A second assessment of the whelk fishery *Buccinum undatum* in the southwest Irish Sea with particular reference to its history of management by size limit

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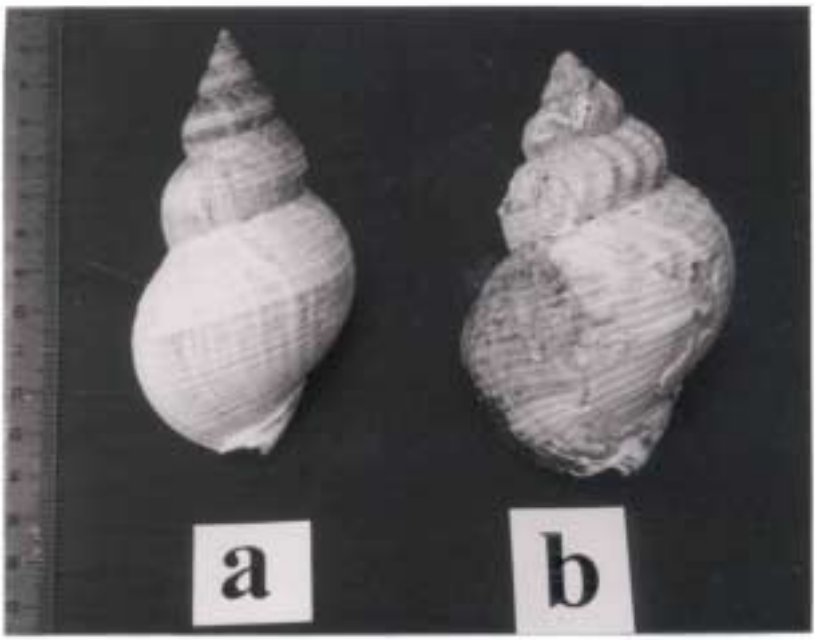

Plate 1. Whelk shells from the Irish/ Celtic Sea: a) The light shell is characteristic of the fishery in the southwest Irish Sea, b) the more heavily armoured shell of a whelk of similar length from the vicinity of Kilmore Quay in Co. Wexford, which is better known as a fishery for large crustaceans.

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ABSTRACT

Whelk landings in the southwest Irish Sea increased from 56 t in 1990 to 6,575 t in 1996 after which they stabilized between 3,600 and 4,600 t annually. At its peak the fishery supported approximately 80 vessels but this number has halved since. In 1994 a size limit of 50 mm was introduced for conservation purposes. Age based assessments of the landings were carried out in 1994, 1996, 1997 and 1999, for which purpose the fishery, ranging from 52º10' to 53º30', is divided into four sectors. Landings to the four sectors display biological characteristics which indicate the occurrence of a number of stocklets rather than a single stock unit.

Whelk in the south west Irish Sea are relatively thin shelled and the fishery has a low density of large crustacean predators. There is no evidence of contamination by TBT. The northern and southern ends of the fishery have relatively lower densities of larger/older animals; the centre sectors have smaller whelk of shorter life span at higher densities, some of them showing symptoms of a Lee phenomenon and slower growth. A survey of cpue places heaviest densities on the Codling and Rusk Banks, in strong tidal currents, at depths of < 20 m. Growth and maturation rates vary among stocklets. $L\infty$ ranges from 102 to 116 mm. Length at 50% male maturation is usually within the range of 63 – 68 mm and ages of 6.1-7.2 years although landings to one sector have a 50% male maturation rate of 83 mm and 8.5 years of age. The existing size limit of 50 mm would, at best, afford protection to 40% of spawning males. Compliance with the size limit has been poor. From 20 to 33% of total landings in any of the assessed years have been less than the legal limit and in 1994 51% of landings in one sector were below the acceptable size. Trends in cpue have been monitored since 1990 and some areas do not show any marked tendency. On the contrary, some fishermen in the centre sectors improved their yield between 1994 and 1998. There are two explanations for this: the movement of pots onto virgin ground and the fact that fewer fishermen are competing for landings in the same areas. Whelk have responded to a reduction in fishing effort since 1996 immediately following which mortality coefficients (Z) were highest (0.79); they declined to an average 0.61 in 1999. In terms of yield per recruit however they remain high. The southern sector of the fishery is regarded as being most depleted although very few sub-size limit whelks were caught there.

The survival of the whelk fishery in the southwest Irish Sea is attributed to the instability of the market which is dominated by a single customer, South Korea. A more effective size limit for this fishery would be 68mm (83 mm in the northern sector) and this is considered unrealistic, suggesting that alternative management measures will have to be considered.

1. INTRODUCTION

A small whelk potting fishery, supplying a niche market in the United Kingdom, expanded rapidly in the 1990s in response to demand from the Far East. In 1990 recorded whelk landings were 56t and by 1996 they had risen to 6,575t; after this landings declined and stabilised at between 3,600 and 4,600 t annually.

The whelk stocks of the southwest Irish Sea were first investigated by Mahon (1986). A minimum size order was introduced for conservation purposes in September 1994 (Fahy *et al*, 1995). Age based assessments of the fishery were carried out in 1994, 1996, 1997 and 1999. The objective of this work is to review the progress of the fishery since the introduction of conservation regulations with particular reference to their application and effectiveness.

The life history of *Buccinum undatum* is characterised by larval stages (trochophore and veliger), which take place inside the egg capsule. As a result dispersal by the larva does not occur. Tagging experiments have revealed the adults to be fairly sedentary (Hancock, 1963; Himmelman *et al*, 1993) so that local stocklets develop distinctive characteristics (Valentinsson *et al*, 1999). For these reasons the latest assessment considers the south west Irish Sea fishery as four sectors rather than a single homogenous unit.

1.1 Commercial development

Demand for whelk meat is limited to certain parts of the world. The flesh is regarded as tough and has to be tenderised by pounding. There is a small niche market for whelk in Britain (<100 tonnes) but otherwise most demand in Europe comes from Italy (Herbst, 1995). In South Korea whelk meat is greatly appreciated and has a reputation as an aphrodisiac. It is prepared for consumption in a variety of ways and is canned in soy sauce as “bai-tops”.

The whelk fishery in the southwestern Irish Sea dates from the 1960s when it supplied the Britain market. In the early 1990s trade with the far East opened up leading to a rapid expansion in demand. Japan and South Korea have been the principal destinations for whelk meat, the latter purchasing most, although exactly what proportion it is difficult to state with certainty because whelk are not separately reported but are included under “other molluscs” in the relevant statistics (Fitzsimons and McMahon, 1999). One substantial exporter reports that 90% of his sales go to Korea and 10% to Japan.

Dependence on a single large customer can expose producers to an uneven market and the whelk trade has encountered serious obstacles resulting in fluctuations in prices and occasional closures of the fishery, which are likely to have discouraged fishermen from participating in it.

An unsettled situation arose in January 1994 when the South Korean government imposed an import levy (adjustment tax) of 100% on imports of whelk, presumably at the behest of the Korean fishing industry. By the following autumn

a rumour circulated that the Koreans intended to raise the import levy to 200%. The European Union had however made its views on import levies known to the Korean authorities and in response to their actions, revoked the preferential tariff on Korean textiles on 1st July 1994 for a period of six months. A more likely scenario was that the tariff would be reduced to 70% on the 1st January 1995 (Source: correspondence with the Department of the Marine and Natural Resources). In the event the duty was reduced to 50% in 1995 and it currently stands at 20% (source, Lorcan Barden, pers comm).

In 1998 a Korean processor used formalin in the preparation on whelk meat. When this was discovered the whelk market virtually closed down and all whelk, irrespective of origin, were suspect. Formalin had never been used in the preparation of whelk meat in Ireland but when a statement to this effect was prepared for the local Fish Trades Gazette and a daily newspaper in Korea, both refused to carry it (source: Correspondence with the Department of the Marine and Natural Resources, conversations with processors and Departmental officials).

A reduction in demand in 1999 was attributed to a worsening economic situation in the Far East. During that year quantities of whelk held in storage declined and prices rose to Ie£600 per tonne early in 2000 – though possibly for only a brief period while holdings were replenished – attracting fishermen who had left the fishery back into it.

1.2 Landings and progress of the fishery

Landings of whelk are made on all coasts of Ireland but they are heavily concentrated on the southeast, from north of Dublin to Carne in Co Wexford - from 52°10’ to 53°30’ (Fig 1). This is the principal area of interest although adjoining ports have, irregularly, received landings of whelk also (Table 1). Within the area of interest, landings rose from 56 t in 1990 to 5,943 t in 1996 after which they declined to between 3,650 and 4,560 t per year.

