Irish Fisheries Investigations (New Series) No. 3 – 1999

THE STATE OF STOCKS OF COD, WHITING, SOLE AND PLAICE ON THE WEST AND SOUTHWEST COASTS OF IRELAND

by

S. B. WHEATLEY, P. L. CONNOLLY, F. WOODS,
M. KEATINGE AND M. DOHERTY

Dublin
The Marine Institute, 80 Harcourt Street, Dublin 2

Copyediting and technical typesetting by Mayo Editorial Services
ISSN 0578-7467

CONTENTS

Introduction **1**

Materials and Methods **3**

Landings sampling methods 3
Von Bertalanffy growth curves 3
Current exploitation rates 4
Catch curve and yield per recruit analysis 4

Catch trends **5**

Cod **5**

Distribution and movements 5
Growth 6
Current exploitation rates 6
Yield per recruit 6

Whiting **7**

Distribution and movements 7
Growth 7
Current exploitation rates 7
Yield per recruit 8

Sole **8**

Distribution and movements 8
Growth 8
Current exploitation rates 9
Yield per recruit 9

Plaice **9**

Distribution and movements 9
Growth 9
Current exploitation rates 10
Yield per recruit 10

Discussion and Conclusions **10**

Biology of stocks 10
State of stocks 11
Fisheries management aspects 12

Acknowledgements **12**

References **12**

Tables **14**

Figures **24**

THE STATE OF STOCKS OF COD, WHITING, SOLE AND PLAICE ON THE WEST AND SOUTHWEST COASTS OF IRELAND

S. B. WHEATLEY, P.L. CONNOLLY, F. WOODS, M. KEATINGE AND M. DOHERTY

Marine Institute, Fisheries Research Centre, Abbotstown, Dublin 15.

ABSTRACT

Stocks of cod, whiting, plaice and sole in ICES Divisions VIIb,c and VIIj,k are an important part of the Irish fishing resource yet, until 1993, were not subject to any assessment. Landings of these stocks in 1996 were valued at £8.6 million, representing 17% of the overall value of all Irish landings of demersal species. In 1993, the Fisheries Research Centre initiated a stock monitoring programme with the aim of providing adequate data to enable an assessment of these stocks. This paper presents the results of growth, catch curve and yield per recruit analyses from the monitoring programme conducted between 1993 and 1996. Preliminary results show that all of these stocks but sole in VIIb,c are over-exploited. TAC levels (based on reported catches in previous years) may be inappropriate for the current stock sizes. It is also important to compare biological characteristics between ICES Divisions to determine the appropriate assessment areas. Comparisons of biological parameters between areas have so far been inconclusive.

INTRODUCTION

Total Irish landings of cod, whiting, sole and plaice in ICES Divisions VIIb,c and VIIj,k in 1996 were valued at IR£8.6 million (Table 1). Figure 1 shows the locations of the ICES Divisions around the Irish coast. Landings of these stocks accounted for 37% of the total value of Irish landings of these species and 17% of the overall value of Irish landings of all demersal species in 1996. Clearly, they are an important part of the Irish fishing resource yet, until 1993, were not subject to routine fisheries monitoring. Hence prior to 1993 little was known about the state of these stocks. As a result, they are subject to total allowable catches (TACs) which are based on average reported catches in preceding years (Table 2). Such TACs are agreed by the EU Council of Ministers (on the basis of proposals by the European Commission) when no analytical assessment is available and may not be appropriate to the current state of a stock.

In 1993, Ireland initiated a stock monitoring programme in VIIb,c and VIIj,k with the aim of providing an adequate time series of biological data for a full analytical assessment. At least five years of age-composition data are required to carry out a virtual population analysis (VPA)-based analytical assessment. In the meantime, it is important to make some attempt to assess the state of these stocks using the available data, so that advice can be given on the appropriate current rate of exploitation. In addition, it is important to compare biological characteristics between ICES Divisions to examine the appropriate assessment areas. This paper presents the preliminary findings of these investigations for the years 1993–1996.

There is little published work available on cod, whiting, sole and plaice in this area. An early reference to gadoid and flatfish stocks in the area was that of Andrews (1865). There was controversy in the mid-1800s surrounding the use of trawling gears in Galway Bay. Large numbers of young cod, haddock and sole were reported to be taken by trawl nets, indicating the presence of nursery grounds in Galway Bay at that time (Andrews, 1865). Ogilby (1885) reported that whiting and haddock were abundant in 1877 on the North coast, after being scarce for many years.

Surveys of the West of Ireland fishing grounds and the Irish Atlantic slope were conducted by the Royal Dublin Society, (Holt, 1891; Holt and Calderwood, 1895; Holt and Byrne, 1910), but these make little reference to the species concerned in this paper. Elkin (1955) compared spawning, growth, feeding, parasitology and population structure between east and west coast stocks of whiting.

Fives (1970) reported the occurrence of cod larvae and post-larvae (during March–April), whiting larvae and post-larvae (during May–June) and sole post-larvae (during March and August) from

surveys of plankton off the West coast. More recent work includes studies of icthyplankton distribution in the Celtic Sea (Horstman and Fives, 1994) and the West coast (O'Brien and Fives, 1995) and species distribution observed during the English Celtic Sea groundfish surveys (Warnes and Jones, 1995).

Table 3 lists surveys which currently collect information on cod, whiting, sole and plaice in ICES Divisions VIIb,c and VIIj,k.

Fishery independent data-research surveys

The first annual Irish groundfish survey off the West coast of Ireland took place in 1990 and includes ICES Divisions VIa, VIIb and VIIj. Survey data can be used to determine the geographical distribution of fish populations. To give a true picture of the distribution of the population a survey should extend beyond the known boundaries (Hilborn and Walters, 1992). As the station positions of this survey, from 1990 to 1996, are generally located in fishable grounds, it is not possible to use this data set as an indication of any changes in distribution across ICES Divisions. The positions of the sampling stations for this survey were revised in 1997. Research survey catch data can be used to estimate total biomass using the swept area method (Sparre *et al.*, 1989). However, as the locations of the stations are clumped in fishable grounds, these data would probably give an overestimate of abundance if used in a swept-area assessment. Therefore, the swept-area method has not been applied to this data set. In the future this survey may provide an index of abundance to be used as tuning data in a full VPA-based assessment.

The south and west young fish survey covers ICES Divisions VIa, VIIb, VIIg and VIIj and commenced in 1994. This survey was primarily designed to map inshore nursery areas over a 3 year period (1995–1997). It is hoped that this survey will provide information on spawning and nursery grounds off the west coast of Ireland.

The UK Celtic Sea groundfish survey commenced in 1981, with the primary objective of investigating the distribution and biology of the Western mackerel stock (Warnes and Jones, 1995). In 1982, the objectives of the survey were expanded to include demersal species. Warnes and Jones (1995) have documented the distributions of species observed during the survey between 1984 and 1991. These UK Celtic Sea ground fish survey data could be used to estimate the biomass of the VIIj,k stocks using the swept-area method. This data set may also provide a tuning time series for a full VPA assessment of these stocks.

The ICES co-ordinated western mackerel and horse mackerel egg survey has taken place every three years since 1977. One of its aims is to determine the distribution of mackerel and other species within the survey area. However, eggs of cod, whiting, sole and plaice are rarely observed during the survey (Steve Milligan, CEFAS, personal communication).

Tagging studies

In November–December 1996 and March–April 1997, the Marine Institute Fisheries Research Centre (MIFRC) conducted a cod tagging study in the Irish and Celtic sea (Anonymous, 1997b). One aim of the study was to examine movements of cod within these areas.

Fishery dependent data-monitoring of catches

The Marine Institute FRC monitoring programme for stocks in VIIb,c and VIIj,k includes analysis

of landings data using the Department of the Marine and Natural Resources (DOMNR) EU log-book data and sampling of the commercial catch for length, weight and age-composition. Preliminary assessments using these data include estimates of current fishing mortality (F) and the fishing mortality which gives maximum yield (F_{max}) using catch curve and yield per recruit analysis, respectively (Anonymous, 1997c). The mesh selectivity data used in the age-based Thompson and Bell yield per recruit analyses presented in this paper were derived from North Sea data (Wileman, 1988) and are given in the text table below. The mesh sizes used were 86 mm (cod), 81 mm (whiting), 69 mm (sole) and 82 mm (plaice). The minimum legal mesh size for all towed gears fishing all target species, excluding *Nephrops norvegicus*, in Sub-area VII is 80 mm and for all towed gears fishing for *N. norvegicus* is 70 mm (Anonymous, 1997a). Additional international material collected as part of this programme includes French catch and effort data. It would be useful to map catch per unit effort (CPUE) data for the Irish fleet to examine the spatial distribution of CPUE, but Irish effort data are not available. The French catch and effort data are available for VIIb,c and VIIj,k. However, the French effort time series in VIIb,c and VIIj,k is not considered representative of fishing activities in the area (A. Biseau, IFREMER, personal communication).

Mesh selectivity data used in the age-based Thompson and Bell yield per recruit analyses presented in this paper. Derived from Wileman (1988).

Stock	Age 0	1	2	3	4	5	6	7	8
Cod VIIb,c	0.00	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Cod VIIj,k	0.00	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Whiting VIIb,c	0.08	0.63	0.85	0.96	1.00	1.00	1.00	1.00	1.00
Whiting VIIj,k	0.12	0.64	0.87	0.97	1.00	1.00	1.00	1.00	1.00
Sole VIIb,c	0.00	0.00	0.33	0.88	0.97	0.99	0.99	1.00	1.00
Sole VIIj,k	0.00	0.00	0.62	0.85	0.93	0.97	0.99	0.99	1.00
Plaice VIIb,c	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Plaice VIIj,k	0.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00

MATERIALS AND METHODS

Landings sampling methods

Sampling of landings taken from ICES Divisions VIIb,c and VIIj,k are conducted in the fishing ports of Rossaveal, Dingle, Union Hall and Killybegs. Demersal landings are sampled for length on a weekly basis in proportion to the quantity and size grades landed for each species. Sampling for age and weight is conducted on a quarterly basis and 10 individual fish are weighed, measured and aged for each length category landed during the quarter. This quarterly age length key (ALK) is then applied to the quarterly length frequency and the resulting numbers at age data are raised to total Irish landings for that quarter. The quarterly landings at age data are then summed to give the annual landings numbers at age. Table 4 gives the number of fish sampled in each ICES Division for each species.

Von Bertalanffy growth curves

Estimates were made of the length growth coefficients from the von Bertalanffy growth equation (Ricker, 1975):

$$L_t = L_\infty(1 - \exp[-k(t - t_0)])$$

where L_t is length at age at time t, L_∞ is the theoretical maximum length, t_0 is the theoretical age at length zero and k is the growth coefficient. The growth coefficients, L_∞, t_0 and k, were estimated by fitting a growth curve to the observed mean length at age data (1996 mean lengths at age during the spawning period), which minimised the squared residuals between the observed and expected length values.

Current exploitation rates

The estimated annual fishing mortality in 1996 (F_{96}) for VIIb,c and VIIj,k stocks were estimated using catch curve analysis, while F_{96} in adjacent stocks were estimated using VPA-based methods and taken from the relevant ICES working group documents (Anonymous, 1998a,b).

Catch curve and yield per recruit analysis

Estimates of total mortality (Z) and fishing mortality (F) were obtained using catch curve analysis (Ricker, 1975). The 1996 catch numbers at age data were plotted as natural logarithms against age. Assuming constant mortality between age groups, *Z* was estimated from the linear equation:

$$LnN_t = LnN_0 - Z$$

where N_t is the number of fish surviving at time t and Z is estimated from the regression line of best fit.

F was estimated from the equation:

$$Z = F + M$$

where M is natural mortality and was assumed to be similar to that in stocks in adjacent areas (Anonymous, 1998a,b).

The F_{max} was determined from fishing mortality at maximum yield on the yield per recruit curve. Yield per recruit from all year classes within a given year was calculated using the age based Thompson and Bell yield per recruit model (Ricker, 1975):

$$\sum_{t_c}^{t_x} \frac{F}{Z}(M_t \times N_t \times (1 - \exp(-((S \times F) + M))))$$

where t_c is age at first capture, t_x is the last age of capture, M_t is mean weight at age t, N_t is number of recruits at age t, S is the probability of capture at age t, F is fishing mortality and M is natural mortality. The age-based Thompson and Bell yield per recruit model was used as it includes the effects of mesh selectivity and this gives a more realistic yield per recruit curve. Furthermore, this method is the basis of the yield per recruit methods applied to predict catches and set quotas in the ICES area (Sparre *et al.*, 1989).

Where the yield per recruit curve did not reach a maximum, as in plaice, or where the curve was flat-topped, as in sole, the optimum fishing mortality $F_{0.1}$ was also calculated. $F_{0.1}$ can be defined

as the fishing mortality at which the slope of the yield per recruit curve is 10% of its value near the origin. $F_{0.1}$ was estimated here by calculating the rate of change in yield per recruit for successive values of F and by interpolating to yield per recruit at $F_{0.1}$ (King, 1995).

CATCH TRENDS

Tables 5–8 show the estimated annual Irish landings for each species from ICES Divisions VIIb,c (1980–1996) and VIIj,k (1987–1996) and the international landings (1987–1996) for both areas combined. The official VIIj,k and total international landings data are available for the years 1987–1996 only, as the way in which the different countries reported Sub-area landings prior to 1987 does not allow for VIIj,k landings to be reported separately from VIIg landings.

Total international landings of each of these stocks are taken mainly by Ireland, the exception being cod landings early in the time series. France and England also exploit the gadoid stocks, but take insignificant catches of the flatfish species. Landings of all species are generally higher in Divisions VIIj,k than in VIIb,c. Estimated international landings of cod in VIIb,c and VIIj,k show a decreasing trend between 1989 and 1993 with a slight increase in the period 1994–1996 (Table 5). Estimated international landings of whiting have increased steadily over the period from just 2,000 t in 1988 to just under 8,000 t in 1995 (Table 6). Landings of both sole and plaice have remained relatively steady over the period, although both show an increase in landings up to the period 1991 (sole) and 1992 (plaice) with a decreasing trend thereafter (Tables 7 and 8).

Irish catches of cod, plaice and sole are taken mainly by otter trawl in both VIIb,c and VIIj,k. Irish catches of whiting are taken by both seine net and otter trawl in VIIb,c and in VIIj,k. Catches by other gear types such as fixed gill nets are insignificant in these areas. Irish catches in Divisions VIIc and VIIk are relatively low.

Figures 2 to 5 show the proportion of the total Irish landings of cod, whiting, sole and plaice taken in each statistical rectangle in 1996. Cod are taken mainly in near-shore areas with higher catches taken in VIa, VIIa and VIIg than in other areas. Irish catches of whiting are concentrated in ICES Divisions VIIb, VIIg and VIIj. Irish catches of sole are relatively dispersed with a larger proportion of catches being taken from VIIj (just off the Dingle Peninsula) and from VIIa (Morecambe Bay area). Catches of plaice are more evenly distributed than for sole, with a large proportion of the catches being taken from VIa, VIIa and VIIj. It is worth noting that for sole, and also to some degree for plaice, high catches are recorded just outside of VIIb (north and south). This may indicate mis-reporting of sole caught in VIIb in adjacent TAC areas. However, the extent of such mis-reporting, if it exists, is not known.

COD

Distribution and movements

Cod are distributed throughout area VII and in general are found from the shore line to 600 m (Wheeler, 1969). Adult cod undertake extensive feeding and spawning migrations while juveniles do not undertake such extensive migrations. Catches of cod from the Irish west coast groundfish survey 1993–1996 indicate a relatively higher abundance of cod in areas off the Northwest coast of Ireland (ICES Division VIa). The UK Celtic Sea groundfish survey conducted in ICES Divisions VIIe–j indicates that abundance varies strongly between years depending on year class

strength (Warnes and Jones, 1995). Although only low numbers of cod are recorded per haul in normal years, they are distributed mainly on the plateau inside the 200 m line and no consistent distribution pattern is evident over the time series, although abundance decreases from North to South.

