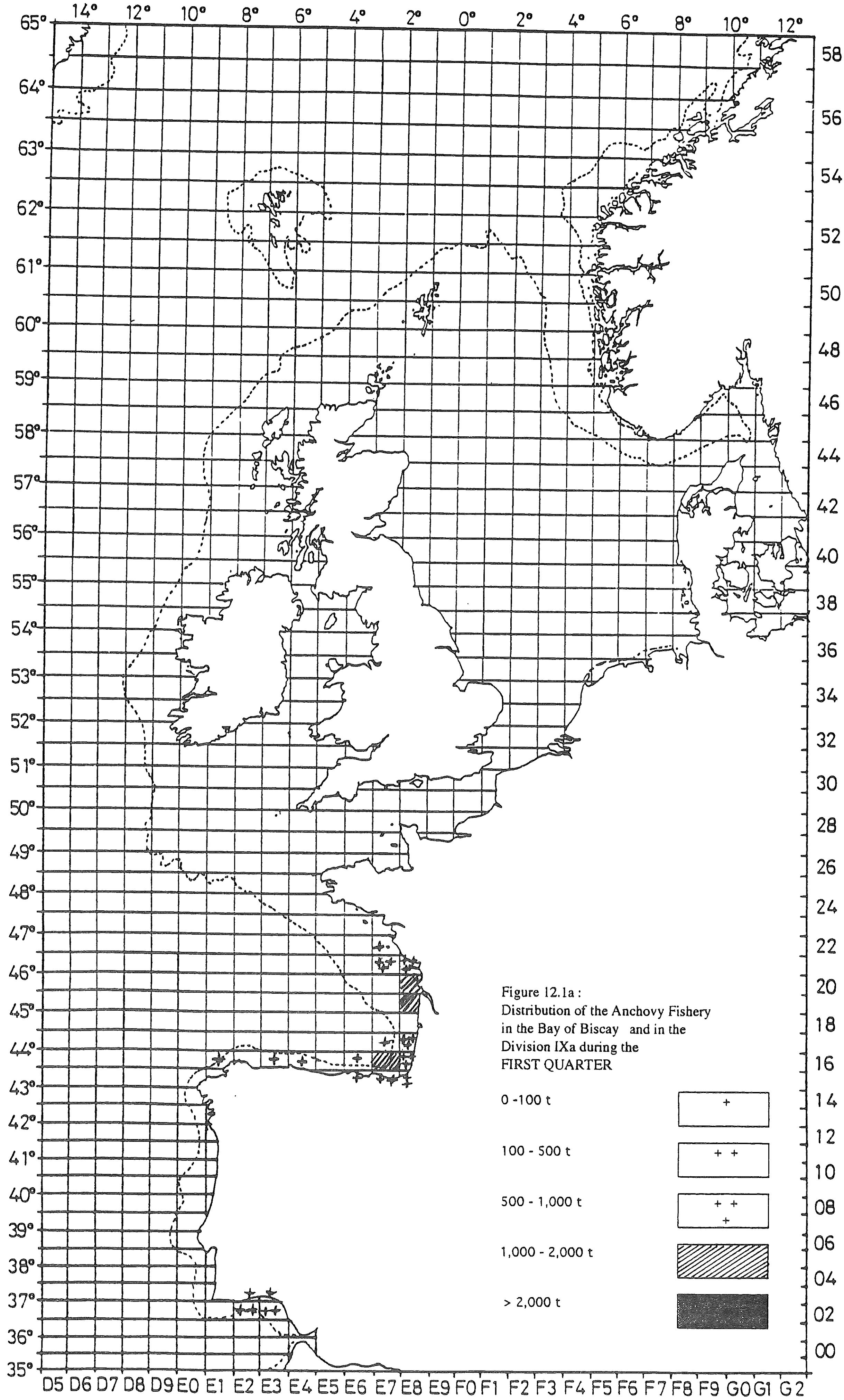
# FISH STOCK SUMMARY
## STOCK: Sardine in Fishing Areas VIIIc and IXa
## 29–6–1994




(run: YRDOMED) **C**




(run: DOMED6) **D**


14° 12° 10° 8° 6° 4° 2° 0° 2° 4° 6° 8° 10° 12°
65° 64° 63° 62° 61° 60° 59° 58° 57° 56° 55° 54° 53° 52° 51° 50° 49° 48° 47° 46° 45° 44° 43° 42° 41° 40° 39° 38° 37° 36° 35°
58 56 54 52 50 48 46 44 42 40 38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 08 06 04 02 00
D5 D6 D7 D8 D9 E0 E1 E2 E3 E4 E5 E6 E7 E8 E9 F0 F1 F2 F3 F4 F5 F6 F7 F8 F9 G0 G1 G2
Figure 12.1a :
Distribution of the Anchovy Fishery
in the Bay of Biscay and in the
Division IXa during the
FIRST QUARTER
0 -100 t
100 - 500 t
500 - 1,000 t
1,000 - 2,000 t
> 2,000 t

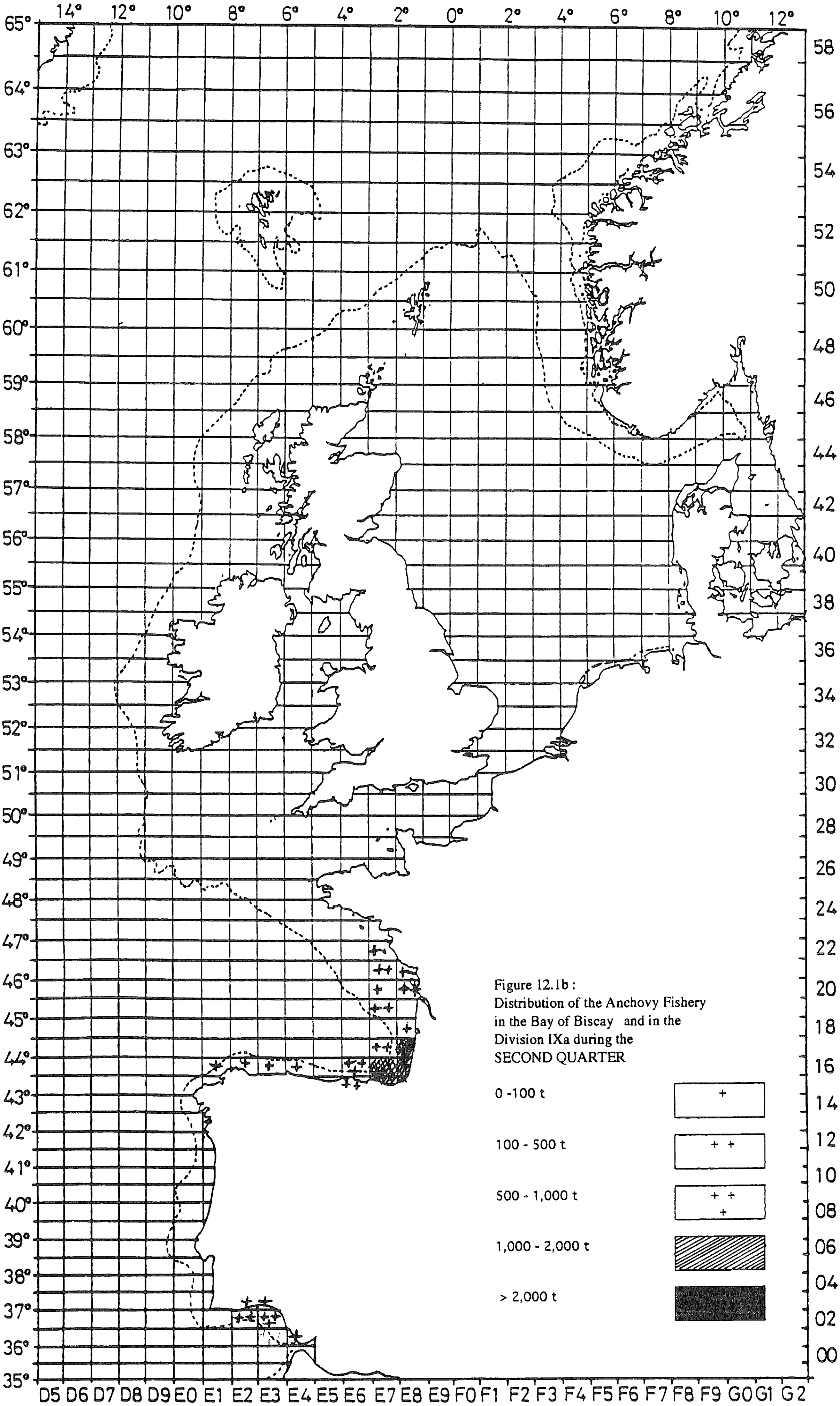



Figure 12.1b :
Distribution of the Anchovy Fishery in the Bay of Biscay and in the Division IXa during the SECOND QUARTER

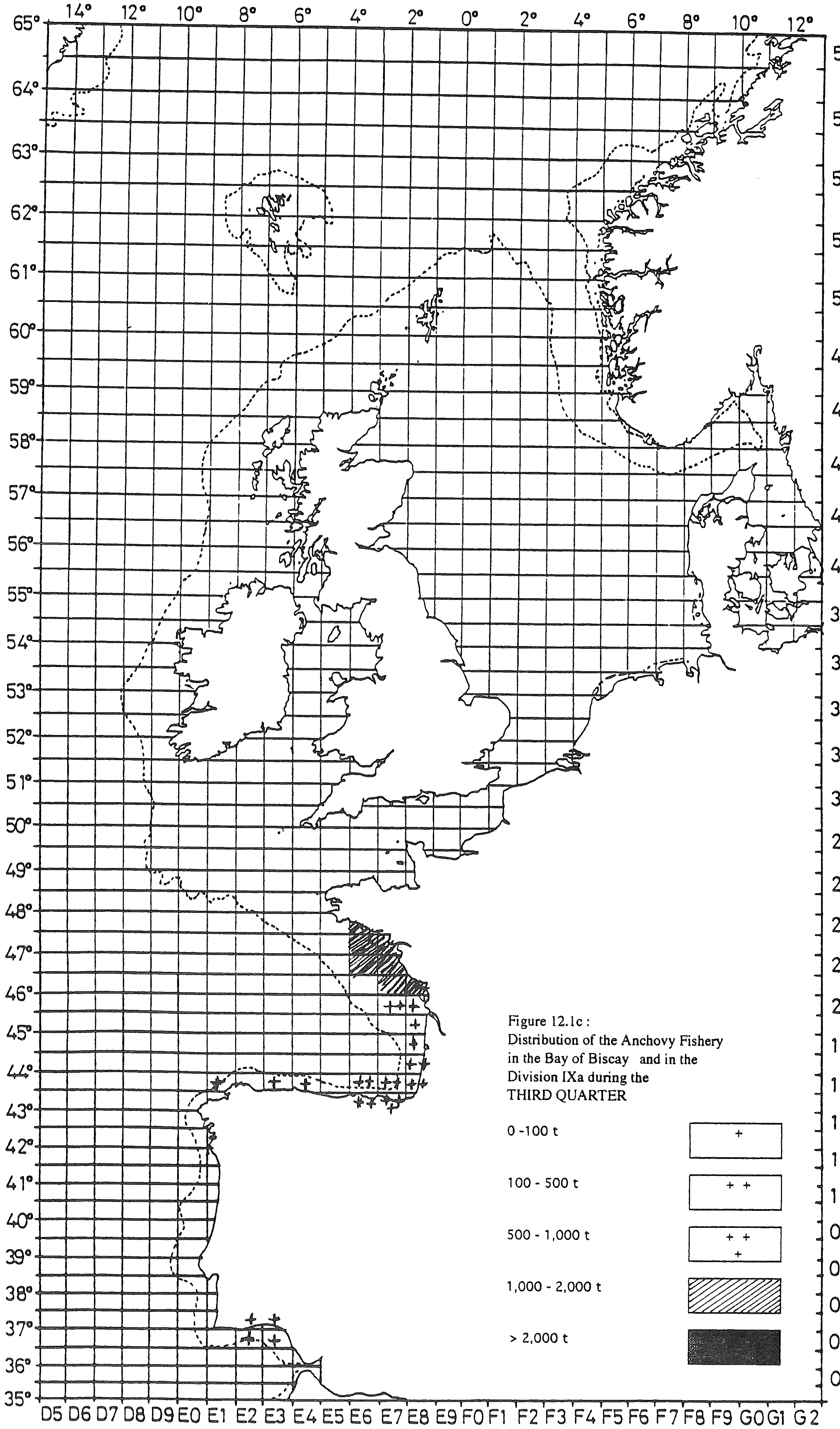



Figure 12.1c :
Distribution of the Anchovy Fishery in the Bay of Biscay and in the Division IXa during the THIRD QUARTER

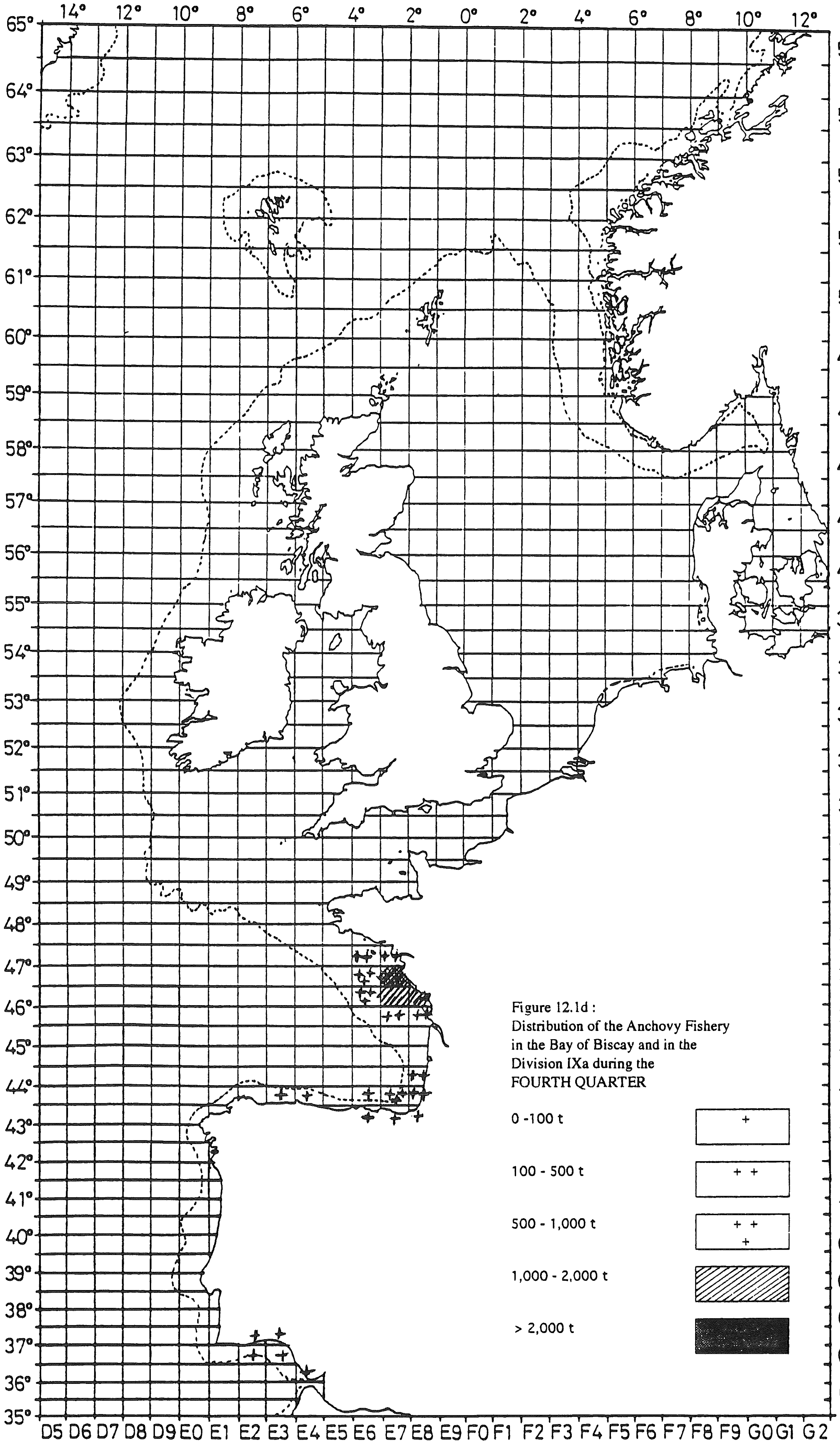



Figure 12.1d :
Distribution of the Anchovy Fishery in the Bay of Biscay and in the Division IXa during the FOURTH QUARTER

Figure 12.2a : Length distributions of landings of Bay of Biscay anchovy in Divisions VIIIa,b and c for the first quarter

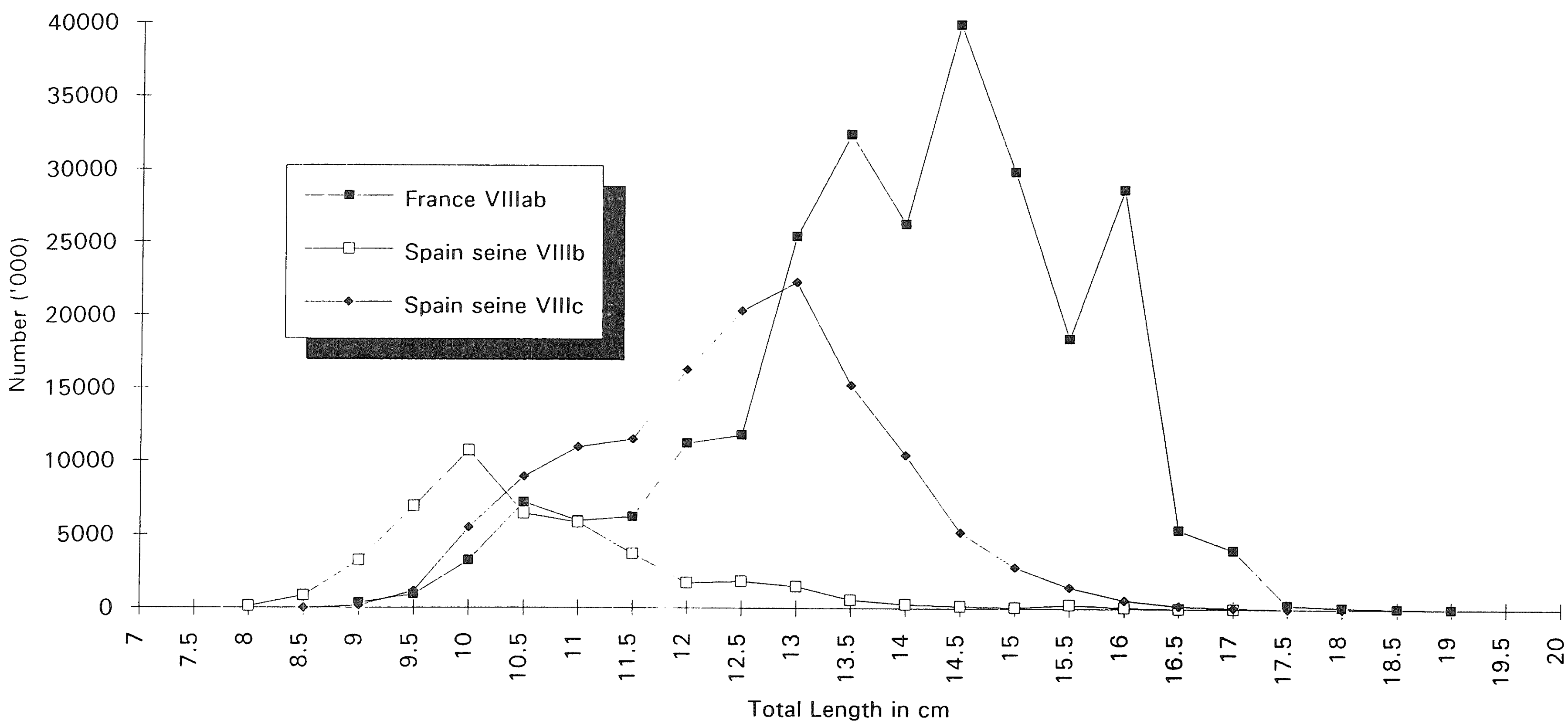


Figure 12.2b : Length distributions of landings of Bay of Biscay anchovy in Divisions VIIIa,b and c during the second quarter

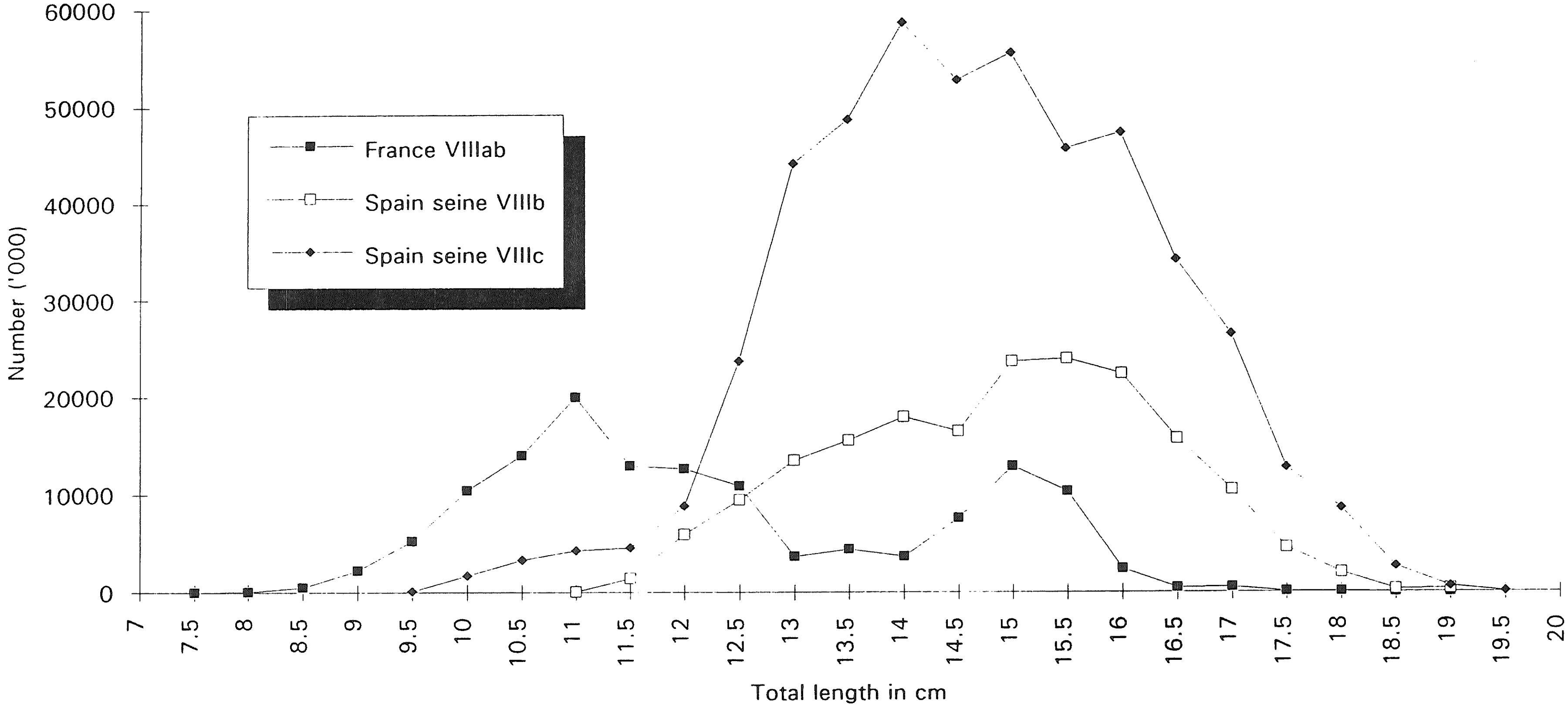


Figure 12.2c : Length distributions of landings of Bay of Biscay anchovy in Divisions VIIIa, b and c during the third quarter.

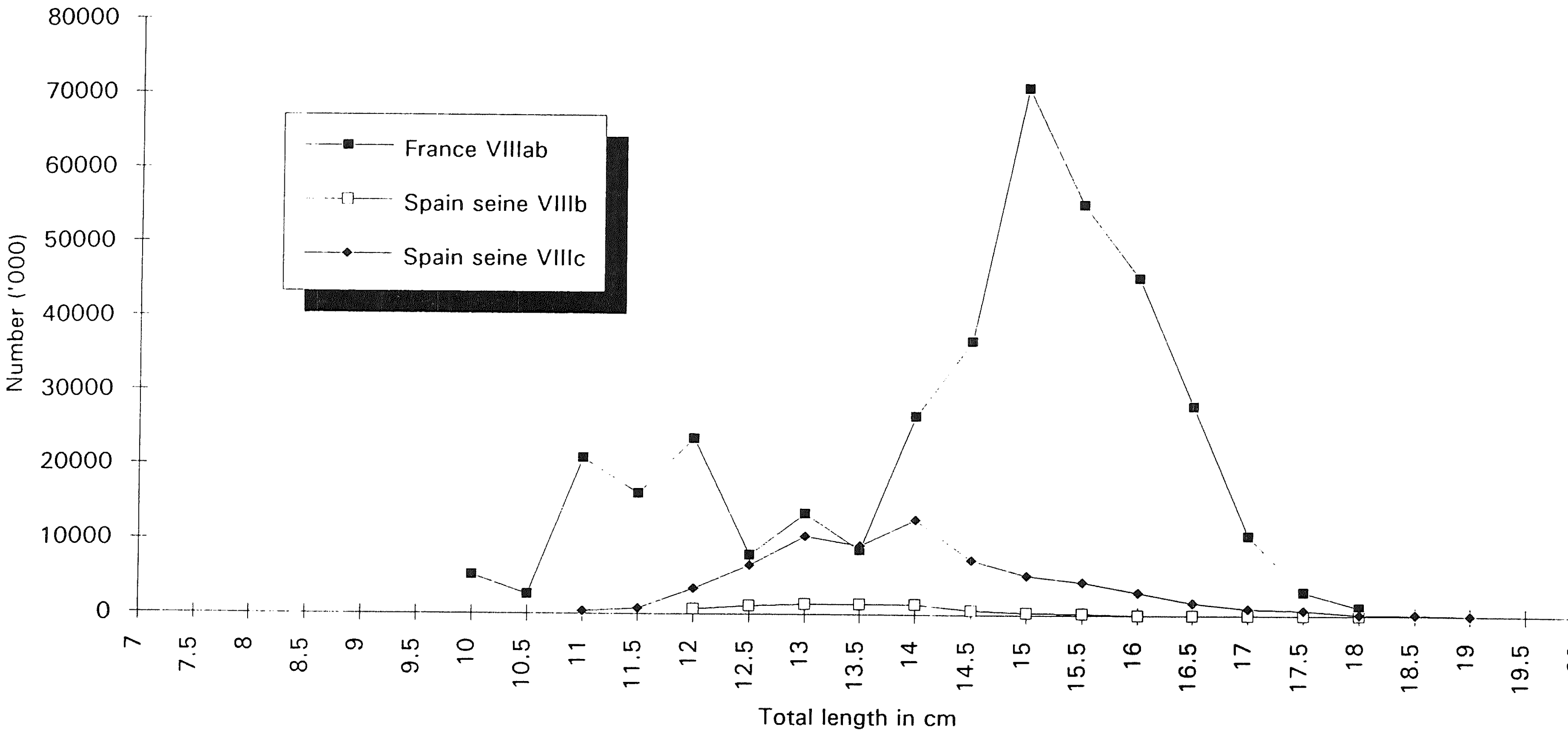


Figure 12.2d : Length distributions of landings of Bay of Biscay anchovy in Divisions VIIIa, b and c during the fourth quarter.