1.3 The organization of the fishery

Within the coastal areas stretching from 52º10’ to 53º30’ whelk are distributed over north-south orientated mud, sand and gravel banks in strong tidal currents most of which are within 5 nautical miles of shore.

The majority of whelk are fished close to the ports at which they are landed but some are likely to have been fished farther away. The fishery is considered in four sectors: The northernmost which extends south to 53°10’ supports low densities of whelk potted by vessels berthed in Dun Laoghaire and Howth; it is referred to as the Dublin Sector. Some 16% of landings up to 1998 originated here.

Continuing southwards, the two principal ports in the next sector are close neighbours Wicklow and Arklow. These ports landed between them approximately 40% of the whelk catch. Vessels fishing these grounds, known as the Arklow sector, are the largest and most mobile in the whelk fleet. They range as far south as 52°25’. The Codling bank is a substantial part of this sector and it supports heavy local concentrations of whelk.

The Courtown sector is situated within the range of the Arklow vessels. Courtown is a small port, liable to silt up, and its fleet of smaller boats does not venture further north than 52°44'; they share their southern boundary with the Arklow fleet. Heavy concentrations of whelk are fished by the Courtown boats. Some 16% of whelk landings were to Courtown.

The final sector, Wexford, is served by three landing places: Carne, Rosslare and Wexford. Densities of whelk in this sector are relatively low. It extends from 52°34' in the north to approximately 52°8' in the south and its vessels overlap with those from Arklow and Courtown. Wexford received approximately 27% of landings up to 1998.

2. MATERIALS AND METHODS

There are three components to this assessment:

2.1 Biological characteristics

Stock assessments were undertaken in the years 1994, 1996, 1997 and 1999. Investigative work in 1998 was concentrated on elucidating the reproductive biology of the animals in the southwest Irish Sea, samples being collected from two sectors only. The sampling procedure remained the same throughout however and the general characteristics of whelk landed within the four sectors are established on bulked data from all samples collected between 1994 and 1999.

Whelk samples were randomly collected from consignments brought into the largest factories in southeast Ireland and they were later traced back to port of landing. The animals were frozen until they were examined. Total length (mm) (from the apex of the shell to the end of the siphonal canal) was measured to the nearest 0.1 mm using callipers. The total weight (g) was established, the sex ascertained and the length of the penis measured, to the nearest 0.1 mm. In 1998 the weights of the testis and ovary (g) were also recorded and, in 2000 some additional shell and meat weights were taken to make comparison of whelk from the Irish Sea with those from Kilmore Quay, in the Celtic Sea. The operculum was removed and stored dry; it was later interpreted using the methods of Santarelli *et al* (1985). Age was expressed as the number of striae counted, which means that additional (plus) growth is assumed to be included in the recorded age.

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

$$Lt = L\infty\ (1-exp[-k(t-t0)])$$

Where Lt is the length at age at time t, $L\infty$ is the theoretical maximum length, $t0$ is the theoretical age at length zero and k is the growth coefficient. The values of $L\infty$, $t0$ and k were estimated by fitting a growth curve to the observed mean length at age data.

Length of penis was interpreted as indicative of maturation when it reached 50% the length of the shell in accordance with the findings of Hancock *et al* (1962), Köie (1969) and Gendron (1992). A logistic curve was fitted to the maturation data at each landing place using the formula from King (1995):

$$P=1/(1+\exp[-r(A-Ac)])$$

Where ***P*** is the length of the penis expressed as a percentage of the shell length, ***A*** is the age/length of the animal and ***Ac*** is the mean age/length at 50% maturity. The values of ***r*** and ***Ac*** are derived by regressing ***LN[(1-P)/P)]*** on ***A*** where the slope is ***–r*** and the intercept is ***rAc***; ***Ac=intercept/r***.

2.2 Survey of whelk distribution

Data on cpue accompanied by GPS data were collected from fishermen's logs and by questionnaire over the period February 1994 to June 1999; a survey of less productive whelk grounds by staff of Bord Iascaigh Mhara, the Irish Sea Fisheries Marketing Board, (BIM) was also made available. In all 3,524 data points were assembled and plotted using Surfer Win 32 Ver 6.01 to produce smoothed contours of cpue. Catches in the third quarter of the year were raised by 15%, this being the degree of seasonal reduction in catches which is usually observed (Fahy *et al*, 1995). Some additional data on the influence of soak time on cpue were also obtained from this exercise.

2.3 Monitoring whelk landings for changes in cpue

Books-inwards of two of the largest whelk processors in southeast Ireland (Companies A and B) were abstracted every year from 1990. Daily consignments were traced back to their ports of landing. Because whelk are landed daily, the cpue was expressed as the weight of landings without consideration of how many pots contributed to the total or, indeed, the soak time involved. It had to be assumed that uniform fishing effort was exerted throughout a fishing period. Additional information was sought by inquiring about the number of pots used per fisherman over the period 1995-1999.

3. RESULTS

3.1 Length frequencies from ports

Landings from the four sectors of the fishery are bulked in Fig 2. Dublin has the widest range of lengths; larger animals are absent from the two centre sectors, landings into Arklow and particularly Courtown containing a large percentage of undersized whelk. Very few undersized animals are contained among whelk landed into Wexford.

There is some variability in length frequencies landed within the sectors over the period of investigations (Figs 3- 6). Dublin whelks are usually large but they displayed more variability than landings into any other sector (Fig 3). Animals landed into Arklow (Fig 4) are fairly similar throughout (the samples used to elucidate maturation in 1998 are included here and in Fig 6). There was some variation in landings into Courtown which, in 1994 contained a large proportion of undersized individuals (Fig 5), their numbers declining until 1997 and then

increasing again in 1999. Wexford samples are also variable from one year to another (Fig 6), those used in the examination of maturation and fecundity in 1998 being larger than any others.

3.2 Age distribution and recruitment

Whelks are long lived; 3.5% were estimated at greater than 15 years old in the earlier assessment of this fishery (Fahy *et al*, 1995). In the present investigation four age at length keys (ALKs) were prepared, one for each sector, containing all of the aged material landed to the ports in question (Appendices 1-4). These were applied to every annual length frequency of sampled materials (Table 2) whose outcome demonstrates that the widest representation of age groups occurs in the Dublin and Wexford sectors, a narrower range of predominantly younger animals being landed into Arklow and Courtown.

The pots used to capture whelk are polyethylene industrial liquid containers which have been adapted for the purpose (Fahy *et al*, 1995). They are drilled with holes of 25 mm diameter which are supposed to permit smaller whelk to escape. Smaller whelks are retained in the catches but at a smaller size and younger age they are fewer. In the course of the ageing work in the southwest Irish Sea only one animal with a single stria was encountered. There were relatively few 2 year olds but thereafter the numbers increase with age and recruitment to the fishery was taken as complete at 5 years (Fig 7). Whelks are known to become more attracted to whelk pots as they grow and there is evidence to suggest they have different habitat preferences when young (Jalbert *et al*, 1989), possibly because their dietary requirements change (Nielson, 1975) or because they have a more cryptic behaviour in their early years (Gunnarsson *et al*, 1995).

There is considerable variation in length at age among whelk in the southwest Irish Sea (Fig 8).

3.3.Growth

Mean lengths at age were obtained for each sector and they were used to make Ford-Walford plots. Because of the great variability in length at age (Fig 8), an average figure was calculated only where there was a minimum of 25 individual measurements of length at a particular age within a sector. These details are set out in Table 3.

Kideys (1991) estimated growth parameters by a variety of methods and found that $L\infty$ ranged between 123.7 and 125 mm and k values ranged between 0.20 and 0.22 in whelk populations situated close to the Isle of Man. Santarelli *et al* (1985) provided values for $L\infty$ ranging from 85.5 to 139.5 mm (averaging at 112.49 mm) and k values of 0.071-0.180, averaging at 0.125. Compared with these, the growth pattern of the southwest Irish Sea is characterised by a slightly lower $L\infty$ having an average value of 106 mm.

The growth curves derived from the parameters in Table 3 are set out in Fig 9 from which it can be seen that the most distinctive is the Courtown one. However, similar as they may appear, there are significant differences in mean length at age

among the four sectors. Tables 4 and 5 contain details of a series of comparisons of lengths at age using Student's t test.