In November–December 1996 and March–April 1997, MIFRC conducted a cod tagging study in the Irish and Celtic Sea (Anonymous, 1997b). One aim of the study was to examine movements of cod within these areas. A total of 1,685 cod were tagged. By November 1998, returns numbered 166, the majority from within 7 to 15 km of the area of tagging.

The abundance of larval cod observed during the international mackerel and horse mackerel egg survey in April to June in ICES Divisions VIa,b, VIIb,c and VIIj,k is very low (Horstman and Fives, 1994). Therefore, conclusions on the dispersal of cod larvae in these areas could not be made. O'Brien and Fives (1995) analysed samples of ichthyoplankton from the international mackerel and horse mackerel egg survey and report that the abundance of cod larvae was low.

Growth

Figures 6 and 7 give the quarterly length frequency distributions of cod landed by Irish vessels into Irish ports from ICES Divisions VIIb,c and VIIj,k in 1996 and show similar patterns between ICES Divisions. Figure 8 shows the von Bertalanffy growth curves for VIIb,c and VIIj,k cod caught in April to June. Cod in VIIj,k showed a slightly higher growth rate compared to VIIb,c cod (k = 0.32 and 0.26, respectively). Figure 9 compares the annual mean weights and lengths at age of cod taken from Divisions VIIb,c with those taken from Divisions VIIj,k; 95% confidence intervals of the VIIb,c and VIIj,k mean lengths and weights are also given. Mean lengths and weights are similar between both Divisions except at age groups 3 and 8. However, comparison of older age groups is not meaningful, as sample sizes are small. Table 9 compares observed mean weights at age for cod in VIIb,c and VIIj,k in 1996 with catch weight at age estimated for adjacent Divisions in 1996 (Anonymous, 1998a,b). Between the ages of 2 and 5 (from the age of full recruitment), VIIg mean weights at age are higher than in either VIIb,c or VIIj,k, VIIa mean weights vary relative to both VIIb,c and VIIj,k and VIa mean weights are lower than in either VIIb,c or VIIj,k.

Current exploitation rates

Tables 10 and 11 show the international landings numbers at age data raised using the annual Irish age length key for each year in 1993 to 1996. Table 12 compares fishing mortality in 1996 (F_{96}) for cod in ICES Divisions VIIb,c and VIIj,k with those in adjacent ICES Divisions.

F_{96} for cod in Divisions VIIb,c is estimated to be 1.09 and in Divisions VIIj,k to be 1.05. F_{96} in ICES Divisions VIIb,c and VIIj,k is greater than that observed in either Division VIa or Division VIIa. F_{96} for cod in Divisions VIIb,c is similar to that observed in 1995, while the value of F_{96} in Divisions VIIj,k is lower than observed in 1995 (Tables 13 and 14).

Yield per recruit

Tables 13 and 14 give the estimates of F and F_{max} for cod in 1996 and 1995. F_{max} in 1996 was estimated to be 0.30 (VIIb,c) and 0.35 (VIIj,k), which is consistent with that estimated for 1995 (Anonymous, 1997c). Fishing mortality was far in excess of F_{max} for both VIIb,c and VIIj,k cod in both years.

WHITING

Distribution and movements

Whiting is abundant in Area VII and is a shallow water species, occurring mostly between depths of 30 and 100 m (Wheeler, 1969). Immature fish are found inshore in depths of 5–30 m. Catches of whiting observed during the Irish west coast groundfish survey 1993–1996 indicate that whiting are abundant throughout the survey area, with a relatively high abundance both west of Donegal Bay (in VIa and VIIb) and Galway Bay (VIIb). The UK Celtic Sea groundfish survey conducted in ICES Divisions VIIe–j indicates that whiting occur over the whole of ICES Divisions VIIe–j but do not extend into deeper waters (Warnes and Jones, 1995).

Tagging studies conducted off the west coast of Scotland indicated that large-scale movements of whiting do not occur, most of the movements observed being of less than 60 miles (Newton, 1986). There was evidence of a cyclic movement between the Stanton Banks and Donegal Bay and that these movements could be associated with a minor spawning migration. However, both of these fishing grounds are within ICES Division VIa and so do not concern the current discussion of the distribution of the VIIb,c and VIIj,k stocks.

The abundance of larval whiting observed during the ICES co-ordinated western mackerel and horse mackerel egg surveys is very low (Horstman and Fives, 1994). O'Brien and Fives (1995) also analysed samples of ichthyoplankton from the above survey and report that the abundance of whiting larvae in April to June in ICES Divisions VIa,b, VIIb,c and VIIj,k was low.

Growth

Figures 10 and 11 give the quarterly length frequency distributions of whiting landed by Irish vessels into Irish ports from the ICES Divisions VIIb,c and VIIj,k in 1996. The length frequencies showed similar patterns between Divisions, although modal values were generally higher in Divisions VIIb,c. Figure 12 shows the von Bertalanffy growth curves for VIIb,c and VIIj,k whiting caught in April to June. Whiting in VIIb,c had a higher growth rate than those in VIIj,k ($k = 0.83$ and 0.52, respectively). Figure 13 compares the annual mean weights and lengths for Divisions VIIb,c with those for Divisions VIIj,k. The annual mean lengths in age groups 3 and 4 are higher in VIIj,k than in VIIb,c whiting. Comparison of mean lengths and weights in older age groups is not feasible as the sample sizes are small.

Table 15 compares observed mean weights at age for whiting in VIIb,c and VIIj,k in 1996 with catch weight at age estimated for adjacent Divisions in 1996 (Anonymous, 1998a,b). Growth of whiting in ICES Divisions VIIb,c and VIIj,k was higher than that in either ICES Divisions VIa or VIIa. These findings concur with Elkin (1955) who compared growth of commercially caught whiting between the East coast and West coast of Ireland stocks (Nov. 1952–June 1954) and found that west coast stocks weighed slightly more than east coast stocks for the equivalent length groups. Growth in whiting in VIIb,c and VIIj,k was also higher than that observed in VIIg, apart from at age 5 and older.

Current exploitation rates

Tables 16 and 17 show the international landings numbers at age data raised using the annual Irish age length key for each year in 1993–1996. Table 12 compares fishing mortality in 1996 (F_{96}) for whiting in ICES Divisions VIIb,c and VIIj,k with those in adjacent ICES Divisions.

F_{96} in VIIb,c is more similar to that in VIIa than in VIa, while F_{96} in VIIj,k is lower than that observed in either VIIb,c, VIa or VIIa (Table 12). F_{96} in VIIb,c is similar to that observed in 1995, although F_{96} in VIIj,k is reduced compared to that in 1995 (Tables 13 and 14). The value of F_{96} in Divisions VIIj,k is just 0.52 in contrast to a value of 0.72 for 1995. A possible explanation is that there are large 1993 and 1994 year classes being exploited in the fishery (Table 16).

Yield per recruit

Tables 13 and 14 give the estimates of F and F_{max} for whiting in 1996 and 1995. F_{max} in 1996 was 0.70 (VIIb,c) and 0.80 (VIIj,k), which were both higher than those values estimated for 1995. Fishing mortality was in excess of F_{max} in VIIb,c in both 1995 and 1996. While fishing mortality was in excess of F_{max} in 1995, it was slightly lower than F_{max} in 1996, perhaps due to the large 1993 and 1994 year classes being exploited in the fishery.

SOLE

Distribution and movements

Sole is distributed throughout Area VII and is common in waters from 0 to 73 m (Wheeler, 1969). Horwood (1993) reviewed the biology of sole in ICES Divisions VIIf,g and reports that sole in these ICES Divisions is relatively isolated in that spawning grounds are discreet, nursery grounds are exclusive, a large proportion of adult sole remain in this region and few sole appear to recruit into the region.

Catches of sole observed during the Irish west coast groundfish survey 1993–1996 indicate that the abundance of sole observed throughout the survey area is relatively low. Tagging studies in the Irish Sea and adjacent waters indicate that there are probably separate stocks of sole in the Irish Sea and Bristol Channel (Anonymous, 1966). Horstman and Fives (1994) report that larvae of sole were not observed during the ICES co-ordinated western mackerel egg and larval survey.

Growth

Figures 14 and 15 give the quarterly length frequency distributions of sole landed by Irish vessels into Irish ports from ICES Divisions VIIb,c and VIIj,k in 1996. Length frequency patterns are different between the Divisions, particularly in Quarters 3 and 4, with sole in VIIb,c generally showing higher modal lengths. Figure 16 shows the von Bertalanffy growth curves for VIIb,c and VIIj,k sole. Growth rates are slightly higher in Divisions VIIj,k sole than in VIIb,c sole (k = 0.20 and 0.28, respectively). Figure 17 compares the annual mean weights and lengths at age of sole taken from Divisions VIIb,c with those taken from Divisions VIIj,k; 95% confidence intervals of the VIIb,c and VIIj,k mean weights and lengths are also given. There was little difference between mean lengths and weights of sole taken from Divisions VIIb,c and VIIj,k. Table 18 compares observed mean weights at age for sole in VIIb,c and VIIj,k in 1996 with catch weight at age estimates from adjacent Divisions in 1996 (Anonymous, 1998a, 1998b). From age 4 and older (fully recruited fish), both VIIb,c and VIIj,k observed mean weights at age were higher than those estimated for VIIa sole. However, the VIIa mean weight at age data have been obtained by smoothing the international weights at age using a quadratic fit representing July 1 values. Therefore, comparison between VIIb,c,j,k and VIIa sole mean weights at age is meaningless. Nevertheless, it is well documented that sole in the Irish sea (Division VIIa) are slower growing than stocks in adjacent areas (Anonymous, 1966). Mean weights at age of sole in VIIg were higher than that observed in

VIIb,c and VIIj,k sole.

Current exploitation rates

Tables 19 and 20 show the international landings numbers at age data raised using the annual Irish age length key for each year in 1993 to 1996. Table 12 compares fishing mortality in 1996 (F_{96}) for sole in ICES Divisions VIIb,c and VIIj,k with those in adjacent ICES Divisions.

F_{96} in sole in VIIb,c was estimated to be 0.18 and in VIIj,k to be 0.42 (Table 12). F_{96} in VIIj,k was higher, by 110%, in 1996 compared to 1995. A possible explanation is that there were fewer cod in the 10 to 11 age groups in the catch in 1996 (Table 20). F_{96} for VIIj,k cod was 133% higher than that in VIIb,c and was more similar to that observed in VIIa cod. F_{96} for VIIj,k is higher than that observed for 1995 (Tables 13 and 14).

Yield per recruit

Tables 13 and 14 give the estimates of F and F_{max} for sole in 1996 and 1995. F_{max} was estimated to be 0.45 and 0.40 in VIIb,c and VIIj,k, respectively. $F_{0.1}$ in 1996 was estimated to be 0.30 (VIIb,c) and 0.27 (VIIj,k), indicating that the VIIb,c and VIIj,k stocks are under and over-exploited, respectively.

PLAICE

Distribution and movements

Plaice is a shallow water species found from the shore line to 120 m depth throughout Sub-area VII (Wheeler, 1969). Young plaice (0–3+) are found in very shallow waters from 0 to 3 m depth. Catches of plaice observed during the Irish west coast groundfish survey 1993–1996 indicate that plaice is consistently abundant in inshore areas of VIa and across into ICES Division VIIb.

The abundance of larval plaice observed during the ICES co-ordinated western mackerel and horse mackerel egg surveys is very low (Horstman and Fives, 1994). Similarly, O'Brien and Fives (1995) analysed samples of ichthyoplankton from the above survey and report that the abundance of plaice larvae in April to June in ICES Divisions VIa,b, VIIb,c and VIIj,k is low.

Growth

Figures 18 and 19 give the quarterly length frequency distributions of plaice landed by Irish vessels into Irish ports from ICES Divisions VIIb,c and VIIj,k in 1996. Generally VIIj,k plaice show higher modal values than in VIIb,c. However, sampling levels of VIIj,k plaice in 1996 were poor (Table 2). Figure 20 shows the von Bertalanffy growth curves for VIIb,c and VIIj,k plaice. Growth coefficients are poorly estimated, however, because of high variation within older age groups. This is apparent in Figure 21, which shows very large confidence intervals in the older age groups. Mean weights and lengths at age were higher in the VIIj,k group than in the VIIb,c group. Table 21 compares the annual observed mean weights at age for plaice in VIIb,c and VIIj,k in 1996 with catch weight at age data estimates from adjacent Divisions in 1996 (Anonymous, 1998a,b). The VIIa mean weight at age data have been obtained by smoothing the international weights at age using a quadratic fit representing July 1 values. Growth rates of VIIb,c plaice (from age 4 and older) were lower than in either VIIa or VIIg. In contrast, in age groups 2–6 mean weights of VIIj,k plaice are higher than in VIIa or VIIg.

Current exploitation rates

Tables 22 and 23 show the international landings numbers at age data raised using the annual Irish age length key for each year in 1993–1996. Table 12 compares fishing mortality in 1996 (F_{96}) for plaice in ICES Divisions VIIb,c and VIIj,k with those in adjacent ICES Divisions.

F_{96} in plaice in VIIb,c was 0.34 and in VIIj,k 0.54 (Table 12). F_{96} in VIIb,c and VIIj,k was similar to that observed in 1995 (Tables 13 and 14). F_{96} in VIIb,c plaice was more similar to that in VIIa than in VIIj,k.

Yield per recruit

Tables 13 and 14 give the estimates of F and F_{max} for plaice in 1996 and 1995. F_{max} in 1996 could not be estimated for plaice in VIIb,c as the yield per recruit curve did not reach a maximum. F_{max} for VIIj,k plaice was 0.35, which indicates that plaice in VIIj,k are over-exploited. $F_{0.1}$ in 1996 was estimated to be 0.30 and 0.25 in VIIb,c and VIIj,k, respectively, also indicating that plaice in both areas are over-exploited.

DISCUSSION AND CONCLUSIONS

Biology of stocks

Prior to conducting a full assessment of the state of a given fish population, it is important to gather together all of the available information on the biology of these stocks in order to determine the distribution, population parameters and hence the geographical boundaries of these stocks. For stock assessment and management purposes it is assumed that the stock being assessed is a homogenous group of animals. That assumption means that the population has known boundaries of distribution, is not part of some larger homogenous stock and can be defined using the same population parameters for all animals in the population. An initial step in any stock assessment is to define the stock under investigation.

To date this has not been carried out for stocks of cod, whiting, plaice or sole in the ICES Divisions VIIb,c or VIIj,k. It is not known if the above stocks are separate and definable or if they are in fact part of other ICES-assessed stocks, e.g. VIa or VIIg. Ideally stock discrimination can best be achieved through genetic investigations. Previous ICES study groups have reviewed genetic methods of stock identification for fish and shellfish (Anonymous, 1993). However, there is no information on genetic discrimination of marine stocks of fish off the west and southwest coasts of Ireland. Therefore, the VIIb,c and VIIj,k stocks may be defined only by a description of the spatial distribution of commercial CPUE, from research survey abundance data, by a description of movements using tagging studies on both adults and juveniles and surveys of egg and larval dispersal and finally by comparison of population parameters between these and adjacent stocks using growth, recruitment and age structure information.

The Irish CPUE data are not available at present and French CPUE data are not considered representative of fishing activity in the area. The research survey data, from various sources, reviewed in this paper provide little basis for a decision on the identity of stocks of cod, whiting, plaice and sole in the ICES Divisions VIIb,c and VIIj,k. The Irish research survey, until 1997, did not cover the west and southwest area sufficiently to identify stock distributions. Catches from the UK ground fish survey are very low and cover only Divisions VIIg and VIIj,k. The mackerel and horse

mackerel egg surveys rarely observed larval cod, whiting, plaice or sole so information on stock distributions cannot be obtained from this source. Until recently, no tagging studies were carried out in these ICES Divisions and relatively few in adjacent areas. However, it is hoped that the recent Irish cod tagging programmes will yield information on cod distributions around the Irish coast.