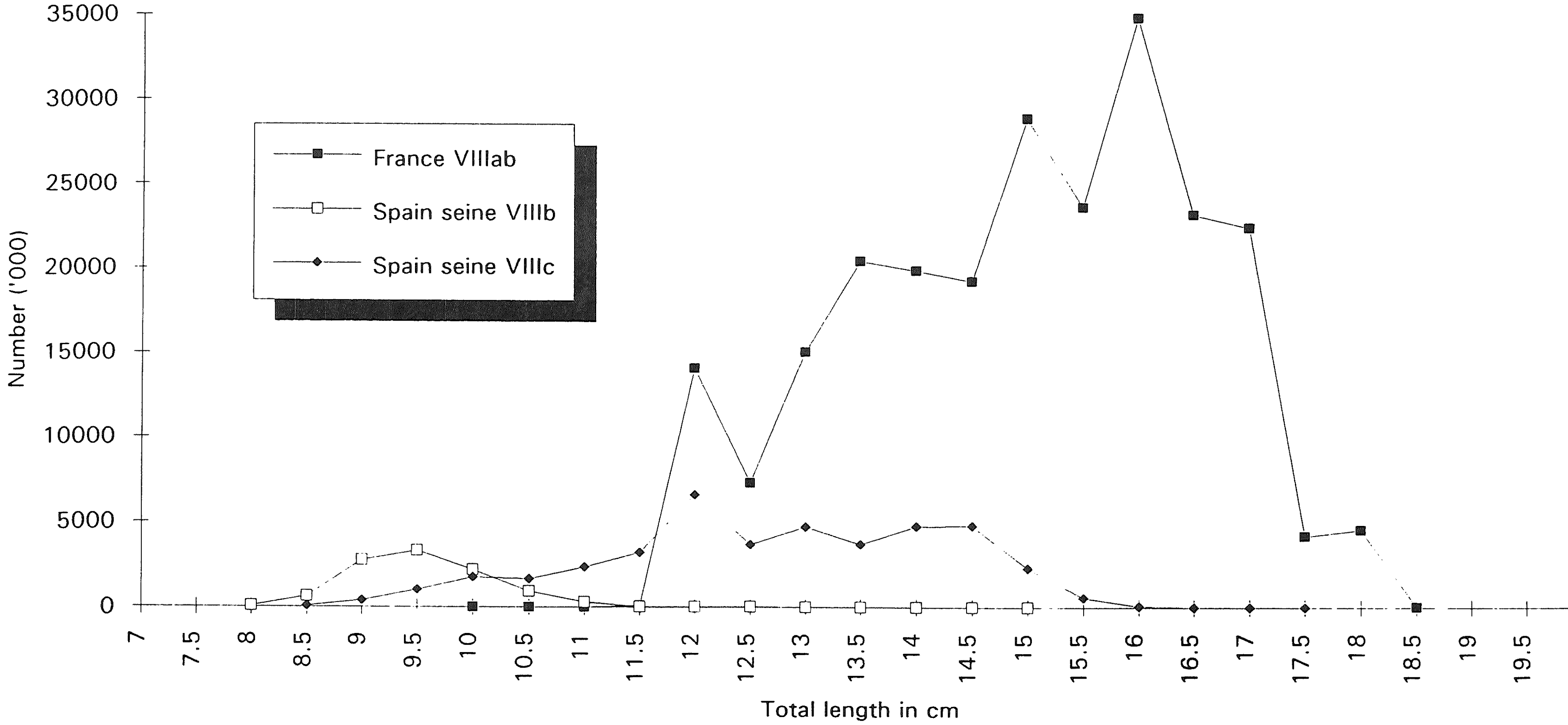
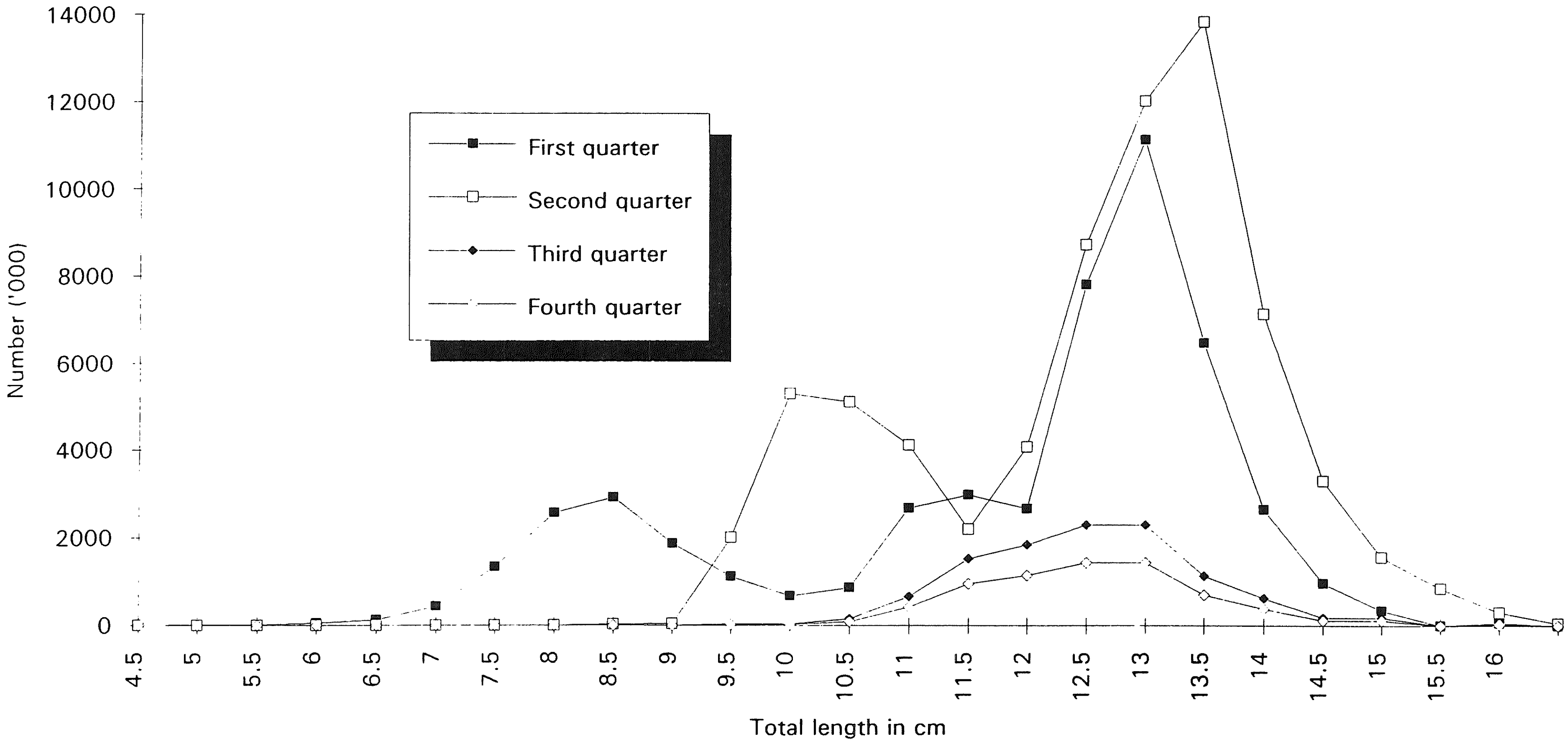


Figure 12.3 : Length distributions of landings of Bay of Cadiz anchovy by quarter in Sub-Division IXa South in 1993



# Figure 13.1 : Bay of Biscay Anchovy
# Historical evolution of the Fishery.
# Landings since 1940

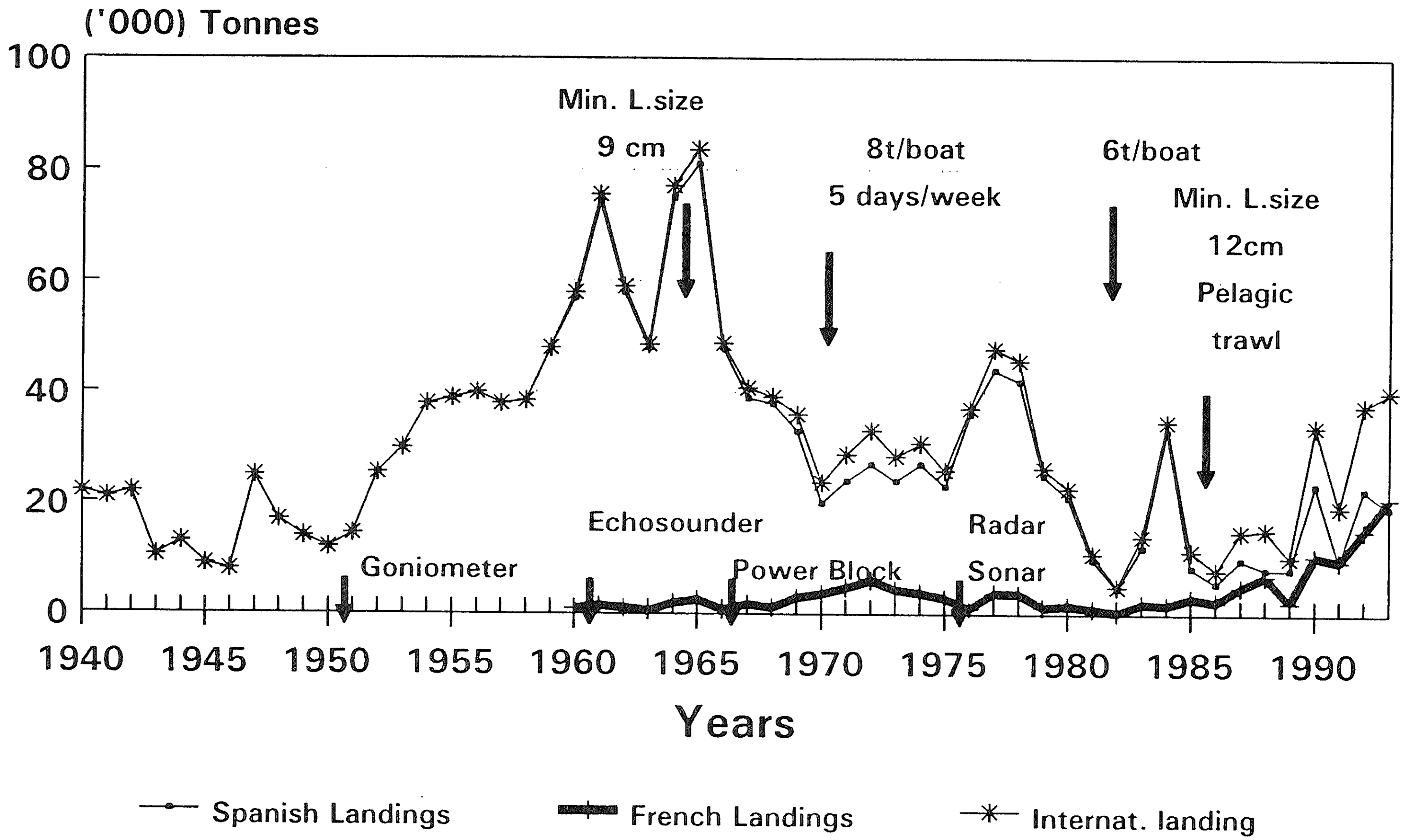


Figure 13.2: Evolution of the fleets fishing for anchovy in the Bay of Biscay

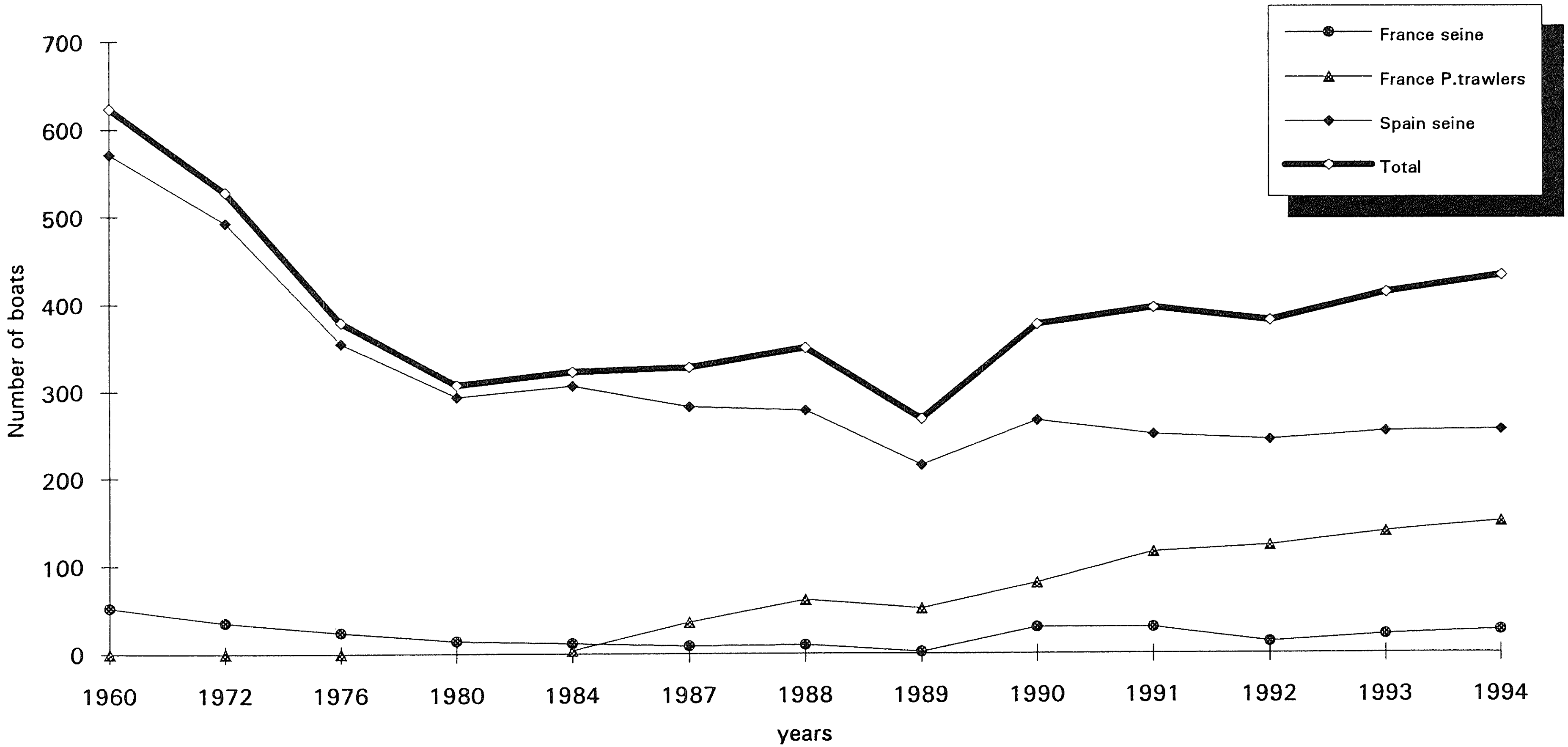


Figure 13.3 Recruitment indices and variation of CPUE for age 1

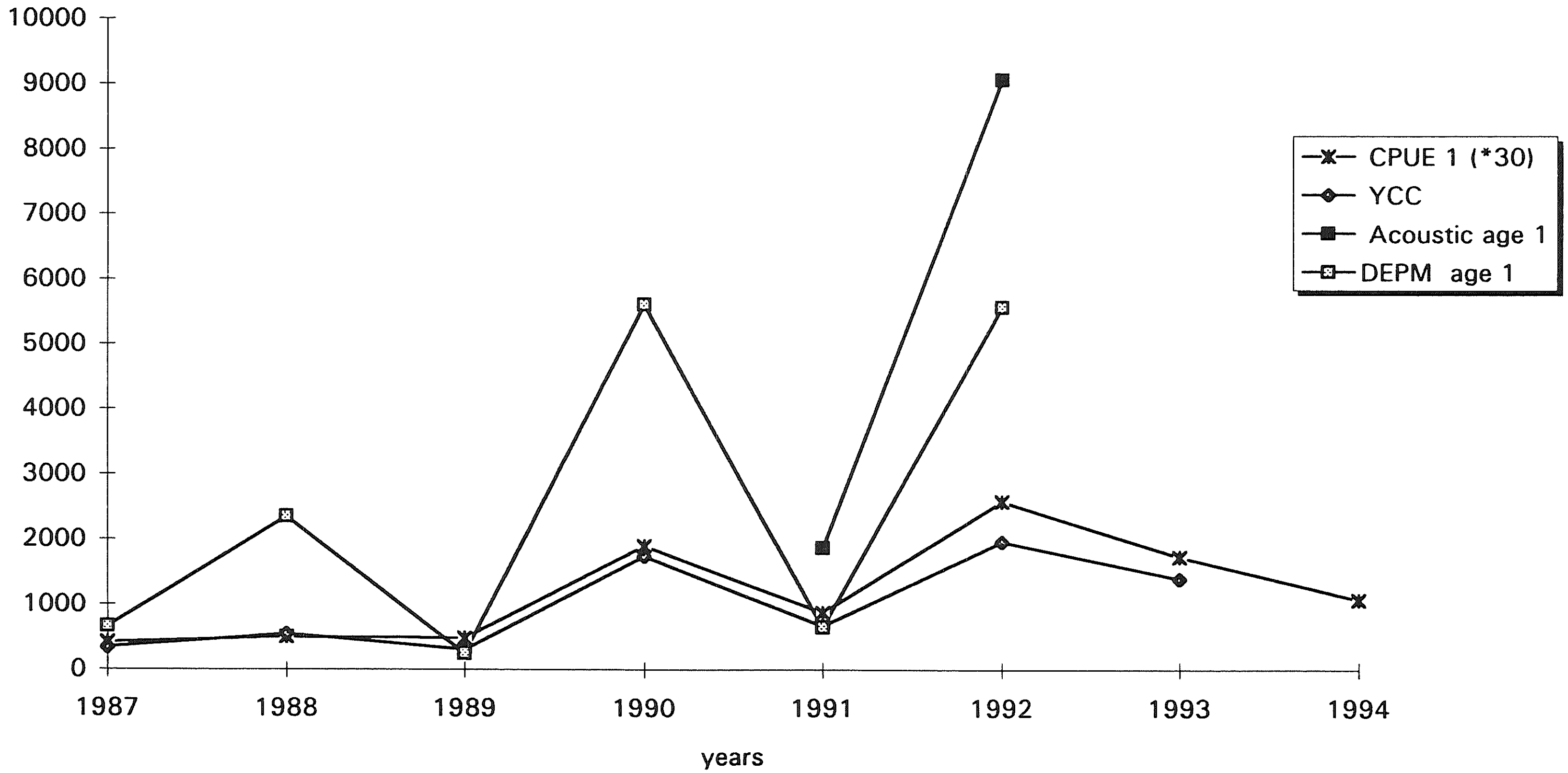


Figure 13.4 : Variation of recruitment level (expressed as millions of one year old recruits per thousand tonnes of SSB the year before) during the 1987 - 1991 period

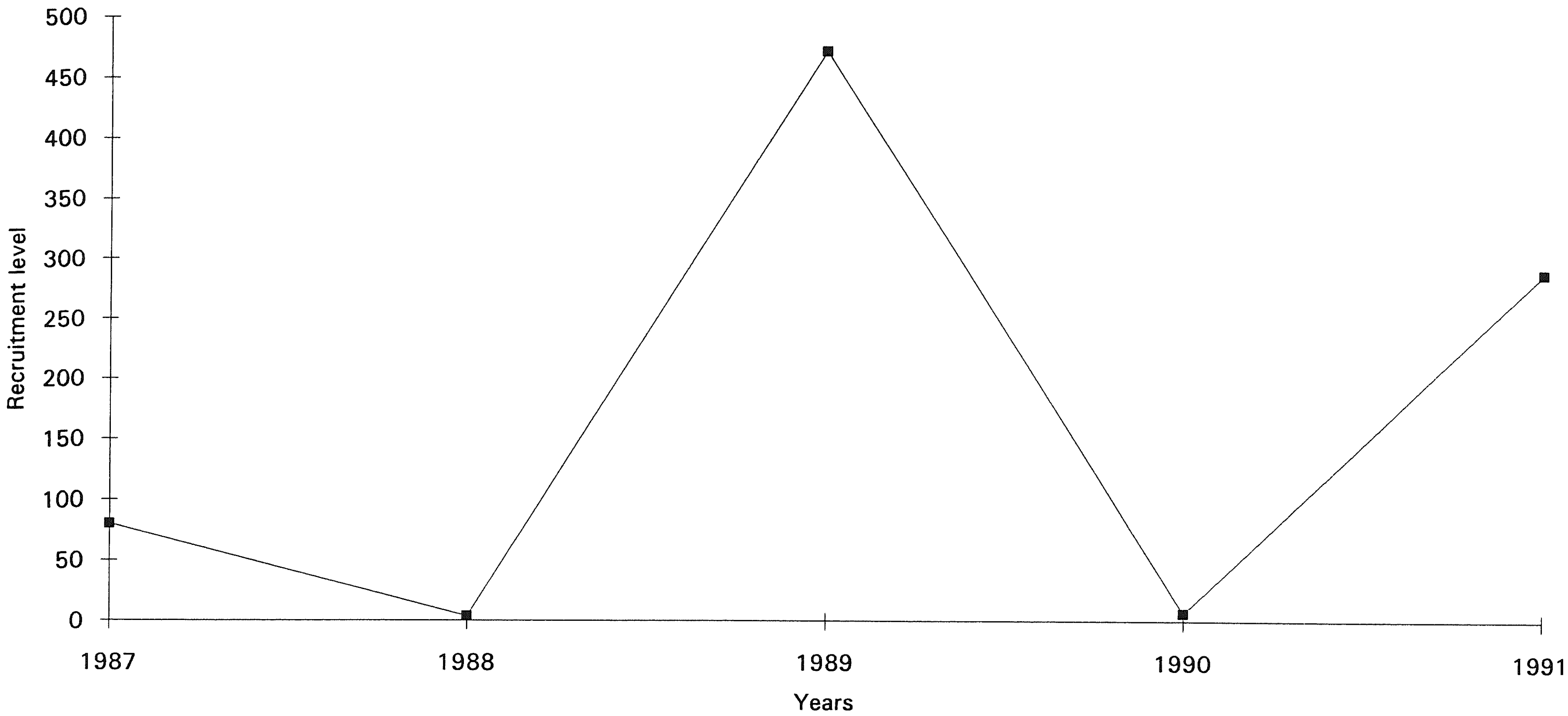
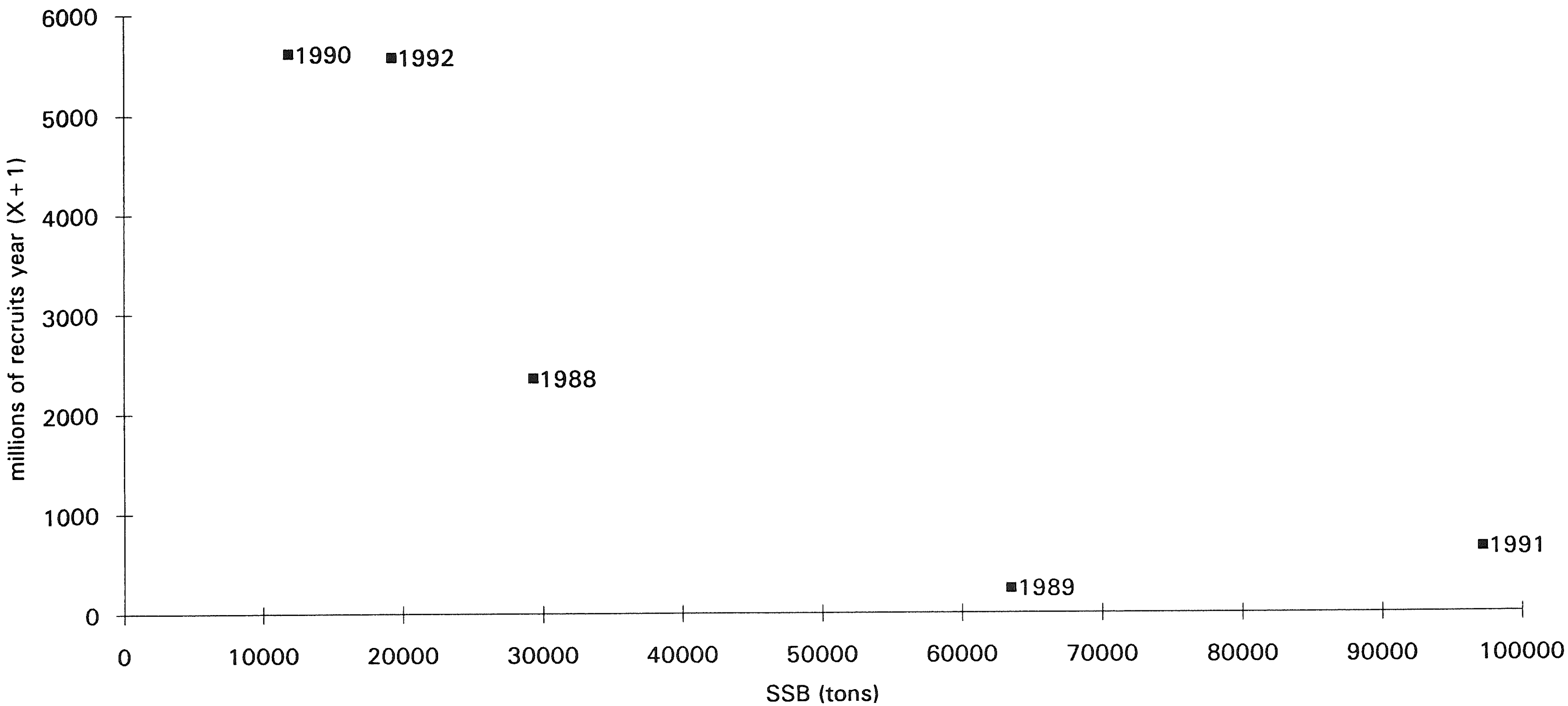


Figure 13.5 : Relationship between the number of recruits (1 year old anchovies) and the SSB estimated from direct estimation method



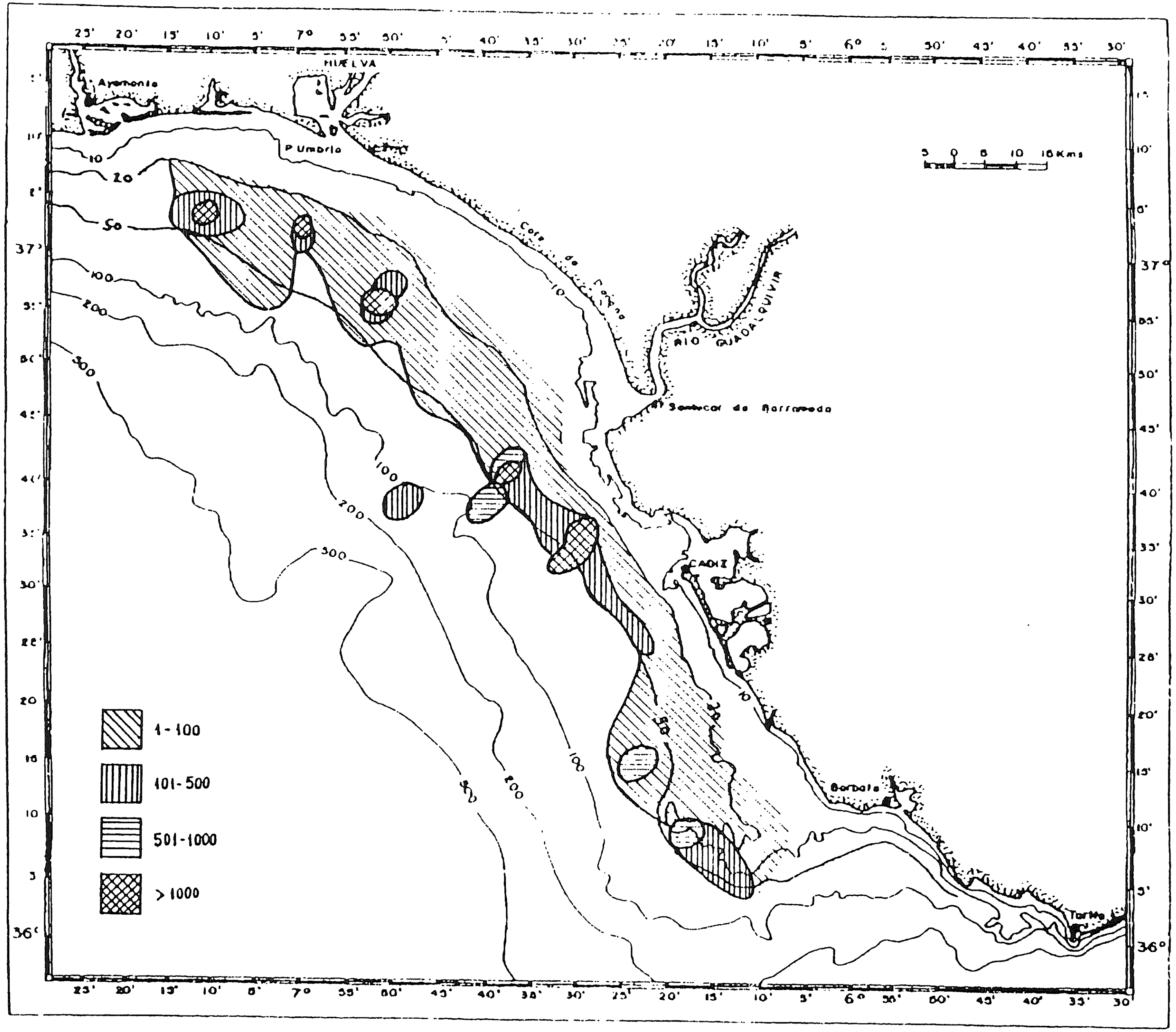



**Figure 14.1** Anchovy density distribution in Sub-division IXa south during June acoustic survey.

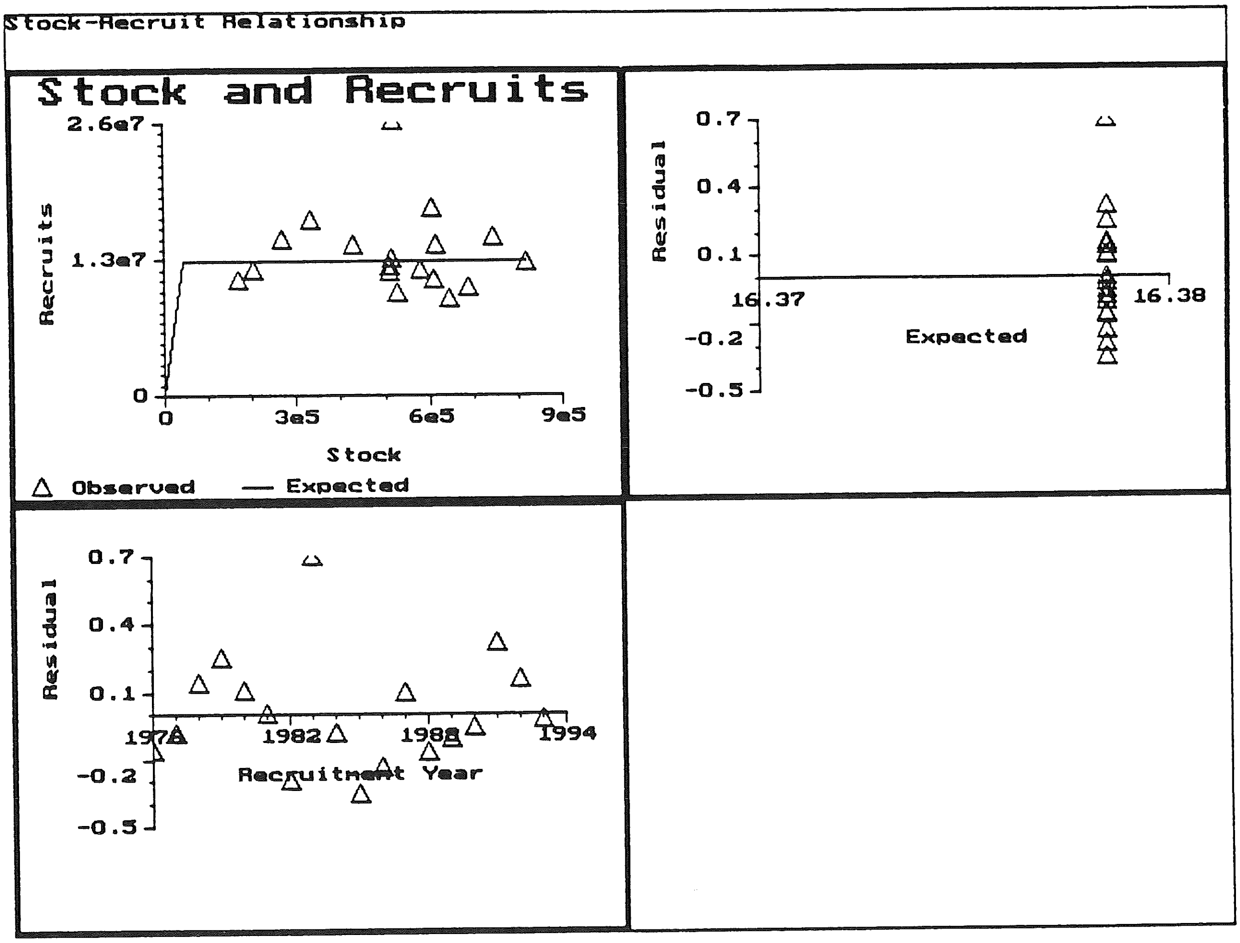
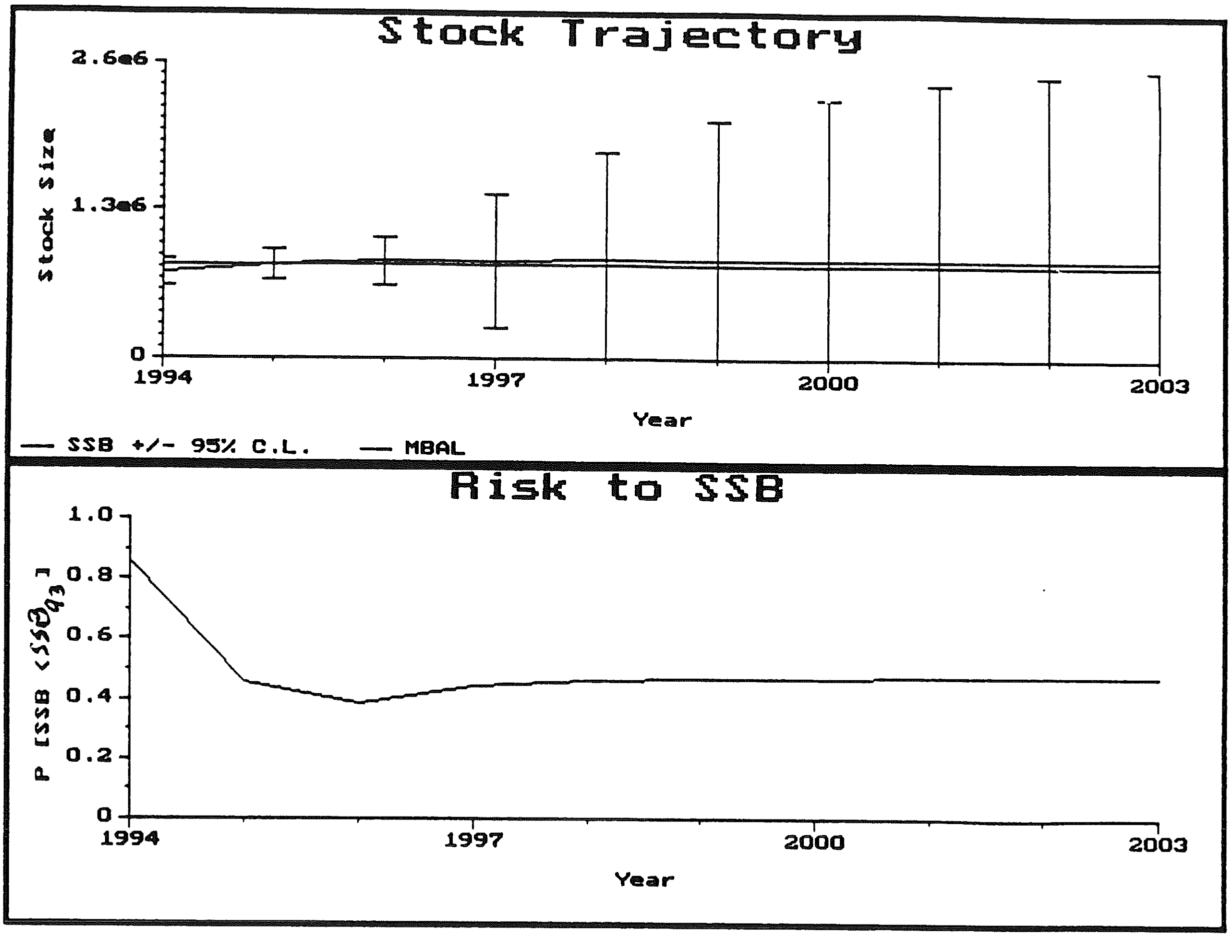



**Figure 16.1.** Sardine in Divisions VIIIc and IXa. Beverton and Holt stock-recruit relationship fitted in the integrated model. There is no detectable relationship, but the variability about this fit is usable for the projections.