Length frequency distributions at age in a sector are invariably unimodal but they are frequently skewed to the left, possibly indicating stunting. The phenomenon, known as the Lee effect, is common in Gastropod populations and it was illustrated among 5-year-old whelk landed into Courtown by Fahy *et al*. (1995) (see also Duncan *et al*, 1989). Stunting might arise as a result of discarding and subsequent survival of smaller individuals which establish a slow growing strain or it might be a consequence of dense nursery concentrations of the animals which do not have sufficient resources to make faster growth.

3.4 Condition

Log weight on log length regressions from the four fishery sectors are summarised in Table 6. Below the regression characteristics the calculated weights of whelk at four lengths from the four sectors are set out. The data suggest that the Courtown whelk were marginally in better condition. Those from Wexford were next well conditioned with Dublin landings having the lowest weight at length. The weight at length parameters in Table 5 are applied throughout for conversion of lengths to weight in the course of raising samples to landings (Appendix 5).

Whelk from the Irish Sea can be described as relatively thin shelled when compared with animals landed into Malin Head (Co Donegal) and Kilmore Quay (Co Wexford). To illustrate this point, two small samples, one from Howth (Dublin Sector), the other from Kilmore Quay (Celtic Sea, approximately 20 miles west of Carne (Wexford Sector)) were collected on 23 May 2000. They were handled in the customary manner and are compared in Table 7. Whelks landed into Kilmore Quay are heavier than those harvested in the Irish Sea and much of the greater weight is accounted for by a thicker shell (Plate 1). In Table 7 comparisons of weight are made at three lengths only, the smallest in Table 5 having been omitted because animals of this length were not included in the exercise. Whelks landed into Kilmore Quay also tend to have a greater average length and some have been observed to have a greater length than any examined from the Irish Sea.

The morphology of the shell in gastropods responds to a number of environmental and other factors and the presence of crustacean predators has been shown to be a significant influence (Vermeij, 1976, Thomas *et al*, 1988). The port of Kilmore Quay has heavy landings of brown crab *Cancer pagurus* and lobster *Homarus gammarus* which are fished in the adjoining Celtic Sea whose stocks extend southwards (Fahy, 1999), but both of these large crustaceans are more scarce in the Irish Sea.

Monthly variation in condition was calculated by regressing weight on length for males, females and both sexes combined from all samples bulked. Weight was calculated at a notional length of 80 mm (Fig 10). Contrary to expectation (see Kideys, 1991) whelk condition is lowest in the early spring after which it rises. June provides low readings which decline again in the autumn.

3.5.Gonad development

It is likely that gonad development influences condition although the testis and ovary are a very small percentage of body weight. According to Kideys (1991) the gonads increase in weight as the year progresses, reaching a maximum in September after which they reduce. In Fig 11 (left) the weight of the ovary in January-February and in October is related to the age of the animal. A log curve is fitted where the data justifies it. In a female whelk of 10 years the ovary in October averages approximately 3.5 g. A similar exercise was undertaken for the testis (Fig 11, right), this time related to the total length of the animal in January-February and October. In January the testis would have averaged 0.2 g in a male of 100 mm; in October a similar animal would have had a testis weighing 1.2 g.

In 1996 comparison was made between length and weight at age in whelk bulked from all sectors of the Irish Sea, in spring samples (collected up to May) and in samples collected in the autumn (August to October) (Fig 12). There are slight and possibly not significant differences between average lengths at a particular age at these times (lower lengths in Spring suggest that the striae had formed during the colder months) although from age 8 the differences become more obvious and they are accentuated in the differences in weight. More dramatic extension in length and increase in weight at these ages are likely to be associated with maturation.

3.6 Maturation

Plots of penis length expressed as a percentage of shell length and correlated with the age and length of the shell in whelk from the Dublin Sector are set out in Fig 13. The ages and lengths at which 50% are mature are presented in Table 8, together with the values of r^2 and P. Correlation of male maturation with age is weaker than with length. Within the Dublin sector, 50% male maturation takes place at 83 mm and 8.5 years; elsewhere comparable lengths ranged from 63 to 68 mm and 6 to 7 years (Table 8).

Santarelli *et al* (1986) reported that male and female maturation took place at 55 mm, a fact they established using gonado-somatic indices. In Britain Hancock *et al* (1962) agreed on a similar figure. Gendron (1992) working in the Gulf of St Lawrence stated that male maturation took place at lengths of 49-76 mm and from 5-6 years of age while Gunnarrson *et al* (1995) gave a similar range (45-80 mm) for 50% size at maturity in Icelandic waters. Valentinnson *et al* (1999) described females as reaching maturity between 51.5 and 71.5 mm in Swedish waters while males became mature between 53.5 and 71.9 mm, both sexes reaching maturation at approximately the same size in the same area. Thus, where a range of lengths are provided for whelk maturation elsewhere, the data from the Irish Sea are broadly within them, although values within the Dublin sector are high.

Recording penis length in the course of sampling whelk is routine but the exercise takes account of one sex only. Valentinsson *et al* (1999) found that whelk in Swedish waters reach sexual maturity at about the same size as whelk in other waters and no sex-specific difference in size at sexual maturity was found. Such

differences have however been reported by Martel *et al* (1986) and by Gendron (1992).

3.7 Sex ratios

There were more females than males in the Irish Sea fishery, the ratio (f/m) being approximately 1.2. Variation in sex ratio was tested by Chi-square according to month and fishery sector (Table 9); neither deviated significantly from the mean of 1.2.

The incidence of imposex was not recorded in the course of these investigations but Nicholson *et al* (1997) included observations on its occurrence in *Buccinum undatum* within some of the fishery sectors defined here where they recorded it as absent. The use of antifouling TBT has been implicated in the demise of whelk elsewhere (Cadée *et al*, 1995) although its impact appears to be less serious on this species than on *Nucella lapidus*. Nicholson *et al* (1997) pointed out that samples having little or no imposex tend to have a higher sex ratio (f/m). It is noteworthy that the Wexford sector of the Irish Sea fishery has a similar sex ratio to other sectors of the fishery. The Wexford sector contains the busy ferry port of Rosslare.

3.8 Whelk cpue distribution in the south west Irish Sea

CPUE data for potted whelk are used as an indication of their density. Information was gathered from three sources: questionnaires were distributed to individual fishermen in 1999 when respondents were asked for GPS readings and the number of boxes of whelk taken per train of pots on a particular date; alternatively they were asked to provide the numbers of 45 kg boxes of whelk landed by a stated number of trains/pots fished in an approximate area for which the central GPS location was provided on a particular date. The results were expressed as the landing (kg) per pot on a particular date.

Two fishermen made their logs, which covered several years, available. It might be surmised that cpue would be expected to alter over any period although both fishermen stated they fished the same places for a period each year and that whelk numbers were maintained there from one year to the next. Such locations are reported to be in areas where the isobaths are close together and the currents are very strong. These factors may facilitate the local concentration of whelks from a wider area.

Sources for the density of whelk are set out in Table 10. Additional records were also provided but could not be utilized for mapping purposes. Some data provided a more specific account of fishery performance because the logbooks enabled cpue to be expressed in terms of kg per individual pot lift based on a train of 30 or 40 pots. This information, summarised in Fig 14, shows a range of 0 - 8.5 kg per pot lift, some 60 % of the recorded performance ranging from 1.5 to 3.5 kg per pot lift. These yields are of the same order as those reported by Valentinsson *et al* (1999) in Swedish waters.

Over the period for which data were provided there would not appear to have been any marked tendency by cpue to augment or decrease (Fig 15) although a fitted trend line might suggest a slight increase over the period 1994 - 1999. The data points come predominantly from the Arklow sector (the Courtown and Wexford sectors contributed fewer and Dublin less) and they may be compared with cpue figures from three sectors between January 1990 and January 1994 (Fahy *et al*, 1995) which do not display any marked trend over that period either.

Finally, the data on which the cpue survey is based enables a comment on soak time because 1,474 records were accompanied by this information (Fig 16). Contrary to what has been reported by, for example, Valentinsson *et al* (1999), cpue did not rise as soak time increased, rather it fell. Because tidal currents over these inshore areas are strong, the usual practice is to lift pots every 24 hours. Some of the largest boats have been known to double lift (raise their pots twice within 24 hours) during neap tides. Prolonged exposure leads to gear becoming tangled and pots are broken and rolled over and whelks are spilled out. The relative paucity of larger crustacean predators in the southwest Irish Sea has been referred to but they are present at lower densities than in the Celtic Sea. Crab is a component of the bait for whelk and *Cancer pagurus* (the largest common predator) will not enter a pot that is so baited. However, the aroma of dead crab rapidly dissipates in strong current at which time crab will enter the pot in search of the whelk which are killed and must be discarded lest, in the course of decaying, they contaminate the material processed in the factory (Fahy, 1999).