Comparison of growth and fishing mortality between ICES Divisions in 1996 had yielded different findings from comparisons of the 1995 data (Anonymous, 1997c). F_{95} in cod in VIIb,c was similar to that in VIIa and VIIf,g,h. However, F_{96} in VIIb,c is higher by 78% than that in VIIa. Similar changes in F_{96} between ICES Divisions are apparent in other stocks, for example sole in Divisions VIIb,c and VIIj,k had a lower exploitation rate in 1995 compared to VIIa, while F_{96} in VIIj,k sole is similar to that in VIIa. Comparison of growth between Divisions VIIb,c and VIIj,k stock indicates that growth is similar between cod, sole and plaice, while growth in whiting is higher in VIIj,k than that in VIIb,c. A more detailed analysis over time of the changes in growth and exploitation rate is required before any conclusions can be drawn using growth and exploitation rate data.

Once the issue of stock identity has been addressed, it may be possible to determine the appropriate assessment areas for the VIIb,c and VIIj,k stocks. The 1995 ICES Southern Shelf Working Group considered the assessment areas of stocks of cod, whiting, hake, sole, plaice and anglerfish in the Irish Sea, Celtic Sea and English Channel on the basis of the available biological information on these stocks (Anonymous, 1996). That working group concluded that there was insufficient information to allow the group to redefine the assessment areas of the above stocks and suggested that further biological work is required before a decision can be made.

In conclusion any decision on the inclusion of cod, whiting, sole and plaice in assessments of adjacent areas until further information is available may be premature. Further information is required before a reliable decision can be made. Further work, which could enable a more reliable decision to be made could include analysis of the west coast ground fish survey data which includes all areas in ICES Divisions VIa, VIIb and VIIj (data from 1997 onwards), analysis of the Irish south and west coast young fish survey to identify nursery and spawning grounds, further tagging studies in ICES Divisions VIa, VIIb and VIIj and continuation of current monitoring and description of population parameters.

Nevertheless, the current management areas for the gadoid stocks include VIIb,c and VIIj,k in a larger Sub-area VII (excluding VIIa) TAC and for this reason the 1997 ICES Southern Shelf Working Group included the cod and whiting VIIj,k data in the VIIg (Celtic sea) assessments.

State of stocks

This paper presents estimates of F, F_{max} and $F_{0.1}$ in 1995 and 1996. The results of these analyses are consistent between years with two exceptions. Analysis of 1995 data estimated that for VIIj,k sole, F_{95} was below F_{max} by 33%. However, analysis of the 1996 catch data indicates that F_{96} for VIIj,k sole is above F_{max} and $F_{0.1}$. F_{96} for whiting in VIIj,k is lower than F_{max} by 35% while analysis of the 1995 catch data estimated that F_{95} was in excess of F_{max}. This may be explained by the large 1993 year class which is currently being exploited in this fishery as well as a relatively large 1994 year class.

The yield per recruit analyses presented in this paper indicates that the following stocks are over-exploited: cod in Divisions VIIb,c and VIIj,k, whiting in VIIb,c, sole in VIIj,k and plaice in VIIb,c and VIIj,k. In contrast, the following stocks show values of F_{96} below F_{max} and/or $F_{0.1}$ in 1996: sole in VIIb,c and whiting in VIIj,k. Whiting recruitment can fluctuate considerably between years (Anonymous, 1997c) and it is important to note that this stock indicated over-exploitation in 1995. The only stock which can reliably be described as under-exploited from this analysis is sole in VIIb,c.

While this assessment indicates that sole in VIIb,c is under-exploited in terms of the yield per recruit curve, it must be pointed out that the curve is flat-topped, as is generally the case with this species. Therefore, caution must be exercised when drawing any management inference from the relative magnitudes of F and $F_{max.}$ The more conservative point of $F_{0.1}$ (0.3) is still higher than the current level of F. On that criterion, it is clear that the stock is under-exploited and indicates some capacity to yield increased catch weights in return for a moderate increase in fishing effort.

Fisheries management aspects

These stocks are subjected to TACs based on average reported catches in previous years (see Table 2). These TAC levels may be inappropriate to the current state of these stocks. MIFRC monitoring of these stocks indicates that all but sole in Divisions VIIb,c are over-exploited and it is clear that the current precautionary TACs are inappropriate and will only lead to further over-exploitation of these stocks. Future work should focus on efforts to describe the biology of these stocks and to quantify sustainable exploitation levels by conducting full analytical assessments.

ACKNOWLEDGEMENTS

The authors wish to thank Brian Casburn, John Holland, Richie Browne and Paddy O'Mahony for assistance throughout the MIFRC monitoring programme. Many thanks are also due to the workers in the auction halls and fish processors who assisted with sampling with much good will. Finally, thanks to DOMNR personnel for both supplying and for giving advice on the preparation of logbook landings data.

REFERENCES

Andrews, W. (1865) On the sea fisheries of Ireland, with reference to trawling. *The Journal of the Royal Dublin Society.* Nos XXXII–XXXIII. pp. 295–324.

Anonymous (1966) *ICES Cooperative research report.* Series B. Annex II: 60 pp.

Anonymous (1993) Report of the study group on stock identification protocols for finfish and shellfish stocks. *ICES CM 1993*/M:3.

Anonymous (1996) Report of the working group on the assessment of southern shelf demersal stocks. *ICES CM 1996*/Assess: 5.

Anonymous (1997a) Council Regulation (EC) No. 894/97. *Official Journal* No. L 132/1.

Anonymous (1997b) Cod tagging programme. *FRC Fish stock data leaflet* D;15/1997.

Anonymous (1997c) Report of the working group on the assessment of southern shelf demersal stocks. *ICES CM 1997*/ Assess: 5.

Anonymous (1998a) Report of the working group on the assessment of northern shelf demersal stocks. *ICES CM 1998*/ Assess: 1.

Anonymous (1998b) Report of the working group on the assessment of southern shelf demersal stocks. *ICES CM 1998*/ Assess: 4.

Elkin, H.W. (1955) Whiting (*Gadus merlangus* L.) in Irish waters. *The Scientific Proceedings of the Royal Dublin Society.* Vol. 27 (NS-No. 2). pp. 17–33.

Fives, J.M. (1970) Investigations of the plankton of the West coast of Ireland-IV. Larval and post-larval stages of fishes taken from the plankton of the West coast surveys during the years 1958–1966. *Proceedings of the Royal Irish Academy.* 70B (3).

Hilborn and Walters (1992) *Quantitative fisheries stock assessment: choice, dynamics and uncertainty.* Chapman and Hall, London.

Holt, E.W.L. (1891) Survey of fishing grounds, West coast of Ireland, 1890. I.-On the eggs and larvae of teleosteans. *The Scientific Transactions of the Royal Dublin Society.* Vol. 4 (Series 2).

Holt, E.W.L. and Byrne, L.W. (1910) Fourth report on the fishes of the Irish Atlantic slope. *Scientific Investigations*, 1908. No. 5.

Holt E.W.L. and Calderwood, W.L. (1895) Survey of fishing-grounds, West coast of Ireland, 1980–1891. Report on the rarer fishes. *The Scientific Transactions of the Royal Dublin Society.* Vol. 5 (Series 2).

Horwood, J. (1993) The Bristol Channel sole (*Solea solea* (L.)): A fisheries case study. *Advances in Marine Biology*. 29: 215–367.

Horstman, K.R. and Fives, J.M. (1994) Ichthyoplankton distribution and abundance in the Celtic sea. *ICES J. Mar. Sci*., 51: 447–460.

King, M. (1995) *Fisheries biology, assessment and management*. Fishing News Books, Oxford. 341 pp.

Newton, A. (1986) Scottish whiting tagging experiments in Division VIa. *ICES CM 1986*/ G: 9.

O'Brien, B. and Fives, J.M. (1995) Ichthyoplankton distribution and abundance off the West Coast of Ireland. *ICES J. Mar. Sci.*, 52: 233–245.

Ogilby, J.D. (1885) Notes on some Irish fishes. *The Scientific Proceedings of the Royal Dublin Society.* Vol. 4 (NS). pp. 510–535.

Ricker, W.E. (1975) Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Board Can*., 191: 382 pp.

Sparre, P., Ursin., E. and Venema, S.C. (1989) Introduction to tropical fish stock assessment. Part 1. *FAO Fisheries Technical Paper*. No. 360.1.

Warnes, S. and Jones, B.W. (1995) Species distributions from English Celtic Sea groundfish surveys 1984 to 1991. *Fisheries Research Technical Report* No. 98. MAFF, Lowestoft, UK.

Wheeler, A. (1969) *The fishes of the British Isles and North West Europe*. Michigan State University Press. 613 pp.

Wileman, D. (1988) Cod end selectivity, updated review of available data. Published in 3 parts. Danish Institute for Fisheries Technology and Aquaculture. *Commission of the European Communities, Directorate General-Fisheries*, Study Contract 1991.15.

Table 1. Value of Irish landings (IR£) of whitefish species in 1996. Source: Department of the Marine and Natural Resources, EU Logbook Programme.

	VIIb,c	VIIj,k	Total
Cod	486,308	1,176,478	1,662,787
Whiting	758,226	2,794,316	3,552,543
Sole	439,542	1,311,758	1,751,300
Plaice	326,663	367,169	693,832
Total	2,344,105	6,298,865	8,642,970
Total Irish landings of these species			23,573,827
Total Irish demersal landings			50,951,328

Table 2. Management areas, associated total allowable catch, and Irish quota for 1998.

Species	Management area	TAC	Irish quota
Cod	VIIb–k, VIII, IX, X and CECAF	20,000	2,040
Whiting	VIIb–k	27,000	7,510
Sole	VIIb,c	100	85
Sole	VIIh,j,k	720	325
Plaice	VIIb,c	300	240
Plaice	VIIh,j,k	1350	590

Table 3. Surveys providing data currently collected on cod, whiting, plaice and sole in ICES Divisions VIIb,c and VIIj,k.

Data set	Country of origin	ICES Division	Year (s)	Time of year
West coast ground fish survey	Ireland	VIa, VIIb,c,j,k	1993–1996	November – Annual
South and west coast young fish survey	Ireland	VIa, VIIb, VIIg, VIIj	1994–1997	July – Annual
Celtic sea groundfish survey	UK	VIIf,g,j	1982–1997	March/April – Annual
Mackerel and Horse mackerel egg survey	International	VIa, VIIb,c,g,h,j,k, VIII, IX	1977–1995	April/May/June – Triennial
Cod tagging study	Ireland	VIIa, VIIg	1996/1997	November–December and March–April
Landings	International	VIIb,c,j,k	1988–1996	Annual
Age-composition	Ireland	VIIb,c,j,k	1993–1996	Quarterly
Length and weight composition	Ireland	VIIb,c,j,k	1993–1996	Quarterly
Discard data	Ireland	VIa,b, VIIa–c, VIIg, VIIj,k	1994–1996	Quarterly
Catch and effort	France	VIIb,c,j,k	1988–1996	Annual

Table 4: Sampling levels from 1993 to 1996 of Irish landings of cod, whiting, sole and plaice.

Year	1993				1994				1995				1996			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Divisions VIIb,c																
Cod																
No. measured	778	1214	324	1782	259	286	222	478	221	488	390	359	271	444	420	190
No. aged	153	228	8	381	27	93	106	13	190	50	39	133	288	162	122	178
% of landings sampled	–	–	–	–	0.42	1.04	1.58	0.65	0.33	0.64	1.28	1.30	0.73	1.56	4.31	2.14
Whiting																
No. measured	2468	8948	2743	1596	663	950	504	1311	680	118	1258	1499	1585	958	1045	1555
No. aged	204	556	100	760	204	265	96	158	117	87	143	57	256	83	90	39
% of landings sampled	–	–	–	–	0.58	1.56	0.17	0.45	1.30	0.18	0.20	0.08	0.09	0.26	0.25	0.62
Sole																
No. measured	602	1870	516	2472	651	631	1143	1254	347	643	819	648	751	879	759	988
No. aged	0	214	0	214	66	0	81	96	53	55	0	92	38	154	133	137
% of landings sampled	–	–	–	–	0.69	0.59	0.82	0.72	3.80	1.72	2.25	1.64	3.36	3.45	2.00	2.53
Plaice																
No. measured	1164	3692	941	4856	1126	944	76	1052	512	1222	1384	1158	1446	1427	1973	1532
No. aged	112	212	0	324	69	144	0	32	148	38	0	57	162	93	86	123
% of landings sampled	–	–	–	–	1.16	0.65	0.03	0.49	0.71	0.58	0.59	0.32	0.76	1.70	0.75	1.05
Divisions VIIj,k																
Cod																
No. measured	155	1229	638	1347	477	735	574	147	147	312	139	121	88	33	126	53
No. aged	118	241	70	396	244	122	96	0	116	155	103	162	123	285	136	28
% of landings sampled	–	–	–	–	0.84	0.56	0.79	0.53	0.13	0.18	0.35	0.72	0.16	0.24	0.97	0.28
Whiting																
No. measured	2482	4696	2804	7174	1170	2064	2096	293	500	1481	1178	207	855	691	46	1659
No. aged	100	282	75	382	75	128	66	65	109	163	65	70	155	136	847	160
% of landings sampled	–	–	–	–	0.05	0.08	0.07	0.02	0.01	0.03	0.05	0.01	0.03	0.02	0.00	0.08
Sole																
No. measured	1166	2446	1441	3612	544	720	140	155	130	104	129	17	382	388	128	173
No. aged	79	139	0	218	78	87	48	130	0	0	90	63	96	137	216	39
%. of landings sampled	–	–	–	–	1.00	0.34	0.17	0.29	0.11	0.03	0.24	0.09	0.44	0.14	0.50	0.36
Plaice																
No. measured	1642	4293	2584	5935	1132	1336	1122	77	489	319	189	23	733	151	263	65
No. aged	130	278	160	408	67	52	107	52	0	71	41	29	71	52	117	77
%. of landings sampled	–	–	–	–	0.70	0.60	0.60	0.12	0.26	0.10	0.08	0.02	0.15	0.09	0.22	0.09

Table 5. Estimated international landings (t) and official Irish landings of cod reported from ICES Divisions VIIb,c and VIIj,k (N/A, not available).

Year	Estimated international VIIb,c and VIIj,k	Official Irish VIIb,c	Official Irish VIIj,k	% of estimated international landings taken by Irish fleets
1980	N/A	320	N/A	N/A
1981	N/A	765	N/A	N/A
1982	N/A	1234	N/A	N/A
1983	N/A	579	N/A	N/A
1984	N/A	524	N/A	N/A
1985	N/A	494	N/A	N/A
1986	N/A	619	N/A	N/A
1987	2315	758	543	56
1988	2311	388	868	54
1989	2828	915	857	63
1990	2792	795	994	64
1991	2554	612	1372	78
1992	2031	507	839	66
1993	1198	357	435	66
1994	1463	289	649	64
1995	1941	282	1127	73
1996	1930	353	1059	73

Table 6. Estimated international landings (t) and official Irish landings of whiting reported from ICES Divisions VIIb,c and VIIj,k (N/A: Not available).

Year	Estimated international VIIb,c and VIIj,k	Official Irish VIIb,c	Official Irish VIIj,k	% of estimated international landings taken by Irish fleets
1980	N/A	1648	N/A	N/A
1981	N/A	925	N/A	N/A
1982	N/A	2364	N/A	N/A
1983	N/A	1203	N/A	N/A
1984	N/A	944	N/A	N/A
1985	N/A	616	N/A	N/A
1986	N/A	994	N/A	N/A
1987	2709	1105	1316	89
1988	3098	922	1771	87
1989	3164	1199	1483	85
1990	2399	770	1304	86
1991	1964	540	1068	82
1992	2674	730	1455	82
1993	4318	826	2977	88
1994	5265	1042	3705	90
1995	7700	1894	5193	92
1996	6942	1233	4994	90

Table 7. Estimated international landings (t) and official Irish landings of sole reported from ICES Divisions VIIb,c and VIIj,k (N/A: Not available).