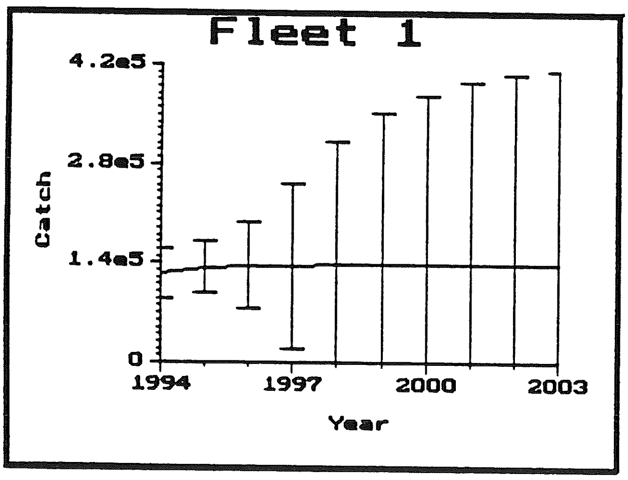




**Figure 16.2.** Sardine in Divisions VIIIc and IXa. Stock trajectory for fishing at 1993 levels of F in the period 1994-2003, and projected catches.

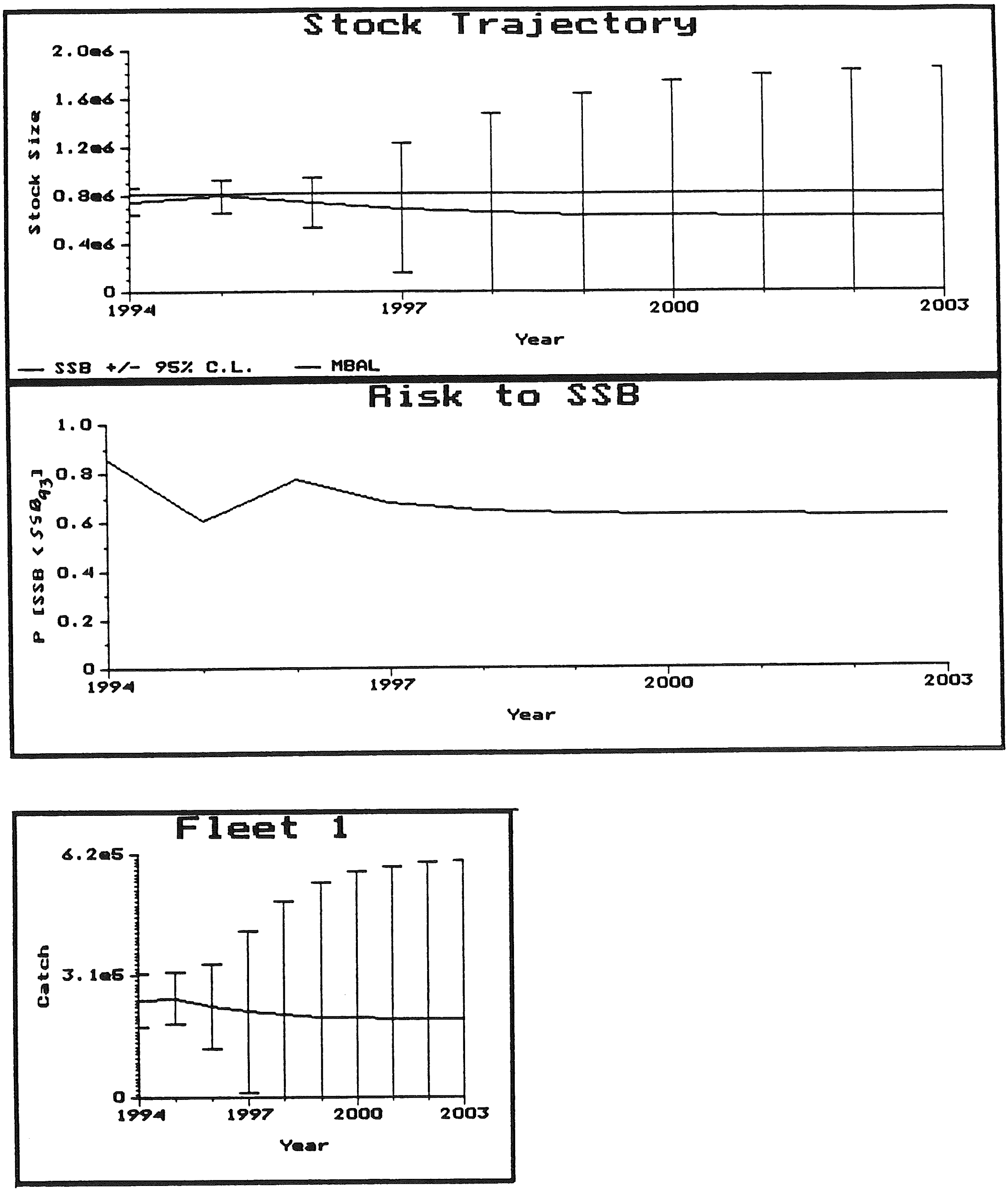



**Figure 16.3.** Sardine in Divisions VIIIc and IXa. Stock trajectory for fishing at twice 1993 levels of F in the period 1994-2003, and projected catches.

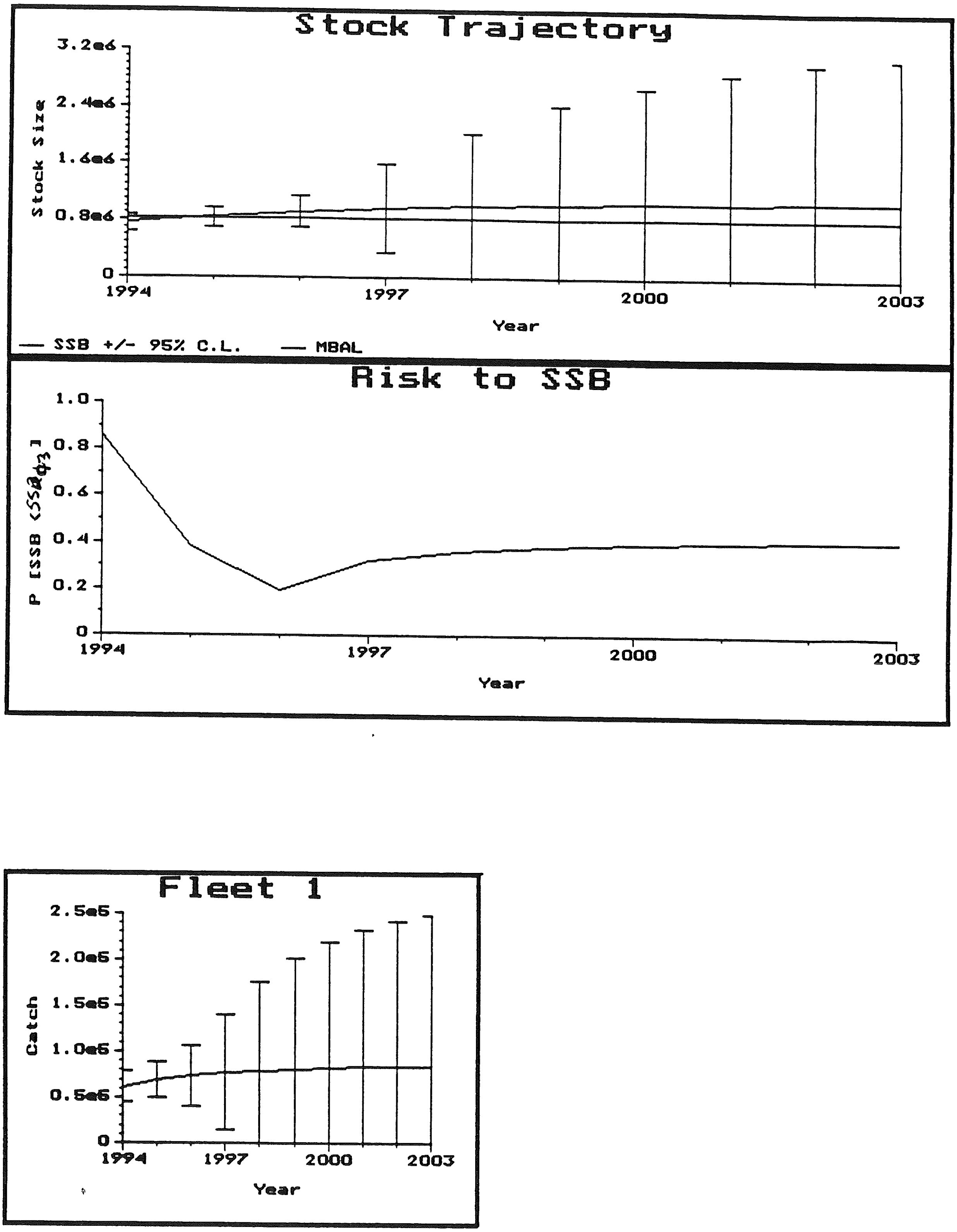
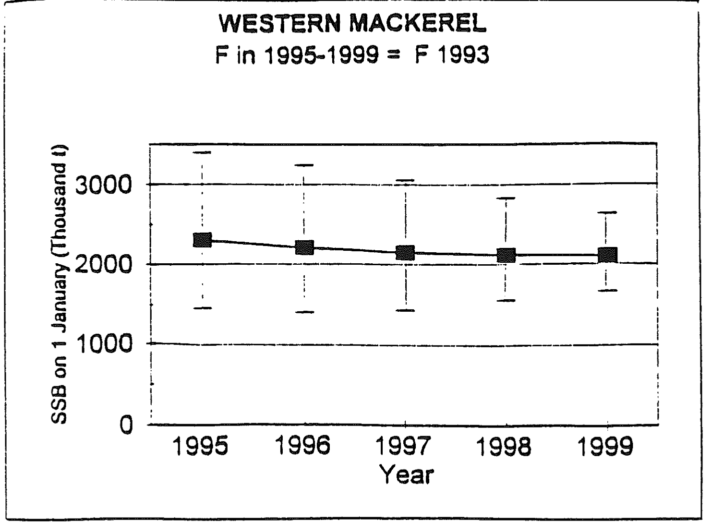
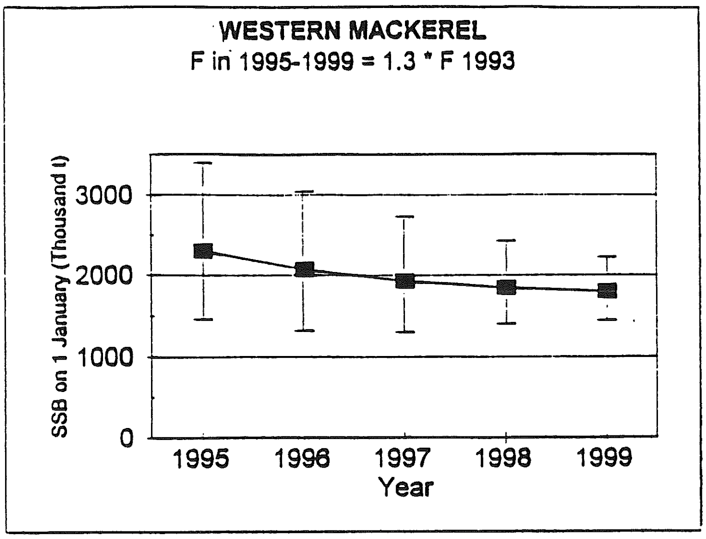



**Figure 16.4.** Sardine in Divisions VIIIc and IXa. Stock trajectory for fishing at half 1993 levels of F in the period 1994-2003, and projected catches.



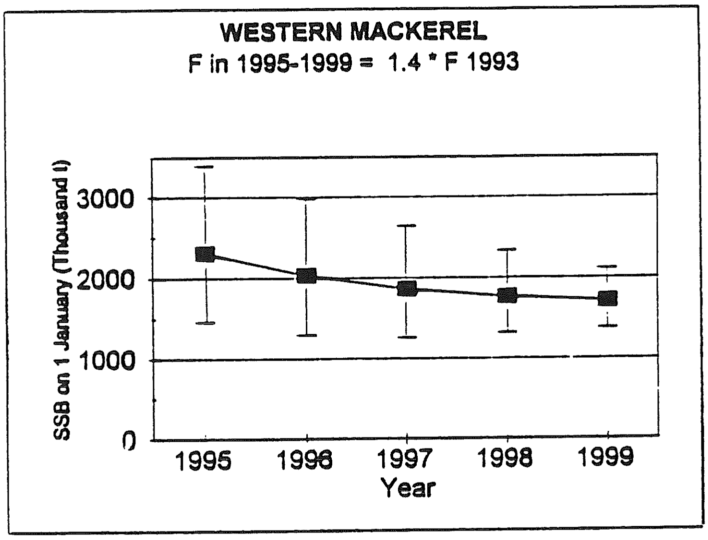




**Figure 16.5.** Western Mackerel. Projected stock trajectories (+/- 95% confidence intervals) for fishing at (1) 1993 levels; (2) 1.3 times 1993 levels; (3) 1.4 times 1993 levels in the period 1995-1999.

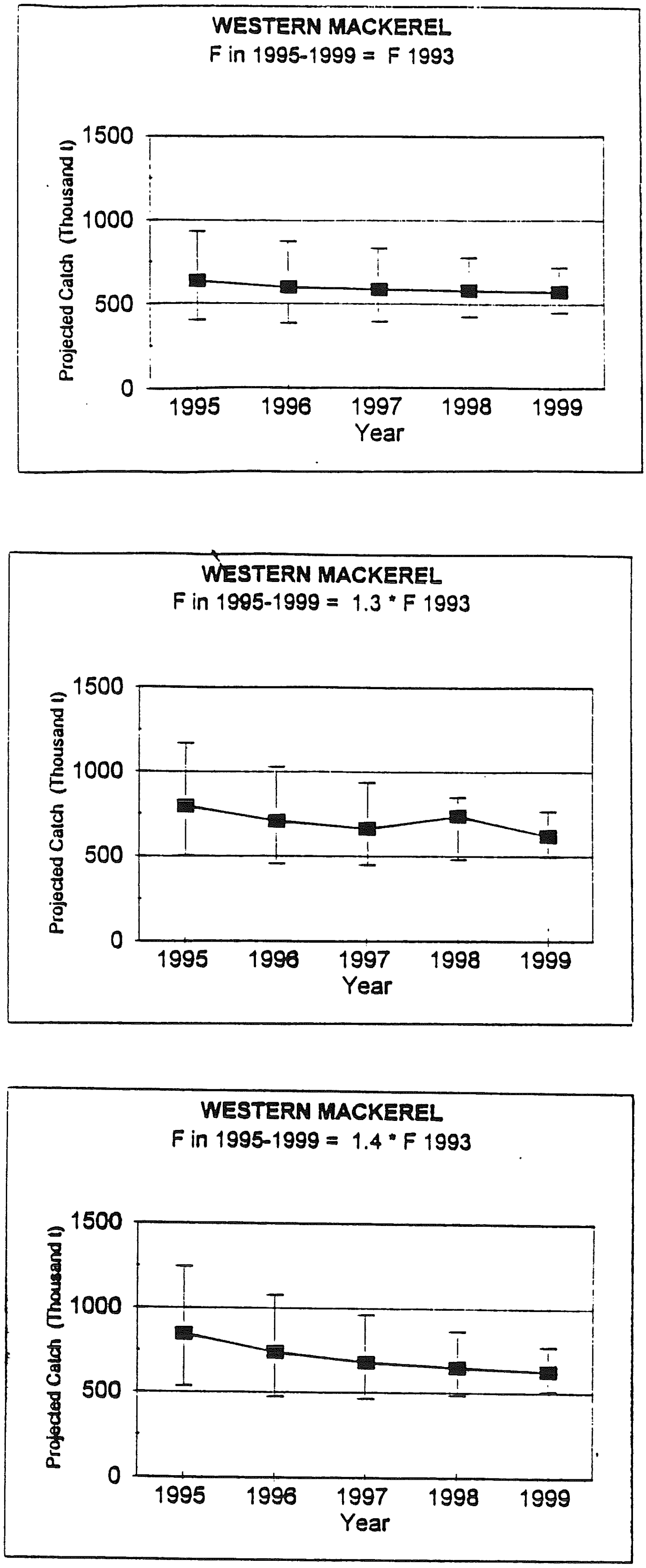



**Figure 16.6.** Western Mackerel. Projected catches (+/- 95% confidence intervals) for fishing at (1) 1993 levels; (2) 1.3 times 1993 levels; (3) 1.4 times 1993 levels in the period 1995-1999.

## APPENDIX 1

### ASSESSMENT OF THE BAY OF BISCAY ANCHOVY

Assessment based only on direct estimates of biomass using them as free of errors. (=Past assessments performed by this Working Group).

This methodology for calculating natural and fishing mortalities on this stock of anchovy was explained in an earlier Working Group report (Anon., 1991). The rates of mortality were calculated from the direct estimates of abundance (Anon.1993), provided by the Daily Egg Production Method (DEPM estimates), which are considered as absolute estimates.

These estimates of F and M arising form this assessment are presented in Table A1.1 (Anon. 1993d):

- The estimates of natural mortality (M) fluctuate between years and are high, ranging from 0.5 to 2.2; In the range of values known for other species like anchovies.
- Over the period 1987-92, the estimates of fishing mortality on all age groups together show an increasing trend from 0.32 in 1987/1988 to 1.1 in 1991/1992;

This assessment of M and F is highly dependent on the precision of the direct estimates of the stock and better estimates might be obtained by taking the uncertainties of the estimates into account.

### Integrated assessment of the Bay of Biscay anchovy using the ICA program.

An age-structured assessment was attempted using an integrated statistical analysis of the type used by Deriso *et al.* (1985), Gudmundsson (1986), Kimura (1989) in an implementation presented and reviewed in Anon. (1994) (ICA programmes). The ICA program was used to to look for estimates of the recruitment and fishing mortality for a set of different natural mortalities (0.8, 1.2, 1.6) in the range of those calculated by the former assessment for this stock. For every run the assumption of a constant natural mortality among years is required.

The following inputs were done:

- 50% of M and 50% of F are incurred before the egg production surveys ;
- 42% of M and 20% of F are incurred before the acoustic surveys ;
- The egg production and acoustic surveys measure stock size with lognormal error but no bias. The acoustic Index was used as a relative index of Biomass.

Age-disaggregated estimates of abundance from the egg surveys were used, but only estimates of stock size for ages 1-3 were significant in the estimates, therefore they are the only ones used for the analysis. Moreover, due to low percentages of anchovies of ages 3 or older, their estimates of abundance are considered less reliable and more subject of errors than the estimates for ages 1 and 2. Therefore the tuning to this population estimates by age will be downweighted for age 3. Concerning the data of catch at age, only the figure for the period 1983-1993 were used (Table A1.1), because it is believed that age readings for years prior to 1982 may not be consistent with later ones.

As there are so few ages in the catch-at-age matrix, the estimation of selection pattern is problematic. The approach taken here was to 'fill in' the many zeroes in the catch-at-age matrix with an arbitrary 1 Million catch in numbers, but to assign these observations a very low weight in the analysis. The model was thus fitting only to the actual observations of catches at the younger ages (ages 0-3). This approach is not usable with conventional VPA, but is an appropriate way to deal with the problem in the context of the type of integrated model fitted here.

Selection appeared to be highest on age 2 and to fall off thereafter. A reasonably consistent, if domed exploitation pattern was obtained by setting terminal selection = 0.6. The age of reference for the analysis is age 2. Nevertheless, the analysis was robust to the use of age 1 or 2 as the reference age. Selection on age 2 has been chosen for convenience.

The form of the objective function fitted in the model was:

$$\sum_{a,y} \lambda_C (\ln(C_{a,y}) - \ln(\hat{C}_{a,y}))^2 + \sum_{y} \lambda_{AC} (\ln(AC_y) - \ln(\hat{B}_y))^2 + \sum_{y} \lambda_{EPB} (\ln(EPB_{a,y}) - \ln(N^*_{a,y}))^2$$

where $N^*_{a,y}$ is the fitted population size at the time of the egg survey, $\tilde{B}$ is the estimated population size at the time of the acoustic surveys, $C_{a,y}$ and $\tilde{C}_{a,y}$ are the observed and fitted catches at age, $EPB_{a,y}$ are the egg production estimates of stock size, and $AC_y$ are the acoustic estimates of stock size. Weights on the catches at age (λ C) were set = 0.1 for age 0, = 1 for age 1-3 and 0.01 for ages 4 and 5. Weights for the egg survey were set so that one year's catch-at-age information receives the same weight in the analysis as one survey observation and at the same time EPB estimates at age 3 were downweighted in relation to ages 1 and 2 (λ EPB = 1.33 for ages 1 and 2 and = 0.33 at age 3). Weights for the egg production estimate were also set so that one year's catch-at-age information receives the same weight in the analysis as one survey observation (λ ACU = 3).

Finally a second trial was run taking into account only the DEPM estimates of Biomass both in SSB and in population numbers at age, for comparison purposes with the assessment performed in the last years.

**Results :** The data are known to be very noisy and highly variable. For this reason, no VPA had been presented on this stock in the past. Figure A1.1 for M = 0.8 illustrates this well : the sums of squares surface for the model fit is highly irregular, with a shallow depression around F = 0.4 and a sharp minimum at about F = 1.5, as tested using conventional separable VPAs over a range of fishing mortalities. Figure A1.3 for M=1.6 shows a SSQ surface with one minimum very flat, not very well determined and around F = 0.4. Nevertheless these figures show that the two surveys indicate rather closely similar trends in the population size.

On account of possible difficulties in convergence, the formal multidimensional programme (ICA2) was restarted from a number of possible terminal Fs. (range = 0.04 to 3). Nevertheless all these trials converge to the same unique solutions.

Table A1.2-A, shows the residuals obtained between the observed and estimated biomasses (Acoustic index) and the observed and estimated population numbers at age (DEPM values). The analysis of the residuals shows no significant differences among the sum of squares of the residuals obtained with the 3 values of M choosen (0.8, 1.2, 1.6).

With the DEPM biomass estimates used as SSB index (Table A1.2-B), the same conclusion is achieved : regardless the natural mortality used, all fits of the model result in the same level of residuals.

Table A1.3 shows, for the two kind of trials for tuning, the different estimates of fishing mortalities [$F_{bar}$ (87-93)] and explotation rates ($E_{bar}$ = F/Z) deduced from the 3 natural mortality values selected as inputs. The asssessments produced similar estimates with the 2 tuning options.

Figures A1.3a,b,c give as example the different fits obtained with an M = 1.6 and a reference age = 2 and the SSB index estimated with the Acoustic survey.

### Discussion: Uncertainty in the Assessment

The anchovy catch-at-age data cover only a small age-range and are highly variable on account of strongly-variable recruitment. The fitted populations are subject to considerable uncertainty.

The precision of the reference fishing mortality is poor, the estimate given in the above example for the reference age 2 is 0.92 but between 0.49 and 1.75 (+/- one standard deviation). This is not surprising as the last survey was carried out in 1992, and the rather high mortalities in this stock will mean that the F experienced by the anchovy in 1993 will be only weakly dependent on the population parameters in 1992.

The main results show that the data are very noisy and highly variable. Whatever natural mortality is used, the fits remain rather similar. Therefore the model underlying the ICA programme does not allow you to define a best constant natural mortality to this stock. The estimates of the fishing mortality show for all ages an increasing tendency up to 1991 and a decrease after this period. The evolution of the fleets however suggest a continuous increasing of fishing effort, even taking into account the recent significant recruitments. The highest rate of fishing mortality detected in 1991 coincides with a very low level of the stock spawning biomass; this F estimate could therefore indicates increasing catchability at low levels of the stock. The rate of exploitation of the fishery (F/Z) remains uncertain as far as it is dependant on the estimate of natural mortality used.

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Gudmundsson G., 1986. Statistical considerations in the analysis of catch-at-age observations. J. Cons. Int. Explor. Mer, 43 : 83-90.

Kimura D.K., 1986. Variability tuning and simulation for the Doubleday-Deriso Catch-at-age model. Can. J. Fish. Aquat. Sci. 46 : 941-949.

Table A1.1 : Fishing and natural mortality (F/M) estimates for the Bay of Biscay anchovy from the DEPM SSB estimates and catches between surveys

| Years | 1987/88 | 1988/89(*) | 1989(*)/90 | 1990/1991 | 1991/92 |
|---|---|---|---|---|---|
| Age group | | | | | |
| 1+ | 0.39/0.96 | 0.44/1.74 | 0.4/0.72 | 0.89/2.13 | 1.08/0.36 |
| 2+ | | 0.45/1.96 | 0.43/1.74 | 1.26/1.0 | 1.1/1.72 |

(*) 1989 SSB estimate raised up to 1 standard deviation because of the presumption of underestimation according Motos & Santiago (1990)

TableA1.2 : Analysis of residuals obtained from ICA program

A : Use of Acoustic data for the SSB index

| **M = 0.8** | | | **M = 1.2** | | | **M = 1.6** | | |
|---|---|---|---|---|---|---|---|---|
| observed | estimated | SSQ | observed | estimated | SSQ | observed | estimated | SSQ |
| 9.649 | 9.921 | 0.073984 | 9.649 | 9.961 | 0.097344 | 9.649 | 10.004 | 0.126025 |
| 11.067 | 10.681 | 0.148996 | 11.067 | 10.666 | 0.160801 | 11.067 | 10.657 | 0.1681 |
| 11.396 | 11.509 | 0.012769 | 11.396 | 11.485 | 0.007921 | 11.396 | 11.45 | 0.002916 |
| | **Total SSQ** | **0.235749** | | **Total SSQ** | **0.266066** | | **Total SSQ** | **0.297041** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| observed | estimated | SSQ | observed | estimated | SSQ | observed | estimated | SSQ |
| 13.394 | 13.3886 | 2.92E-05 | 13.394 | 13.727 | 0.110889 | 13.394 | 14.087 | 0.480249 |
| 14.67 | 13.527 | 1.306449 | 14.669 | 13.851 | 0.669124 | 14.669 | 14.199 | 0.2209 |
| 12.413 | 12.952 | 0.290521 | 12.413 | 13.243 | 0.6889 | 12.413 | 13.545 | 1.281424 |
| 15.54 | 14.629 | 0.829921 | 15.541 | 14.86 | 0.463761 | 15.54 | 15.11 | 0.1849 |
| 13.38 | 13.725 | 0.119025 | 13.38 | 13.97 | 0.3481 | 13.38 | 14.227 | 0.717409 |
| 15.533 | 14.97 | 0.316969 | 15.533 | 15.097 | 0.190096 | 15.533 | 15.235 | 0.088804 |
| 12.71 | 12.321 | 0.151321 | 12.71 | 12.515 | 0.038025 | 12.71 | 12.689 | 0.000441 |
| 12.461 | 11.851 | 0.3721 | 12.461 | 11.966 | 0.245025 | 12.46 | 12.053 | 0.165649 |
| 12.236 | 11.948 | 0.082944 | 12.236 | 12.052 | 0.033856 | 12.235 | 12.128 | 0.011449 |
| 12.155 | 11.365 | 0.6241 | 12.155 | 11.413 | 0.550564 | 12.154 | 11.429 | 0.525625 |
| 12.539 | 12.689 | 0.0225 | 12.539 | 12.711 | 0.029584 | 12.539 | 12.717 | 0.031684 |
| 12.25 | 11.974 | 0.076176 | 12.25 | 11.923 | 0.106929 | 12.25 | 11.859 | 0.152881 |
| 11.238 | 11.569 | 0.109561 | 11.238 | 11.561 | 0.104329 | 11.238 | 11.516 | 0.077284 |
| 11.097 | 11.096 | 1E-06 | 11.097 | 10.902 | 0.038025 | 11.097 | 10.655 | 0.195364 |
| 9.798 | 10.465 | 0.444889 | 9.798 | 10.235 | 0.190969 | 9.798 | 9.939 | 0.019881 |
| 10.596 | 10.419 | 0.031329 | 10.597 | 10.174 | 0.178929 | 10.597 | 9.856 | 0.549081 |
| 8.294 | 9.778 | 2.202256 | 8.294 | 9.407 | 1.238769 | 8.294 | 8.971 | 0.458329 |
| 9.741 | 10.559 | 0.669124 | 9.741 | 10.225 | 0.234256 | 9.741 | 9.8 | 0.003481 |
| | **Total SSQ** | **7.649215** | | **Total SSQ** | **5.46013** | | **Total SSQ** | **5.164835** |

B : Use of DEPM data for the SSB index

| **M = 0.8** | | | **M = 1.2** | | | **M = 1.6** | | |
|---|---|---|---|---|---|---|---|---|
| observed | estimated | SSQ | observed | estimated | SSQ | observed | estimated | SSQ |
| 10.287 | 10.356 | 0.004761 | 10.288 | 10.379 | 0.008281 | 10.288 | 10.4 | 0.012544 |
| 11.059 | 10.441 | 0.381924 | 11.059 | 10.484 | 0.330625 | 11.058 | 10.54 | 0.268324 |
| 9.381 | 9.845 | 0.215296 | 9.381 | 9.842 | 0.212521 | 9.381 | 9.832 | 0.203401 |
| 11.485 | 11.104 | 0.145161 | 11.485 | 11.145 | 0.1156 | 11.484 | 11.185 | 0.089401 |
| 9.867 | 10.321 | 0.206116 | 9.867 | 10.252 | 0.148225 | 9.867 | 10.177 | 0.0961 |
| 11.416 | 11.407 | 8.1E-05 | 11.416 | 11.374 | 0.001764 | 11.416 | 11.337 | 0.006241 |
| | **Total SSQ** | **0.953339** | | **Total SSQ** | **0.817016** | | **Total SSQ** | **0.676011** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| observed | estimated | SSQ | observed | estimated | SSQ | observed | estimated | SSQ |
| 13.394 | 13.437 | 0.001849 | 13.394 | 13.733 | 0.114921 | 13.394 | 14.062 | 0.446224 |
| 14.669 | 13.787 | 0.777924 | 14.669 | 14.127 | 0.293764 | 14.669 | 14.486 | 0.033489 |
| 12.413 | 12.893 | 0.2304 | 12.413 | 13.185 | 0.595984 | 12.413 | 13.505 | 1.192464 |
| 15.541 | 14.648 | 0.797449 | 15.541 | 14.91 | 0.398161 | 15.541 | 15.592 | 0.002601 |
| 13.38 | 13.326 | 0.002916 | 13.38 | 13.564 | 0.033856 | 13.38 | 13.826 | 0.198916 |
| 15.533 | 15.029 | 0.254016 | 15.533 | 15.195 | 0.114244 | 15.533 | 15.387 | 0.021316 |
| 12.71 | 12.305 | 0.164025 | 12.71 | 12.497 | 0.045369 | 12.71 | 12.667 | 0.001849 |
| 12.46 | 11.874 | 0.343396 | 12.461 | 11.971 | 0.2401 | 12.461 | 12.039 | 0.178084 |
| 12.235 | 12.131 | 0.010816 | 12.236 | 12.293 | 0.003249 | 12.236 | 12.404 | 0.028224 |
| 12.155 | 11.228 | 0.859329 | 12.155 | 11.322 | 0.693889 | 12.155 | 11.385 | 0.5929 |
| 12.539 | 12.622 | 0.006889 | 12.539 | 12.696 | 0.024649 | 12.539 | 12.75 | 0.044521 |
| 12.25 | 11.537 | 0.508369 | 12.25 | 11.503 | 0.558009 | 12.25 | 11.479 | 0.594441 |
| 11.238 | 11.552 | 0.098596 | 11.238 | 11.511 | 0.074529 | 11.238 | 11.445 | 0.042849 |
| 11.097 | 11.067 | 0.0009 | 11.097 | 10.877 | 0.0484 | 11.097 | 10.637 | 0.2116 |
| 9.798 | 10.365 | 0.321489 | 9.798 | 10.183 | 0.148225 | 9.798 | 9.91 | 0.012544 |
| 10.597 | 10.428 | 0.028561 | 10.597 | 10.298 | 0.089401 | 10.597 | 10.059 | 0.289444 |
| 8.294 | 9.579 | 1.651225 | 8.294 | 9.297 | 1.006009 | 8.294 | 8.918 | 0.389376 |
| 9.741 | 10.373 | 0.399424 | 9.741 | 10.119 | 0.142884 | 9.741 | 9.797 | 0.003136 |
| | **Total SSQ** | **6.457573** | | **Total SSQ** | **4.625643** | | **Total SSQ** | **4.283978** |

Table A1.3 : Values of Fbar(87-93) and Ebar(87-93) for different values of M during the studied period (83-93)

**A : With acoustic as SSB index**

| | M = 0.8 | | M = 1.2 | | M = 1.6 | |
|---|---|---|---|---|---|---|
| Age | Fbar | Ebar | Fbar | Ebar | Fbar | Ebar |
| 1 | 0.47 | 0.37 | 0.37 | 0.23 | 0.28 | 0.15 |
| 2 | 1.17 | 0.6 | 1.04 | 0.46 | 0.956 | 0.37 |
| 3 | 0.65 | 0.45 | 0.78 | 0.4 | 1.04 | 0.39 |

**B : With DEPM as SSB index**

| | M = 0.8 | | M = 1.2 | | M = 1.6 | |
|---|---|---|---|---|---|---|
| Age | Fbar | Ebar | Fbar | Ebar | Fbar | Ebar |
| 1 | 0.5 | 0.38 | 0.4 | 0.25 | 0.29 | 0.15 |
| 2 | 1.43 | 0.64 | 1.19 | 0.5 | 1.21 | 0.43 |
| 3 | 1.029 | 0.56 | 1.05 | 0.47 | 1.1 | 0.41 |

Figure A1.1 : Shape of the SSQ surface for M = 0.8 and SSB index estimated with Acoustic survey.