The different consequences of soak time on cpue in the work reported here and the Swedish investigations reported by Valentinsson *et al* (1999) demonstrates the fundamental differences between the south west Irish Sea and the potential fishery in Swedish waters. The south west Irish Sea is an area of strong tidal currents (Robinson, 1979) in which pots require constant attention to replace baits and to prevent tangling of gear while the Swedish waters they investigated permitted baits to survive for considerably longer; up to 20 days.

The distribution of 3,524 data points of cpue is shown in Fig 17a and the contours of cpue in Fig 17b. The heaviest concentrations (>6.5 kg per pot lift) are indicated in black and there are clearly two places at which catches are heaviest, one on the Codling Bank, the other concentrated on the Rusk Bank (Fig 1) in depths of <20 m approximately. These banks are, respectively, within the Arklow and Courtown sectors.

3.9 Performance of the fishery by sector

The fact that small vessels are not required to complete log sheets presents a problem when monitoring the performance of inshore fisheries. Purchases by the two largest buyers in southeast Ireland, who between them accounted for approximately 60% of landings, were examined over the period 1995 – 1998 (from just before the peak landing year of 1996 to two years afterwards) to ascertain how the fishery had performed. Fishermen were identified by name and associated with one of the sectors into which the fishery has been divided.

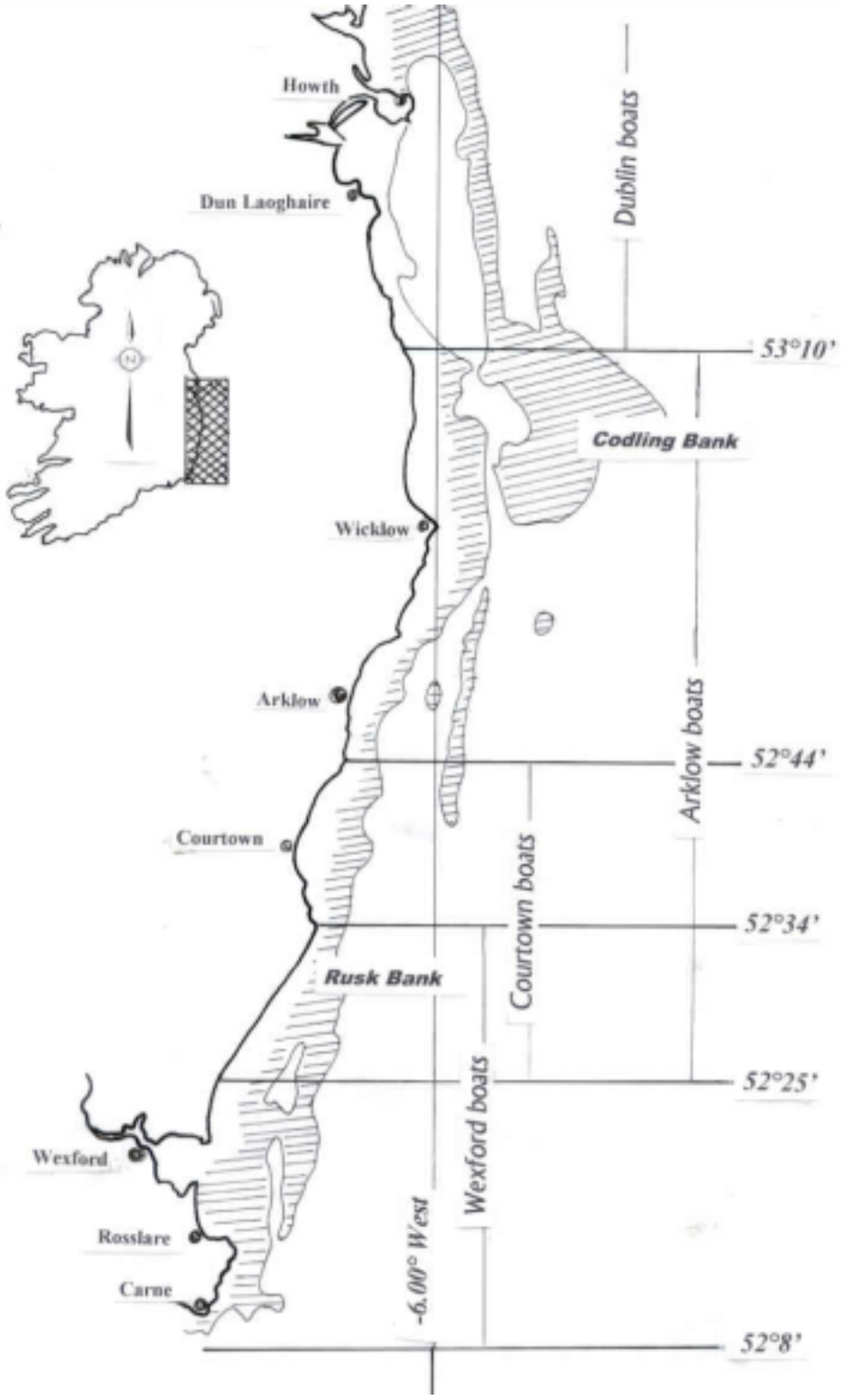

Fig. 1 The whelk fishery in the southwest Irish Sea (double hatched on inset map). The fishing grounds are shaded (single hatching) and the principal ones referred to in the text are identified, as are the landing places. The ranges of vessels belonging to each of the four sectors into which the fishery is divided are shown.

Whelks are purchased live on a daily basis so the landings are expressed in these terms. This assumes that effort is standard and, in the absence of more detailed information that assumption must apply. In fact, inclement weather may curtail activities so that the full complement of pots may not be recovered on a particular day.

There are other difficulties associated with the interpretation of landings records. In the shrimp fishery for example, the numbers of pots have been stated to increase over a period and the soak time has varied (Fahy, 1996) as effort gradually expanded. This question was addressed to fishermen in each sector of the whelk fishery.

Small inshore fisheries are characterised by a rapid turnover of participants. There is often reticence about revealing commercial details of persons selling to a factory and about soliciting such details either from the purchaser or the fishermen themselves. It is possible that not all of the information obtained by the search through documents was fully realised. The name of the seller may have altered if more than one crew member from the same boat actually handed over the landings. Or the fisherman might be referred to as a code number in one set of records and by his name in another without an established link between them.

To what extent landings were divided between processors is not known. It did happen however, and it was possible to identify a small number of names associated with the same landing places on the books of the two processors whose accounts were scrutinised. In general however, fishermen remained loyal to a single purchaser, in the short term at least.

3.9.1 Dublin

While there is reasonable certainty that whelk landed into the Dublin sector come from the area so marked on Fig 1, there was an interchange of vessels with the ports of Arklow and Wicklow. Boats which fish this sector of the fishery are more conveniently berthed in DunLaoghaire when fishing there. Their owners find it more cost-effective and convenient to travel to that port from Arklow town by road rather than to steam onto the grounds from the port of Arklow. Accounting for the number of vessels working the Dublin sector at any time is problematical. Maximum numbers of four based in Howth and eight in Dun Laoghaire have been reported. At time of writing five vessels are working in the Dublin sector.