Year	Estimated international VIIb,c and VIIj,k	Official Irish VIIb,c	Official Irish VIIj,k	% of estimated international landings taken by Irish fleets
1980	N/A	24	N/A	N/A
1981	N/A	47	N/A	N/A
1982	N/A	55	N/A	N/A
1983	N/A	40	N/A	N/A
1984	N/A	17	N/A	N/A
1985	N/A	44	N/A	N/A
1986	N/A	29	N/A	N/A
1987	221	39	168	94
1988	227	34	182	95
1989	263	38	206	93
1990	314	41	266	98
1991	365	46	306	96
1992	316	43	255	94
1993	307	59	237	96
1994	241	60	176	98
1995	303	59	232	96
1996	226	52	163	95

Table 8. Estimated international landings (t) and official Irish landings of plaice reported from ICES Divisions VIIb,c and VIIj,k (N/A: Not available).

Year	Estimated international VIIb,c and VIIj,k	Official Irish VIIb,c	Official Irish VIIj,k	Percentage of estimated international landings taken by Irish fleets
1980	N/A	142	N/A	N/A
1981	N/A	135	N/A	N/A
1982	N/A	122	N/A	N/A
1983	N/A	108	N/A	N/A
1984	N/A	110	N/A	N/A
1985	N/A	150	N/A	N/A
1986	N/A	114	N/A	N/A
1987	510	153	300	89
1988	588	157	369	89
1989	660	159	454	93
1990	602	130	338	78
1991	702	179	478	94
1992	755	180	477	87
1993	636	191	383	90
1994	524	200	251	86
1995	664	239	317	84
1996	597	248	295	91

Table 9. Comparison of mean weights at age (g) for cod in VIIb,c and VIIj,k in 1996 with those in adjacent Divisions in 1996 (Anonymous, 1998a,8b); 95% confidence intervals of the VIIb,c and VIIj,k mean weights are also given (NA previous age is plus group).

Age	VIIb,c Mean	VIIb,c 95% Conf.	VIIj,k Mean	VIIj,k 95% Conf.	VIIg Mean	VIIa Mean	VIa Mean
1	706	102.2	489	34.4	870	951	667
2	1510	109.7	1506	110.5	1947	1572	1218
3	3134	156.6	4482	259.3	4785	3184	2708
4	6145	503.5	6315	853.1	7350	5213	5035
5	7246	1125.5	9101	2102.2	9861	7579	6877
6	9453	3713.1	8848	1528.2	11700	8522	8069
7	12119	–	–	–	14013	11800	10740
8+	11883	–	–	–	NA	NA	NA

Table 10. ICES Divisions VIIb,c COD catch numbers (’000s) at age raised to international landings from Irish ALK for 1993–1996.

Age	1993	1994	1995	1996
0	0.0	0.0	0.00	0.0
1	0.6	39.0	12.16	4.5
2	97.5	164.9	305.57	55.8
3	59.9	63.0	42.24	111.5
4	21.1	33.0	25.53	20.2
5	5.7	5.7	8.69	12.6
6	3.8	2.8	1.47	1.8
7	2.2	2.9	0.94	0.1
8+	0.0	0.0	0.00	0.1
Total	190.9	311.2	396.6	206.6

Table 11. ICES Divisions VIIj,k COD catch numbers (’000s) at age raised to international landings from Irish ALK for 1993–1996.

Age	1993	1994	1995	1996
0	0.0	0.0	0.0	0.0
1	40.6	86.5	60.2	479.0
2	237.4	190.3	570.7	209.4
3	30.6	99.3	46.7	163.5
4	7.5	18.5	34.9	19.4
5	2.4	4.4	1.9	4.4
6	1.8	0.8	1.0	2.5
7	0.6	0.0	0.1	0.0
8+	0.0	0.0	0.0	0.5
Total	320.8	399.8	715.5	878.6

Table 12. Comparison of $F_{current}$ estimates obtained from catch curves for cod, whiting, sole and plaice in ICES divisions VIIb,c and VIIj–k with mean F (1996) of stocks in adjacent areas.

	This study				Anonymous, 1998a			
Stock	F_{96}-VIIb,c	Age range	F_{96}-VIIj,k	Age range	F_{96}-VIa	Age range	F_{96}-VIIa	Age range
Cod	1.09	3–6	1.05	2–6	0.86	2–5	0.61	2–5
Whiting	1.20	3–6	0.52	2–6	0.79	2–4	1.08	2–4
Sole	0.18	4–9	0.42	4–9	–	–	0.45	4–7
Plaice	0.34	3–7	0.54	3–7	–	–	0.34	3–6

Table 13. Estimates of Z, F and F_{max} obtained from catch and Thompson Bell yield per recruit curves for cod, haddock, whiting, sole and plaice in ICES divisions VIIb,c and VIIj,k in 1996.

Stock	Z	F	Age range	F_{max}	M (Anonymous, 1998a,b)
Cod VIIb,c	1.29	1.09	3–6	0.30	0.2 (VIa and VIIa COD)
Whiting VIIb,c	1.40	1.20	3–6	0.70	0.2 (VIa and VIIa WHITING)
Sole VIIb,c	0.28	0.18	4–9	0.45	0.1 (VIIa SOLE)
Plaice VIIb,c	0.46	0.34	3–7	–	0.12 (VIIa AND VIIg PLAICE)
Cod VIIj,k	1.25	1.05	2–6	0.35	0.2 (VIa and VIIa COD)
Whiting VIIj,k	0.72	0.52	2–6	0.80	0.2 (VIa and VIIa WHITING)
Sole VIIj,k	0.52	0.42	4–9	0.40	0.1 (VIIa SOLE)
Plaice VIIj,k	0.66	0.54	3–7	0.35	0.12 (VIIa AND VIIg PLAICE)

Table 14. Z, F and F_{max} estimates obtained from catch and Thompson Bell yield per recruit curves for cod, haddock, whiting, sole and plaice in ICES divisions VIIb,c and VIIh–k in 1995.

Stock	Z	F	Age range	F_{max}	M (Anonymous, 1998a,b)
Cod VIIb,c	1.23	1.03	2–6	0.30	0.2 (VIa and VIIa COD)
Whiting VIIb,c	1.09	0.89	2–6	0.60	0.2 (VIa and VIIa WHITING)
Sole VIIb,c	0.34	0.24	4–9	0.60	0.1 (VIIa SOLE)
Plaice VIIb,c	0.53	0.41	3–7	–	0.12 (VIIa AND VIIg PLAICE)
Cod VIIh–k	1.59	1.39	2–6	0.30	0.2 (VIa and VIIa COD)
Whiting VIIh–k	0.92	0.72	2–5	0.50	0.2 (VIa and VIIa WHITING)
Sole VIIh–k	0.30	0.20	4–9	0.30	0.1 (VIIa SOLE)
Plaice VIIh–k	0.66	0.54	2–7	0.25	0.12 (VIIa AND VIIg PLAICE)

Table 15. Comparison of mean weights at age (g) for whiting in VIIb,c and VIIj,k in 1996 with those in adjacent Divisions in 1996 (Anon., 1998a and Anon., 1998b). 95% confidence intervals of the VIIb,c and VIIj,k mean weights are also given (NA previous age is plus group).

Age	VIIb,c Mean	VIIb,c 95% Conf.	VIIj,k Mean	VIIj,k 95% Conf	VIIg Mean	VIIa Mean	VIa Mean
1	242	110.4	259	26.5	165	144	98
2	288	26.3	296	19.8	264	203	198
3	434	24.7	442	25.5	347	268	257
4	583	41.6	528	36.9	475	338	336
5	638	81.0	567	91.4	622	414	480
6	516	235.6	625	270.0	687	496	517
7	618	–	–	–	1017	584	530
8	–	–	–	–	NA	677	NA
9+	NA	NA	NA	NA	NA	925	NA

Table 16. ICES Divisions VIIb,c WHITING catch numbers ('000s) at age raised to international landings from Irish ALK for 1993–1996.

Age	1993	1994	1995	1996
0	1.9	0.0	0.0	0.0
1	135.5	132.9	364.9	47.0
2	1567.4	1711.9	2718.5	956.3
3	1816.5	1909.4	2031.4	1730.8
4	197.6	447.5	1452.7	693.3
5	63.7	84.4	84.0	278.4
6	10.2	10.5	57.2	22.4
7	3.7	8.6	3.7	5.2
8+	0.9	4.0	0.0	0.0
Total	3797.3	4309.2	6712.4	3733.4

Table 17. ICES Divisions VIIj,k WHITING catch numbers ('000s) at age raised to international landings from Irish ALK for 1993-1996.

Age	1993	1994	1995	1996
0	2.8	0.0	17.3	0.0
1	394.7	814.4	175.2	1265.6
2	3836.6	3321.4	7247.8	4608.9
3	6014.1	5415.7	5308.3	4817.1
4	1142.0	1193.2	3237.8	3013.8
5	243.5	255.7	399.6	1251.2
6	84.9	30.1	24.0	242.5
7	9.0	6.6	0.0	0.0
8+	0.0	4.1	0.0	0.0
Total	11727.6	11041.2	16410.0	15199.0

Table 18. Comparison of mean weights at age (g) for sole in VIIb,c and VIIj,k in 1996 with those in adjacent Divisions in 1996 (Anonymous, 1998a,b); 95% confidence intervals of the VIIb,c and VIIj,k mean weights are also given (NA previous age is plus group).

Age	VIIb,c Mean	VIIb,c 95% Conf.	VIIj,k Mean	VIIj,k 95% Conf.	VIIg Mean	VIIa* Mean
1	–	–	–	–	100	100
2	111	9.3	149	35.8	161	150
3	192	24.7	172	25.1	194	190
4	235	16.8	252	30.1	277	228
5	316	21.2	300	34.3	392	265
6	383	28.3	406	46.7	450	299
7	446	32.7	401	48.9	463	332
8	460	62.1	517	68.7	543	363
9	519	68.7	552	247.7	507	392
10	507	102.3	651	239.0	702	469
11	560	122.1	651	308.3	NA	NA
12	609	91.5	773	168.2	NA	NA
13	616	99.3	854	1516.3	NA	NA
14	631	159.6	734	362.8	NA	NA
15+	628	69.1	691	105.2	NA	NA

* quadratically smoothed to give corrected SOP

Table 19. ICES Divisions VIIb,c SOLE catch numbers ('000s) at age raised to international landings from Irish ALK for 1993–1996.

Age	1993	1994	1995	1996
0	0.0	0.0	0.0	0.00
1	0.0	0.0	0.0	0.10
2	1.2	0.2	0.7	3.86
3	18.9	11.5	3.5	8.45
4	50.6	43.7	26.4	21.92
5	28.4	39.8	34.2	17.53
6	14.3	11.1	23.9	25.26
7	14.6	9.0	10.6	25.78
8	8.9	5.7	11.7	8.24
9	3.41	11.36	5.3	5.01
10	2.58	3.25	6.5	3.86
11	1.24	3.75	3.1	4.80
12	1.96	2.23	2.5	6.37
13	1.45	4.36	0.7	3.44
14	0.93	1.32	1.7	3.97
15+	1.03	11.36	4.6	11.58
Total	149.5	158.5	135.5	150.2

Table 20. ICES Divisions VIIj,k SOLE catch numbers ('000s) at age raised to international landings from Irish ALK for 1993–1996.

Year	1993	1994	1995	1996
0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0
2	58.6	18.9	0.0	7.2
3	258.3	64.2	59.7	71.3
4	231.7	150.0	118.1	185.9
5	77.4	131.3	160.9	164.3
6	53.8	74.7	52.1	71.2
7	48.1	33.0	37.8	72.2
8	29.4	14.6	43.4	36.0
9	14.6	6.6	32.8	12.4
10	12.4	15.2	23.9	4.9
11	14.6	12.1	40.2	6.8
12	4.9	9.9	4.0	7.1
13	6.0	1.1	2.4	5.6
14	6.7	1.5	1.7	5.2
15+	6.3	10.5	4.8	21.1
Total	822.6	543.5	581.7	671.0

Table 21. Comparison of mean weights at age (g) for plaice in VIIb,c and VIIj,k in 1996 with those in adjacent Divisions in 1996 (Anon., 1998a and Anon., 1998b). 95% confidence intervals of the VIIb,c and VIIj,k mean weights are also given (NA previous age is plus group).

Age	VIIb,c Mean	VIIb,c 95% Conf.	VIIj,k Mean	VIIb,c 95% Conf.	VIIg Mean	VIIa** Mean
1	184	226.8	–	–	223	144
2	220	17.7	351	40.2	261	203
3	281	18.5	423	35.3	309	268
4	325	17.4	470	44.8	368	338
5	337	26.4	581	69.4	438	414
6	391	49.1	710	18.1	518	496
7	369	68.3	572	182.7	609	584
8	370	132.2	818	474.7	710	667
9	785	2281.8	400	366.9	822	925
10+	–	–	2014	11487	NA*	NA

*Previous value is not the mean weight at age of plus group.

**Quadratically smoothed to give corrected SOP.

Table 22. ICES Divisions VIIb,c PLAICE catch numbers ('000s) at age raised to international landings from Irish ALK for 1993-1996.

Age	1993	1994	1995	1996
0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.8
2	46.9	110.7	63.2	53.1
3	206.6	333.7	254.3	157.7
4	183.0	126.8	376.0	233.9
5	80.4	47.1	170.5	162.9
6	39.5	27.1	90.1	96.8
7	33.9	19.8	37.3	25.1
8	3.8	8.3	9.3	12.6
9	0.0	2.89	1.1	2.2
10+	0.0	1.45	0.0	5.2
Total	594.0	677.9	1001.7	750.2

Table 23. ICES Divisions VIIj,k PLAICE catch numbers ('000s) at age raised to international landings from Irish ALK for 1993–1996

Year	1993	1994	1995	1996
0	0.0	0.0	0.0	0.0
1	6.1	4.4	0.0	0.5
2	121.9	87.5	138.8	53.6
3	538.7	386.9	634.6	320.1
4	349.8	251.2	455.8	227.9
5	94.2	67.7	128.6	144.5
6	62.3	44.8	28.0	43.5
7	24.7	17.8	9.0	27.2
8	13.2	9.5	10.6	7.9
9	9.1	6.5	8.5	9.4
10+	2.5	1.7	0.0	0.2
Total	1222.4	877.9	1414.0	834.6

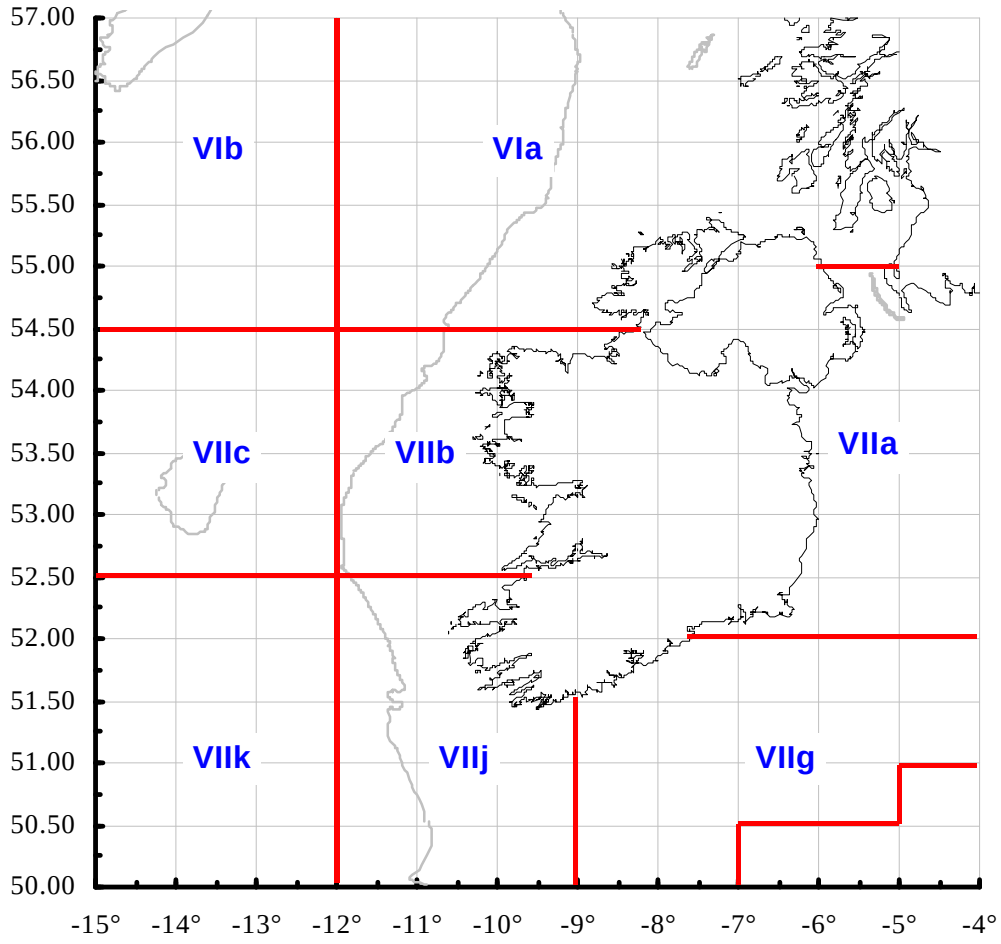

Figure 1. Map of ICES Divisions around the Irish coast.