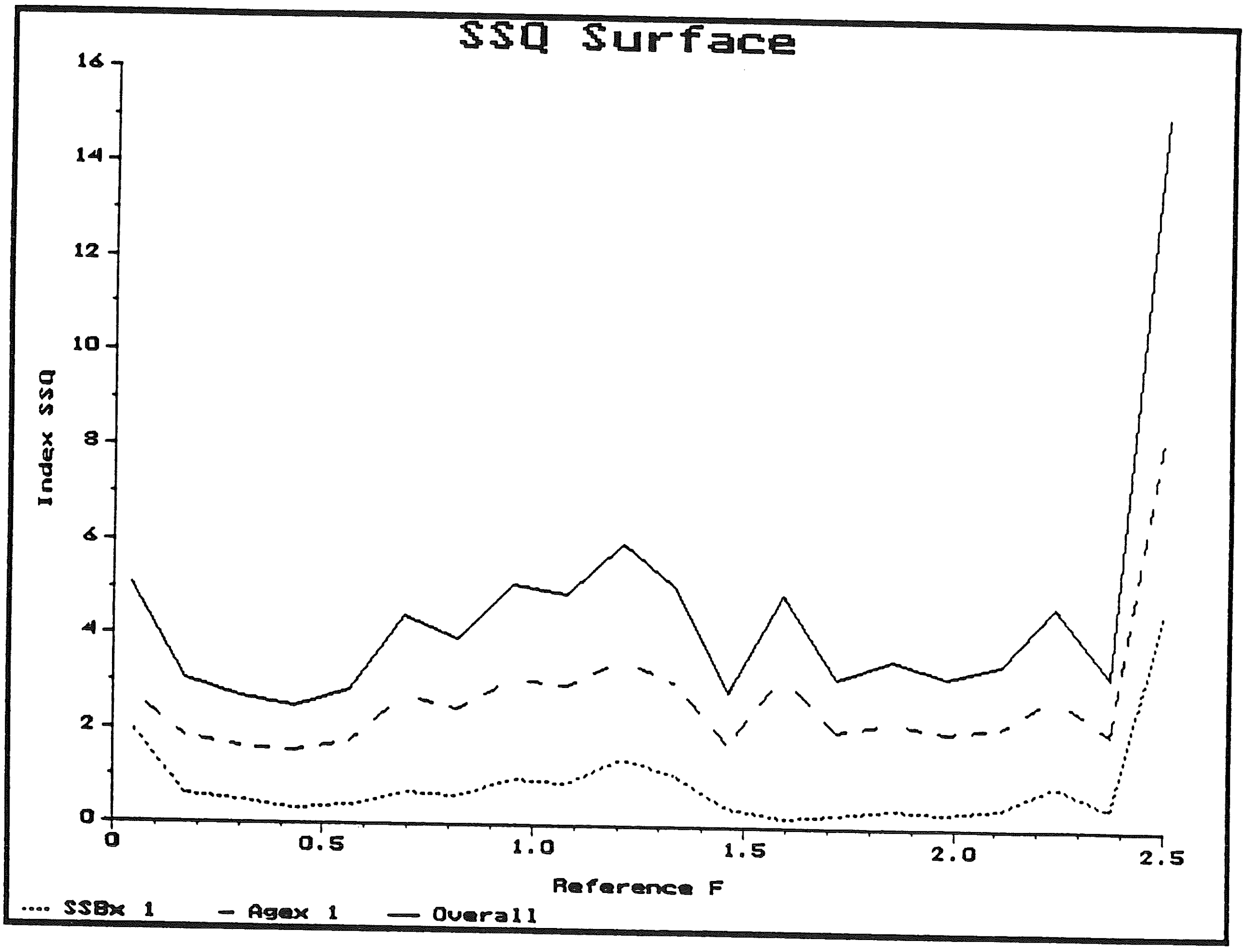


Figure A1.2 : Shape of the SSQ surface for M = 1.6 and SSB index estimated with Acoustic survey.

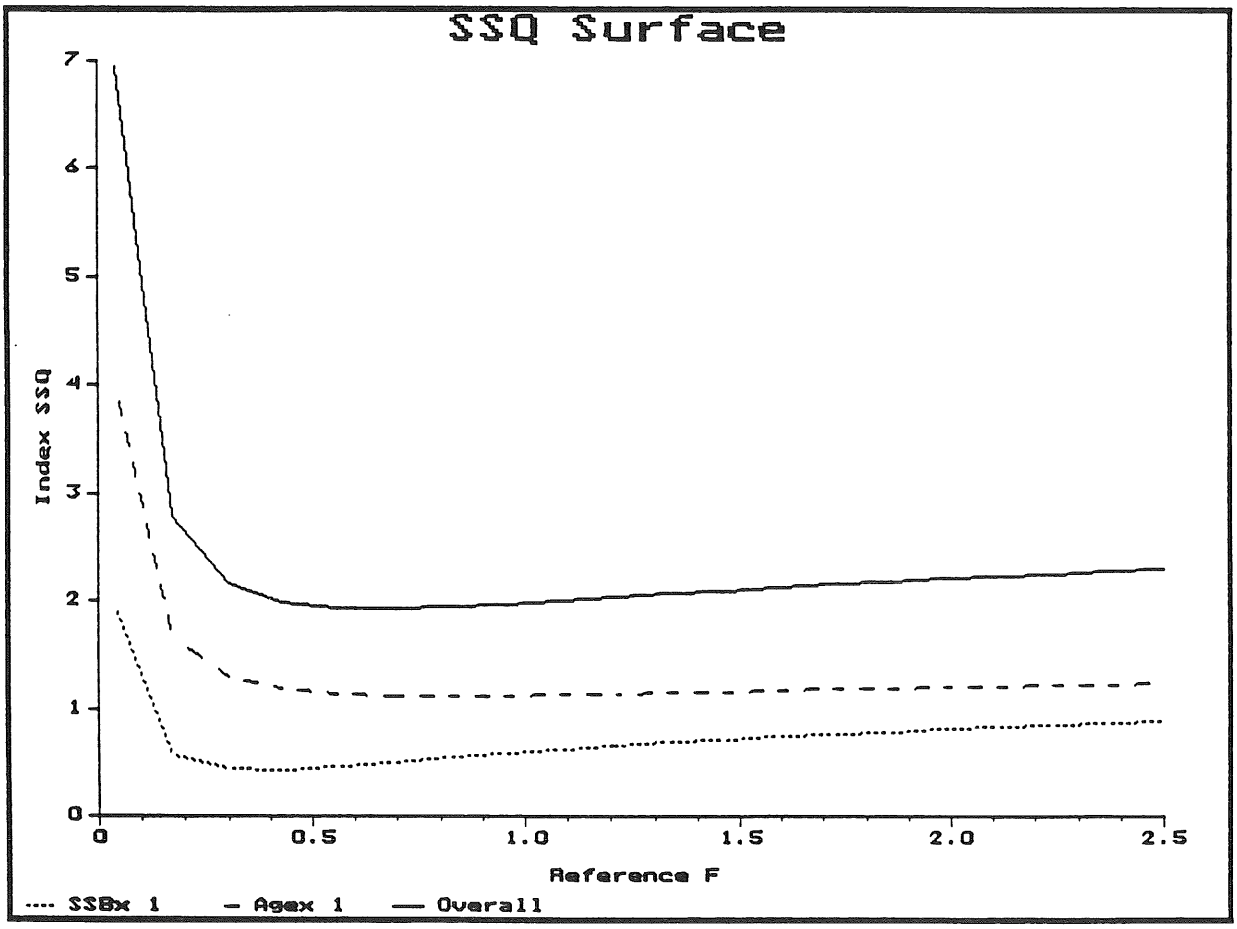
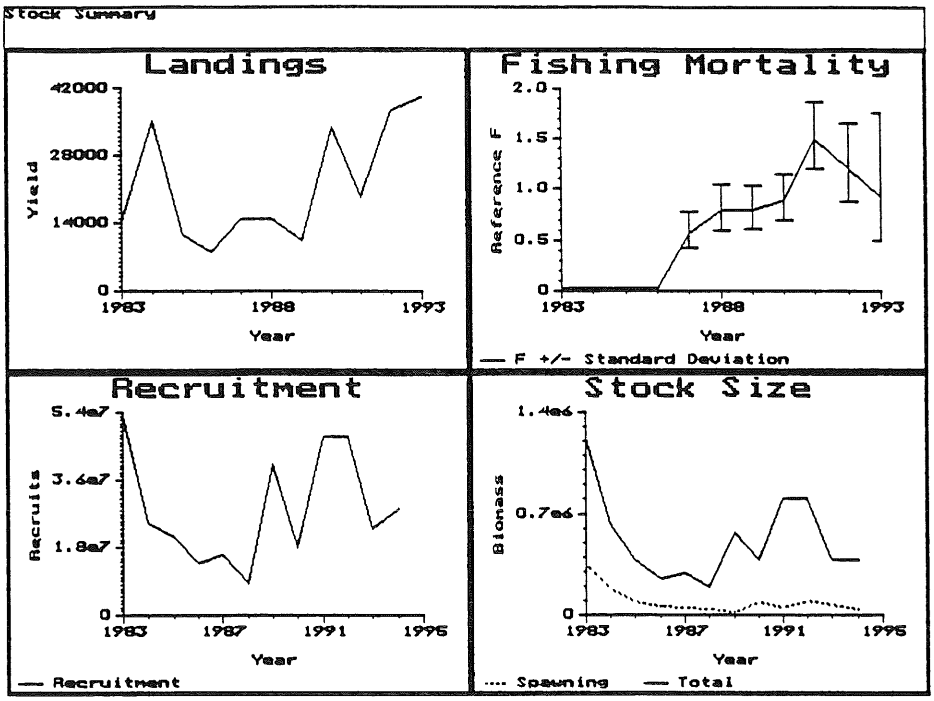


Figure A1.3a : Stock summary and Separable Model Diagnostics.



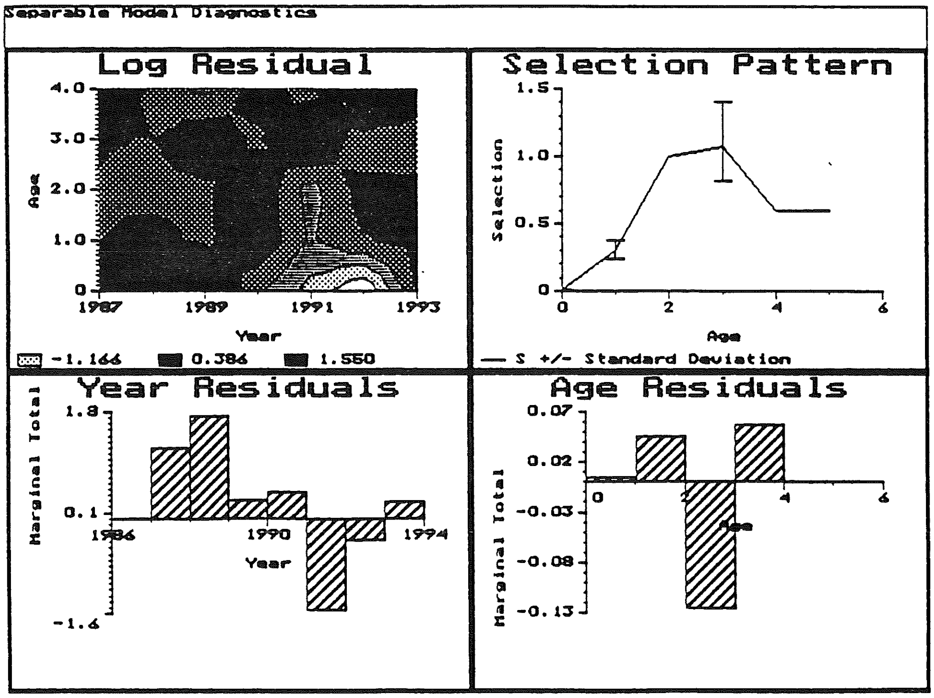
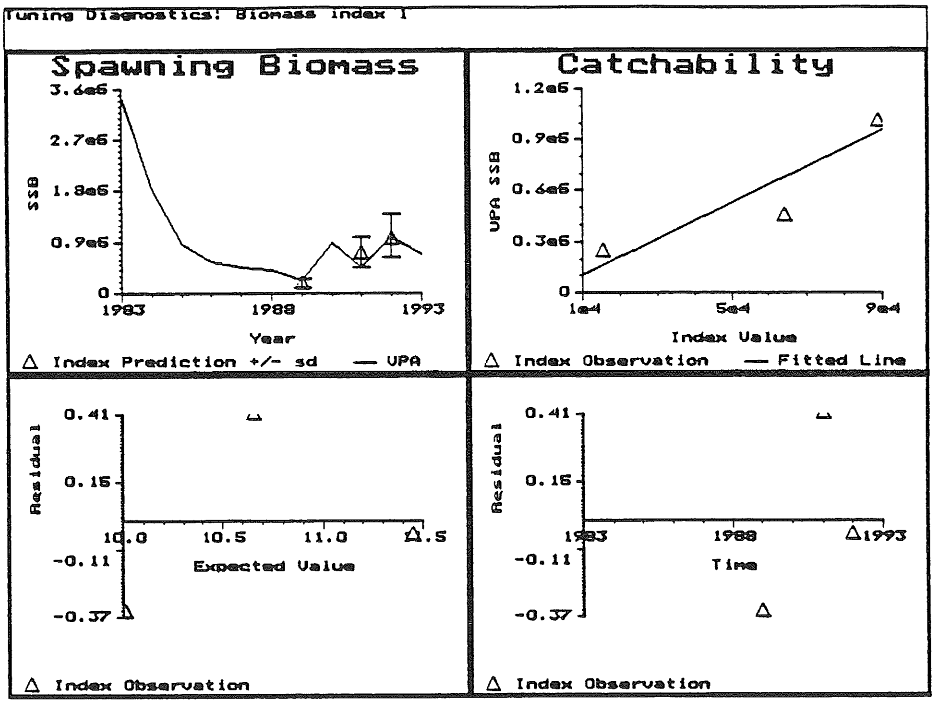



Figure A1.3b : Tuning Diagnostics : Biomass index 1 and Aged index at age 1



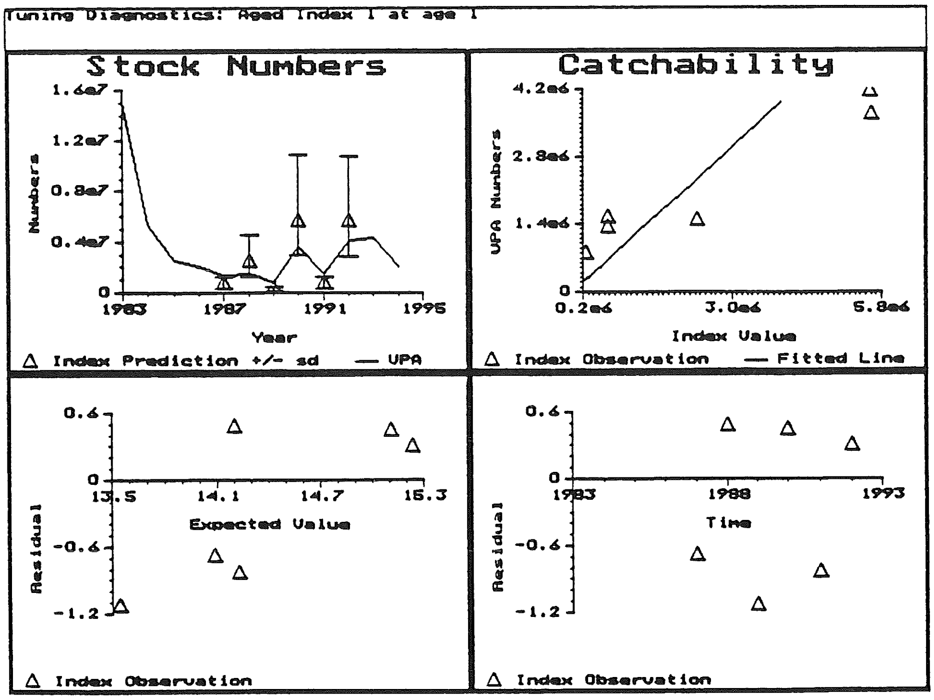
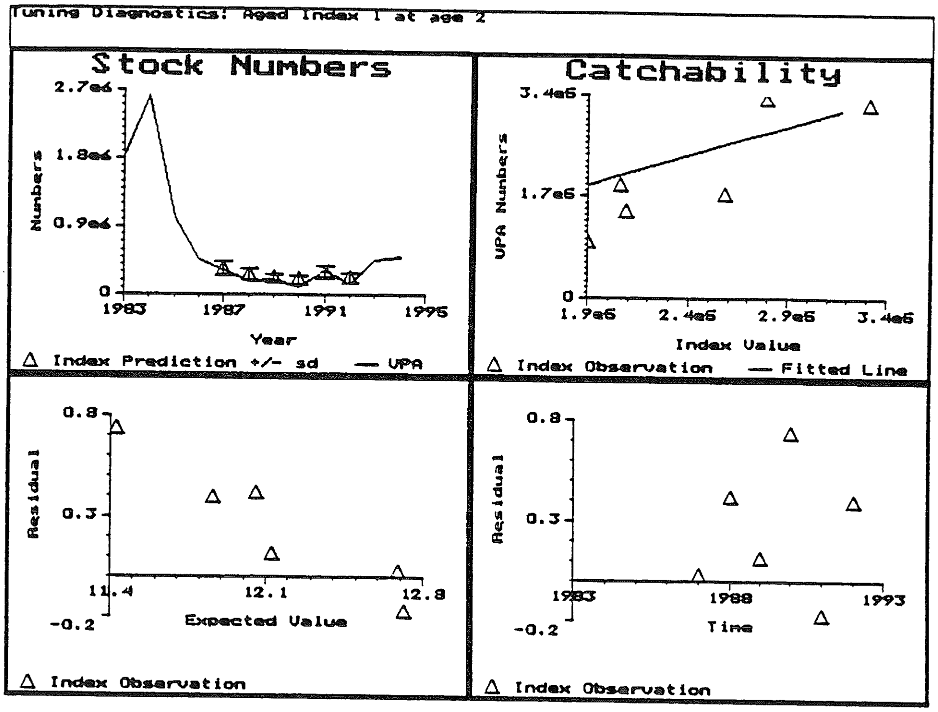
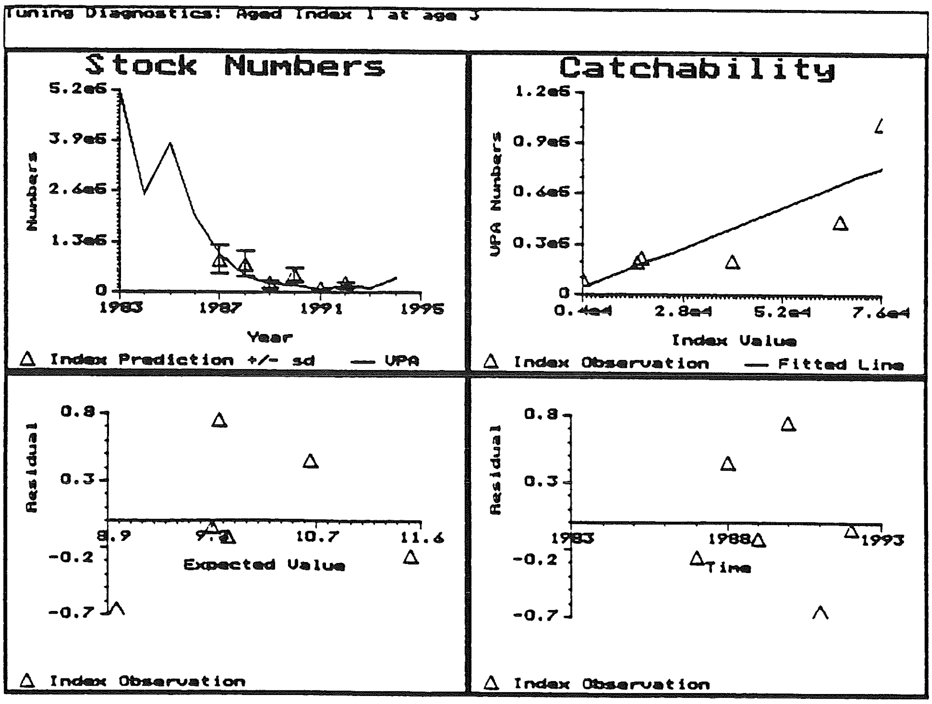



Figure A1.3c : Tuning Diagnostics : Aged index at age 2 and at age 3



## APPENDIX 2

## TESTING A MODEL FOR THE ASSESSMENT OF WESTERN MACKEREL

### A2.1. Introduction

Three substantial problems have been identified in the assessment of the Western Mackerel:

1) The egg production estimates may not necessarily be best treated as absolute estimates of stock size, but could better be treated as proportionate measures of abundance (Darby, 1993a).

2) Selection pattern appears to be changing in this stock (Darby, 1993b; Patterson, 1994a). The method used by the Working Group to overcome this problem in 1993 was not optimal in that data in the terminal year were downweighted (Anon. 1993).

3) Stock assessments have been calculated using either egg-surveys using a manually-tuned separable VPA, or using an age-disaggregated demersal survey (Darby, 1993c). It is undesirable to have two separate assessments, each of which uses only a part of the available data set.

A method was proposed for resolving these three problems in the framework of an integrated statistical analysis (Patterson, 1994b). This method has been evaluated by comparing results obtained with those from the two other methods available (manually-tuned separable VPA and shrunk XSA). A retrospective analysis is calculated in Patterson (1994b), and simulation testing of the method has been performed by Patterson (1994c) and in Appendix I to Anon. (1994). A description of the programmes is given in Patterson (1994d).

### A2.2. Manually-tuned assessment of Western Mackerel

A separable VPA adjusted by hand to the egg production estimates of stock size is given in Section 5.5.6.

### A2.3. Integrated Analysis Using a Single Selection Pattern

Integrated catch-at-age analysis (Fournier and Archibald, 1982; Deriso *et al.*, 1985; Gudmundsson, 1986; Kimura, 1989) as implemented in the ICA programmes (Patterson, 1994) was used to fit a separable model for the Western Mackerel. Such models have already been proposed for the assessment of this stock (Anon. 1991).

An integrated model was fitted to the catch at age data, egg production estimates of biomass, and Western Approaches survey data. The objective function fitted was:

$$\sum_{a,y} \lambda_a(\ln(C_{a,y}-\ln(F_y.S_a.\bar{N}_{a,y}))^2+$$
$$\sum_{a,y} \lambda_E(\ln(EPB)-\ln(S\hat{S}B))^2+$$
$$\sum_{a,y} \lambda_{CP}(\ln(A_{a,y}-K.\ln(Q.N^*))^2$$

Here $S_a$ represents selection at age, $S\hat{S}B$ is the spawning stock size estimated from the fitted populations, $F_y$ are the reference fishing mortalities at age 5, $N^*$ are the fitted populations calculated at the time of the surveys. $C_{a,y}$ are the observed catches at age, where $\lambda_c$ was set to 1.0 for all ages except age 0, at which it was set to 0.01 in order to reduce the influence of high variability in the recruitment. $\lambda_E$ was set to 5.0, corresponding to the large importance given to the egg production surveys in the traditional assessments. $\lambda_{CP}$ was set $=1.0$ for all ages. No inverse-variance weighting was attempted.

In prior trials which allowed a proportionate relationship between the egg production estimate of stock size, the estimate of the coefficient of proportionality was very close to 1.0, suggesting that the use of this survey as an absolute measure of biomass is appropriate.

Results are given in Table A2.1 and in Figure A2.1. These indicate a departure from the assumption of separability, with a region of high residuals above age 6 and after 1988. The model fits rather poorly to the catch at age data since 1988.

### A2.4. Integrated Analysis Using A Varying Selection Pattern

An analysis by Patterson (1994a) suggested that selection was stable prior to 1988, but that a marked change in selection occurred after this year. The model was modified to allow selection pattern to change in 1989. The objective function fitted in the new formulation was:

$$\sum_{a,y=1982}^{a,y=1988} \lambda_a(\ln(C_{a,y}-\ln(F_y.S1_a.\bar{N}_{a,y}))^2+$$
$$\sum_{a,y=1989}^{a,y=1993} \lambda_a(\ln(C_{a,y}-\ln(F_y.S2_a.\bar{N}_{a,y}))^2+$$
$$\sum_y \lambda_E(\ln(EPB)-\ln(S\hat{S}B))^2+$$
$$\sum_{a,y} \lambda_{CP}(\ln(A_{a,y}-K.\ln(Q.N^*))^2$$

Results and diagnostics of the model fit are given in Figures A2.1 - A2.12 and Table A2.1. The revised model formulation fits well to the observed data, with no strong groups of residuals.

As in the XSA assessments, when fitting to the Western Approaches survey data with assumed power relationships, these fits departed strongly from linearity (exponent = *ca.* 0.2).

Performance of this assessment method in retrospective analyses has been tested by Patterson (1994b), albeit in a slightly different model formulation. As one might expect, the assessment was found to be subject to revisions in perception of stock size at three-yearly intervals, when new egg survey data are included in the assessments.

### A2.5. XSA assessment of Western Mackerel

#### A2.5.1 The assessment methodology

Darby (1993a WD) demonstrated that the Western mackerel VPA could be tuned by applying XSA to a ground fish survey data set previously used only for the estimation of recruits (Dawson et al 1988). The resulting assessments showed good agreement with separable analyses tuned to the egg survey estimates. The tuning is independent of the egg survey results and provides a means by which the separable analysis can be cross validated, especially for the years between egg surveys. The XSA analysis has been repeated at this Working Group with the updated catch data.

The tuning diagnostics from the run are presented in Table A2.3. Ages 1 - 4 of the tuning data range exhibit high correlations between log catchability and log population abundance. The slopes are significantly different from 1. The slopes are severe and the estimated catchability values exhibit a wide range e.g. 115x for age 2. Ages < 5 were treated as recruits to the survey.

Unshrunk XSA analyses were used to examine the variation in catchability with age and time. The residuals for each area show year effects but no overall trends. Ages 5 and above had no significant differences in their log catchabilities and catchability was held constant at the value for age 5.

Anon (1993a) describes a series of retrospective runs with a range of shrinkage c.v.s, as used to examine the influence of shrinkage on the estimated F and population abundances for the most important ages. This follows the recommendations of the Working Group on Methods of Fish Stock Assessment (Anon 1993b). The optimum skrinkage cv was found to be 0.5. An examination of the contribution to the weighted mean terminal populations shows that the mean contributes approximately 20% to each of the estimates (Table A2.4).

XSA allows a minimum threshold to be set for the standard errors derived from the fleets. The value was set at 0.4 to reduce the influence of the extremely good correlations between log CPUE and log abundance noted for ages 1 -

4. This reduces the weight given to the population estimates at these ages and prevents them from dominating the assessment (Darby 1993a WD).

An examination of the tuning diagnostics for the assessment shows that the log CPUE data for the first four ages are well correlated with the log populations at age. The slopes of the regressions are severe, indicating a strong non-linear relationship in catchability. The information provided by the older ages in the tuning range is of poorer quality. The standard errors of the Log catchability are indicating high coefficients of variation (>60%) and will have a reduced influence on the weighted estimates for the terminal populations.

### A.2.6. Conclusions and Recommendations

Population size estimates from the three methods are compared in Figure 5.10. They are extremely close, and at present it does not seem that the perception of the size of this stock is dependent on the assessment method used. However it would be desirable to use a single assessment method rather than three separate methods.

The XSA assessment method does not allow inclusion of the egg survey information, which in the past has been the principal measure of the size of this stock. Although useful for comparative purposes in years when there are no egg surveys, the method is not suitable for definitive assessments when new egg surveys are to be included in the assessment. Furthermore, some problems of stability in the algorithm were noted by the Working Group (Section 11.11).

The manually-tuned separable VPA which has been used as the standard method to date suffers from two disadvantages. Firstly, a changing selection pattern violates the assumption that selection is constant over the entire time series that is made in the separable VPA. In the assessment of the stock made in 1993 it was found to be necessary to downweight important data in the fit in order to obtain consistent results. This is highly undesirable. Secondly, the method does not allow the inclusion of the Western Approaches surveys in the assessments, which have been shown to fit well to VPA estimates of population size.

The ICA programmes are at present the only method that is available to the working group for the analysis of all the relevant available information on this stock in a fashion which is consistent with prior belief about the fishery. The assumption of an abrupt change in selection in 1988 is an improvement over the assumption of constant selection, but may not be a realistic way to model the behaviour of a fishery which may be concentrating on abundant cohorts, or which has gradually changed its exploitation onto older fish. Alternative methods such as ADAPT (which assumes fixed catches at age) or other models of selection pattern may be preferable, and further testing work would be welcomed. Despite these caveats, however, the Working Group notes that the ICA programmes are the most appropriate of the tools presently available for the assessment of this stock. The ICA programmes also provide a test that a solution has been reached, in contrast to the XSA programme which does not indicate whether a stable solution has been found. On account of these perceived advantages, it is recommended to perform the next assessment of the Western Mackerel using the ICA method with changing selection pattern.

Comments and advice from the Methods Working Group are welcomed.

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Table A2.1 Summary results of integrated catch-at-age analysis using the objective function given in Section A2.3. The populations are fitted to the egg survey estimates of stock size and the 'Western Approaches' survey data. The latter are assumed to bear a power relationship to stock size. Selection pattern is assumed to be constant over the years of the analysis.