In Table 11 the number of vessels selling to Company B over the period 1995 – 1998 is set out, along with the number of reported daily landings and the years in which each participated in the fishery. Eight fishermen made landings into the Dublin sector which were sold to Company B; participants in an any one year rose to a maximum (6) in 1996 but declined thereafter. Two vessels fished in the Dublin sector for four years. One, which might occasionally have been confused with another fishing elsewhere, was not considered further. A second, belonging to fisherman No 7 was and additional records of his landings were located in the records of Company A. It is understood that Fisherman No 7 did not increase his

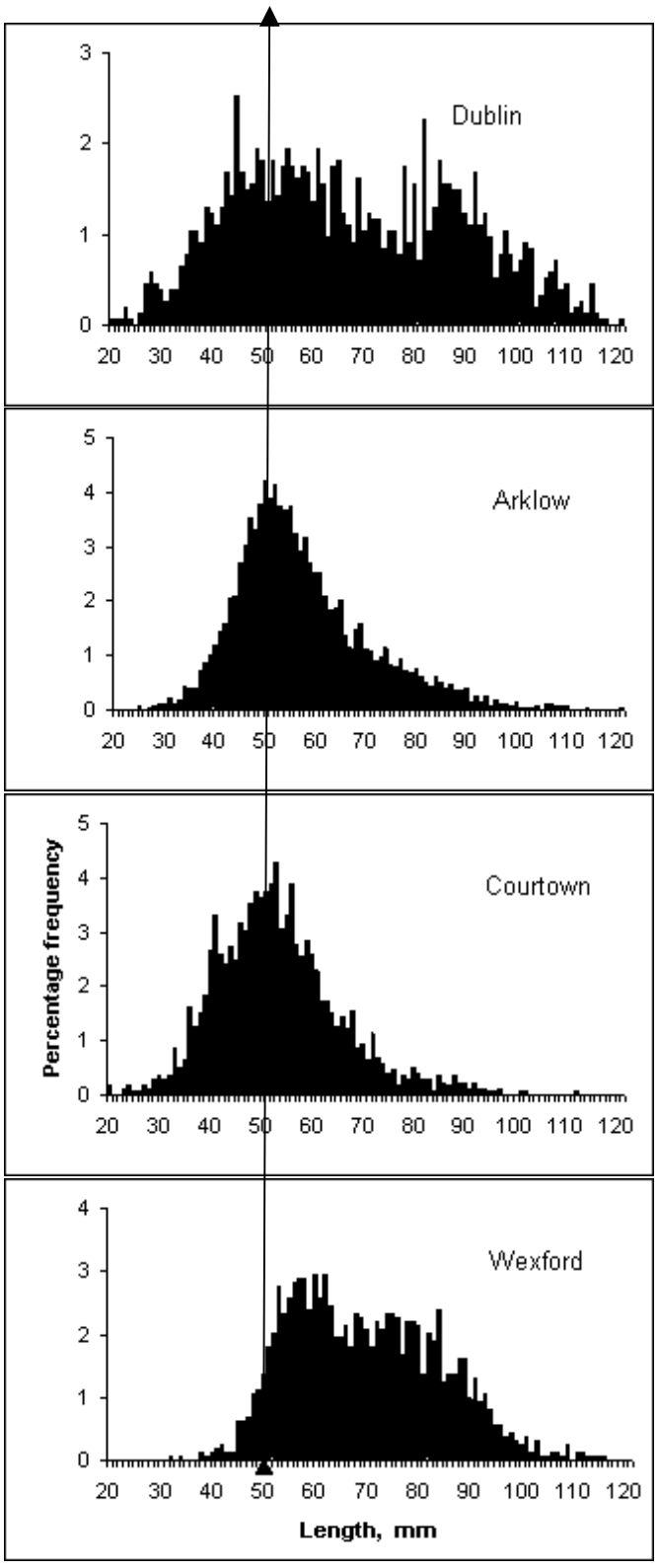

Fig.2 The length frequency distributions of all whelk in each of the four sectors (1994-1999) compared. The vertical arrow marks the size limit.

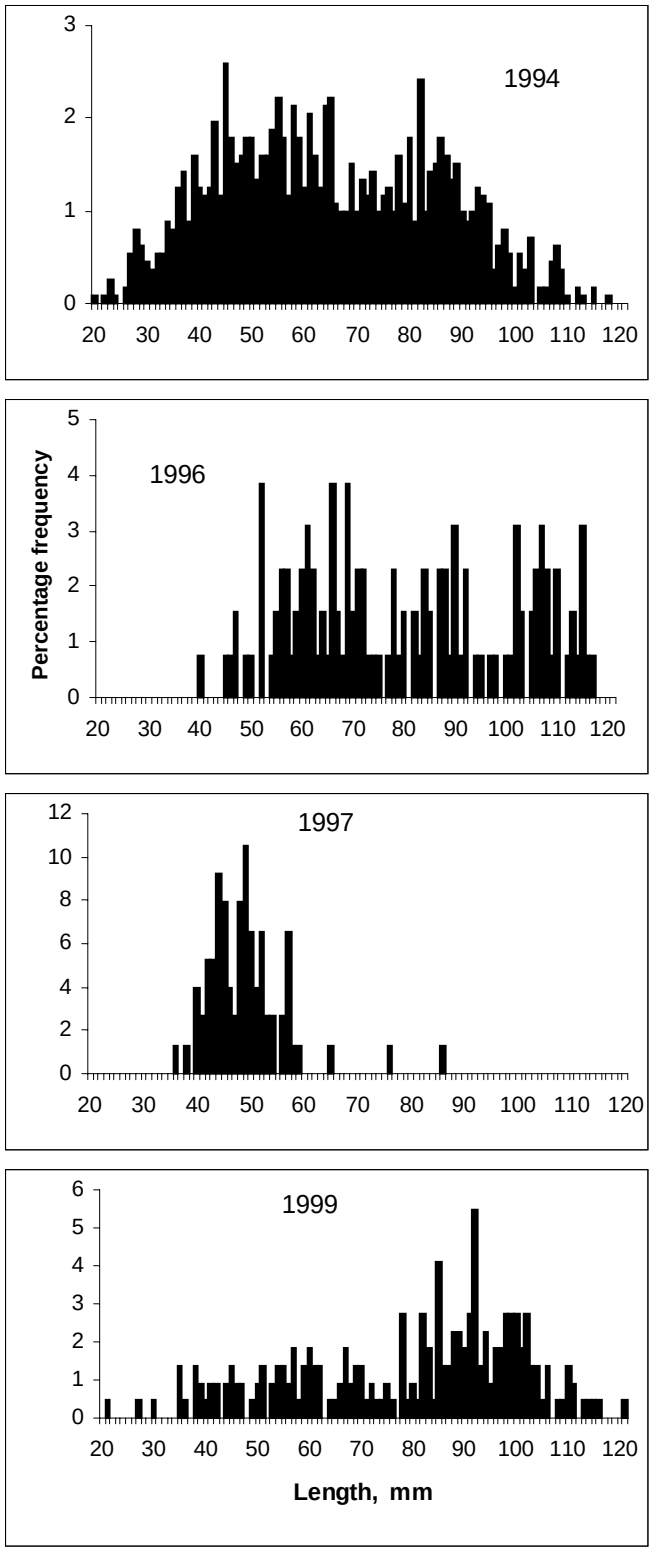

Fig.3 Length frequency of whelk sampled in each year in the Dublin sector.

gear over the period. His landings are set out in Fig 18; there is no significant correlation of landings with time (N= 277; r^2=0.00049).

3.9.2 Arklow

Information suggests that there has been little change in the number of boats involved in the fishery between 1996 (30-33) and 2000 (30), the occasional berthing of some vessels in the Dublin sector has been referred to. Opinion on the performance of the fishery varies and two divergent ones have been expressed. One source observed that the inshore grounds have become depleted and the boats have constantly have had to move seawards in search of new fishing areas: the Bay of Arklow is reportedly fished out while the "south ground" – outside the Blackwater Bank has been fished down. This information contrasts with that provided by other fishermen who reported that certain areas can be fished annually and they repeatedly provide worthwhile yield. The two explanations may not conflict however, the passive transport of animals may be a factor where currents are strong and where the isobaths are close together these factors might combine to concentrate the animals in certain locations. Within the Arklow and Courtown sectors fishermen speak of fishing down populations in certain localities and returning to them the following year to repeat the process.

In the books-inwards of Company B, 45 fishermen were identified as landing into the Arklow sector during the four years under review and, in keeping with what has been said about the number of vessels fishing this sector, there was not a marked decline in boat numbers after the peak landings in 1996. Daily landings by six of the best documented fishermen were traced and are set out in Fig 19. Where a correlation between daily landings and time has proved significant, the relationship is shown. Taking each in turn: Fisherman No 45: r^2 =0.109, N= 566, X-var = 0.194; Fisherman No 43: r^2 = 0.142, N = 498, X-var = 0.481; Fisherman No 38: r^2 = 0.530, N = 287, X-var = 1.401; Fisherman No 44: r^2 = 0.000003, N = 509; Fisherman No 42: r^2 = 0.00009, N = 491; Fisherman No 38: r^2 = 0.530, N = 287, X-var = 1.401. All of the significant correlations have positive X-variables, suggesting that the daily landings of the vessels in question have risen over the period. Fishermen from this sector who were questioned about this phenomenon were adamant that gear had not been increased, citing strong tides as a major obstacle to increasing fishing capacity (see above). Other explanations might include better use of the same gear as experience of the fishery grew or the discovery of better fishing areas.