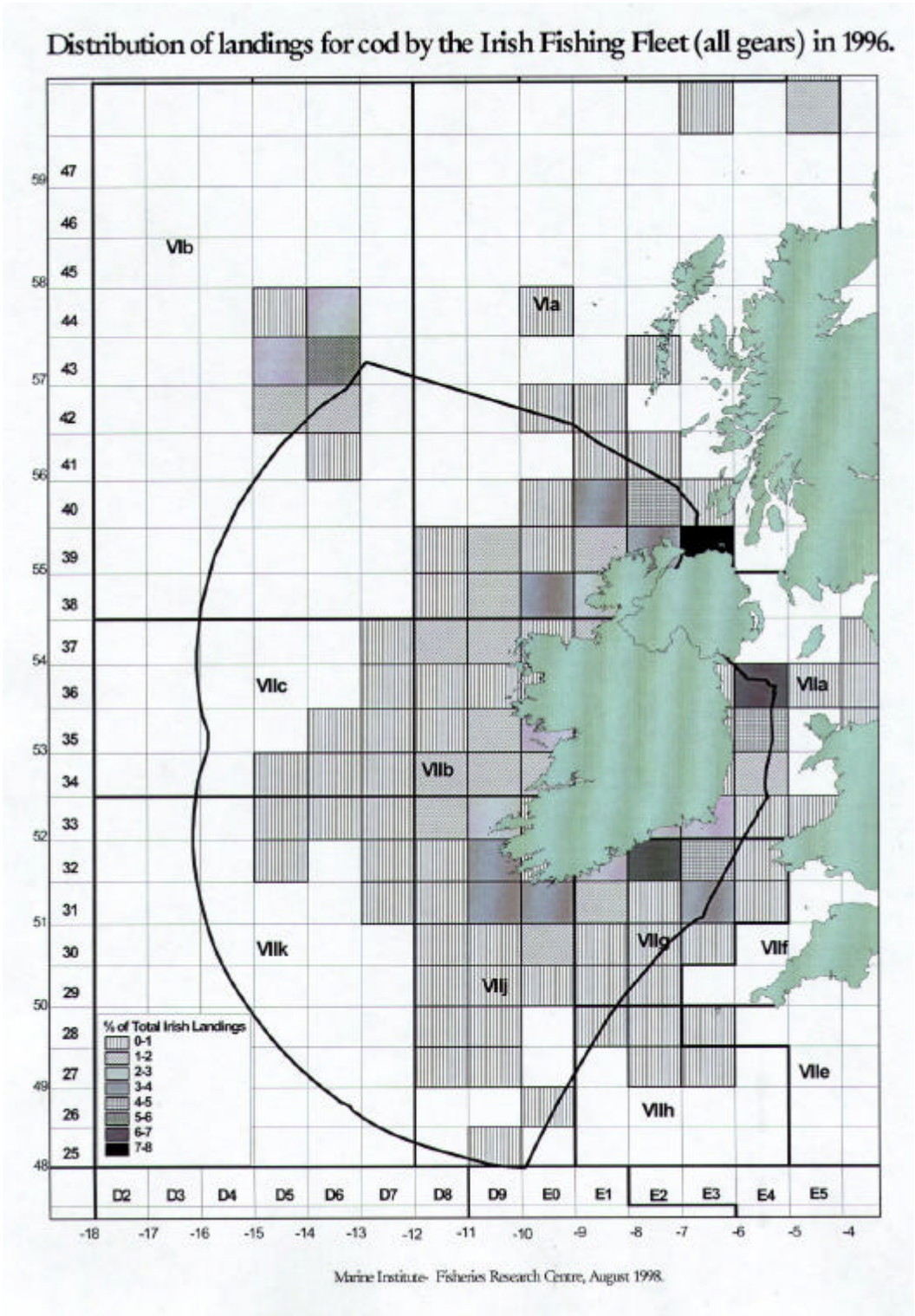

Figure 2. Quantity of landings of cod by Irish fishing vessels in 1996, from each statistical rectangle, as a percentage of total Irish landings.

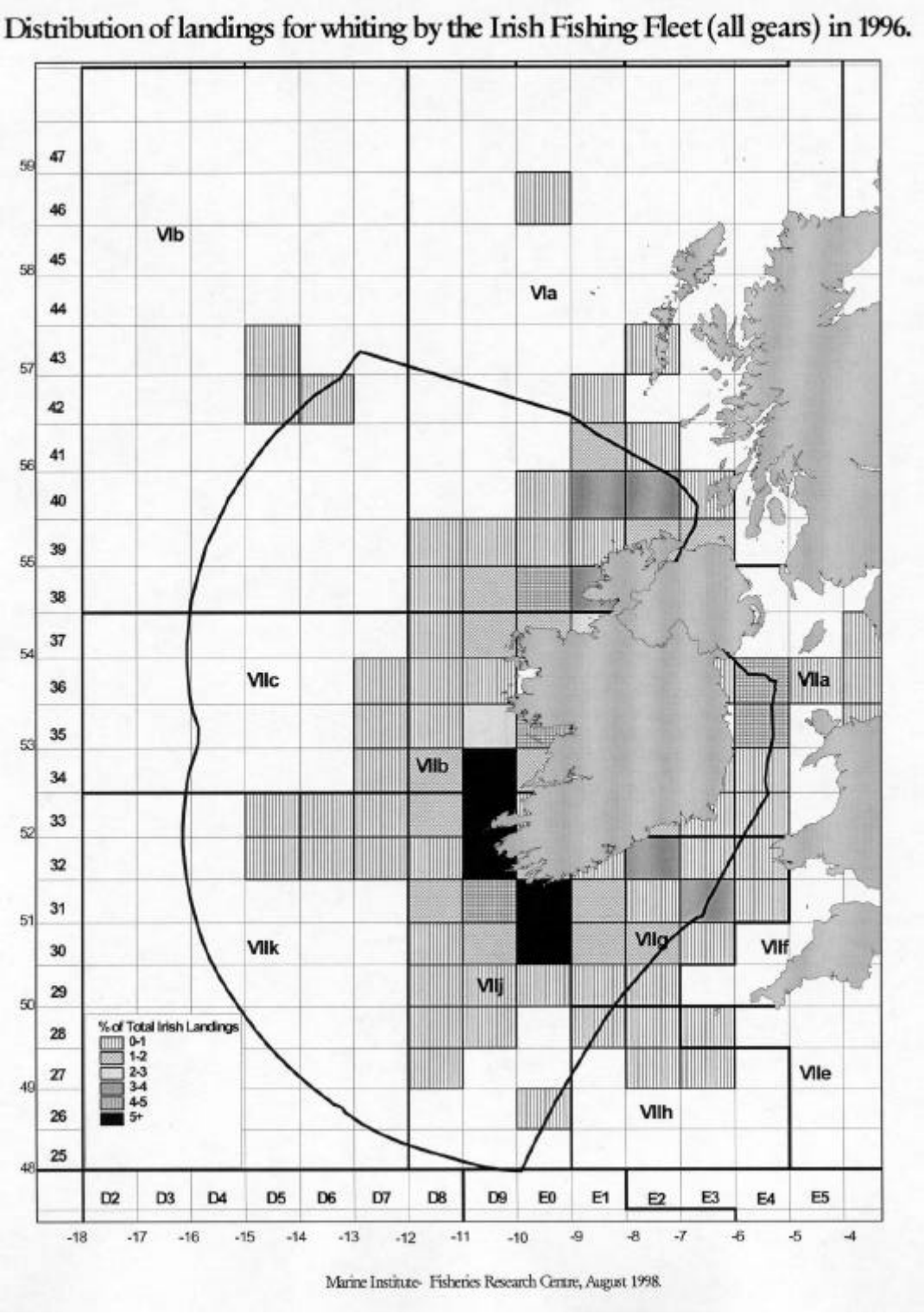

Figure 3. Quantity of landings of whiting by Irish fishing vessels in 1996, from each statistical rectangle, as a percentage of total Irish landings.

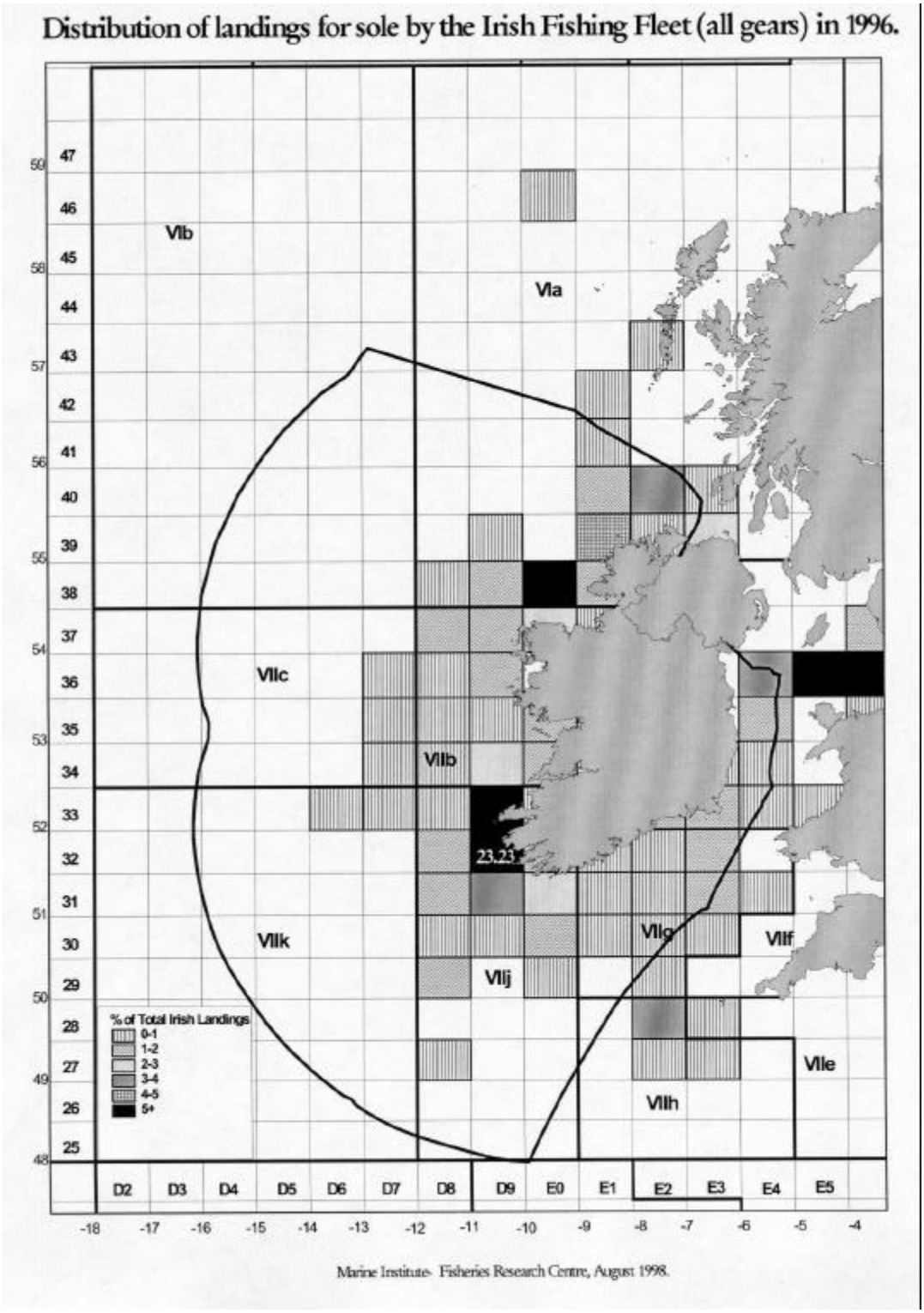

Figure 4. Quantity of landings of sole by Irish fishing vessels in 1996, from each statistical rectangle, as a percentage of total Irish landings.

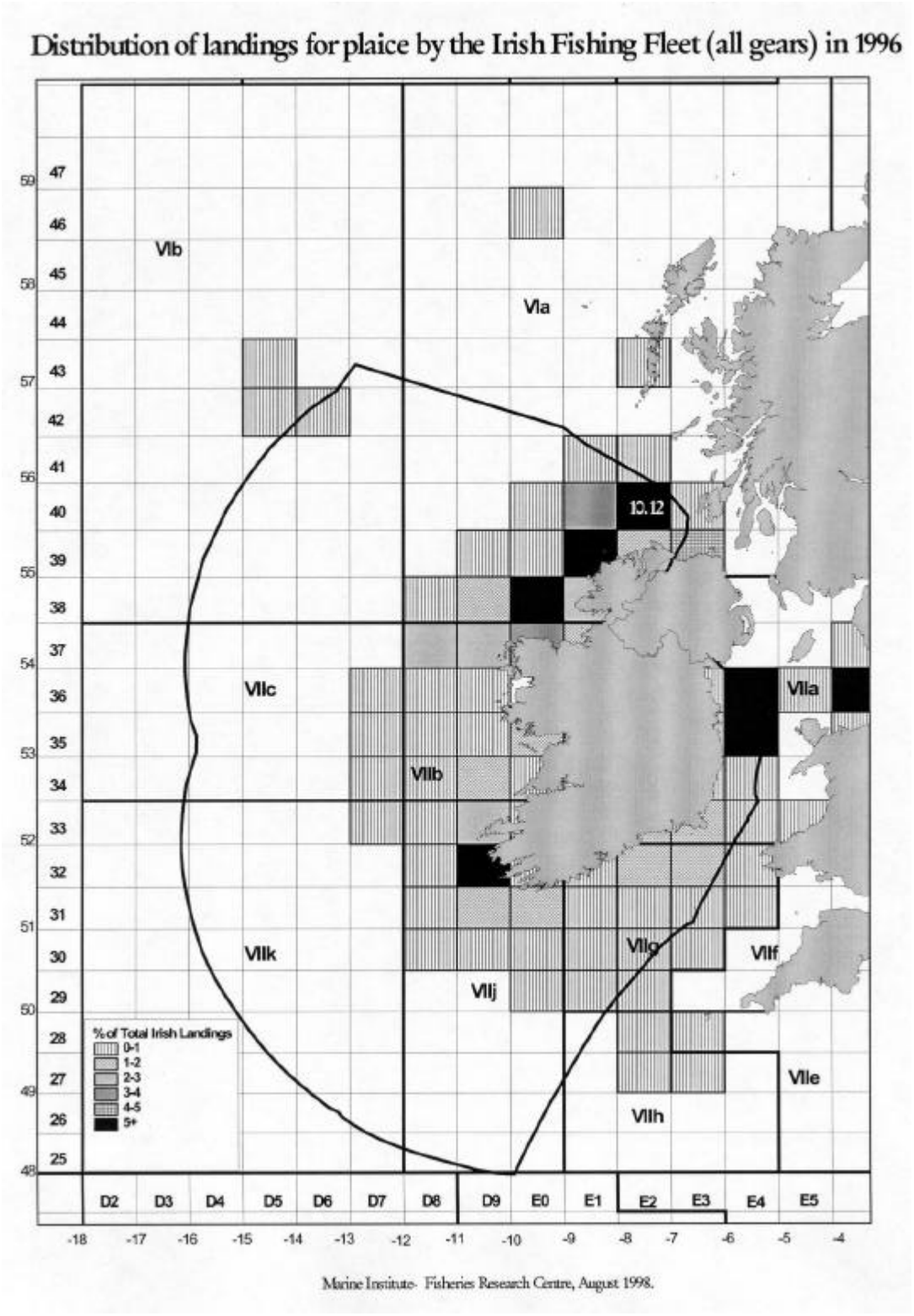

Figure 5. Quantity of landings of plaice by Irish fishing vessels in 1996, from each statistical rectangle, as a percentage of total Irish landings.