INDICES OF SPAWNING STOCK BIOMASS

| | 1977 | 1980 | 1983 | 1986 | 1989 | 1992 |
|---|---|---|---|---|---|---|
| 1 | .322E+07 | .241E+07 | .249E+07 | .201E+07 | .224E+07 | .293E+07 |

AGE - STRUCTURED INDICES

INDEX : 1 from 1984 to 1993

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .606E-01 | .321E+01 | .443E+00 | .340E+01 | .214E+02 | .118E+02 | .190E+01 | .248E+01 | .107E+01 | .467E+01 |
| 2 | .611E+00 | .310E-01 | .940E+01 | .387E+00 | .130E+01 | .865E+01 | .476E+01 | .184E+02 | .320E+01 | .405E+01 |
| 3 | .571E+01 | .809E+00 | .221E+00 | .636E+01 | .263E+01 | .389E+01 | .987E+01 | .674E+01 | .792E+01 | .453E+01 |
| 4 | .393E+01 | .515E+01 | .344E+00 | .304E-01 | .108E+02 | .354E+01 | .333E+01 | .580E+01 | .325E+01 | .331E+01 |

INDEX : 2 from 1984 to 1993

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .411E+02 | .212E+03 | .196E+01 | .134E+02 | .304E+01 | .223E+03 | .362E+01 | .162E+02 | -.100E+01 | .104E+03 |
| 2 | .441E+03 | .229E+02 | .431E+02 | .200E+02 | .485E+02 | .209E+03 | .640E+02 | .125E+04 | .138E+03 | .171E+03 |
| 3 | .760E+03 | .121E+03 | .119E+02 | .732E+02 | .165E+03 | .131E+03 | .117E+03 | .437E+03 | .459E+03 | .149E+03 |
| 4 | .451E+03 | .275E+03 | .958E+01 | .433E+01 | .269E+03 | .417E+02 | .332E+02 | .216E+03 | .500E+02 | .141E+03 |

FISHING MORTALITY

| | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .0002 | .0073 | .0025 | .0032 | .0144 | .0032 | .0060 | .0010 | .0001 | .0001 | .0001 | .0001 | .0001 | .0001 | .0001 | .0001 | .0001 | .0001 | .0002 |
| 1 | .0193 | .0744 | .0390 | .0458 | .1334 | .1082 | .0522 | .0380 | .0230 | .0191 | .0172 | .0152 | .0169 | .0164 | .0155 | .0172 | .0188 | .0231 | .0268 |
| 2 | .0332 | .0828 | .0976 | .1855 | .1132 | .2498 | .1493 | .1075 | .0811 | .0674 | .0605 | .0536 | .0596 | .0579 | .0545 | .0607 | .0663 | .0814 | .0943 |
| 3 | .0982 | .1293 | .0873 | .1920 | .2914 | .1861 | .1725 | .1966 | .1351 | .1123 | .1007 | .0893 | .0994 | .0965 | .0908 | .1011 | .1104 | .1356 | .1570 |
| 4 | .1087 | .2433 | .0863 | .1833 | .2374 | .2861 | .1057 | .1971 | .1844 | .1532 | .1375 | .1219 | .1356 | .1317 | .1239 | .1379 | .1507 | .1851 | .2143 |
| 5 | .2391 | .1344 | .1007 | .1776 | .2334 | .2746 | .1943 | .1063 | .2327 | .1934 | .1735 | .1538 | .1711 | .1661 | .1564 | .1741 | .1902 | .2335 | .2705 |
| 6 | .1388 | .2154 | .0846 | .1904 | .2277 | .2284 | .2312 | .2165 | .2132 | .1772 | .1590 | .1409 | .1568 | .1522 | .1433 | .1595 | .1742 | .2140 | .2478 |
| 7 | .4695 | .4085 | .1645 | .1179 | .3477 | .2255 | .2285 | .2321 | .2291 | .1904 | .1708 | .1514 | .1685 | .1636 | .1539 | .1714 | .1872 | .2299 | .2663 |
| 8 | .2466 | .2820 | .2081 | .2019 | .1595 | .3448 | .2437 | .2918 | .2400 | .1994 | .1789 | .1586 | .1765 | .1714 | .1613 | .1795 | .1961 | .2408 | .2789 |
| 9 | .2558 | .1438 | .1473 | .2875 | .3893 | .2007 | .3886 | .2733 | .2490 | .2068 | .1856 | .1645 | .1831 | .1777 | .1673 | .1862 | .2034 | .2498 | .2893 |
| 10 | .2391 | .1344 | .1007 | .2807 | .4252 | .4184 | .2960 | .4797 | .2327 | .1934 | .1735 | .1538 | .1711 | .1661 | .1564 | .1741 | .1902 | .2335 | .2705 |
| 11 | .2391 | .1344 | .1007 | .2807 | .4252 | .4184 | .2960 | .4797 | .2327 | .1934 | .1735 | .1538 | .1711 | .1661 | .1564 | .1741 | .1902 | .2335 | .2705 |

Table A2.1 Contd.

NUMBERS AT AGE (Millions)

| | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 4870. | 5057. | 877. | 3523. | 5990. | 6562. | 6849. | 2265. | 1080. | 5762. | 2881. | 3604. | 6115. | 4859. | 5747. | 4128. | 3970. | 5397. | 91161. | 5247. |
| 1 | 2964. | 4191. | 4321. | 753. | 3023. | 5082. | 5630. | 5860. | 1948. | 930. | 4958. | 2479. | 3101. | 5263. | 4182. | 4946. | 3552. | 3417. | 4644. | 78451. |
| 2 | 3431. | 2502. | 3348. | 3577. | 619. | 2277. | 3926. | 4599. | 4856. | 1638. | 785. | 4195. | 2102. | 2625. | 4456. | 3544. | 4184. | 3000. | 2874. | 3892. |
| 3 | 1087. | 2856. | 1982. | 2614. | 2557. | 476. | 1526. | 2910. | 3555. | 3854. | 1318. | 636. | 3422. | 1704. | 2132. | 3632. | 2871. | 3371. | 2381. | 2251. |
| 4 | 3197. | 848. | 2160. | 1564. | 1857. | 1645. | 340. | 1106. | 2058. | 2673. | 2965. | 1026. | 501. | 2667. | 1332. | 1676. | 2826. | 2213. | 2533. | 1751. |
| 5 | 970. | 2469. | 572. | 1706. | 1120. | 1260. | 1063. | 263. | 781. | 1473. | 1974. | 2224. | 782. | 376. | 2012. | 1013. | 1256. | 2092. | 1583. | 1760. |
| 6 | 1193. | 657. | 1857. | 445. | 1229. | 764. | 824. | 754. | 204. | 533. | 1045. | 1428. | 1641. | 567. | 274. | 1481. | 732. | 894. | 1425. | 1039. |
| 7 | 3561. | 894. | 456. | 1469. | 317. | 843. | 523. | 563. | 522. | 142. | 384. | 767. | 1068. | 1208. | 419. | 205. | 1087. | 530. | 621. | 958. |
| 8 | 0. | 1916. | 511. | 333. | 1124. | 193. | 579. | 358. | 384. | 358. | 101. | 279. | 567. | 777. | 883. | 309. | 148. | 776. | 362. | 410. |
| 9 | 0. | 0. | 1244. | 357. | 234. | 825. | 117. | 390. | 230. | 260. | 252. | 73. | 205. | 409. | 563. | 647. | 222. | 105. | 525. | 236. |
| 10 | 0. | 0. | 0. | 924. | 231. | 137. | 581. | 69. | 256. | 155. | 182. | 180. | 53. | 147. | 295. | 410. | 462. | 156. | 70. | 338. |
| 11 | 0. | 0. | 0. | 0. | 585. | 150. | 123. | 254. | 99. | 131. | 138. | 152. | 169. | 86. | 101. | 107. | 181. | 205. | 127. | 130. |

STOCK SUMMARY

| Year | Recruits x10^6 | Total B tonnes | Spawn B tonnes | Landings tonnes | Yld/SSB |
|---|---|---|---|---|---|
| 1975 | 4870. | 4111975. | 3006971. | 491380. | .1634 |
| 1976 | 5057. | 3726438. | 2655858. | 507178. | .1910 |
| 1977 | 877. | 3625427. | 2640786. | 325974. | .1234 |
| 1978 | 3523. | 3593872. | 2814604. | 503913. | .1790 |
| 1979 | 5990. | 3299273. | 2468810. | 605744. | .2454 |
| 1980 | 6562. | 2935972. | 1969832. | 604761. | .3070 |
| 1981 | 6849. | 2955018. | 1967549. | 661762. | .3363 |
| 1982 | 2265. | 2825456. | 1880415. | 623819. | .3317 |
| 1983 | 1080. | 3184565. | 2334531. | 614287. | .2631 |
| 1984 | 5762. | 3203944. | 2561647. | 550929. | .2151 |
| 1985 | 2881. | 3268588. | 2498189. | 561292. | .2247 |
| 1986 | 3604. | 3191987. | 2165205. | 537615. | .2483 |
| 1987 | 6115. | 3174234. | 2457297. | 615380. | .2504 |
| 1988 | 4859. | 3529412. | 2644034. | 628000. | .2375 |
| 1989 | 5747. | 3790384. | 2795495. | 567400. | .2030 |
| 1990 | 4128. | 3660161. | 2720127. | 605937. | .2228 |
| 1991 | 3970. | 4171801. | 3177362. | 646169. | .2034 |
| 1992 | 5397. | 4377398. | 3291137. | 742305. | .2255 |
| 1993 | 91161. | 4270822. | 3139427. | 805039. | .2564 |

Table A2.1 Contd.

Separable Model: Populations at age 10

| | | | | |
|---|---|---|---|---|
| 32 | 1983 | 255677.9805 | 119012.9933 | 549278.0908 |
| 33 | 1984 | 154556.1195 | 85237.7838 | 280246.5409 |
| 34 | 1985 | 182091.9978 | 108125.2488 | 306658.2138 |
| 35 | 1986 | 180247.4663 | 112234.4270 | 289475.7873 |
| 36 | 1987 | 52982.5892 | 33931.0530 | 82731.1417 |
| 37 | 1988 | 146746.2434 | 95337.8047 | 225875.3495 |
| 38 | 1989 | 294998.5573 | 197589.4902 | 440429.0365 |
| 39 | 1990 | 410018.6473 | 293428.3614 | 572934.7033 |
| 40 | 1991 | 461919.1578 | 331244.4857 | 644144.4842 |
| 41 | 1992 | 156205.3895 | 110381.0819 | 221053.4930 |

SSB Index catchabilities
SSB Index 1 was used as absolute estimator.
No fitted catchability for this index.

Age-structured index catchabilities
Age-Structured Index 1

Power model fitted. Slopes (Q) and exponents (K) at age:

| | | | | | |
|---|---|---|---|---|---|
| 42 | 1 | Q | .16851E+02 | .91257E+01 | .31116E+02 |
| 43 | 1 | K | -.41608E+02 | -.50781E+02 | -.32436E+02 |
| 44 | 2 | Q | .31900E+02 | .16515E+02 | .61618E+02 |
| 45 | 2 | K | -.50316E+02 | -.60014E+02 | -.40618E+02 |
| 46 | 3 | Q | .76997E+01 | .46470E+01 | .12758E+02 |
| 47 | 3 | K | -.28506E+02 | -.35856E+02 | -.21157E+02 |
| 48 | 4 | Q | .16647E+02 | .94177E+01 | .29425E+02 |
| 49 | 4 | K | -.39539E+02 | -.47691E+02 | -.31387E+02 |

Age-Structured Index 2

Power model fitted. Slopes (Q) and exponents (K) at age:

| | | | | | |
|---|---|---|---|---|---|
| 50 | 1 | Q | .11137E+01 | .70582E+00 | .17571E+01 |
| 51 | 1 | K | .14501E+01 | -.53925E+01 | .82927E+01 |
| 52 | 2 | Q | .27043E+01 | .17016E+01 | .42980E+01 |
| 53 | 2 | K | -.99947E+01 | -.16821E+02 | -.31681E+01 |
| 54 | 3 | Q | .47259E+01 | .29528E+01 | .75636E+01 |
| 55 | 3 | K | -.17585E+02 | -.24431E+02 | -.10738E+02 |
| 56 | 4 | Q | .12773E+02 | .74081E+01 | .22023E+02 |
| 57 | 4 | K | -.32235E+02 | -.40032E+02 | -.24438E+02 |

Table A2.1 Contd.

PARAMETER ESTIMATES +/- SD

Separable Model: Reference F by year

| | | | | |
|---|---|---|---|---|
| 1 | 1983 | .2327 | .1643 | .3297 |
| 2 | 1984 | .1934 | .1362 | .2745 |
| 3 | 1985 | .1735 | .1226 | .2455 |
| 4 | 1986 | .1538 | .1089 | .2173 |
| 5 | 1987 | .1711 | .1212 | .2417 |
| 6 | 1988 | .1661 | .1179 | .2341 |
| 7 | 1989 | .1564 | .1110 | .2202 |
| 8 | 1990 | .1741 | .1233 | .2457 |
| 9 | 1991 | .1902 | .1344 | .2690 |
| 10 | 1992 | .2335 | .1634 | .3337 |
| 11 | 1993 | .2705 | .1843 | .3968 |

Separable Model: Selection (S) by age

| | | | | |
|---|---|---|---|---|
| 12 | 0 | .0006 | .0001 | .0054 |
| 13 | 1 | .0990 | .0722 | .1358 |
| 14 | 2 | .3485 | .2555 | .4754 |
| 15 | 3 | .5807 | .4283 | .7872 |
| 16 | 4 | .7925 | .5901 | 1.0644 |
| | 5 | 1.0000 | Fixed : Reference age | |
| 17 | 6 | .9163 | .6965 | 1.2055 |
| 18 | 7 | .9846 | .7534 | 1.2867 |
| 19 | 8 | 1.0313 | .7918 | 1.3434 |
| 20 | 9 | 1.0697 | .8180 | 1.3989 |
| | 10 | 1.0000 | Fixed : last true age | |

Separable Model: Populations in year 1993

| | | | | |
|---|---|---|---|---|
| 21 | 0 | 91161088. | 54543. | 152362149163. |
| 22 | 1 | 4644254. | 3469604. | 6216587. |
| 23 | 2 | 2873814. | 2348178. | 3517112. |
| 24 | 3 | 2380676. | 1963762. | 2886103. |
| 25 | 4 | 2533190. | 2087850. | 3073523. |
| 26 | 5 | 1582736. | 1278143. | 1959916. |
| 27 | 6 | 1425483. | 1106631. | 1836204. |
| 28 | 7 | 621368. | 475509. | 811969. |
| 29 | 8 | 362203. | 269159. | 487410. |
| 30 | 9 | 524867. | 377541. | 729685. |
| 31 | 10 | 70350. | 47165. | 104933. |

Table A2.1 Contd.

RESIDUALS ABOUT THE MODEL FIT
------------------------------

Separable Model Residuals: log(Observed Catch) - log(Expected Catch), and we
ights in the analysis
---------------------------------------------- -------------------

| Age | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | -.71987E+01 | .56321E+00 | .70652E+01 | .61782E+00 | .19389E+01 | -.14731E+01 | -.58990E+01 | -.87256E+00 | -.74364E+00 | -.38945E-01 | -.10978E+00 | .10000E-01 |
| 1 | -.15047E-01 | -.71611E-01 | -.22146E+00 | .55334E+00 | .58502E-01 | -.11808E-01 | .13322E+00 | -.38619E+00 | -.15631E+00 | -.14193E+00 | -.68858E-02 | .10000E+01 |
| 2 | -.78858E+00 | .10944E+01 | -.98382E+00 | -.87217E+00 | .17098E+00 | -.18724E+00 | .10313E+00 | .48002E-01 | .52375E-01 | .55118E-01 | .20104E+00 | .10000E+01 |
| 3 | .41170E+00 | -.30297E+00 | .67063E+00 | -.52422E+00 | -.54311E+00 | .11803E+00 | .10464E+00 | .17536E+00 | .67262E-02 | .80354E-01 | .17929E+00 | .10000E+01 |
| 4 | .14976E+00 | -.74744E+00 | .27209E+00 | .77537E+00 | -.12865E+00 | -.36649E+00 | .68794E-01 | -.35017E-01 | -.18192E-01 | .33935E-01 | .84030E+00 | .10000E+01 |
| 5 | -.39303E-01 | .21625E+00 | -.75301E-01 | .18551E+00 | .50099E+00 | .21580E+00 | .44865E-01 | .55437E-01 | -.20206E-01 | -.18354E+00 | -.81891E-01 | .10000E+01 |
| 6 | .39340E+00 | -.33151E+00 | .33459E+00 | .16724E+00 | .12406E+00 | .27406E+00 | .29915E+00 | -.29587E-01 | -.14570E+00 | -.19122E+00 | -.23497E+00 | .10000E+01 |
| 7 | .26386E+00 | .32470E+00 | .42802E-01 | .22880E+00 | .21753E-01 | .98673E-02 | .19684E+00 | .30378E+00 | -.50164E-01 | -.24548E+00 | -.65990E+00 | .10000E+01 |
| 8 | .24990E+00 | -.26698E+00 | -.20727E+00 | -.35918E+00 | -.13652E-01 | -.10793E+00 | .13709E+00 | .10709E+00 | .70452E+00 | .97297E-01 | -.91621E-01 | .10000E+01 |
| 9 | .94198E-01 | .32746E-01 | -.36762E+00 | -.13501E+00 | -.28705E+00 | -.30737E+00 | -.49354E-01 | .99041E-01 | -.13185E+00 | .84592E+00 | .16024E+00 | .10000E+01 |
| 10 | -.80361E-10 | .58607E-02 | -.16993E+00 | -.19761E+00 | -.16087E+00 | -.37639E+00 | -.16458E+00 | .72926E-01 | .15198E+00 | -.30994E-01 | .87787E+00 | .10000E+01 |
| Wts | .10000E+01 | .10000E+01 | .10000E+01 | .10000E+01 | .10000E+01 | .10000E+01 | .10000E+01 | .10000E+01 | .10000E+01 | .10000E+01 | .10000E+01 | |

Table A2.1 Contd.

Biomass Index Residuals: log(Observed Index) - log(Expected Index)

| Idx | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | .19830E+00 | -.10000E+01 | -.10000E+01 | .20168E+00 | -.10000E+01 | -.10000E+01 | .64472E-01 | -.10000E+01 | -.10000E+01 |

| Idx | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|---|
| 1 | -.74380E-01 | -.10000E+01 | -.10000E+01 | -.22153E+00 | -.10000E+01 | -.10000E+01 | -.11623E+00 | -.10000E+01 |

Aged Index Residuals: log(Observed Index) - log(Expected Index)

Aged Index 1

| Age | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .12910E+00 | -.63184E+00 | -.65618E+00 | .75013E+00 | .10981E+01 | .11473E+01 | -.11483E+01 | .52640E-01 | -.67655E+00 | -.64383E-01 |
| 2 | .49426E+00 | .52781E-01 | -.42232E-01 | -.83343E+00 | -.39356E+00 | -.33339E+00 | -.13096E+00 | .65121E+00 | .68755E-01 | .46656E+00 |
| 3 | -.54969E+00 | -.32080E+00 | -.13834E+00 | -.20703E+00 | .33120E+00 | .26344E+00 | .11178E+00 | .21597E+00 | .64297E-01 | .22916E+00 |
| 4 | -.46181E+00 | -.49523E+00 | -.23138E+00 | -.62747E+00 | .53626E+00 | .13687E+01 | .67230E+00 | -.23169E+00 | -.94983E-01 | -.43473E+00 |

Aged Index 2

| Age | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .79231E+00 | .22541E+01 | -.23549E+01 | -.46165E+00 | -.19990E+01 | .23210E+01 | -.18177E+01 | -.28160E+00 | -.10000E+01 | .15473E+01 |
| 2 | .19102E+01 | -.31609E+00 | -.13550E+01 | -.14319E+01 | -.76899E+00 | .16646E+00 | -.78915E+00 | .20211E+01 | .15115E+00 | .41217E+00 |
| 3 | .78500E+00 | .60724E+00 | -.58764E+00 | -.13768E+01 | .52031E+00 | -.64192E-01 | -.99543E+00 | .68886E+00 | .49906E+00 | -.76413E-01 |
| 4 | .87371E+00 | .10429E+00 | -.56197E+00 | .48177E+00 | .34625E+00 | .24529E+00 | -.55676E+00 | -.44482E-02 | -.82096E+00 | -.10717E+00 |

PARAMETERS OF THE DISTRIBUTION OF ln CATCHES AT AGE

Separable model fitted from 1983 to 1993

| | | |
|---|---|---|
| Variance | : | 2.1940 |
| Skewness test statistic | : | -14.8369 |
| Kurtosis test statistic | : | 57.3301 |
| Partial chi-square | : | 31.0827 |
| Probability of chi-square | : | 1.0000 |
| Degrees of freedom | : | 41 |

Table A2.1 Contd.

PARAMETERS OF THE DISTRIBUTION OF THE SSB INDICES

DISTRIBUTION STATISTICS FOR ln SSB INDEX 1
Index used as absolute measure of abundance.

| | | |
|---|---|---|
| Variance | : | .0253 |
| Skewness test statistic | : | .1408 |
| Kurtosis test statistic | : | -.7445 |
| Partial chi-square | : | .0103 |
| Probability of chi-square | : | 1.0000 |
| Number of observations | : | 6 |
| Degrees of freedom | : | 6 |
| Weight in the analysis | : | 4.0000 |

PARAMETERS OF THE DISTRIBUTION OF THE AGE-STRUCTURED INDICES

DISTRIBUTION STATISTICS FOR ln AGED INDEX 1
Power catchability relationship assumed.

| Age | : | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Variance | : | .7143 | .2341 | .0952 | .4713 |
| Skewness test stat. | : | .2689 | -.2871 | -.8117 | 1.3648 |
| Kurtosis test stat. | : | -.7907 | -.4536 | -.5350 | -.0753 |
| Partial chi-square | : | 7.1045 | 6.9159 | 1.4221 | 19.5881 |
| Prob. of chi-square | : | .5254 | .5457 | .9939 | .0120 |
| Number of data | : | 10 | 10 | 10 | 10 |
| Degrees of freedom | : | 8 | 8 | 8 | 8 |
| Weight in analysis | : | 1.0000 | 1.0000 | 1.0000 | 1.0000 |

DISTRIBUTION STATISTICS FOR ln AGED INDEX 2
Power catchability relationship assumed.

| Age | : | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Variance | : | 3.8040 | 1.6443 | .6526 | .3122 |
| Skewness test stat. | : | .0264 | .7618 | -.8556 | -.0708 |
| Kurtosis test stat. | : | -.9148 | -.5058 | -.6174 | -.5863 |
| Partial chi-square | : | 8.6449 | 2.8224 | 1.0058 | .7567 |
| Prob. of chi-square | : | .2792 | .9450 | .9982 | .9994 |
| Number of data | : | 9 | 10 | 10 | 10 |
| Degrees of freedom | : | 7 | 8 | 8 | 8 |
| Weight in analysis | : | 1.0000 | 1.0000 | 1.0000 | 1.0000 |

Table A2.2 Summary results of integrated catch-at-age analysis using the objective function given in Section A2.4. The populations are fitted to the egg survey estimates of stock size and the 'Western Approaches' survey data. The latter are assumed to bear a power relationship to stock size. Two selection patterns are fitted for the periods 1982 - 1988 and for 1988 - 1993 independently.

FISHING MORTALITY

| | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | .0002 | .0074 | .0025 | .0032 | .0145 | .0032 | .0061 | .0010 | .0000 | .0000 | .0000 | .0000 | .0000 | .0007 | .0006 | .0007 | .0007 | .0009 | .0011 |
| 1 | .0196 | .0752 | .0393 | .0463 | .1334 | .1090 | .0528 | .0383 | .0235 | .0195 | .0174 | .0154 | .0172 | .0167 | .0156 | .0173 | .0189 | .0231 | .0267 |
| 2 | .0341 | .0842 | .0987 | .1871 | .1146 | .2498 | .1505 | .1087 | .0864 | .0716 | .0641 | .0567 | .0632 | .0565 | .0528 | .0587 | .0638 | .0781 | .0903 |
| 3 | .0984 | .1333 | .0889 | .1944 | .2946 | .1889 | .1726 | .1986 | .1382 | .1145 | .1026 | .0907 | .1010 | .0981 | .0917 | .1018 | .1108 | .1356 | .1568 |
| 4 | .1142 | .2439 | .0892 | .1871 | .2412 | .2902 | .1075 | .1972 | .1792 | .1485 | .1330 | .1176 | .1310 | .1405 | .1314 | .1459 | .1587 | .1943 | .2247 |
| 5 | .2470 | .1421 | .1010 | .1845 | .2394 | .2802 | .1979 | .1084 | .2657 | .2201 | .1972 | .1744 | .1943 | .1499 | .1401 | .1557 | .1693 | .2072 | .2397 |
| 6 | .1442 | .2243 | .0900 | .1911 | .2387 | .2359 | .2374 | .2214 | .2208 | .1829 | .1639 | .1449 | .1615 | .1567 | .1464 | .1627 | .1770 | .2166 | .2505 |
| 7 | .4973 | .4296 | .1728 | .1263 | .3492 | .2393 | .2380 | .2399 | .2276 | .1886 | .1689 | .1494 | .1664 | .1768 | .1652 | .1836 | .1997 | .2444 | .2826 |
| 8 | .2187 | .3068 | .2229 | .2143 | .1728 | .3469 | .2629 | .3077 | .2352 | .1949 | .1746 | .1544 | .1720 | .1910 | .1785 | .1983 | .2157 | .2640 | .3053 |
| 9 | .2351 | .1353 | .1636 | .3142 | .4221 | .2210 | .3921 | .3018 | .2528 | .2095 | .1877 | .1660 | .1849 | .1962 | .1834 | .2037 | .2216 | .2712 | .3137 |
| 10 | .2470 | .1421 | .1010 | .3205 | .4842 | .4734 | .3356 | .4863 | .2657 | .2201 | .1972 | .1744 | .1943 | .1799 | .1682 | .1868 | .2032 | .2487 | .2876 |
| 11 | .2470 | .1421 | .1010 | .3205 | .4842 | .4734 | .3356 | .4863 | .2657 | .2201 | .1972 | .1744 | .1943 | .1799 | .1682 | .1868 | .2032 | .2487 | .2876 |

NUMBERS AT AGE (Millions)

| | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 4823. | 5020. | 867. | 3522. | 5949. | 6496. | 6803. | 2230. | 1059. | 5733. | 2850. | 3571. | 6095. | 4832. | 5705. | 4095. | 3942. | 5362. | 13340. | 5247. |
| 1 | 2917. | 4150. | 4289. | 744. | 3022. | 5047. | 5573. | 5819. | 1918. | 912. | 4934. | 2453. | 3074. | 5246. | 4156. | 4907. | 3522. | 3390. | 4611. | 11470. |
| 2 | 3338. | 2462. | 3314. | 3549. | 612. | 2276. | 3895. | 4550. | 4821. | 1612. | 769. | 4174. | 2079. | 2601. | 4441. | 3522. | 4151. | 2975. | 2851. | 3864. |
| 3 | 1085. | 2777. | 1948. | 2584. | 2534. | 469. | 1526. | 2884. | 3513. | 3806. | 1292. | 621. | 3394. | 1680. | 2115. | 3626. | 2859. | 3352. | 2368. | 2242. |
| 4 | 3052. | 846. | 2092. | 1534. | 1831. | 1624. | 334. | 1105. | 2035. | 2633. | 2921. | 1003. | 488. | 2641. | 1311. | 1661. | 2818. | 2203. | 2519. | 1743. |
| 5 | 943. | 2343. | 571. | 1647. | 1095. | 1238. | 1046. | 259. | 781. | 1465. | 1954. | 2201. | 768. | 369. | 1975. | 989. | 1236. | 2070. | 1561. | 1732. |
| 6 | 1151. | 634. | 1750. | 444. | 1179. | 742. | 805. | 739. | 200. | 515. | 1011. | 1381. | 1592. | 544. | 273. | 1477. | 729. | 898. | 1448. | 1057. |
| 7 | 3404. | 858. | 436. | 1376. | 316. | 799. | 504. | 547. | 509. | 138. | 369. | 739. | 1028. | 1166. | 400. | 203. | 1081. | 526. | 622. | 970. |
| 8 | 0. | 1782. | 481. | 316. | 1044. | 192. | 541. | 342. | 370. | 349. | 98. | 269. | 548. | 749. | 841. | 292. | 145. | 762. | 354. | 404. |
| 9 | 0. | 0. | 1128. | 331. | 219. | 756. | 117. | 358. | 217. | 252. | 247. | 71. | 198. | 397. | 533. | 605. | 206. | 101. | 504. | 225. |
| 10 | 0. | 0. | 0. | 825. | 208. | 124. | 522. | 68. | 228. | 145. | 176. | 176. | 52. | 142. | 281. | 382. | 425. | 142. | 66. | 317. |
| 11 | 0. | 0. | 0. | 0. | 527. | 136. | 111. | 251. | 88. | 116. | 122. | 136. | 150. | 80. | 94. | 100. | 171. | 194. | 121. | 121. |

Table A2.2 Contd.

STOCK SUMMARY

| Year | Recruits x10^6 | Total B tonnes | Spawn B tonnes | Landings tonnes | Yld/SSB |
|---|---|---|---|---|---|
| 1975 | 4823. | 3963661. | 2875714. | 491380. | .1709 |
| 1976 | 5020. | 3580218. | 2525562. | 507178. | .2008 |
| 1977 | 867. | 3479306. | 2509192. | 325974. | .1299 |
| 1978 | 3522. | 3453515. | 2685261. | 503913. | .1877 |
| 1979 | 5949. | 3182391. | 2358958. | 605744. | .2568 |
| 1980 | 6496. | 2851906. | 1893459. | 604761. | .3194 |
| 1981 | 6803. | 2877935. | 1900046. | 661762. | .3483 |
| 1982 | 2230. | 2776749. | 1839246. | 623819. | .3392 |
| 1983 | 1059. | 3124055. | 2281475. | 614287. | .2692 |
| 1984 | 5733. | 3144330. | 2508018. | 550929. | .2197 |
| 1985 | 2850. | 3203311. | 2437812. | 561292. | .2302 |
| 1986 | 3571. | 3126294. | 2105164. | 537615. | .2554 |
| 1987 | 6095. | 3100529. | 2391984. | 615380. | .2573 |
| 1988 | 4832. | 3455630. | 2573031. | 628000. | .2441 |
| 1989 | 5705. | 3712006. | 2726950. | 567400. | .2081 |
| 1990 | 4095. | 3597451. | 2664995. | 605937. | .2274 |
| 1991 | 3942. | 4110610. | 3123588. | 646169. | .2069 |
| 1992 | 5362. | 4332017. | 3255220. | 742305. | .2280 |
| 1993 | 13340. | 4238564. | 3113058. | 805039. | .2586 |

PARAMETER ESTIMATES +/- SD

Separable Model: Reference F by year

| | | | | |
|---|---|---|---|---|
| 1 | 1983 | .2657 | .1765 | .3999 |
| 2 | 1984 | .2201 | .1472 | .3292 |
| 3 | 1985 | .1972 | .1332 | .2920 |
| 4 | 1986 | .1744 | .1186 | .2564 |
| 5 | 1987 | .1943 | .1327 | .2844 |
| 6 | 1988 | .1499 | .1014 | .2215 |
| 7 | 1989 | .1401 | .0946 | .2076 |
| 8 | 1990 | .1557 | .1046 | .2316 |
| 9 | 1991 | .1693 | .1135 | .2527 |
| 10 | 1992 | .2072 | .1372 | .3130 |
| 11 | 1993 | .2397 | .1544 | .3719 |

Table A2.2 Contd.

Separable Model: Selection (S) by age

| | | From 1983 to 1988 | | | From 1989 to 1993 | | |
|---|---|---|---|---|---|---|---|
| 12 | 0 | .0001 | .0000 | .0020 | .0044 | .0002 | .1156 |
| 13 | 1 | .0884 | .0554 | .1411 | .1113 | .0731 | .1696 |
| 14 | 2 | .3253 | .2053 | .5155 | .3769 | .2495 | .5696 |
| 15 | 3 | .5201 | .3303 | .8191 | .6542 | .4372 | .9789 |
| 16 | 4 | .6744 | .4288 | 1.0605 | .9376 | .6289 | 1.3977 |
| | 5 | 1.0000 | Fixed : Reference age | | | | |
| 17 | 6 | .8311 | .5434 | 1.2711 | 1.0451 | .7126 | 1.5328 |
| 18 | 7 | .8568 | .5668 | 1.2951 | 1.1793 | .8078 | 1.7216 |
| 19 | 8 | .8855 | .5880 | 1.3336 | 1.2740 | .8759 | 1.8531 |
| 20 | 9 | .9517 | .6264 | 1.4462 | 1.3088 | .8988 | 1.9058 |
| | 10 | 1.0000 | Fixed : last true age | | 1.2000 | | |

Separable Model: Populations in year 1993

| | | | | |
|---|---|---|---|---|
| 30 | 0 | 13339919. | 4621. | 38512769025. |
| 31 | 1 | 4610618. | 3403645. | 6245598. |
| 32 | 2 | 2851473. | 2307960. | 3522979. |
| 33 | 3 | 2368214. | 1937317. | 2894951. |
| 34 | 4 | 2519250. | 2061156. | 3079157. |
| 35 | 5 | 1560972. | 1242810. | 1960584. |
| 36 | 6 | 1448009. | 1110724. | 1887714. |
| 37 | 7 | 622311. | 464541. | 833666. |
| 38 | 8 | 354258. | 252466. | 497092. |
| 39 | 9 | 503549. | 342753. | 739779. |
| 40 | 10 | 66214. | 40825. | 107391. |

Separable Model: Populations at age 10

| | | | | |
|---|---|---|---|---|
| 41 | 1983 | 228003.0823 | 102024.3011 | 509539.4429 |
| 42 | 1984 | 144726.4787 | 75644.3621 | 276897.7496 |
| 43 | 1985 | 175770.7557 | 99014.8119 | 312027.6449 |
| 44 | 1986 | 176469.3141 | 104951.1365 | 296723.0260 |
| 45 | 1987 | 51754.6833 | 31983.8953 | 83746.7489 |
| 46 | 1988 | 141697.2798 | 89117.0430 | 225300.5534 |
| 47 | 1989 | 280810.8424 | 182075.5417 | 433087.9837 |
| 48 | 1990 | 381713.9700 | 262711.2617 | 554622.4169 |
| 49 | 1991 | 424936.5247 | 290051.6021 | 622548.0183 |
| 50 | 1992 | 142235.4139 | 94255.4815 | 214639.1132 |

Table A2.2 Contd.