3.9.3 Courtown

Eighteen fishermen are recorded in the books of Company B as having landed their catches into Courtown between 1995 and 1998. One of these sold only seven daily landings and would appear to have been in the vicinity for a short time only. Six fishermen worked throughout the four-year period under review. After 1996, the peak year for landings, the numbers of fishermen declined from fifteen to fourteen in 1997 and seven in 1998. Fishermen from Courtown recollected the maximum number of whelk boats in Courtown as eleven in the early 1990s. After 1995 they recalled a loss of up to two boats from the fleet annually until in 2000 only four boats remain.

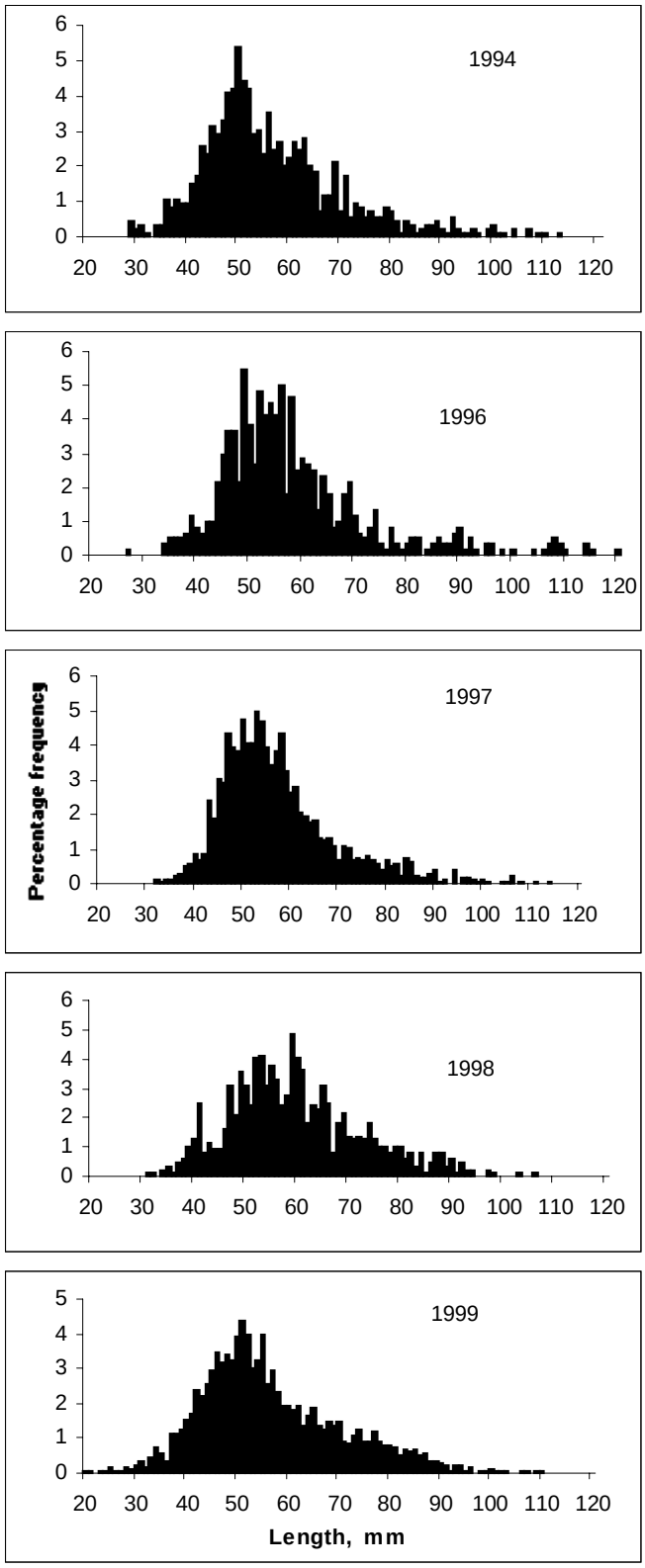

Fig 4. Length frequency of whelk sampled in each year in the Arklow sector.

In order to ascertain the performance of the fishery, daily landings of the four most documented fishermen in Table 13 are examined (Fig 20). Taking each in turn: Fisherman No 1: $r^2 = 0.0008$, N = 529; Fisherman No 6: $r^2 = 0.209$, N = 273; X-var = 0.383; Fisherman No 7: $r^2 = 0.179$, N = 331, X-var = 0.359; Fisherman No 17: $r^2 = 0.146$, N=258, X-var = 0.335. As in the Arklow sector, all values for X-var are positive, suggesting that cpue has increased over the four years.

On the question of fishing effort, the fishermen stated that the number of pots fished per vessel had not altered. They too cited the strong currents in the area which limited the time gear could be left at sea without tangling as the reason for this and they stated that vessels had not been exchanged for larger boats in the course of the fishery, nor had their crews been enlarged. They identified a figure of 12-13 trains of 30 pots each as the norm per boat.

When asked for an explanation for increasing catches, Courtown fishermen alluded to the reduction in the numbers of vessels on their grounds, stating that fewer boats meant a larger harvest for everyone remaining.

3.9.4 Wexford

Fishermen based in Wexford town described the fishery as expanding from a single vessel operating in the sector in 1992; in 1994 eight were fishing regularly from the port and by 1996 there were 25 boats in the Wexford sector. By 1999 these had declined to five; in 2000 only two boats are operating in the sector. During the first years of the fishery in Wexford each boat fished eight trains of 30 pots (240); in 1996 this number was increased to 12 or 13 trains (360 – 390 pots) where it has remained since.

The principal buyer of whelk in Wexford town ceased trading in 1998 and the declining landings were taken over by Company B whose records do not provide as comprehensive an account of this sector as of the others. What information has been gleaned from the books-inwards of Company B are summarised in Table 14. Daily landings by two Wexford fishermen were traced across the books-inwards of the two buyers (Companies A and B) over a period of four years. In Fig 21 their records of daily landings are set out, adjusted in this case by the application of pot numbers. Although there appears to be a reduction in daily cpue per pot, correlations with time were not significant. Details are as follows: Fisherman No 2: $r^2 = 0.010$, N = 148; Fisherman No 8: $r^2 = 0.002$, N = 285.

4. CONSEQUENCES OF THE FISHERY FOR WHELK STOCKS

4.1 Mortality coefficients

The age at length key (ALK) for each fishery sector was applied to the sampled whelk length distributions in each year of assessment and the log numbers were regressed against age from 5 to 15+ inclusive to provide mortality coefficients (Z) which are summarised in Table 15. The averaged coefficients are lowest in Dublin (0.29) and Wexford (0.50) and highest in Arklow and Courtown (0.65 and 0.78

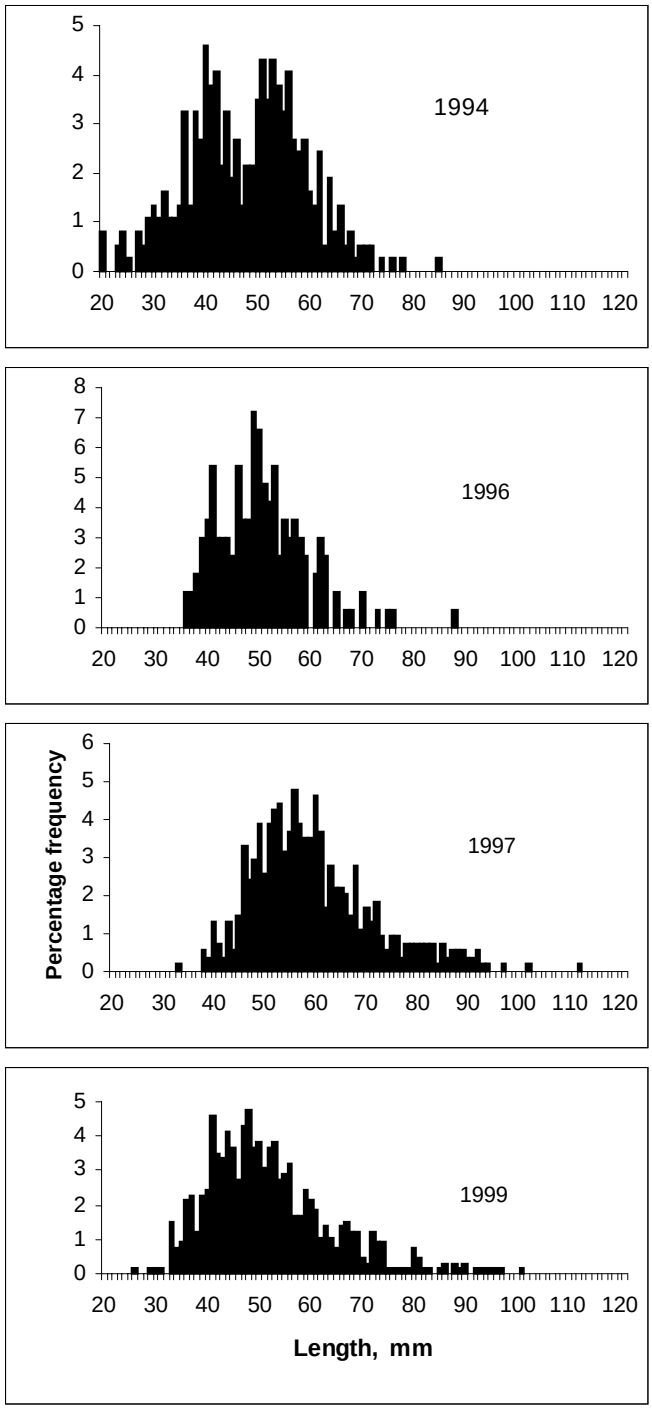

Fig. 5 Length frequency of whelk sampled in each year in the Courtown sector.