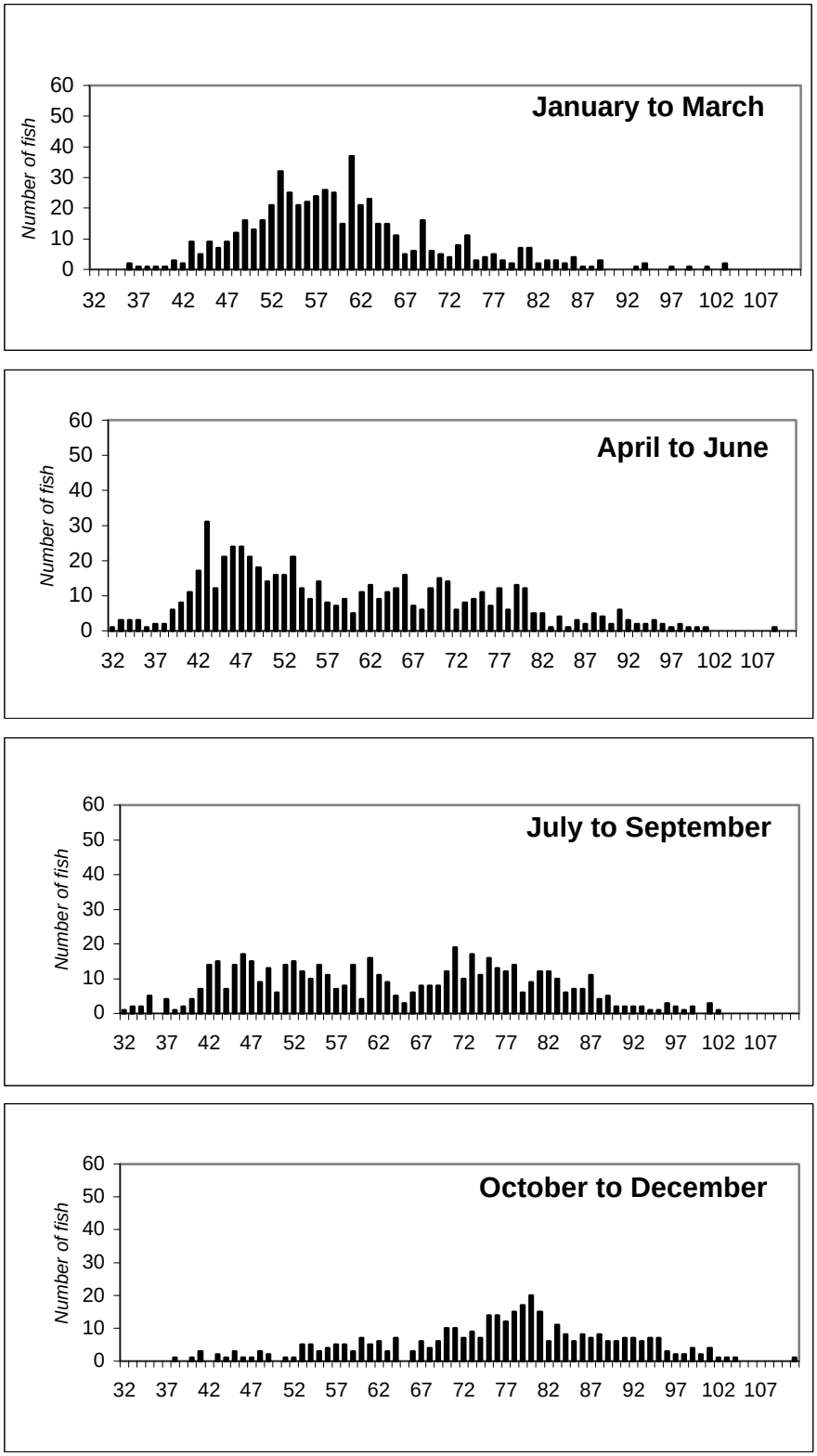

Figure 6. Length (to nearest cm) of cod landed by Irish vessels into Irish ports from ICES Divisions VIIb,c in 1996.

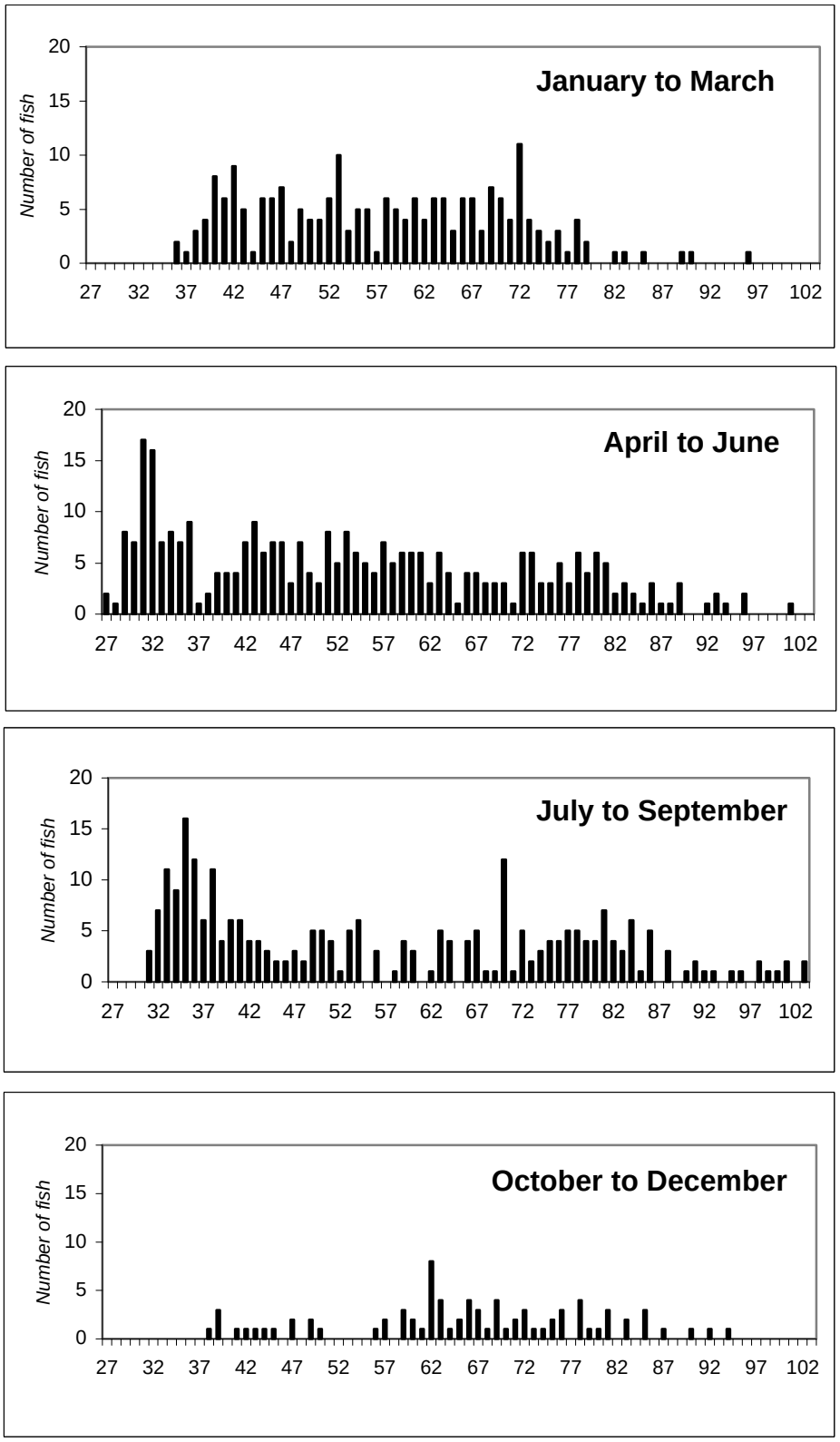

Figure 7. Length (to nearest cm) of cod landed by Irish vessels into Irish ports from ICES Divisions VIIj,k in 1996.

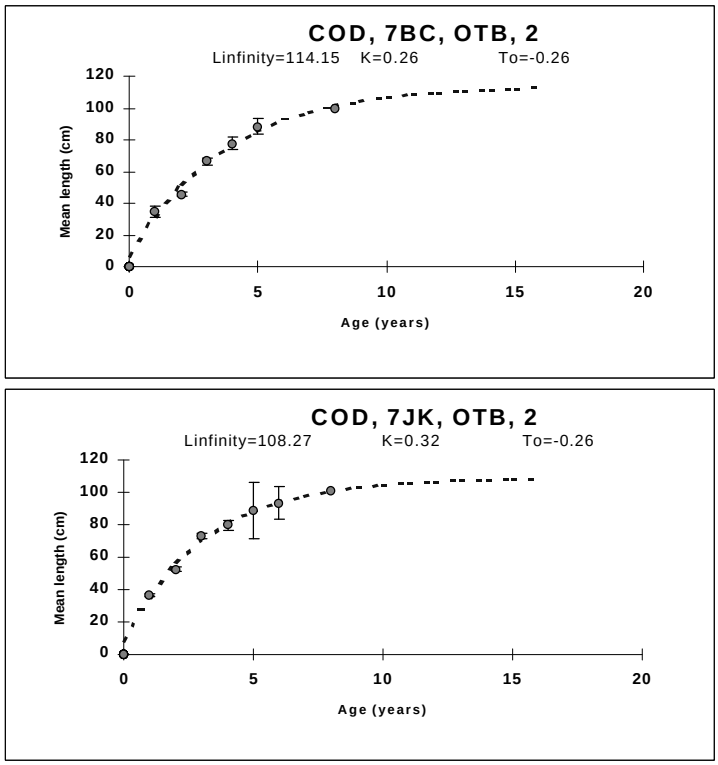

Figure 8. Von Bertalanffy growth curves for cod landed by Irish vessels into Irish ports from ICES Divisions VIIb,c and VIIj,k in the second quarter of 1996. Fitted curve (broken line) and observed values (circles) with 95% confidence intervals.

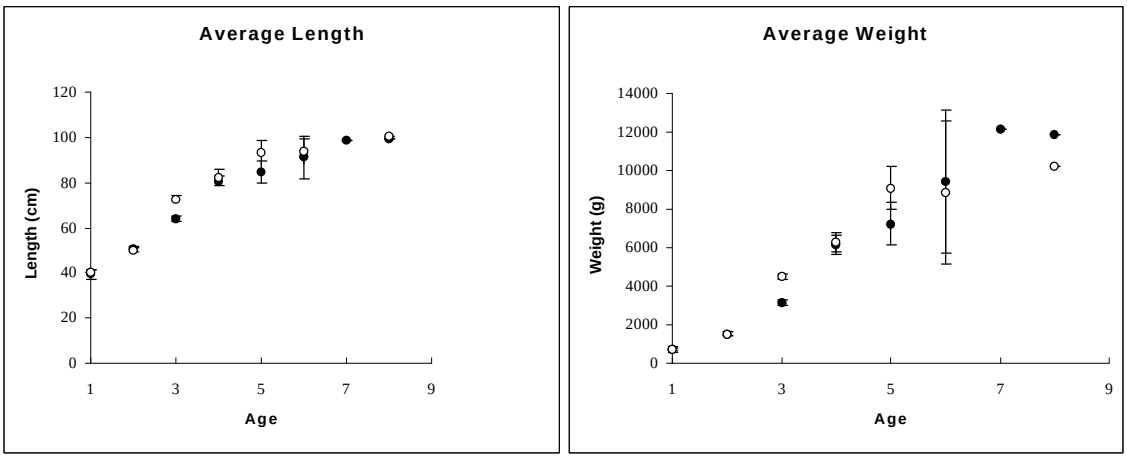

Figure 9. Comparison of mean lengths and weights at age of cod landed by Irish vessels into Irish ports from ICES Divisions VIIb,c (black circle) and VIIj,k (white circle) in 1996. 95% confidence intervals are shown.

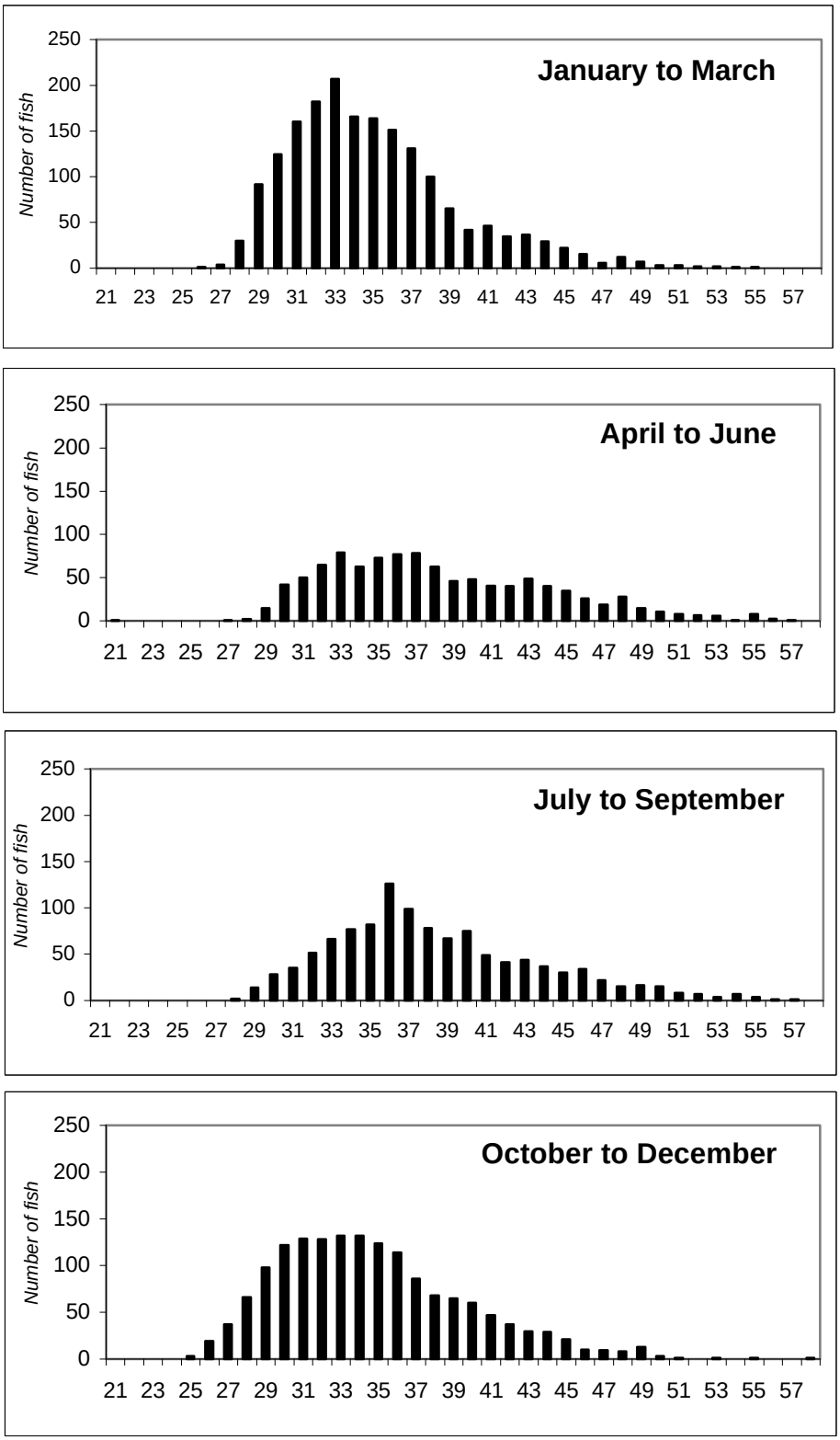

Figure 10. Length (to nearest cm) of whiting landed by Irish vessels into Irish ports from ICES Divisions VIIb,c in 1996.