SSB Index catchabilities
SSB Index 1 was used as absolute estimator.
No fitted catchability for this index.

Age-structured index catchabilities
Age-Structured Index 1

Power model fitted. Slopes (Q) and exponents (K) at age:

| | | | | | |
|---|---|---|---|---|---|
| 51 | 1 | Q | .16494E+02 | .87925E+01 | .30941E+02 |
| 52 | 1 | K | -.41263E+02 | -.50675E+02 | -.31852E+02 |
| 53 | 2 | Q | .30783E+02 | .15666E+02 | .60488E+02 |
| 54 | 2 | K | -.49758E+02 | -.59717E+02 | -.39799E+02 |
| 55 | 3 | Q | .75580E+01 | .45096E+01 | .12667E+02 |
| 56 | 3 | K | -.28215E+02 | -.35734E+02 | -.20695E+02 |
| 57 | 4 | Q | .16245E+02 | .90451E+01 | .29177E+02 |
| 58 | 4 | K | -.39152E+02 | -.47543E+02 | -.30761E+02 |

Age-Structured Index 2

Power model fitted. Slopes (Q) and exponents (K) at age:

| | | | | | |
|---|---|---|---|---|---|
| 59 | 1 | Q | .11127E+01 | .69893E+00 | .17715E+01 |
| 60 | 1 | K | .14633E+01 | -.55103E+01 | .84369E+01 |
| 61 | 2 | Q | .26682E+01 | .16642E+01 | .42780E+01 |
| 62 | 2 | K | -.97874E+01 | -.16741E+02 | -.28342E+01 |
| 63 | 3 | Q | .46366E+01 | .28697E+01 | .74915E+01 |
| 64 | 3 | K | -.17291E+02 | -.24276E+02 | -.10306E+02 |
| 65 | 4 | Q | .12460E+02 | .71226E+01 | .21798E+02 |
| 66 | 4 | K | -.31847E+02 | -.39860E+02 | -.23833E+02 |

Table A2.2 Contd.

RESIDUALS ABOUT THE MODEL FIT

------------------------------

Separable Model Residuals: log(Observed Catch) - log(Expected Catch), and we
ights in the analysis

------------------------------------------------ ------------------

| Age | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | -.52683E+01 | .52593E+00 | .65269E+01 | .52828E+00 | .23134E+01 | -.26377E+01 | -.60058E+01 | -.56203E+00 | -.19108E+00 | .44232E+00 | -.13412E+00 | .10000E-01 |
| 1 | .17679E+00 | -.68728E-01 | -.26426E+00 | .54733E+00 | .10284E+00 | -.12328E+00 | .13732E+00 | -.34960E+00 | -.11210E+00 | -.12086E+00 | -.58277E-01 | .10000E+01 |
| 2 | -.59602E+00 | .10842E+01 | -.10213E+01 | -.86893E+00 | .21693E+00 | -.29397E+00 | .10743E+00 | .97362E-01 | .10105E+00 | .64025E-01 | .11953E+00 | .10000E+01 |
| 3 | .60435E+00 | -.30511E+00 | .62050E+00 | -.51541E+00 | -.48723E+00 | .12408E-01 | .11236E+00 | .22516E+00 | .68945E-01 | .94305E-01 | .84634E-01 | .10000E+01 |
| 4 | .34171E+00 | -.75237E+00 | .22653E+00 | .76774E+00 | -.71244E-01 | -.46455E+00 | .72581E-01 | .14041E-01 | .40604E-01 | .58016E-01 | .74785E+00 | .10000E+01 |
| 5 | -.23275E+00 | .20519E+00 | -.42309E-01 | .18427E+00 | .45002E+00 | .33142E+00 | .59337E-01 | .19599E-01 | -.83582E-01 | -.24277E+00 | -.11978E+00 | .10000E+01 |
| 6 | .20080E+00 | -.33305E+00 | .36835E+00 | .16583E+00 | .85023E-01 | .39477E+00 | .28290E+00 | -.49704E-01 | -.19063E+00 | -.22030E+00 | -.25282E+00 | .10000E+01 |
| 7 | .71526E-01 | .32702E+00 | .81302E-01 | .22339E+00 | -.22142E-01 | .13620E+00 | .18113E+00 | .24812E+00 | -.84244E-01 | -.26131E+00 | -.65298E+00 | .10000E+01 |
| 8 | .57944E-01 | -.25970E+00 | -.16287E+00 | -.35793E+00 | -.59308E-01 | .14982E-01 | .12789E+00 | .54372E-01 | .63801E+00 | .95721E-01 | -.68281E-01 | .10000E+01 |
| 9 | -.97507E-01 | .42568E-01 | -.31986E+00 | -.12944E+00 | -.32688E+00 | -.18983E+00 | -.64499E-01 | .52331E-01 | -.19483E+00 | .81264E+00 | .19799E+00 | .10000E+01 |
| 10 | -.27728E-16 | .16685E-01 | -.12158E+00 | -.19083E+00 | -.19768E+00 | -.25602E+00 | -.18965E+00 | .19441E-01 | .95943E-01 | -.59073E-01 | .88500E+00 | .10000E+01 |
| Wts | .10000E+01 | .10000E+01 | .10000E+01 | .10000E+01 | .10000E+01 | .10000E+01 | .10000E+01 | .10000E+01 | .10000E+01 | .10000E+01 | .10000E+01 | |

Table A2.2 Contd.

Biomass Index Residuals: log(Observed Index) - log(Expected Index)

| Idx | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | .24942E+00 | -.10000E+01 | -.10000E+01 | .24122E+00 | -.10000E+01 | -.10000E+01 | .87460E-01 | -.10000E+01 | -.10000E+01 |

| Idx | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|---|
| 1 | -.46259E-01 | -.10000E+01 | -.10000E+01 | -.19671E+00 | -.10000E+01 | -.10000E+01 | -.10526E+00 | -.10000E+01 |

Aged Index Residuals: log(Observed Index) - log(Expected Index)

Aged Index 1

| Age | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .13256E+00 | -.63381E+00 | -.65719E+00 | .74951E+00 | .10926E+01 | .11450E+01 | -.11421E+01 | .53375E-01 | -.67850E+00 | -.61449E-01 |
| 2 | .50381E+00 | .48884E-01 | -.37480E-01 | -.83381E+00 | -.39621E+00 | -.33716E+00 | -.13372E+00 | .65984E+00 | .66384E-01 | .45947E+00 |
| 3 | -.53469E+00 | -.31015E+00 | -.13468E+00 | -.20303E+00 | .33439E+00 | .25726E+00 | .10315E+00 | .20769E+00 | .61239E-01 | .21882E+00 |
| 4 | -.45198E+00 | -.48299E+00 | -.22419E+00 | -.63008E+00 | .54347E+00 | .13744E+01 | .66385E+00 | -.24459E+00 | -.10738E+00 | -.44056E+00 |

Aged Index 2

| Age | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .79242E+00 | .22541E+01 | -.23549E+01 | -.46168E+00 | -.19992E+01 | .23209E+01 | -.18175E+01 | -.28158E+00 | -.10000E+01 | .15474E+01 |
| 2 | .19114E+01 | -.32112E+00 | -.13521E+01 | -.14327E+01 | -.76977E+00 | .16707E+00 | -.78899E+00 | .20251E+01 | .15086E+00 | .41038E+00 |
| 3 | .79905E+00 | .61266E+00 | -.59113E+00 | -.13717E+01 | .52136E+00 | -.69129E-01 | -.99959E+00 | .68378E+00 | .49871E+00 | -.84046E-01 |
| 4 | .88365E+00 | .11669E+00 | -.55697E+00 | .47597E+00 | .35382E+00 | .24964E+00 | -.56461E+00 | -.14930E-01 | -.83167E+00 | -.11160E+00 |

Table A2.2 Contd.

PARAMETERS OF THE DISTRIBUTION OF ln CATCHES AT AGE

Separable model fitted from 1983 to 1993

| | | |
|---|---|---|
| Variance | : | 1.7267 |
| Skewness test statistic | : | -2.9252 |
| Kurtosis test statistic | : | 44.6266 |
| Partial chi-square | : | 34.6400 |
| Probability of chi-square | : | 1.0000 |
| Degrees of freedom | : | 41 |

PARAMETERS OF THE DISTRIBUTION OF THE SSB INDICES

DISTRIBUTION STATISTICS FOR ln SSB INDEX 1

Index used as absolute measure of abundance.

| | | |
|---|---|---|
| Variance | : | .0285 |
| Skewness test statistic | : | .6849 |
| Kurtosis test statistic | : | -.6719 |
| Partial chi-square | : | .0123 |
| Probability of chi-square | : | 1.0000 |
| Number of observations | : | 6 |
| Degrees of freedom | : | 6 |
| Weight in the analysis | : | 4.0000 |

Table A2.2 Contd.

PARAMETERS OF THE DISTRIBUTION OF THE AGE-STRUCTURED INDICES

DISTRIBUTION STATISTICS FOR ln AGED INDEX 1

Power catchability relationship assumed.

| Age | : | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Variance | : | .7112 | .2365 | .0906 | .4719 |
| Skewness test stat. | : | .2672 | -.2668 | -.7828 | 1.3811 |
| Kurtosis test stat. | : | -.7955 | -.4586 | -.5337 | -.0581 |
| Partial chi-square | : | 7.1109 | 6.9483 | 1.4419 | 18.7616 |
| Prob. of chi-square | : | .5247 | .5422 | .9936 | .0162 |
| Number of data | : | 10 | 10 | 10 | 10 |
| Degrees of freedom | : | 8 | 8 | 8 | 8 |
| Weight in analysis | : | 1.0000 | 1.0000 | 1.0000 | 1.0000 |

DISTRIBUTION STATISTICS FOR ln AGED INDEX 2

Power catchability relationship assumed.

| Age | : | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Variance | : | 3.8040 | 1.6466 | .6555 | .3177 |
| Skewness test stat. | : | .0263 | .7661 | -.8368 | -.0707 |
| Kurtosis test stat. | : | -.9149 | -.5043 | -.6305 | -.5806 |
| Partial chi-square | : | 8.6448 | 2.8274 | 1.0111 | .7594 |
| Prob. of chi-square | : | .2792 | .9447 | .9982 | .9994 |
| Number of data | : | 9 | 10 | 10 | 10 |
| Degrees of freedom | : | 7 | 8 | 8 | 8 |
| Weight in analysis | : | 1.0000 | 1.0000 | 1.0000 | 1.0000 |

**Table A2.3 The tuning diagnostics from an XSA assessment of the Western Mackerel, tuned to the Western approaches ground fish survey**

Lowestoft VPA Version 3.1

5/09/1994 10:42

Extended Survivors Analysis

Western Mackerel 1993 W.G.

CPUE data from file c:\data\mac\mhm94\mact93.csv

Catch data for 22 years. 1972 to 1993. Ages 0 to 12.

| Fleet | First year | Last year | First age | Last age | Alpha | Beta |
|---|---|---|---|---|---|---|
| RV SURVEY VIIJ | 1984 | 1993 | 1 | 10 | 0.23 | 0.35 |
| RV SURVEY VIIh | 1984 | 1993 | 1 | 10 | 0.23 | 0.35 |

Time series weights :

Tapered time weighting applied
Power = 3 over 20 years

Catchability analysis :

Catchability dependent on stock size for ages < 5

Regression type = C
Minimum of 5 points used for regression
Survivor estimates shrunk to the population mean for ages < 5

Catchability independent of age for ages >= 5

Terminal population estimation :

Survivor estimates shrunk towards the mean F
of the final 5 years or the 3 oldest ages.

S.E. of the mean to which the estimates are shrunk = .500

Minimum standard error for population
estimates derived from each fleet = .400

Prior weighting not applied

Tuning converged after 44 iterations

Regression weights

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.751 | 0.82 | 0.877 | 0.921 | 0.954 | 0.976 | 0.99 | 0.997 | 1 | 1 |

**Table A2.3 The tuning diagnostics from an XSA assessment of the Western Mackerel, tuned to the Western approaches ground fish survey**

Fishing mortalities

| Age | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0.006 | 0 | 0 | 0.005 | 0.001 | 0.001 | 0 | 0.002 |
| 1 | 0.013 | 0.043 | 0.011 | 0.008 | 0.023 | 0.012 | 0.027 | 0.015 | 0.024 | 0.028 |
| 2 | 0.065 | 0.016 | 0.091 | 0.075 | 0.055 | 0.088 | 0.068 | 0.062 | 0.056 | 0.078 |
| 3 | 0.22 | 0.05 | 0.037 | 0.202 | 0.113 | 0.11 | 0.153 | 0.082 | 0.135 | 0.125 |
| 4 | 0.212 | 0.2 | 0.08 | 0.078 | 0.224 | 0.139 | 0.147 | 0.187 | 0.143 | 0.208 |
| 5 | 0.241 | 0.196 | 0.227 | 0.128 | 0.129 | 0.231 | 0.175 | 0.178 | 0.218 | 0.179 |
| 6 | 0.25 | 0.237 | 0.224 | 0.238 | 0.169 | 0.117 | 0.235 | 0.202 | 0.211 | 0.268 |
| 7 | 0.109 | 0.238 | 0.266 | 0.254 | 0.268 | 0.161 | 0.136 | 0.273 | 0.265 | 0.301 |
| 8 | 0.214 | 0.15 | 0.226 | 0.286 | 0.29 | 0.237 | 0.185 | 0.233 | 0.297 | 0.359 |
| 9 | 0.208 | 0.257 | 0.137 | 0.293 | 0.271 | 0.266 | 0.268 | 0.249 | 0.369 | 0.436 |
| 10 | 0.197 | 0.256 | 0.264 | 0.324 | 0.263 | 0.248 | 0.183 | 0.361 | 0.326 | 0.485 |
| 11 | 0.207 | 0.23 | 0.232 | 0.36 | 0.364 | 0.283 | 0.181 | 0.244 | 0.351 | 0.438 |

1

XSA population numbers (Thousands)

| YEAR | AGE 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1984 | 6.92E+03 | 1.25E+03 | 1.36E+03 | 3.62E+03 | 2.11E+03 | 1.20E+03 | 4.48E+02 | 1.63E+02 | 2.88E+02 | 2.26E+02 |
| 1985 | 3.02E+03 | 5.95E+03 | 1.06E+03 | 1.09E+03 | 2.50E+03 | 1.47E+03 | 8.11E+02 | 3.00E+02 | 1.26E+02 | 2.00E+02 |
| 1986 | 3.52E+03 | 2.60E+03 | 4.91E+03 | 8.98E+02 | 8.96E+02 | 1.76E+03 | 1.04E+03 | 5.51E+02 | 2.04E+02 | 9.32E+01 |
| 1987 | 5.45E+03 | 3.02E+03 | 2.22E+03 | 3.86E+03 | 7.45E+02 | 7.12E+02 | 1.21E+03 | 7.16E+02 | 3.63E+02 | 1.40E+02 |
| 1988 | 4.52E+03 | 4.69E+03 | 2.57E+03 | 1.77E+03 | 2.71E+03 | 5.93E+02 | 5.39E+02 | 8.21E+02 | 4.78E+02 | 2.35E+02 |
| 1989 | 5.10E+03 | 3.89E+03 | 3.94E+03 | 2.10E+03 | 1.36E+03 | 1.87E+03 | 4.49E+02 | 3.92E+02 | 5.40E+02 | 3.08E+02 |
| 1990 | 4.07E+03 | 4.37E+03 | 3.31E+03 | 3.11E+03 | 1.62E+03 | 1.02E+03 | 1.28E+03 | 3.44E+02 | 2.87E+02 | 3.67E+02 |
| 1991 | 4.01E+03 | 3.50E+03 | 3.66E+03 | 2.66E+03 | 2.30E+03 | 1.20E+03 | 7.37E+02 | 8.68E+02 | 2.58E+02 | 2.05E+02 |
| 1992 | 5.29E+03 | 3.45E+03 | 2.97E+03 | 2.96E+03 | 2.11E+03 | 1.64E+03 | 8.65E+02 | 5.18E+02 | 5.69E+02 | 1.76E+02 |
| 1993 | 5.71E+03 | 4.55E+03 | 2.90E+03 | 2.41E+03 | 2.23E+03 | 1.57E+03 | 1.14E+03 | 6.03E+02 | 3.42E+02 | 3.64E+02 |

Estimated population abundance at 1st Jan 1994

0.00E+00 4.91E+03 3.81E+03 2.31E+03 1.83E+03 1.56E+03 1.13E+03 7.48E+02 3.84E+02 2.06E+02

Taper weighted geometric mean of the VPA populations:

4.18E+03 3.46E+03 2.78E+03 2.15E+03 1.57E+03 1.09E+03 7.45E+02 5.06E+02 3.47E+02 2.40E+02

Standard error of the weighted Log(VPA populations) :

0.4414 0.4697 0.4942 0.5154 0.5174 0.5021 0.4859 0.4864 0.5499 0.6953

| YEAR | AGE 10 | 11 |
|---|---|---|
| 1984 | 1.51E+02 | 1.23E+02 |
| 1985 | 1.58E+02 | 1.07E+02 |
| 1986 | 1.33E+02 | 1.05E+02 |
| 1987 | 6.99E+01 | 8.79E+01 |
| 1988 | 8.98E+01 | 4.35E+01 |
| 1989 | 1.54E+02 | 5.94E+01 |
| 1990 | 2.03E+02 | 1.04E+02 |
| 1991 | 2.42E+02 | 1.46E+02 |
| 1992 | 1.38E+02 | 1.45E+02 |
| 1993 | 1.05E+02 | 8.56E+01 |

Estimated population abundance at 1st Jan 1994

2.03E+02 5.55E+01

Taper weighted geometric mean of the VPA populations:

1.58E+02 1.11E+02

Standard error of the weighted Log(VPA populations) :

0.882 1.0913

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**Table A2.3 The tuning diagnostics from an XSA assessment of the Western Mackerel, tuned to the Western approaches ground fish survey**

Log catchability residuals.

Fleet : RV SURVEY VIIJ

| Age | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -0.09 | -0.41 | -0.21 | 0.28 | 0.42 | 0.41 | -0.27 | 0.03 | -0.21 | -0.03 |
| 2 | 0.36 | -0.19 | -0.2 | -0.26 | -0.09 | 0 | 0.01 | 0.27 | 0.01 | 0.1 |
| 3 | -0.25 | 0.09 | -0.28 | -0.27 | 0.12 | 0.12 | 0.13 | 0.11 | 0.08 | 0.05 |
| 4 | -0.03 | -0.12 | 0.14 | -0.35 | 0 | 0.37 | 0.19 | -0.01 | -0.09 | -0.13 |
| 5 | 0.87 | 0.53 | -0.45 | -1.52 | 0.63 | 0.92 | -0.11 | 0.39 | -0.46 | -0.61 |
| 6 | -0.3 | 0.33 | -0.04 | -1.26 | 1.09 | -0.17 | 0.08 | 0.6 | -1.32 | -1.02 |
| 7 | -0.44 | -0.39 | 0.23 | -0.93 | 0.45 | -0.39 | -1.56 | 0.74 | -0.75 | -0.5 |
| 8 | -0.95 | 0.44 | -0.42 | -1.26 | 0.96 | 0.32 | -1.01 | -0.29 | -0.54 | -1.05 |
| 9 | -0.08 | 0.06 | -0.76 | -2.48 | 1.34 | 0.94 | -0.92 | -1.16 | -1.58 | -1.09 |
| 10 | 0.35 | -0.87 | -0.41 | -2.61 | 1.11 | 1.37 | -0.68 | 0.13 | -0.5 | 99.99 |

Mean log catchability and standard error of ages with catchability
independent of year class strength and constant w.r.t. time

| Age | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|
| Mean Log | -6.4318 | -6.4318 | -6.4318 | -6.4318 | -6.4318 | -6.4318 |
| S.E(Log q) | 0.7827 | 0.847 | 0.7929 | 0.8446 | 1.3282 | 1.2198 |

Regression statistics :

Ages with q dependent on year class strength

| Age | Slope | t-value | Intercept | RSquare | No Pts | Reg s.e | Mean Log q |
|---|---|---|---|---|---|---|---|
| 1 | 0.31 | 2.554 | 7.9 | 0.65 | 10 | 0.31 | -7.29 |
| 2 | 0.27 | 4.643 | 7.68 | 0.85 | 10 | 0.21 | -7.06 |
| 3 | 0.43 | 4.205 | 7.15 | 0.88 | 10 | 0.19 | -6.4 |
| 4 | 0.28 | 4.231 | 7.22 | 0.83 | 10 | 0.22 | -6.6 |

Ages with q independent of year class strength and constant w.r.t. time.

| Age | Slope | t-value | Intercept | RSquare | No Pts | Reg s.e | Mean Q |
|---|---|---|---|---|---|---|---|
| 5 | 0.79 | 0.371 | 6.58 | 0.29 | 10 | 0.65 | -6.43 |
| 6 | 8.15 | -1.266 | 6.3 | 0 | 10 | 6.43 | -6.64 |
| 7 | 0.6 | 1.424 | 6.55 | 0.64 | 10 | 0.4 | -6.79 |
| 8 | 0.94 | 0.101 | 6.75 | 0.3 | 10 | 0.75 | -6.81 |
| 9 | 0.53 | 0.914 | 6.26 | 0.34 | 10 | 0.63 | -7.02 |
| 10 | 0.49 | 0.881 | 5.79 | 0.33 | 9 | 0.6 | -6.66 |

Fleet : RV SURVEY VIIh

| Age | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.03 | 2.88 | -3.15 | -0.5 | -3.09 | 3.36 | -2.77 | -0.36 | 99.99 | 2.1 |
| 2 | 2.59 | -1.15 | -1.8 | -2.04 | -1.02 | 0.53 | -0.89 | 2.99 | 0.24 | 0.56 |
| 3 | 0.61 | 0.56 | -0.77 | -1 | 0.3 | -0.03 | -0.48 | 0.53 | 0.46 | -0.08 |
| 4 | 0.38 | 0.06 | 0.04 | -0.02 | -0.02 | 0.08 | -0.16 | 0.07 | -0.3 | -0.03 |
| 5 | 3.17 | 1.59 | -0.69 | -0.48 | 0.34 | -0.03 | -1.72 | -0.32 | -0.52 | -0.4 |
| 6 | -0.57 | 0.79 | -0.3 | 0.5 | 1.51 | -0.33 | -1.08 | 99.99 | 0.26 | -1.19 |
| 7 | 99.99 | 0.73 | -0.02 | 0.63 | 0.91 | 99.99 | -1.67 | -0.64 | -0.41 | -1.39 |
| 8 | -3.44 | 0.17 | -2.78 | 0.59 | 1.15 | -1.25 | -0.45 | 0.23 | -2.44 | -1.91 |
| 9 | -2.99 | 0.59 | -3.82 | -0.12 | -0.04 | 99.99 | -1.08 | 99.99 | 99.99 | -1.26 |
| 10 | -3.07 | 0.61 | -2.68 | -1.81 | 1.32 | -3.02 | -0.58 | 99.99 | -1.7 | 99.99 |

Mean log catchability and standard error of ages with catchability
independent of year class strength and constant w.r.t. time

| Age | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|
| Mean Log | -3.7778 | -3.7778 | -3.7778 | -3.7778 | -3.7778 | -3.7778 |
| S.E(Log q) | 1.2918 | 0.906 | 1.0252 | 1.8591 | 2.0592 | 2.2024 |

Regression statistics :

Ages with q dependent on year class strength

| Age | Slope | t-value | Intercept | RSquare | No Pts | Reg s.e | Mean Log q |
|---|---|---|---|---|---|---|---|
| 1 | 1.46 | -0.187 | 3.66 | 0.03 | 9 | 2.85 | -5.09 |
| 2 | 1.34 | -0.244 | 1.56 | 0.07 | 10 | 1.82 | -3.17 |
| 3 | 0.66 | 0.755 | 4.36 | 0.4 | 10 | 0.62 | -2.62 |
| 4 | 0.31 | 4.807 | 6.12 | 0.87 | 10 | 0.18 | -3.14 |

Ages with q independent of year class strength and constant w.r.t. time.

| Age | Slope | t-value | Intercept | RSquare | No Pts | Reg s.e | Mean Q |
|---|---|---|---|---|---|---|---|
| 5 | 0.98 | 0.013 | 3.83 | 0.09 | 10 | 1.36 | -3.78 |
| 6 | 3.28 | -0.856 | -2.71 | 0.02 | 9 | 3.02 | -3.83 |
| 7 | 0.63 | 0.555 | 4.9 | 0.29 | 8 | 0.65 | -4.05 |
| 8 | 1.24 | -0.154 | 4.5 | 0.05 | 10 | 2.04 | -4.75 |
| 9 | 0.48 | 0.754 | 5.18 | 0.33 | 7 | 0.8 | -4.98 |
| 10 | 3.59 | -0.352 | 5.77 | 0 | 8 | 6.43 | -5.12 |

**Table A2.3 The tuning diagnostics from an XSA assessment of the Western Mackerel, tuned to the Western approaches ground fish survey**

Terminal year survivor and F summaries :

Age 0 Catchability dependent on age and year class strength

Year class = 1993

| Fleet | Estimated Survivors | Int s.e | Ext s.e | Var Ratio | N | Scaled Weights | Estimated F |
|---|---|---|---|---|---|---|---|
| RV SURVEY VIIJ | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| RV SURVEY VIIh | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| P shrinkage mean | 3455 | 0.47 | | | | 0.531 | 0.004 |
| F shrinkage mean | 7295 | 0.5 | | | | 0.469 | 0.002 |

Weighted prediction :

| Survivors at end of year | Int s.e | Ext s.e | N | Var Ratio | F |
|---|---|---|---|---|---|
| 4905 | 0.34 | 8.51 | 2 | 24.846 | 0.002 |

Age 1 Catchability dependent on age and year class strength

Year class = 1992

| Fleet | Estimated Survivors | Int s.e | Ext s.e | Var Ratio | N | Scaled Weights | Estimated F |
|---|---|---|---|---|---|---|---|
| RV SURVEY VIIJ | 3701 | 0.4 | 0 | 0 | 1 | 0.426 | 0.028 |
| RV SURVEY VIIh | 31065 | 3.156 | 0 | 0 | 1 | 0.007 | 0.003 |
| P shrinkage mean | 2783 | 0.49 | | | | 0.287 | 0.038 |
| F shrinkage mean | 5235 | 0.5 | | | | 0.28 | 0.02 |

Weighted prediction :

| Survivors at end of year | Int s.e | Ext s.e | N | Var Ratio | F |
|---|---|---|---|---|---|
| 3814 | 0.26 | 0.17 | 4 | 0.648 | 0.028 |

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Age 2 Catchability dependent on age and year class strength

Year class = 1991

| Fleet | Estimated Survivors | Int s.e | Ext s.e | Var Ratio | N | Scaled Weights | Estimated F |
|---|---|---|---|---|---|---|---|
| RV SURVEY VIIJ | 2185 | 0.283 | 0.156 | 0.55 | 2 | 0.588 | 0.083 |
| RV SURVEY VIIh | 4055 | 1.929 | 0 | 0 | 1 | 0.013 | 0.045 |
| P shrinkage mean | 2152 | 0.52 | | | | 0.194 | 0.084 |
| F shrinkage mean | 2766 | 0.5 | | | | 0.206 | 0.066 |

Weighted prediction :

| Survivors at end of year | Int s.e | Ext s.e | N | Var Ratio | F |
|---|---|---|---|---|---|
| 2305 | 0.22 | 0.09 | 5 | 0.389 | 0.078 |

**Table A2.3 The tuning diagnostics from an XSA assessment of the Western Mackerel, tuned to the Western approaches ground fish survey**

Age 3 Catchability dependent on age and year class strength

Year class = 1990

| Fleet | Estimated Survivors | Int s.e | Ext s.e | Var Ratio | N | Scaled Weights | Estimated F |
|---|---|---|---|---|---|---|---|
| RV SURVEY VIIJ | 1891 | 0.231 | 0.01 | 0.04 | 3 | 0.61 | 0.122 |
| RV SURVEY VIIh | 1728 | 0.605 | 0.079 | 0.13 | 3 | 0.092 | 0.133 |
| P shrinkage mean | 1569 | 0.52 | | | | 0.144 | 0.145 |
| F shrinkage mean | 1941 | 0.5 | | | | 0.154 | 0.119 |

Weighted prediction :

| Survivors at end of year | Int s.e | Ext s.e | N | Var Ratio | F |
|---|---|---|---|---|---|
| 1833 | 0.19 | 0.03 | 8 | 0.165 | 0.125 |

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Age 4 Catchability dependent on age and year class strength

Year class = 1989

| Fleet | Estimated Survivors | Int s.e | Ext s.e | Var Ratio | N | Scaled Weights | Estimated F |
|---|---|---|---|---|---|---|---|
| RV SURVEY VIIJ | 1535 | 0.201 | 0.115 | 0.57 | 4 | 0.545 | 0.21 |
| RV SURVEY VIIh | 1745 | 0.34 | 0.306 | 0.9 | 4 | 0.209 | 0.187 |
| P shrinkage mean | 1090 | 0.5 | | | | 0.122 | 0.285 |
| F shrinkage mean | 1960 | 0.5 | | | | 0.123 | 0.168 |

Weighted prediction :

| Survivors at end of year | Int s.e | Ext s.e | N | Var Ratio | F |
|---|---|---|---|---|---|
| 1558 | 0.16 | 0.11 | 10 | 0.69 | 0.208 |

Age 5 Catchability constant w.r.t. time and dependent on age

Year class = 1988

| Fleet | Estimated Survivors | Int s.e | Ext s.e | Var Ratio | N | Scaled Weights | Estimated F |
|---|---|---|---|---|---|---|---|
| RV SURVEY VIIJ | 1193 | 0.196 | 0.128 | 0.65 | 5 | 0.622 | 0.171 |
| RV SURVEY VIIh | 1012 | 0.329 | 0.241 | 0.73 | 5 | 0.235 | 0.199 |
| F shrinkage mean | 1084 | 0.5 | | | | 0.142 | 0.187 |

Weighted prediction :

| Survivors at end of year | Int s.e | Ext s.e | N | Var Ratio | F |
|---|---|---|---|---|---|
| 1132 | 0.16 | 0.1 | 11 | 0.622 | 0.179 |

**Table A2.3 The tuning diagnostics from an XSA assessment of the Western Mackerel, tuned to the Western approaches ground fish survey**

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Age 6 Catchability constant w.r.t. time and age (fixed at the value for age) 5

Year class = 1987

| Fleet | Estimated Survivors | Int s.e | Ext s.e | Var Ratio | N | Scaled Weights | Estimated F |
|---|---|---|---|---|---|---|---|
| RV SURVEY VIIJ | 741 | 0.195 | 0.162 | 0.83 | 6 | 0.569 | 0.27 |
| RV SURVEY VIIh | 571 | 0.313 | 0.233 | 0.74 | 6 | 0.25 | 0.338 |
| F shrinkage mean | 1113 | 0.5 | | | | 0.181 | 0.187 |

Weighted prediction :

| Survivors at end of year | Int s.e | Ext s.e | N | Var Ratio | F |
|---|---|---|---|---|---|
| 748 | 0.16 | 0.13 | 13 | 0.785 | 0.268 |

Age 7 Catchability constant w.r.t. time and age (fixed at the value for age) 5

Year class = 1986

| Fleet | Estimated Survivors | Int s.e | Ext s.e | Var Ratio | N | Scaled Weights | Estimated F |
|---|---|---|---|---|---|---|---|
| RV SURVEY VIIJ | 382 | 0.193 | 0.168 | 0.87 | 7 | 0.562 | 0.303 |
| RV SURVEY VIIh | 297 | 0.304 | 0.187 | 0.62 | 7 | 0.248 | 0.375 |
| F shrinkage mean | 545 | 0.5 | | | | 0.189 | 0.221 |

Weighted prediction :

| Survivors at end of year | Int s.e | Ext s.e | N | Var Ratio | F |
|---|---|---|---|---|---|
| 384 | 0.16 | 0.12 | 15 | 0.724 | 0.301 |

1

Age 8 Catchability constant w.r.t. time and age (fixed at the value for age) 5

Year class = 1985

| Fleet | Estimated Survivors | Int s.e | Ext s.e | Var Ratio | N | Scaled Weights | Estimated F |
|---|---|---|---|---|---|---|---|
| RV SURVEY VIIJ | 185 | 0.196 | 0.173 | 0.88 | 8 | 0.555 | 0.391 |
| RV SURVEY VIIh | 168 | 0.322 | 0.284 | 0.88 | 7 | 0.208 | 0.423 |
| F shrinkage mean | 314 | 0.5 | | | | 0.237 | 0.249 |

Weighted prediction :

| Survivors at end of year | Int s.e | Ext s.e | N | Var Ratio | F |
|---|---|---|---|---|---|
| 206 | 0.17 | 0.14 | 16 | 0.799 | 0.359 |

**Table A2.3 The tuning diagnostics from an XSA assessment of the Western Mackerel, tuned to the Western approaches ground fish survey**

Age 9 Catchability constant w.r.t. time and age (fixed at the value for age) 5

Year class = 1984

| Fleet | Estimated Survivors | Int s.e | Ext s.e | Var Ratio | N | Scaled Weights | Estimated F |
|---|---|---|---|---|---|---|---|
| RV SURVEY VIIJ | 181 | 0.214 | 0.169 | 0.79 | 9 | 0.462 | 0.477 |
| RV SURVEY VIIh | 115 | 0.324 | 0.244 | 0.75 | 9 | 0.204 | 0.672 |
| F shrinkage mean | 334 | 0.5 | | | | 0.334 | 0.286 |

Weighted prediction :

| Survivors at end of year | Int s.e | Ext s.e | N | Var Ratio | F |
|---|---|---|---|---|---|
| 203 | 0.2 | 0.15 | 19 | 0.746 | 0.436 |

1

Age 10 Catchability constant w.r.t. time and age (fixed at the value for age) 5

Year class = 1983

| Fleet | Estimated Survivors | Int s.e | Ext s.e | Var Ratio | N | Scaled Weights | Estimated F |
|---|---|---|---|---|---|---|---|
| RV SURVEY VIIJ | 40 | 0.198 | 0.169 | 0.85 | 9 | 0.488 | 0.627 |
| RV SURVEY VIIh | 41 | 0.319 | 0.225 | 0.71 | 8 | 0.186 | 0.612 |
| F shrinkage mean | 108 | 0.5 | | | | 0.326 | 0.277 |

Weighted prediction :

| Survivors at end of year | Int s.e | Ext s.e | N | Var Ratio | F |
|---|---|---|---|---|---|
| 56 | 0.2 | 0.17 | 18 | 0.864 | 0.485 |

Age 11 Catchability constant w.r.t. time and age (fixed at the value for age) 5

Year class = 1982

| Fleet | Estimated Survivors | Int s.e | Ext s.e | Var Ratio | N | Scaled Weights | Estimated F |
|---|---|---|---|---|---|---|---|
| RV SURVEY VIIJ | 42 | 0.226 | 0.224 | 0.99 | 9 | 0.425 | 0.482 |
| RV SURVEY VIIh | 60 | 0.333 | 0.304 | 0.91 | 7 | 0.178 | 0.363 |
| F shrinkage mean | 49 | 0.5 | | | | 0.397 | 0.429 |

Weighted prediction :

| Survivors at end of year | Int s.e | Ext s.e | N | Var Ratio | F |
|---|---|---|---|---|---|
| 48 | 0.23 | 0.13 | 17 | 0.586 | 0.438 |

**Table A2.4 The tuning diagnostics from an XSA assessment of the Western Mackerel, tuned to the Western approaches ground fish survey**

Run title : Western Mackerel 1993 W.G.