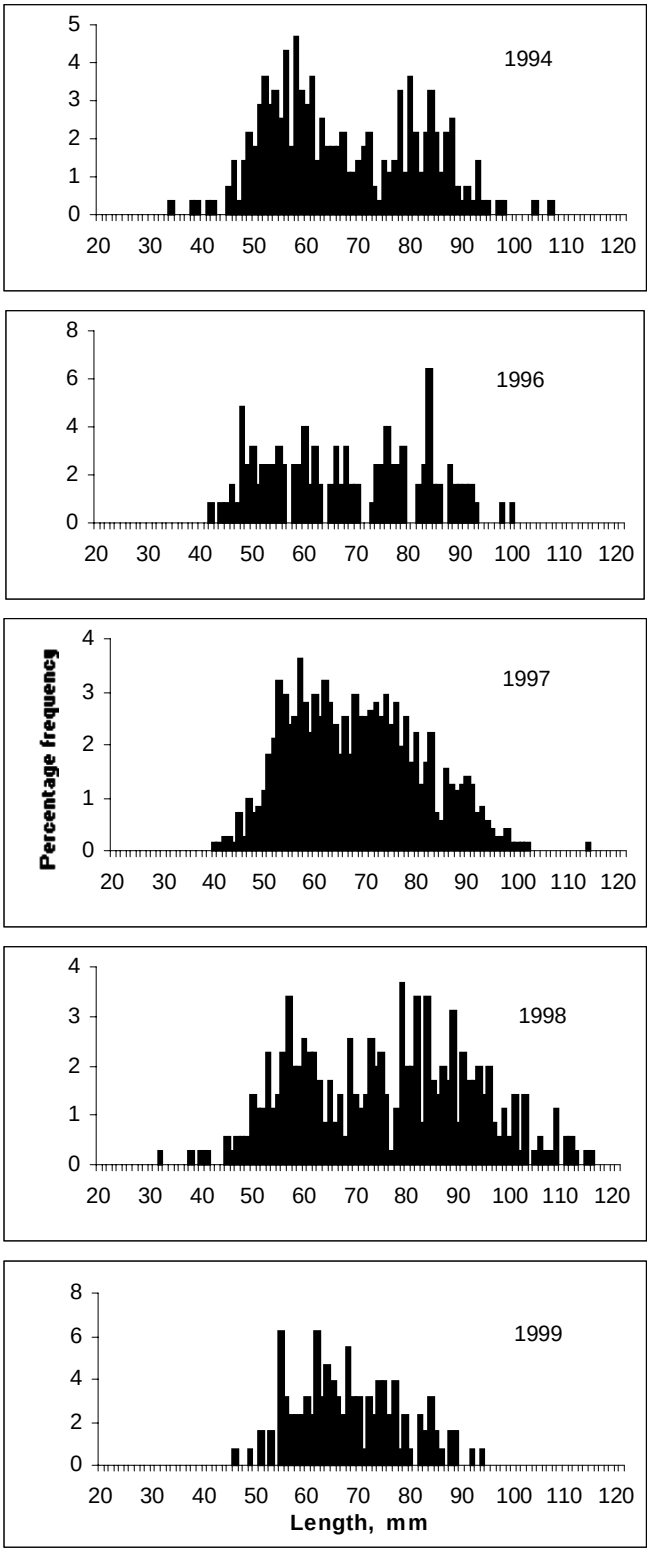

Fig. 6 Length frequency of whelk sample in each year in the Wexford sector.

respectively), which is in keeping with the length and age frequency range throughout the fishery (Fig 2 and Table 2).

Mortality coefficients in all sectors declined from 1994 to 1996 but they increased slightly in 1997, one year later than the recorded peak landings (Table 1). In keeping with the declining effort in the fishery (Tables 11 -14) there was a general improvement in 1999 in all sectors except Wexford.

4.2 Yield per recruit

A Thompson-Bell yield per recruit curve was devised for whelk in two sectors, Dublin and Courtown, whelk originating in these sectors having the greatest differences in size, age and growth rate. Input data were derived from the following: weight at age by multiplying length at age by the weight: length parameters (Table 5); age at full recruitment from Fig 7; partial recruitment was derived by projecting a generalized catch curve from the data in Table 2 back to its origin. The value of ***M*** is assumed to be 0.2. The yield and biomass per recruit curves are shown in Fig 22.

In the Dublin sector ***Fmax*** is at 0.3 (***Z***=0.5) while in Courtown it is at 0.4 (***Z***=0.6), both of which were exceeded in 1997, indeed ***F*** values in the Courtown sector have been higher than ***Fmax*** in every assessment to date. In 1999 ***Fmax*** was exceeded in all sectors except Dublin.

4.3 Compliance with size limit

In September 1994 a size limit of 50 mm (from the apex of the shell to the end of the siphonal canal) was introduced as a conservation measure (Whelk (Conservation of stocks) Order, 1994; S.I. No 278 of 1994). The actual dimension specified was the maximum width which should not be less than 25 mm, this measurement being approximately half the total length.

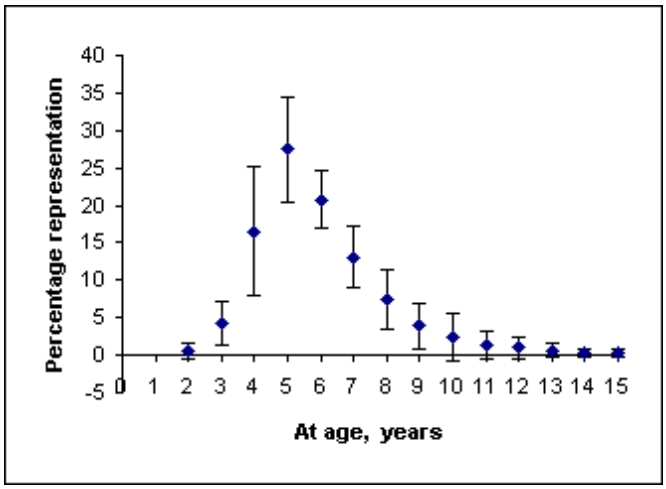

Fig 7. Percentage representation of age groups in all samples, bulked (+/- one SD).