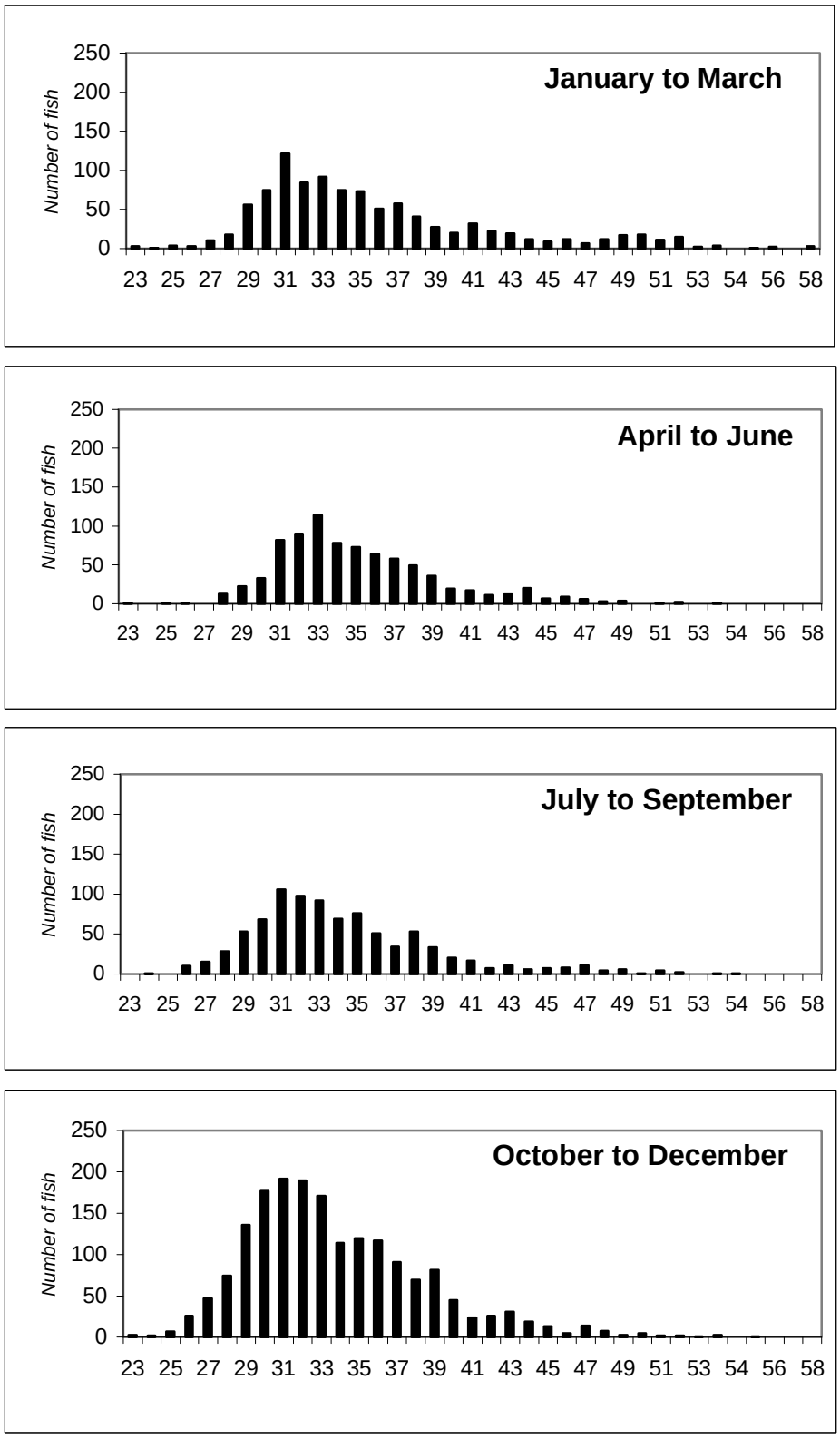

Figure 11. Length (to nearest cm) of whiting landed by Irish vessels into Irish ports from ICES Divisions VIIj,k in 1996.

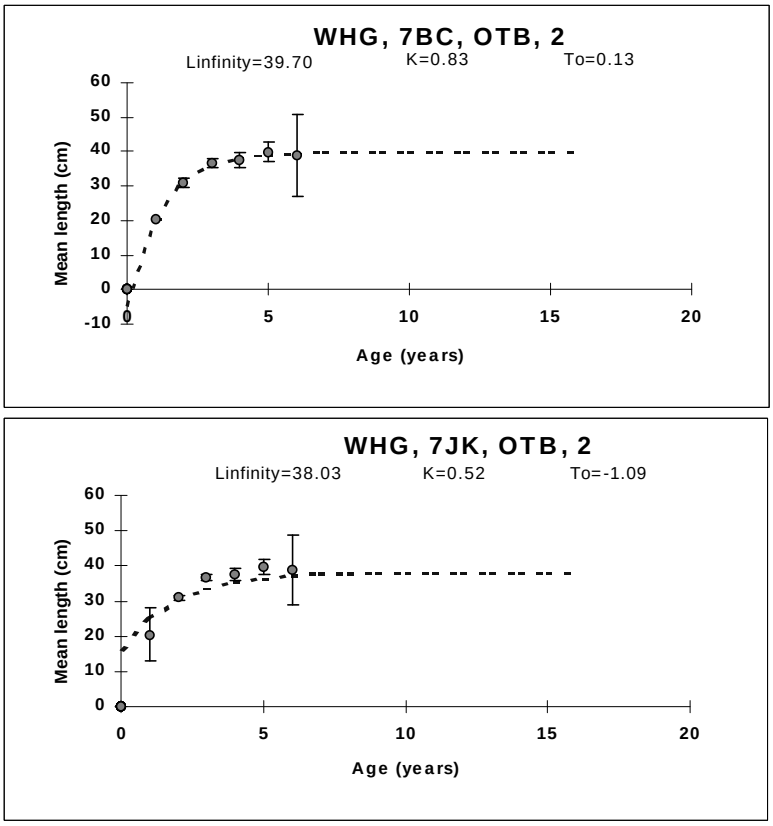

Figure 12. Von Bertalanffy growth curves for whiting landed by Irish vessels into Irish ports from ICES Divisions VIIb,c and VIIj,k in the second quarter of 1996. Fitted curve (broken line) and observed values (circles) with 95% confidence intervals.

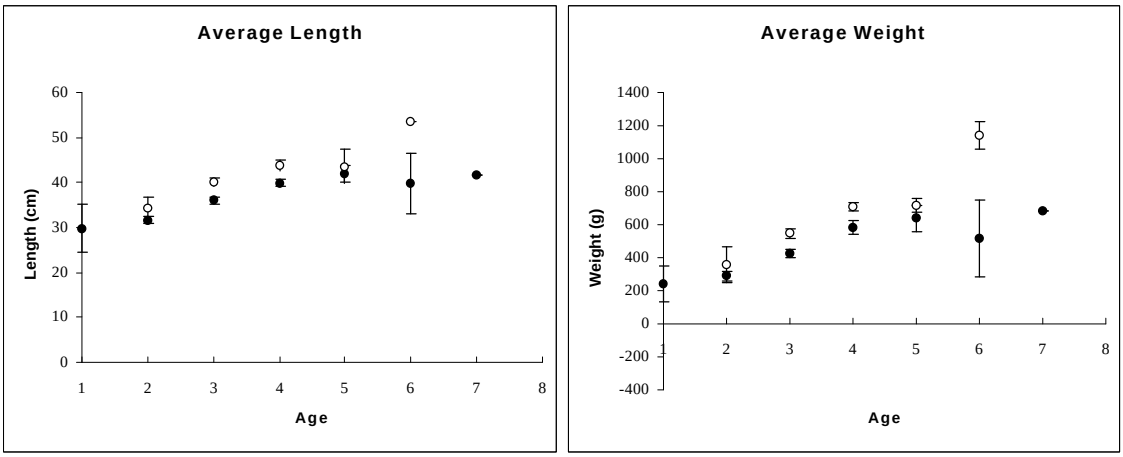

Figure 13. Comparison of mean lengths and weights at age of whiting landed by Irish vessels into Irish ports from ICES Divisions VIIb,c (black circle) and VIIj,k (white circle) in 1996; 95% confidence intervals are shown.

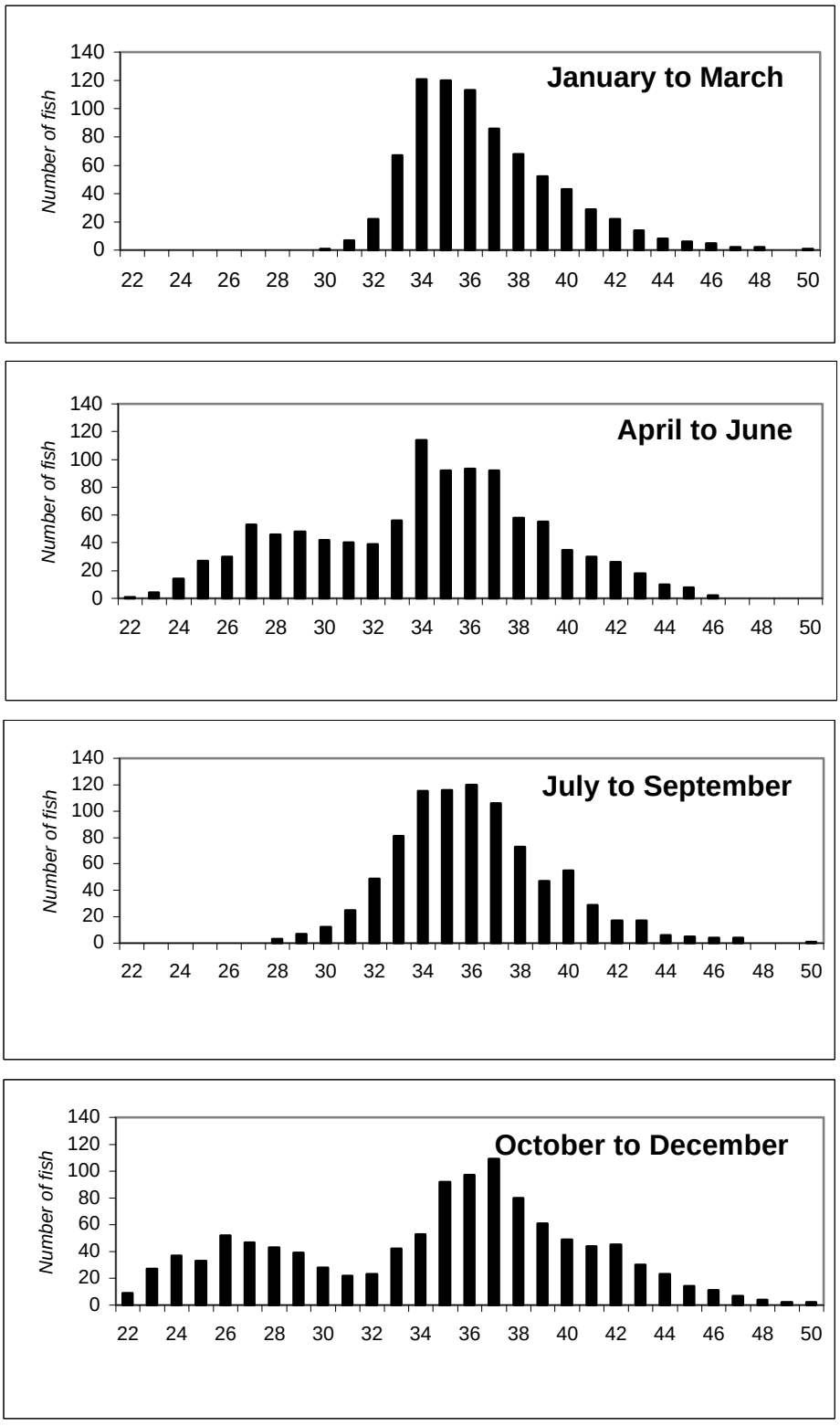

Figure 14. Length (to nearest cm) of sole landed by Irish vessels into Irish ports from ICES Divisions VIIb,c in 1996.

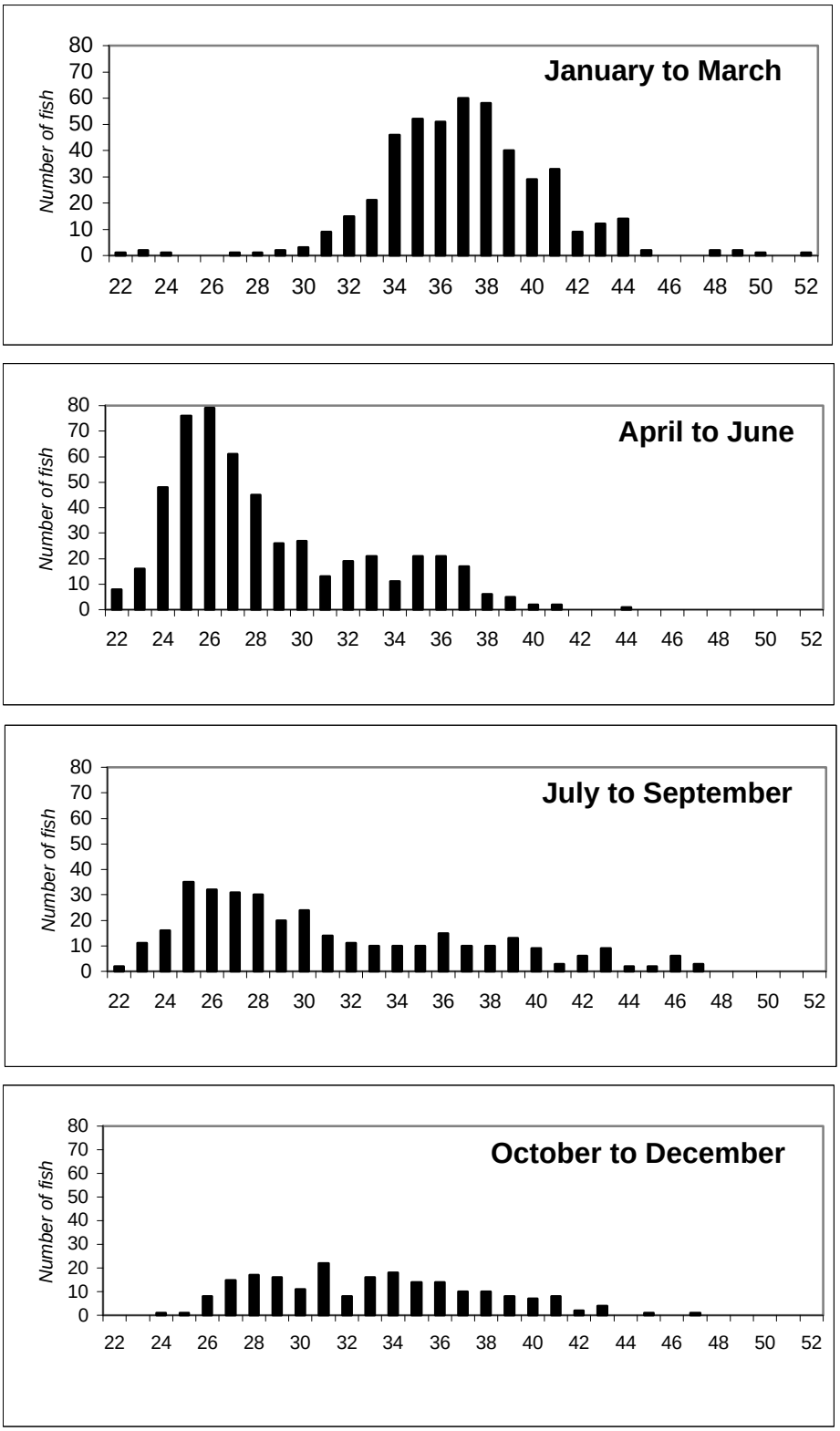

Figure 15. Length (to nearest cm) of sole landed by Irish vessels into Irish ports from ICES Divisions VIIj,k in 1996.