At 5/09/1994 10:43

Terminal Fs derived using XSA (With F shrinkage)

Table 8 Fishing mortality (F) at age

| YEAR | 1972 | 1973 |
|---|---|---|
| AGE | | |
| 0 | 0.0008 | 0 |
| 1 | 0.0025 | 0.0209 |
| 2 | 0.0066 | 0.0117 |
| 3 | 0.0117 | 0.0413 |
| 4 | 0.0639 | 0.0552 |
| 5 | 0 | 0.092 |
| 6 | 0 | 0 |
| 7 | 0 | 0 |
| 8 | 0 | 0 |
| 9 | 0 | 0 |
| 10 | 0 | 0 |
| 11 | 0 | 0 |
| +gp | 0 | 0 |
| 0 FBAR 4- 8 | 0.0128 | 0.0294 |

Table 8 Fishing mortality (F) at age

| YEAR | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|---|---|
| AGE | | | | | | | | | | |
| 0 | 0.0004 | 0.0002 | 0.0077 | 0.0024 | 0.0034 | 0.0156 | 0.0038 | 0.0059 | 0.0011 | 0 |
| 1 | 0.0246 | 0.0193 | 0.0769 | 0.0411 | 0.0449 | 0.1447 | 0.1176 | 0.0617 | 0.0372 | 0.0294 |
| 2 | 0.0178 | 0.0352 | 0.0832 | 0.1011 | 0.1971 | 0.1108 | 0.2765 | 0.1644 | 0.1292 | 0.1678 |
| 3 | 0.0348 | 0.0847 | 0.1381 | 0.0876 | 0.2003 | 0.3155 | 0.1818 | 0.1956 | 0.2209 | 0.1784 |
| 4 | 0.0867 | 0.1076 | 0.2051 | 0.0928 | 0.1844 | 0.2505 | 0.3184 | 0.1028 | 0.2298 | 0.2648 |
| 5 | 0.1159 | 0.2064 | 0.133 | 0.0824 | 0.1934 | 0.2353 | 0.2946 | 0.2228 | 0.1031 | 0.2391 |
| 6 | 0.1155 | 0.1132 | 0.1795 | 0.0835 | 0.1515 | 0.2532 | 0.2307 | 0.2532 | 0.2569 | 0.1089 |
| 7 | 0 | 0.3749 | 0.3158 | 0.1325 | 0.1163 | 0.2607 | 0.2581 | 0.2315 | 0.2606 | 0.2581 |
| 8 | 0 | 0 | 0.2059 | 0.1484 | 0.1565 | 0.1571 | 0.2344 | 0.2901 | 0.297 | 0.2559 |
| 9 | 0 | 0 | 0 | 0.1008 | 0.1899 | 0.2807 | 0.1972 | 0.2316 | 0.345 | 0.2536 |
| 10 | 0 | 0 | 0 | 0 | 0.1791 | 0.2458 | 0.2651 | 0.2898 | 0.2348 | 0.3134 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0.2286 | 0.233 | 0.2715 | 0.2934 | 0.2753 |
| +gp | 0 | 0 | 0 | 0 | 0 | 0.2286 | 0.233 | 0.2715 | 0.2934 | 0.2753 |
| 0 FBAR 4- 8 | 0.0636 | 0.1604 | 0.2078 | 0.1079 | 0.1604 | 0.2314 | 0.2672 | 0.2201 | 0.2295 | 0.2254 |
| 1 | | | | | | | | | | |

Run title : Western Mackerel 1993 W.G.

At 5/09/1994 10:43

Terminal Fs derived using XSA (With F shrinkage)

Table 8 Fishing mortality (F) at age

| YEAR | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | FBAR 91-93 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AGE | | | | | | | | | | | |
| 0 | 0.0001 | 0 | 0.0056 | 0.0005 | 0.0001 | 0.0052 | 0.0014 | 0.0013 | 0.0004 | 0.0025 | 0.0014 |
| 1 | 0.0132 | 0.0433 | 0.0107 | 0.0082 | 0.023 | 0.0119 | 0.0272 | 0.0146 | 0.0237 | 0.0275 | 0.022 |
| 2 | 0.0653 | 0.0164 | 0.0914 | 0.0749 | 0.0548 | 0.0876 | 0.0682 | 0.0615 | 0.0564 | 0.0784 | 0.0655 |
| 3 | 0.2195 | 0.0496 | 0.0366 | 0.2018 | 0.113 | 0.1104 | 0.1526 | 0.0822 | 0.1351 | 0.1255 | 0.1143 |
| 4 | 0.2122 | 0.1998 | 0.0796 | 0.0781 | 0.2241 | 0.1386 | 0.1472 | 0.1866 | 0.1432 | 0.2076 | 0.1791 |
| 5 | 0.2411 | 0.1959 | 0.2268 | 0.1279 | 0.1288 | 0.2306 | 0.1752 | 0.1781 | 0.2182 | 0.1795 | 0.1919 |
| 6 | 0.2502 | 0.2365 | 0.2243 | 0.2377 | 0.1693 | 0.1169 | 0.2346 | 0.202 | 0.211 | 0.2676 | 0.2269 |
| 7 | 0.1085 | 0.2376 | 0.2664 | 0.2537 | 0.2684 | 0.1609 | 0.1363 | 0.2728 | 0.2649 | 0.3015 | 0.2797 |
| 8 | 0.2143 | 0.1495 | 0.2264 | 0.2864 | 0.2898 | 0.2369 | 0.185 | 0.2329 | 0.297 | 0.3586 | 0.2961 |
| 9 | 0.2078 | 0.2569 | 0.1374 | 0.2933 | 0.2706 | 0.2658 | 0.2678 | 0.2491 | 0.3687 | 0.4355 | 0.3511 |
| 10 | 0.197 | 0.2556 | 0.2637 | 0.3244 | 0.263 | 0.248 | 0.183 | 0.3612 | 0.326 | 0.4853 | 0.3908 |
| 11 | 0.2071 | 0.23 | 0.2321 | 0.3602 | 0.3638 | 0.2827 | 0.1808 | 0.2438 | 0.3507 | 0.4378 | 0.3441 |
| +gp | 0.2071 | 0.23 | 0.2321 | 0.3602 | 0.3638 | 0.2827 | 0.1808 | 0.2438 | 0.3507 | 0.4378 | |
| 0 FBAR 4- 8 | 0.2053 | 0.2039 | 0.2047 | 0.1968 | 0.2161 | 0.1768 | 0.1757 | 0.2145 | 0.2268 | 0.2629 | |
| 1 | | | | | | | | | | | |

**Table A2.4 The tuning diagnostics from an XSA assessment of the Western Mackerel, tuned to the Western approaches ground fish survey**

Run title : Western Mackerel 1993 W.G.

At 5/09/1994 10:43

Terminal Fs derived using XSA (With F shrinkage)

Table 10 Stock number at age (start of year) Numbers*10**-6

| YEAR | 1972 | 1973 |
|---|---|---|
| AGE | | |
| 0 | 2046 | 4484 |
| 1 | 5329 | 1760 |
| 2 | 1993 | 4575 |
| 3 | 2727 | 1705 |
| 4 | 8840 | 2320 |
| 5 | 0 | 7138 |
| 6 | 0 | 0 |
| 7 | 0 | 0 |
| 8 | 0 | 0 |
| 9 | 0 | 0 |
| 10 | 0 | 0 |
| 11 | 0 | 0 |
| +gp | 0 | 0 |
| 0 TOTAL | 20936 | 21981 |

Table 10 Stock number at age (start of year) Numbers*10**-6

| YEAR | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|---|---|
| AGE | | | | | | | | | | |
| 0 | 3439 | 4730 | 4814 | 896 | 3274 | 5553 | 5588 | 7009 | 1887 | 1450 |
| 1 | 3859 | 2959 | 4071 | 4112 | 769 | 2809 | 4706 | 4792 | 5997 | 1623 |
| 2 | 1483 | 3241 | 2498 | 3244 | 3397 | 633 | 2092 | 3601 | 3877 | 4974 |
| 3 | 3892 | 1254 | 2693 | 1978 | 2524 | 2400 | 488 | 1365 | 2630 | 2933 |
| 4 | 1408 | 3235 | 992 | 2019 | 1560 | 1778 | 1507 | 350 | 966 | 1815 |
| 5 | 1890 | 1111 | 2500 | 695 | 1584 | 1117 | 1191 | 943 | 272 | 661 |
| 6 | 5603 | 1448 | 778 | 1884 | 551 | 1123 | 760 | 764 | 650 | 211 |
| 7 | 0 | 4297 | 1113 | 560 | 1492 | 408 | 751 | 519 | 510 | 433 |
| 8 | 0 | 0 | 2542 | 699 | 422 | 1143 | 270 | 499 | 354 | 338 |
| 9 | 0 | 0 | 0 | 1781 | 518 | 310 | 841 | 184 | 321 | 227 |
| 10 | 0 | 0 | 0 | 0 | 1386 | 369 | 202 | 594 | 126 | 196 |
| 11 | 0 | 0 | 0 | 0 | 0 | 997 | 248 | 133 | 383 | 86 |
| +gp | 0 | 0 | 0 | 0 | 0 | 0 | 596 | 795 | 623 | 563 |
| 0 TOTAL | 21574 | 22276 | 22001 | 17868 | 17476 | 18641 | 19240 | 21549 | 18597 | 15508 |
| 1 | | | | | | | | | | |

Terminal Fs derived using XSA (With F shrinkage)

Table 10 Stock number at age (start of year) Numbers*10**-6

| YEAR | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | GMST 72-91 | AMST 72-9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AGE | | | | | | | | | | | | | |
| 0 | 6919 | 3024 | 3523 | 5448 | 4522 | 5103 | 4071 | 4009 | 5293 | 5713 | 0 | 3664 | 4090 |
| 1 | 1248 | 5955 | 2603 | 3015 | 4687 | 3892 | 4370 | 3499 | 3446 | 4554 | 4905 | 3214 | 3603 |
| 2 | 1356 | 1060 | 4908 | 2217 | 2574 | 3942 | 3310 | 3660 | 2968 | 2897 | 3814 | 2609 | 2932 |
| 3 | 3620 | 1093 | 898 | 3855 | 1770 | 2097 | 3109 | 2661 | 2963 | 2415 | 2305 | 2042 | 2285 |
| 4 | 2112 | 2501 | 896 | 745 | 2712 | 1361 | 1617 | 2297 | 2110 | 2228 | 1833 | 1653 | 2052 |
| 5 | 1199 | 1470 | 1763 | 712 | 593 | 1866 | 1020 | 1201 | 1640 | 1574 | 1558 | 442 | 1446 |
| 6 | 448 | 811 | 1040 | 1210 | 539 | 449 | 1275 | 737 | 865 | 1135 | 1132 | 120 | 1014 |
| 7 | 163 | 300 | 551 | 716 | 821 | 392 | 344 | 868 | 518 | 603 | 748 | 33 | 712 |
| 8 | 288 | 126 | 204 | 363 | 478 | 540 | 287 | 258 | 569 | 342 | 384 | 9 | 441 |
| 9 | 226 | 200 | 93 | 140 | 235 | 308 | 367 | 205 | 176 | 364 | 206 | 3 | 298 |
| 10 | 151 | 158 | 133 | 70 | 90 | 154 | 203 | 242 | 138 | 105 | 203 | 0 | 204 |
| 11 | 123 | 107 | 105 | 88 | 44 | 59 | 104 | 146 | 145 | 86 | 56 | 0 | 131 |
| +gp | 254 | 420 | 312 | 215 | 184 | 152 | 175 | 260 | 245 | 198 | 158 | | |
| 0 TOTAL | 18107 | 17226 | 17028 | 18794 | 19249 | 20315 | 20251 | 20044 | 21076 | 22212 | 17300 | | |

**Table A2.4 The tuning diagnostics from an XSA assessment of the Western Mackerel, tuned to the Western approaches ground fish survey**

Run title : Western Mackerel 1993 W.G.

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Table 16 Summary (without SOP correction)

Terminal Fs derived using XSA (With F shrinkage)

| | RECRUITS Age 0 | TOTALBIO | TOTSPBIO | LANDINGS | YIELD/SSB | FBAR 4- 8 |
|---|---|---|---|---|---|---|
| 1972 | 2046 | 4771 | 3646 | 171 | 0.0468 | 0.0128 |
| 1973 | 4484 | 4650 | 3735 | 219 | 0.0588 | 0.0294 |
| 1974 | 3439 | 4730 | 3737 | 298 | 0.0798 | 0.0636 |
| 1975 | 4730 | 4594 | 3470 | 491 | 0.1416 | 0.1604 |
| 1976 | 4814 | 4152 | 3073 | 507 | 0.1651 | 0.2078 |
| 1977 | 896 | 3984 | 3004 | 326 | 0.1085 | 0.1079 |
| 1978 | 3274 | 3882 | 3098 | 504 | 0.1626 | 0.1604 |
| 1979 | 5553 | 3528 | 2707 | 606 | 0.2238 | 0.2314 |
| 1980 | 5588 | 3185 | 2222 | 605 | 0.2721 | 0.2672 |
| 1981 | 7009 | 3156 | 2193 | 662 | 0.3017 | 0.2201 |
| 1982 | 1887 | 2994 | 2033 | 624 | 0.3069 | 0.2295 |
| 1983 | 1450 | 3163 | 2294 | 614 | 0.2678 | 0.2254 |
| 1984 | 6919 | 2939 | 2286 | 551 | 0.2410 | 0.2053 |
| 1985 | 3024 | 3096 | 2254 | 561 | 0.2490 | 0.2039 |
| 1986 | 3523 | 3080 | 1940 | 538 | 0.2772 | 0.2047 |
| 1987 | 5448 | 3005 | 2239 | 615 | 0.2748 | 0.1968 |
| 1988 | 4522 | 3246 | 2363 | 628 | 0.2658 | 0.2161 |
| 1989 | 5103 | 3414 | 2467 | 567 | 0.2300 | 0.1768 |
| 1990 | 4071 | 3301 | 2426 | 606 | 0.2498 | 0.1757 |
| 1991 | 4009 | 3816 | 2870 | 646 | 0.2251 | 0.2145 |
| 1992 | 5293 | 4095 | 3054 | 742 | 0.2430 | 0.2268 |
| 1993 | 5713 | 4068 | 2968 | 805 | 0.2713 | 0.2629 |
| Arith. Mean | 4218 | 3675 | 2731 | 540 | 0.2119 | 0.1818 |
| 0 Units | (Millions) | (000' Tonnes) | (000' Tonnes) | (000' Tonnes) | | |

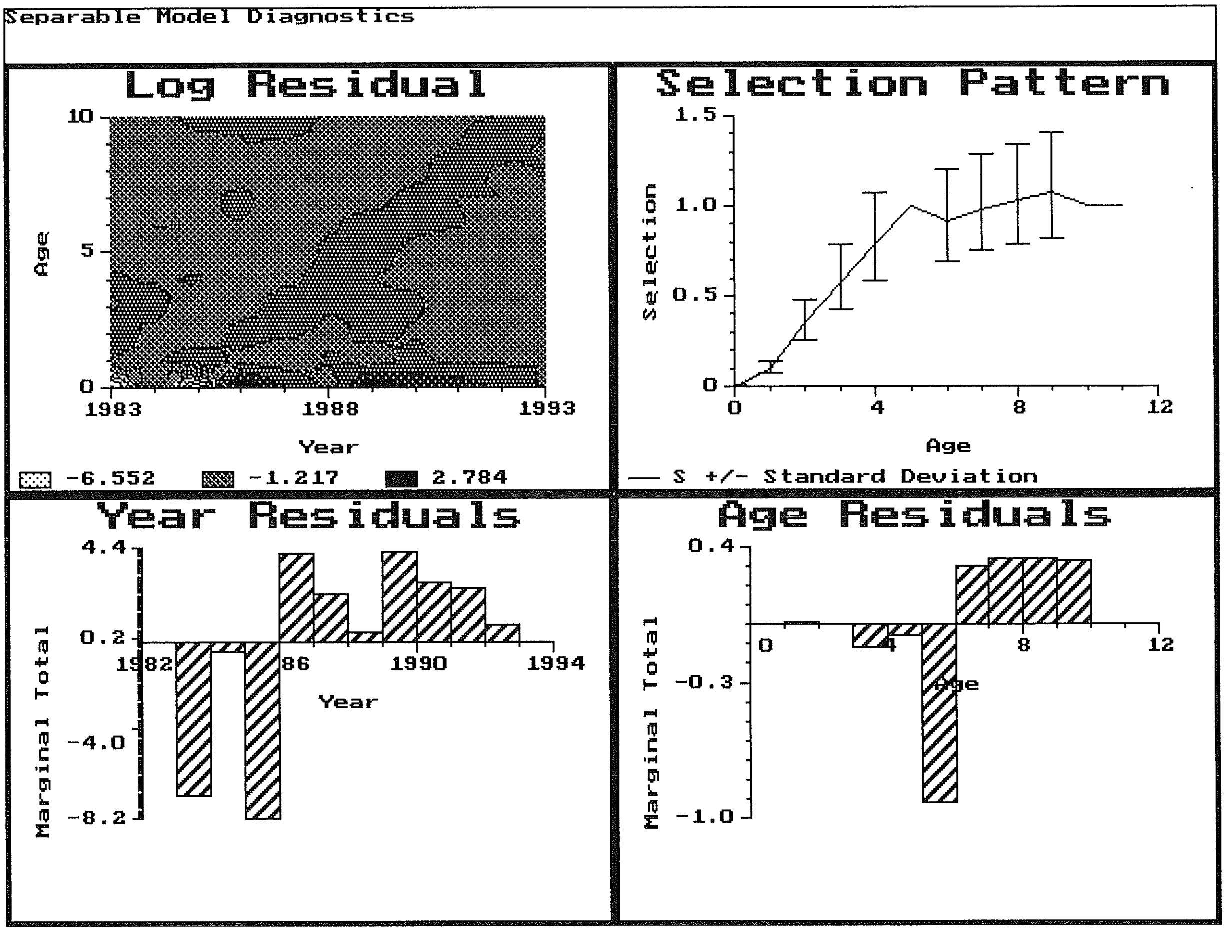


Figure A2.1 The selection pattern and diagnostics obtained when fitting a single selection pattern over the years 1983 - 1993. Note the poor fit indicated by the diagonal band of low residuals.

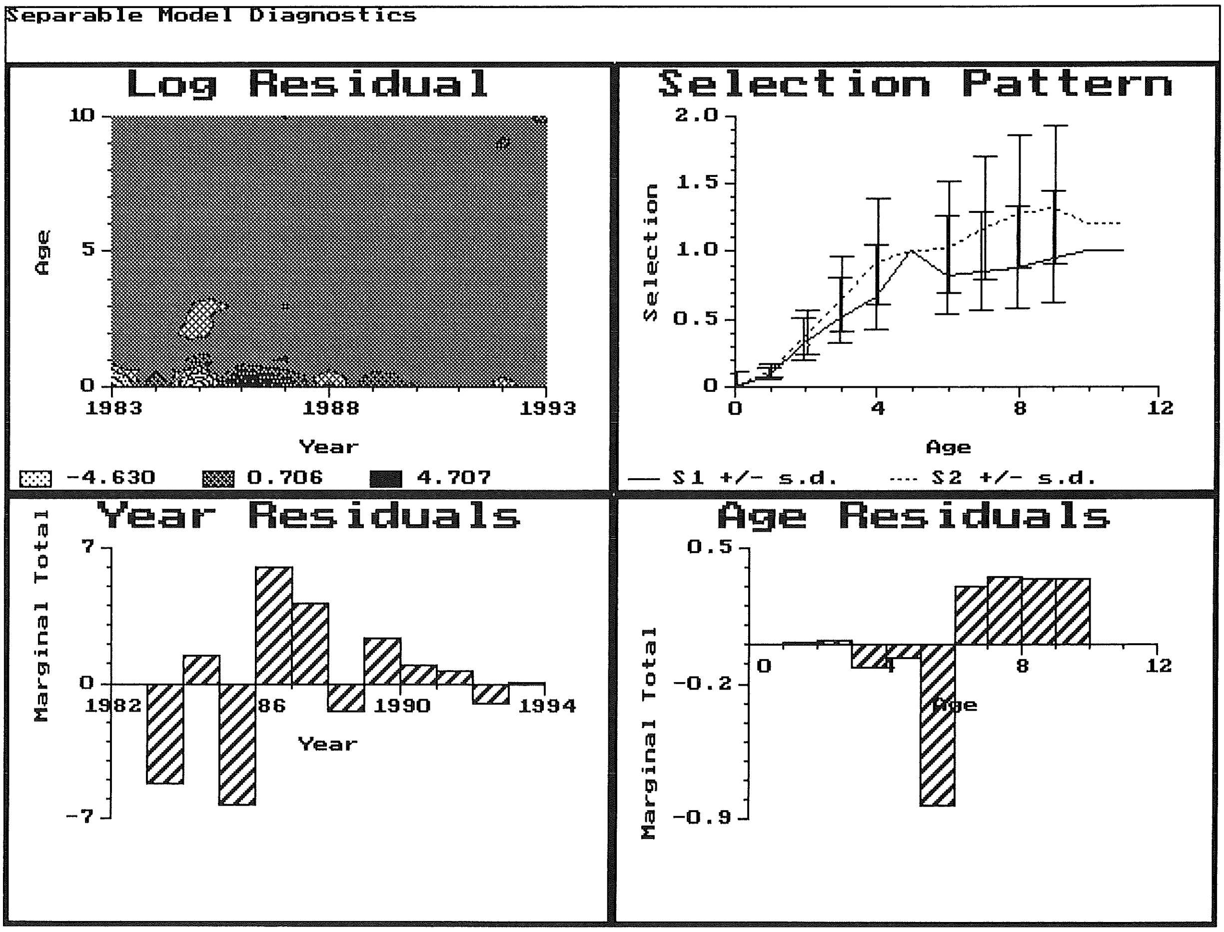


**Figure A2.2** The selection patterns and diagnostics obtained when fitting a double selection pattern model, allowing different selection patterns up to 1988, and from 1989 to 1993. (1) Contour plot of Log (observed catch) - Log (expected catch), (2) selection pattern over the periods 1983 - 1987 and 1989 - 1993, (4 & 5) Marginal (year and age) totals of residuals. High residuals at age 0 have been downweighted in the analysis. Note that a consistent model fit is now obtained. The assessment is fitted using egg survey estimates of stock size which are treated as absolute measures of abundance, and age disaggregeted Western Approaches survey data, assumed to bear a power relationship to stock abundance.

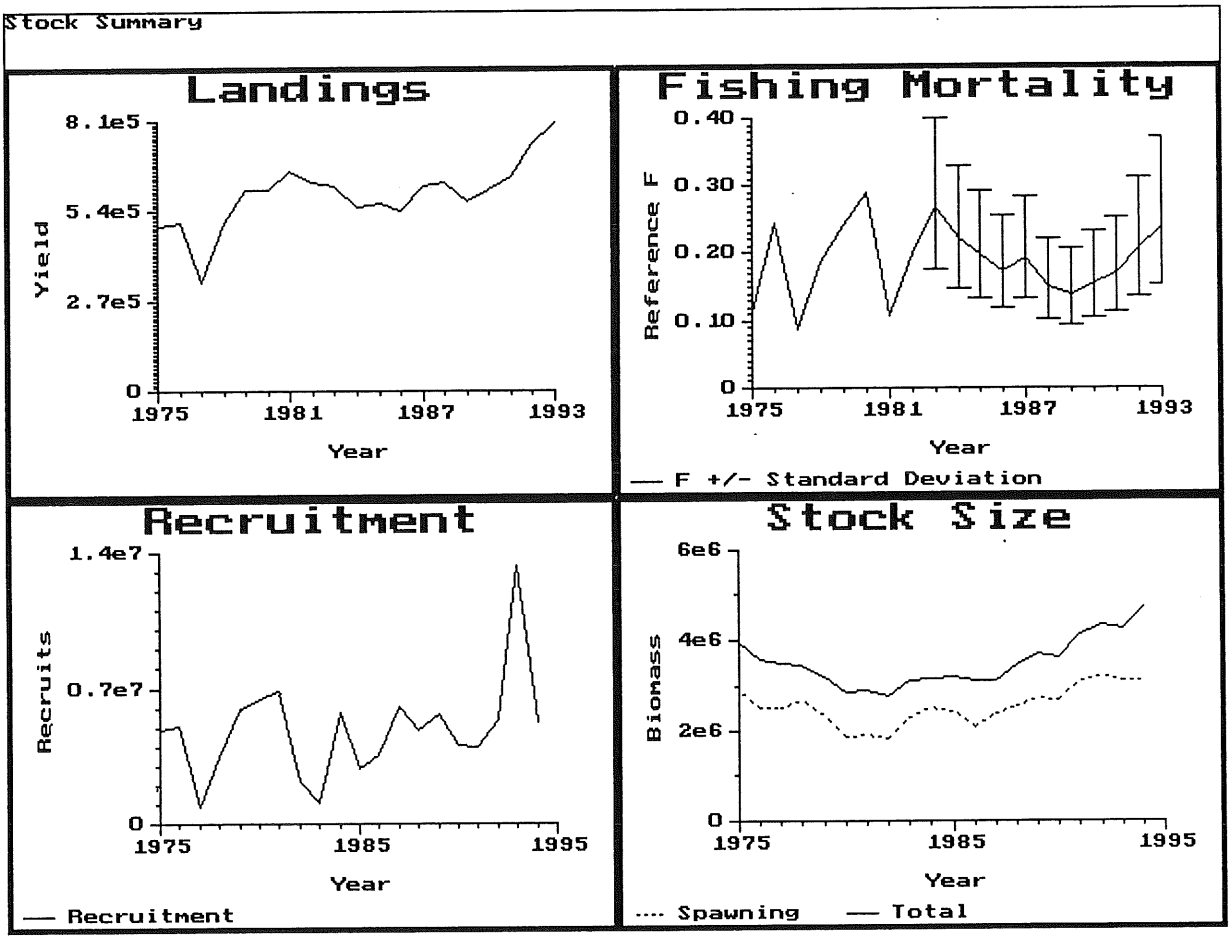


**Figure A2.3** Summary of stock assessment calculated when fitting the double-selection pattern model. Note the increase in fishing mortality in recent years. The high recruitment estimate in 1993 is extremely uncertain (see standard errors in Table A.2.2) Landings, reference fishing mortality in the separable model (+/- one standard deviation of the parameter estimate), estimated recruitment at age 0, and estimates of total and spawning stock size.

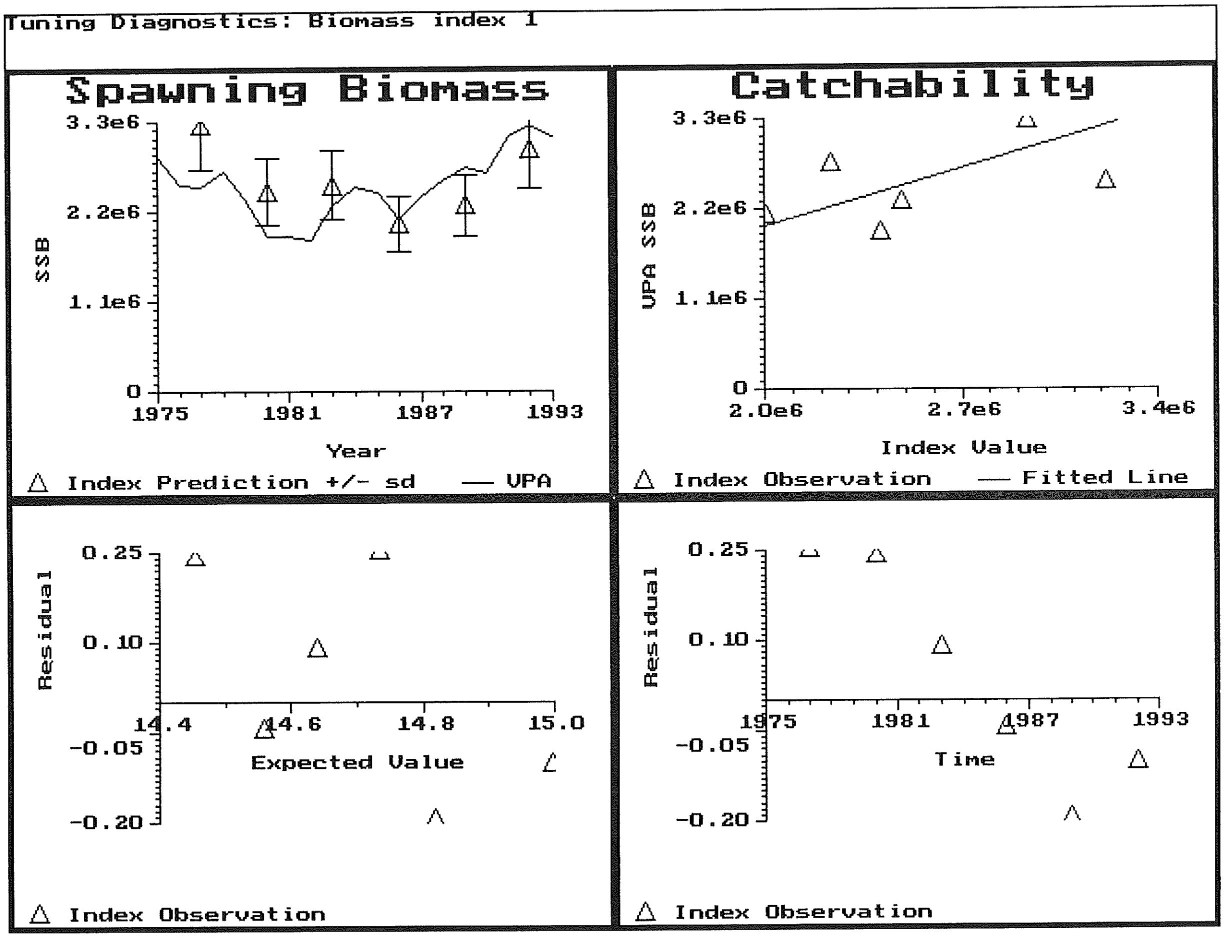


**Figure A2.4** Comparison of egg survey index with fitted stock size. The index is the egg survey estimate of spawning stock biomass, assumed to be an absolute measure of stock size. (1) Spawning stock biomass. The line drawn is the fitted estimate of spawning stock biomass at spawning time. Triangles indicate the egg survey observations, together with estimates of the standard deviation of the index calculated in fitting the model. (2) Catchability. This is a scatter plot of fitted values of SSB against observed index values. The line in this case is drawn through the origin with 45% slope, as an absolute relationship is assumed. (3 and 4) The lower two graphs are standard scatter plots of residuals against expected value (to assess the appropriateness of the model fit) and of residuals against time ( to assess historical consistency of the survey).