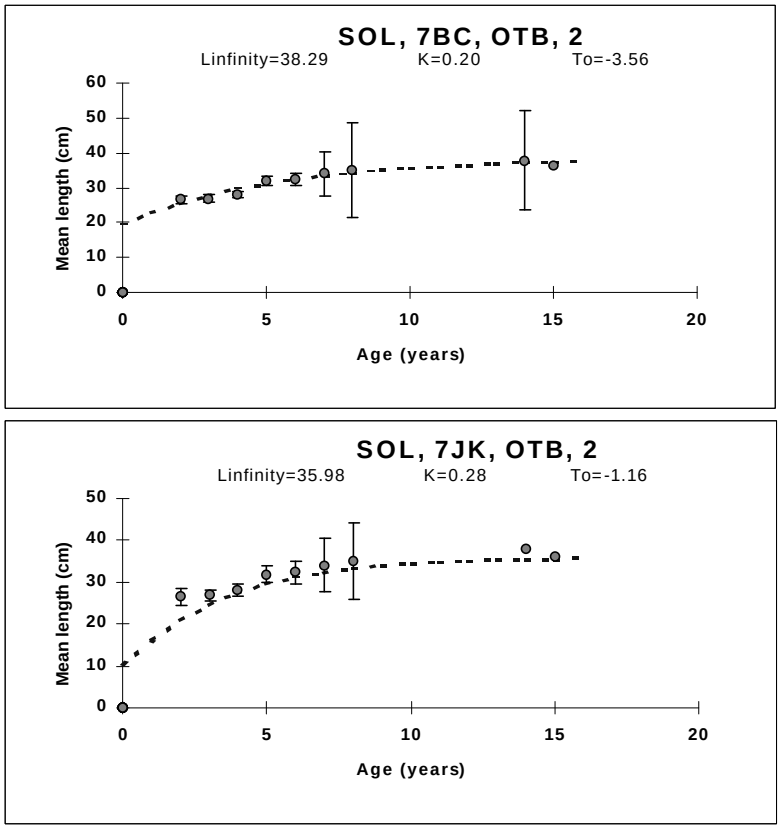

Figure 16. Von Bertalanffy growth curves for sole landed by Irish vessels into Irish ports from ICES Divisions VIIb,c and VIIj,k in the second quarter of 1996. Fitted curve (broken line) and observed values (circles) with 95% confidence intervals.

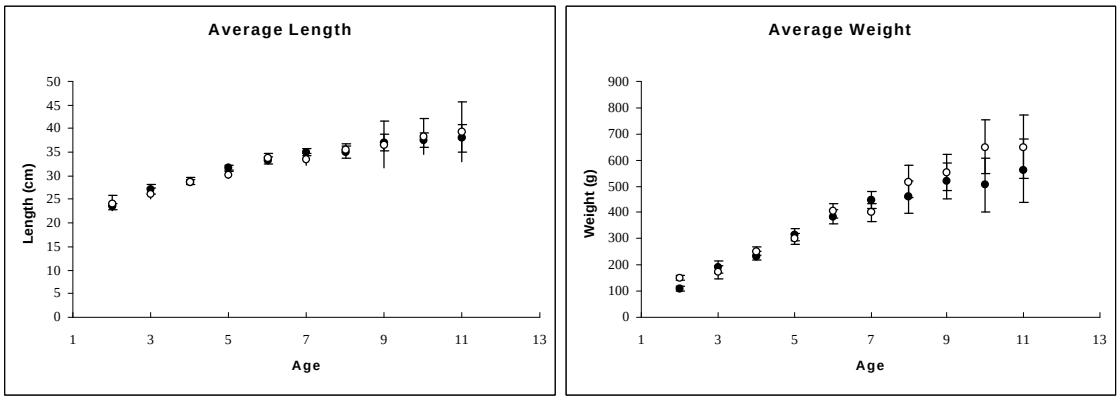

Figure 17. Comparison of mean lengths and weights at age of sole landed by Irish vessels into Irish ports from ICES Divisions VIIb,c (black circle) and VIIj,k (white circle) in 1996; 95% confidence intervals are shown.

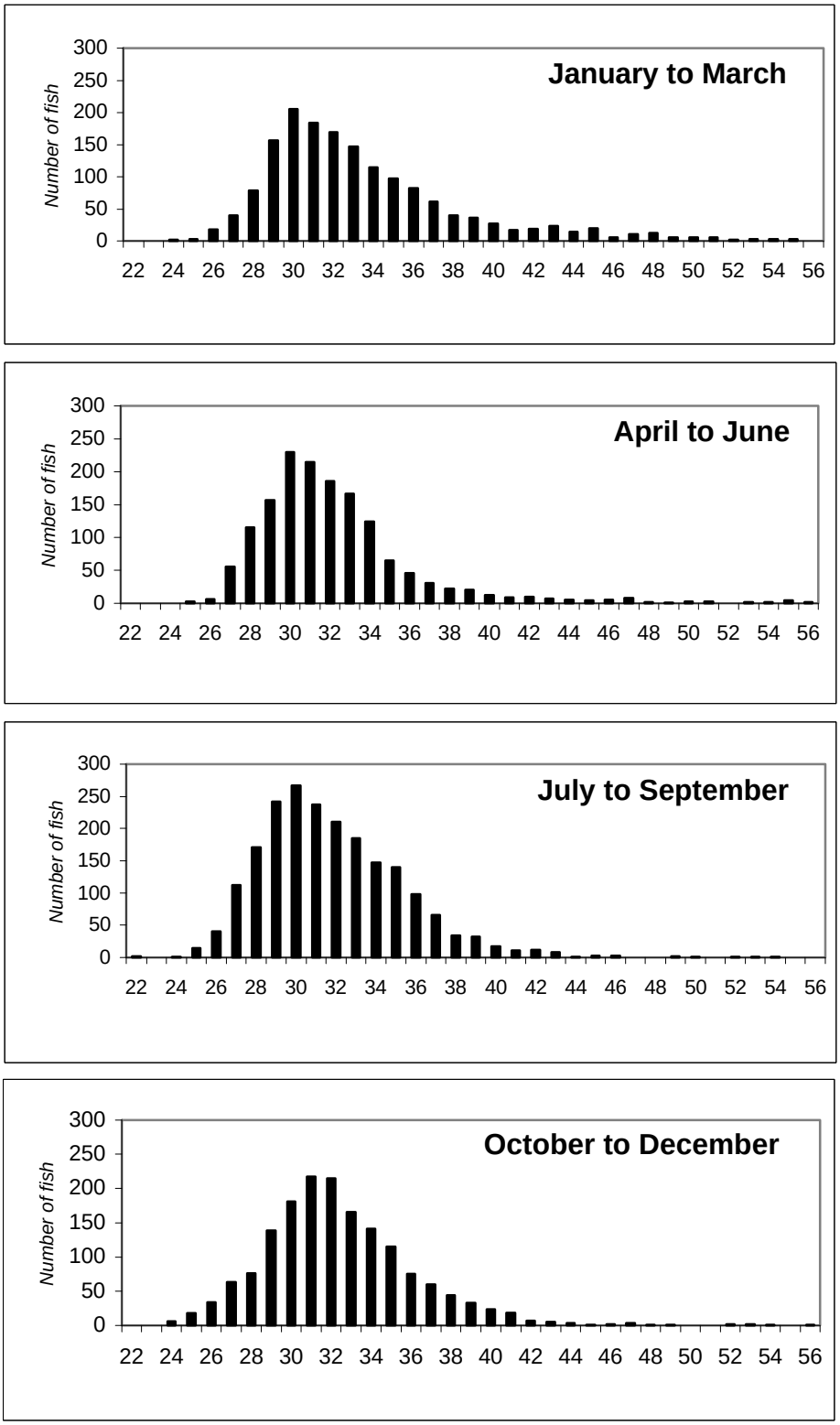

Figure 18. Length (to nearest cm) of plaice landed by Irish vessels into Irish ports from ICES Divisions VIIb,c in 1996.

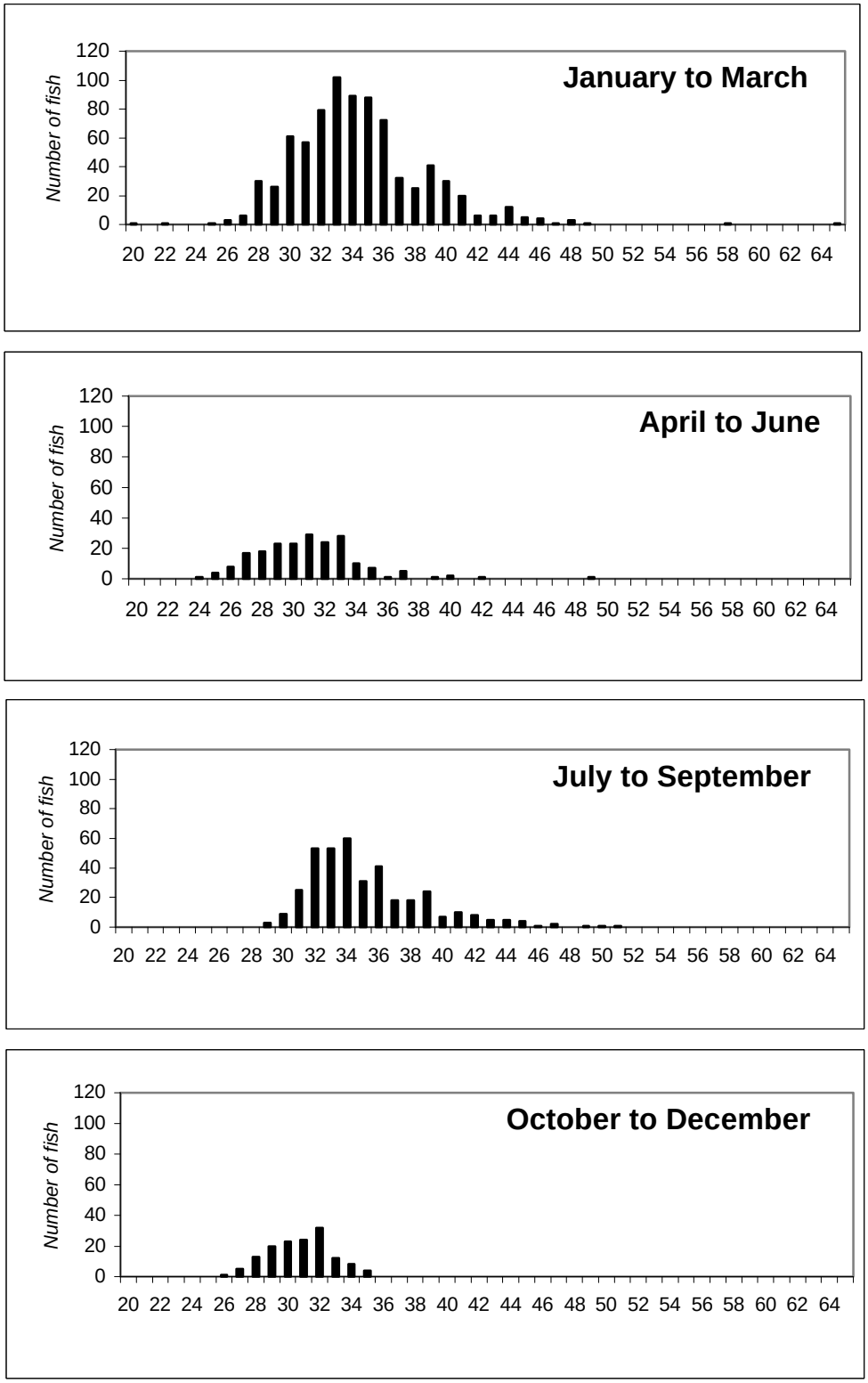

Figure 19. Length (to nearest cm) of plaice landed by Irish vessels into Irish ports from ICES Divisions VIIj,k in 1996.

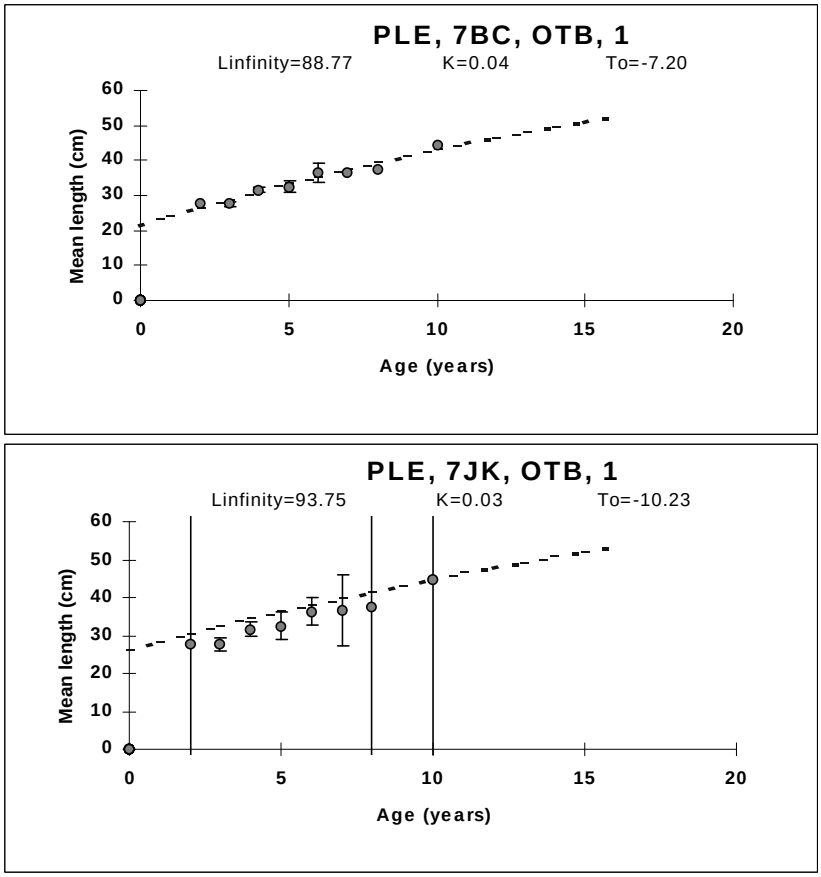

Figure 20. Von Bertalanffy growth curves for plaice landed by Irish vessels into Irish ports from ICES Divisions VIIb,c and VIIj,k in the second quarter of 1996. Fitted curve (broken line) and observed values (circles) with 95% confidence intervals.

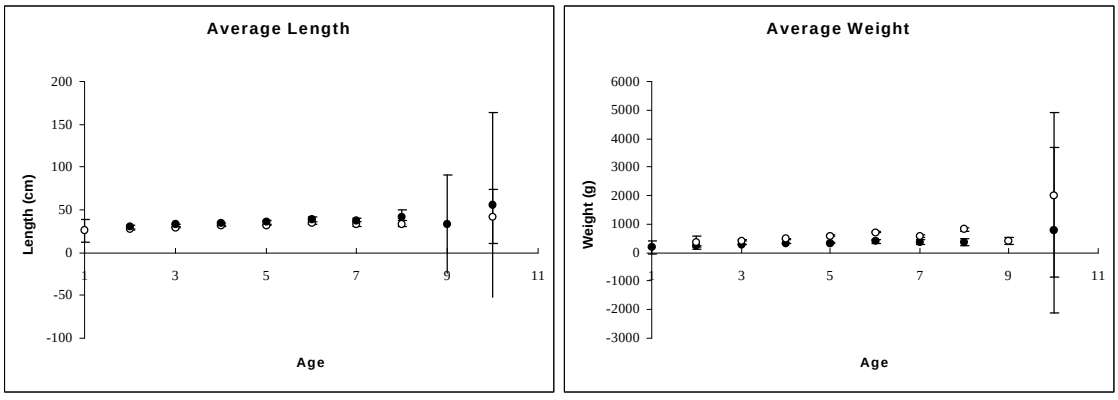

Figure 21. Comparison of mean lengths and weights at age of plaice landed by Irish vessels into Irish ports from ICES Divisions VIIb,c (black circle) and VIIj,k (white circle) in 1996; 95% confidence intervals are shown.