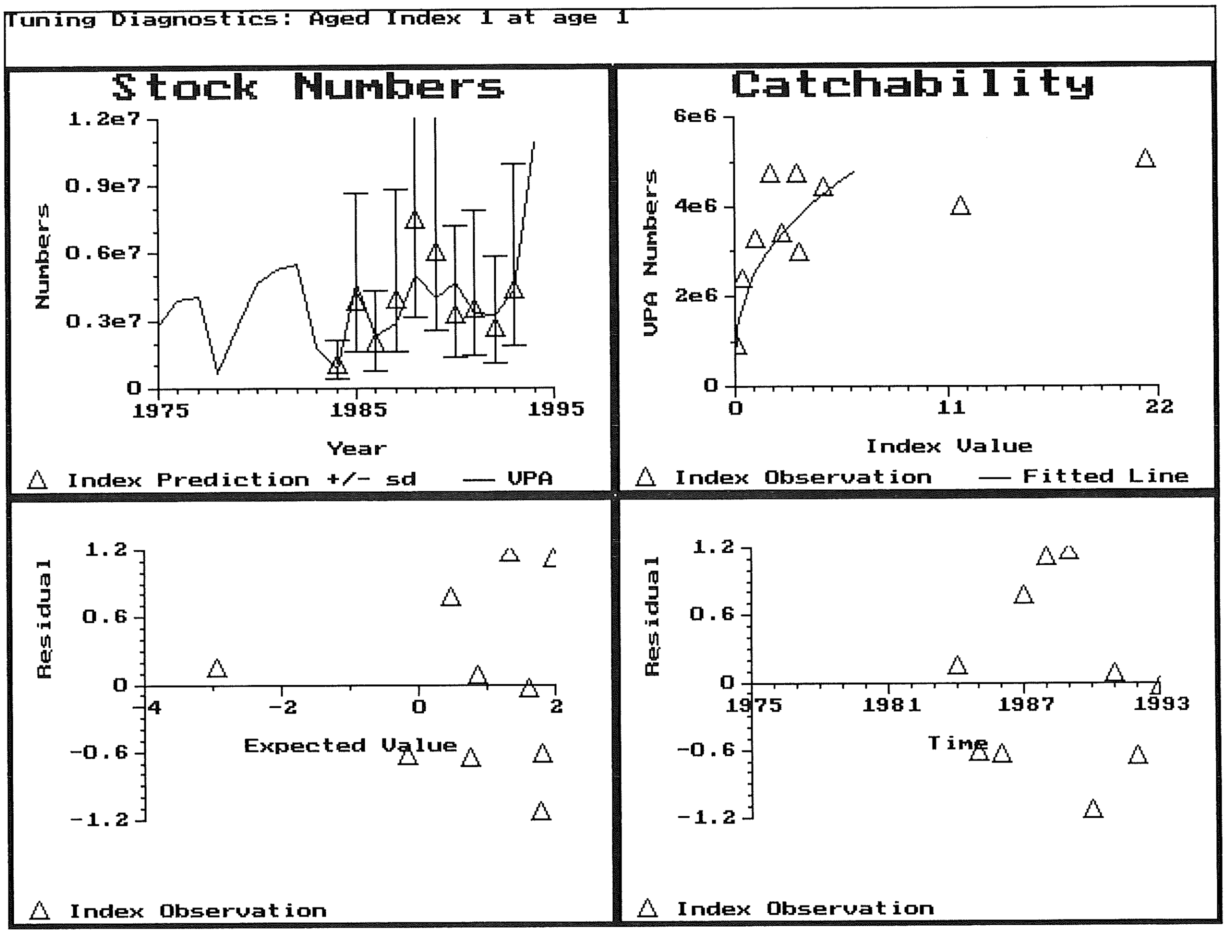


**Figure A2.5** Comparison of the Western Approaches survey Division VIIj at age 1 with fitted stock size at age 1. (1) Stock numbers. The line drawn is the fitted estimate of stock size at age 1 at the time of the survey. Triangles indicate the stock sizes predicted by the survey, i.e. Aa,y / Qa, where A is the index observation and Q is the estimated catchability, together with estimates of the standard deviation of the index calculated in fitting the model. (2) Catchability. This is a scatter plot of fitted values of population size against observed index values. The line has a slope = Q,, as a proportionate relationship is assumed. (3 and 4) The lower two graphs are standard scatter plots of residuals against expected value (to assess the appropriateness of the model fit) and of residuals against time ( to assess historical consistency of the survey).

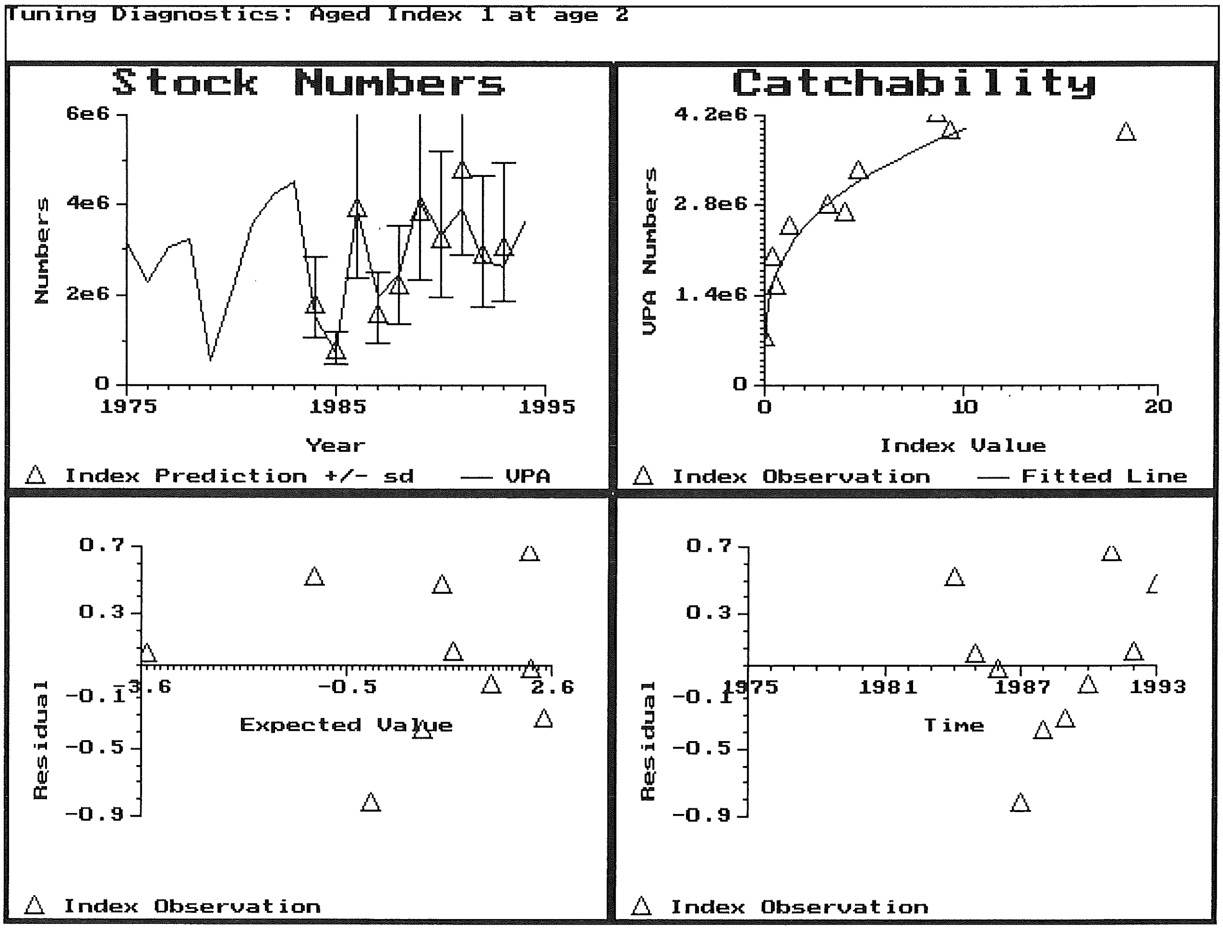


**Figure A2.6** As Figure A1.5, for age 2 of the Western Approaches survey in Division VIIh.

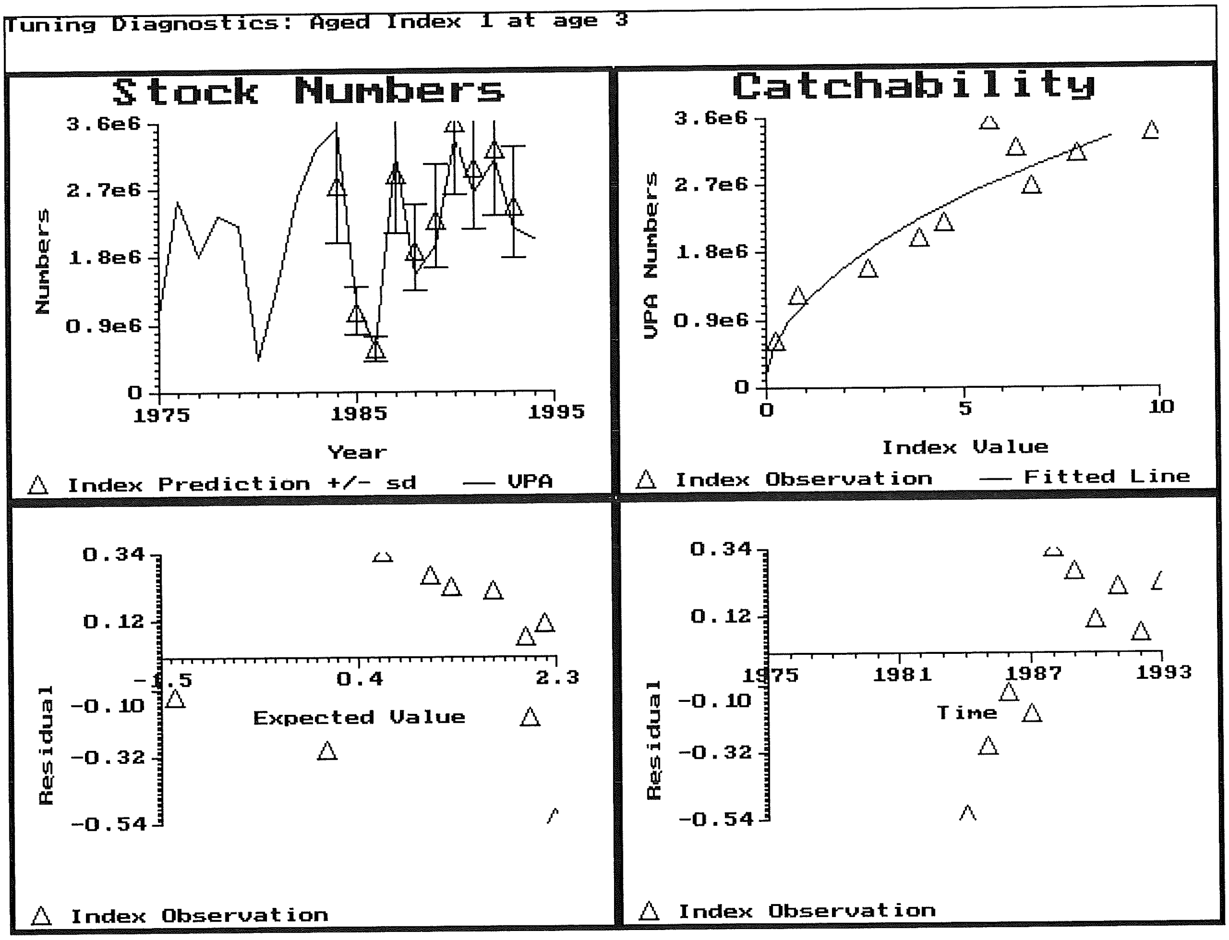


**Figure A2.7** As Figure A1.5, for age 3 of the Western Approaches survey in Division VIIj.

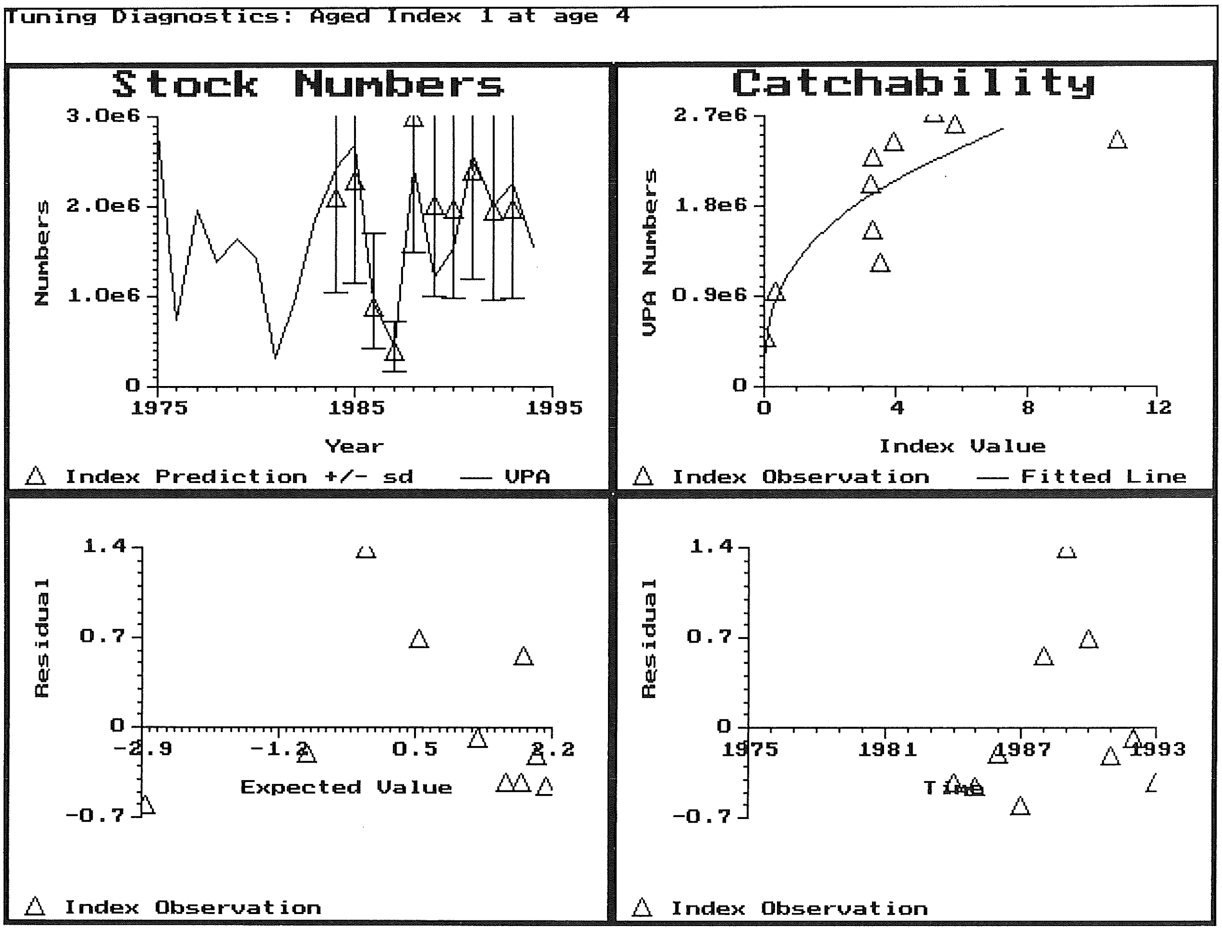


**Figure A2.8** As Figure A1.5, for age 4 of the Western Approaches survey in Division VIIj.

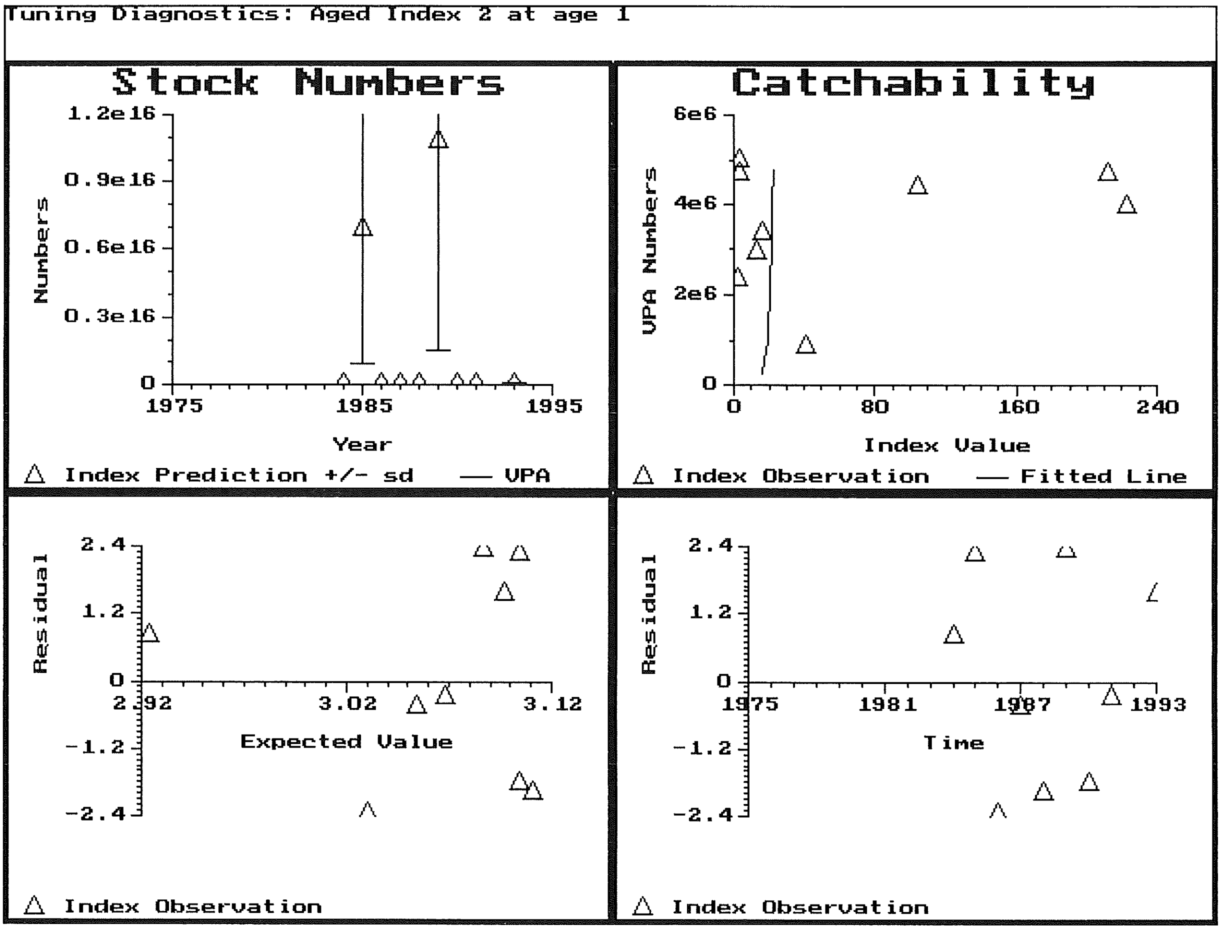


**Figure A2.9** As Figure A1.5, for age 1 of the Western Approaches survey in Division VIIh.

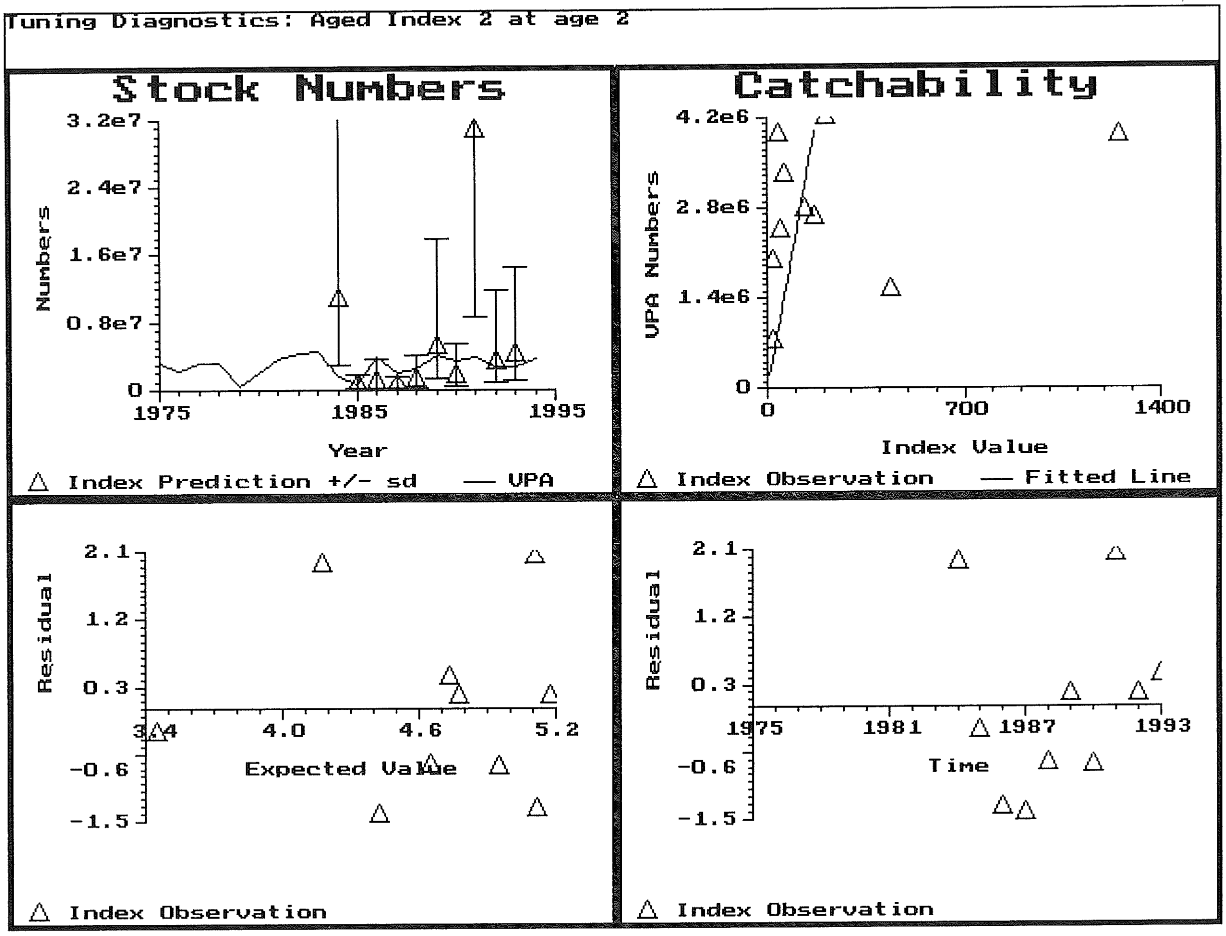


**Figure A2.10** As Figure A1.5, for age 2 of the Western Approaches survey in Division VIIh.

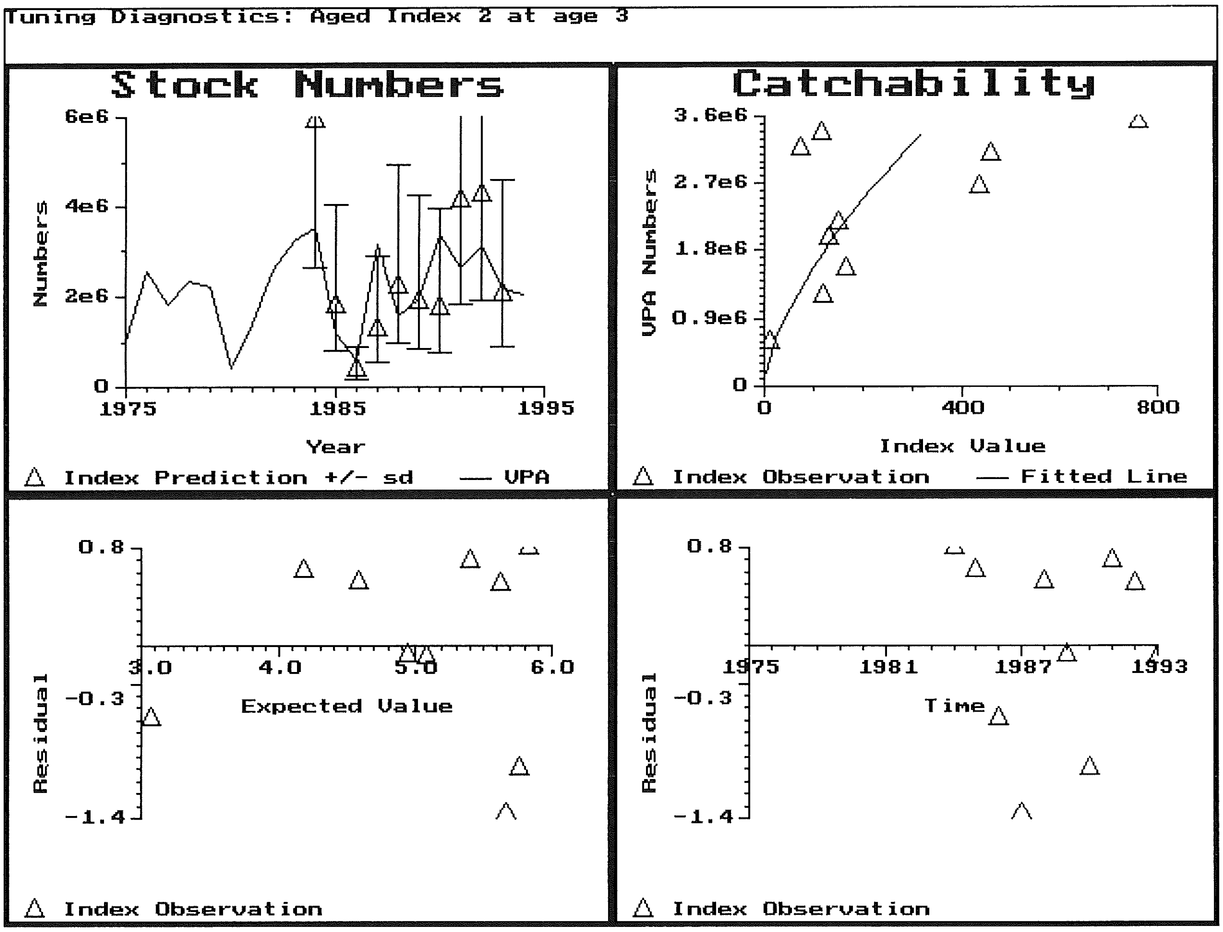


**Figure A2.11** As Figure A1.5, for age 3 of the Western Approaches survey in Division VIIh.

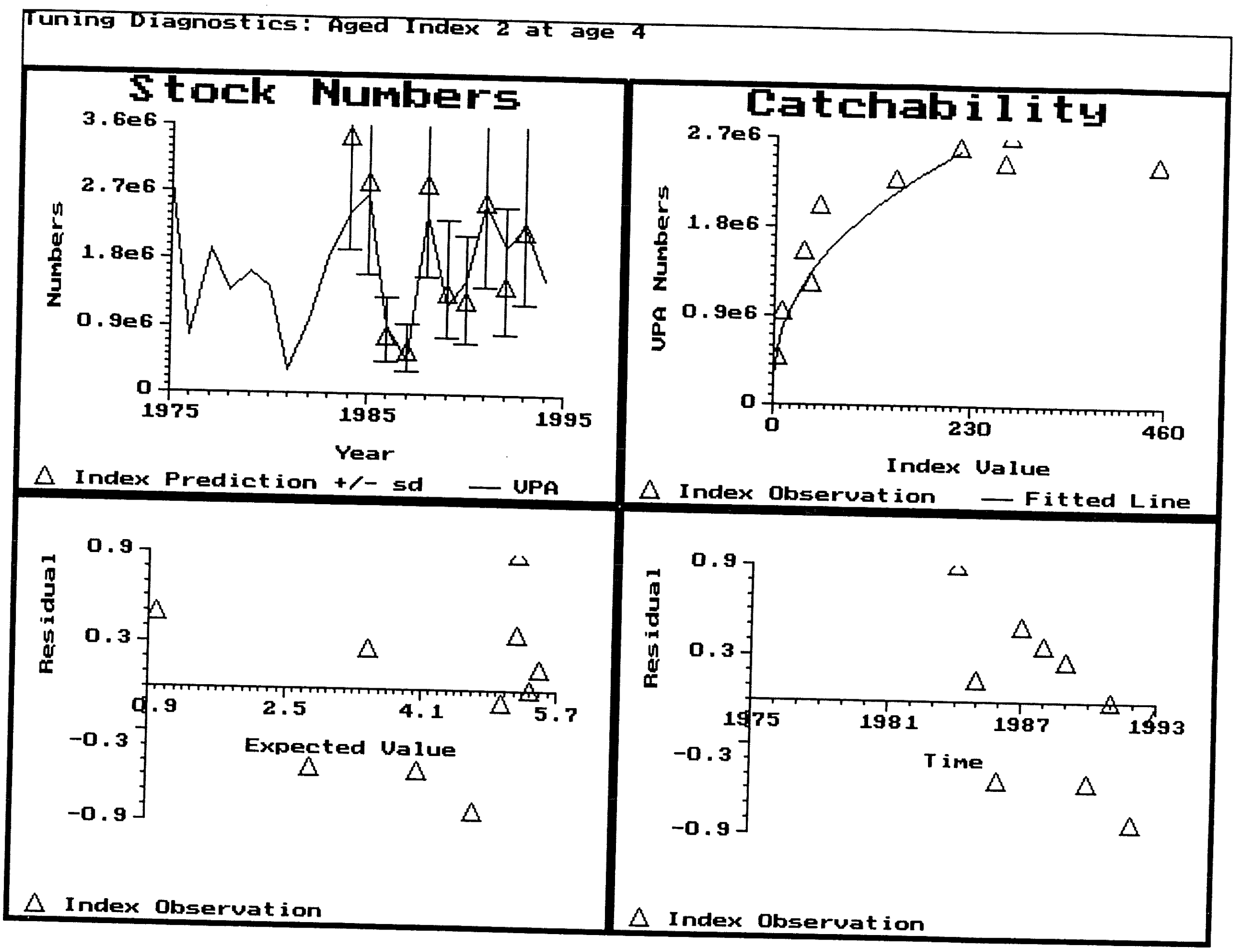


Figure A2.12 As Figure A1.5, for age 4 of the Western Approaches survey in Division VIIh.