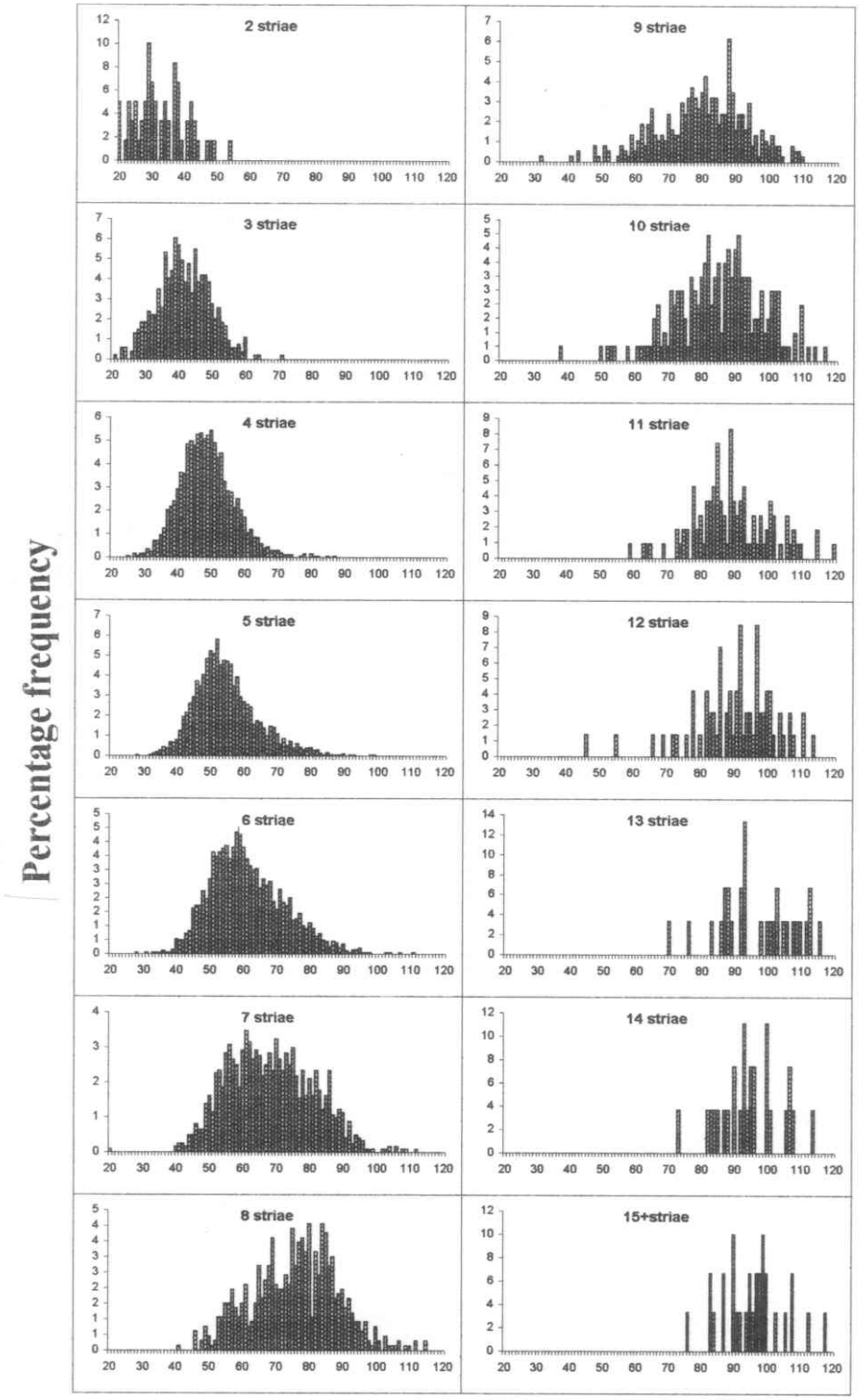

Fig. 8. Length frequency distributions of all aged whelk (bulked) from the southwest Irish Sea.

The degree of compliance with the size limit is estimated from the length frequencies of sampled landings (Figs 3 – 6), raised to total annual landings in each sector after the application of weight at length relationships (Table 6). The actual calculations for the year 1999 are set out in Appendix 5. Percentages undersized whelk landed into each sector in each year of assessment are summarised in Table 16. As might be expected, they are least in Wexford, variable in Dublin, account for one third of all landings into Arklow and occasionally amount to half of all whelk landed into Courtown.

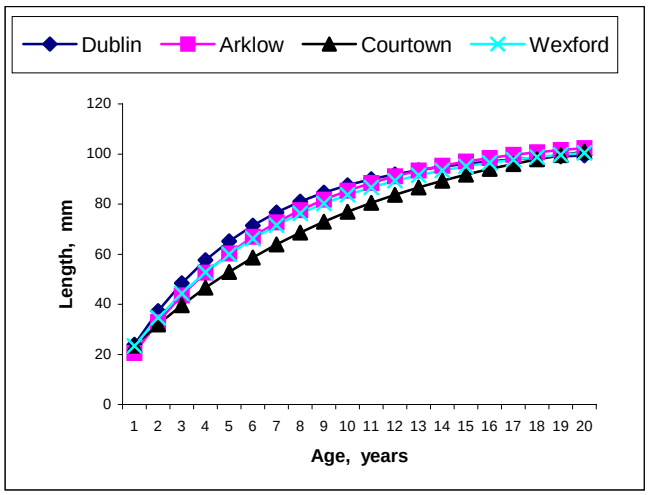

Fig. 9. Calculated growth curves for whelk from each of the four sectors of the southwest Irish Sea fishery.

5. DISCUSSION

The whelk fishery of the southwest Irish Sea exploits a number of stocks or stocklets which may be described as relatively thin shelled. These are distributed over mud, sand and gravel banks, close inshore, in strong tidal currents. The ground has relatively few large crustacean predators. There is no evidence of contamination by TBT, a factor which has been suggested as contributory to the decline of whelk in the North Sea (ten Hallers-Tjabbes *et al*, 1996). The southwest Irish Sea fishery is a substantial one: in 1996, its peak year, it provided 27% of European landings (FAO Fishery Statistics: 82). There is however, potential for a larger fishery in the Kattegat with a calculated harvest of 45,000 to 225,000 t (Velentinsson *et al*, 1999).

Before the development of a human consumption fishery for whelk, they were regarded as a nuisance. Hylleberg (1991) cites an attempt to eliminate whelk some eighty years previously in Danish waters because the animals were perceived as a threat to more conventional fisheries. The experimenters concluded that even with intensified efforts it was impossible to reduce the whelk population. Experience with *Buccinum* and other whelk species has since provided contrary results stimulating enquiry on suitable and workable management measures.

Among several case histories of gastropod management, Anderson *et al* (1993) described the run-down and signs of recovery in the fishery for knobbed and channelled whelk (*Busycon carica* and *B. canaliculatum*) in South Carolina. Like *Buccinum undatum* these species are slow growing and reach maturity at a large size. The recovery of that fishery involved establishing a minimum harvest size and mandatory reporting requirements, limiting the fishing season and restricting exploitation in certain offshore waters. In an earlier paper (1988) the same authors reported the depletion of the *Busycon* fishery in South Carolina; the fishery showed symptoms which are reminiscent of what is happening in the south west Irish Sea: declining cpue (for which there is not much evidence on the data presented here although some of the fishermen interviewed referred to depleted grounds and this might account for some of the loss of vessels from the fishery) and increasing numbers of whelk per unit weight captured even though the total landings were also in decline. The fishery eventually became so run down that it was uneconomical to continue, fishing was discontinued and recovery of the stocks began. In the absence of effective management the Irish Sea fishery will probably follow a similar course. In which case the consequences in this fishery could be very serious. Anderson and Eversole (1984) observed that whelk meat in the South Carolina fishery was extracted from the shells by hand. When the use of machinery to extract whelk meat which was introduced to the south west Irish Sea fishery in the 1990s any size could be processed automatically whereas in earlier years processors discouraged the harvesting of smaller animals from which it would have been more costly to extract the meat by hand.

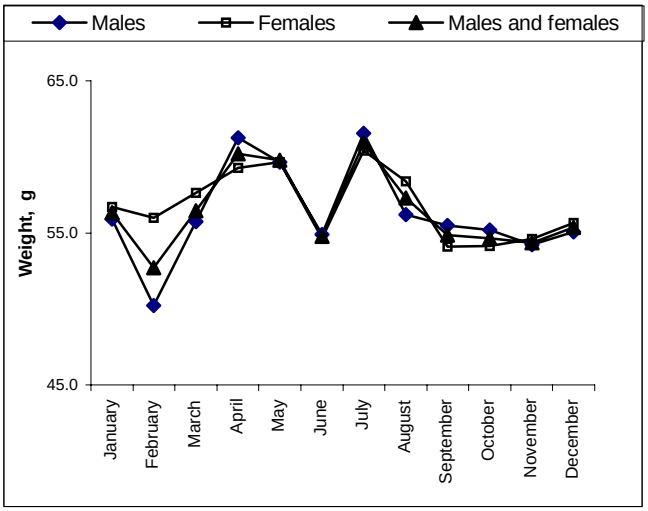

Fig. 10. Variation over a 12 month period of weight at a notional 80 mm total length for males females and both sexes combined in the southwest Irish fishery, all samples bulked.

The inevitable consequence of stock depletion in a slow growing species is a period of recovery during which market share is lost. Whelk-like gastropod species occur in various parts of the world and substantial reserves of *Buccinum undatum* remain to be harvested in Europe.

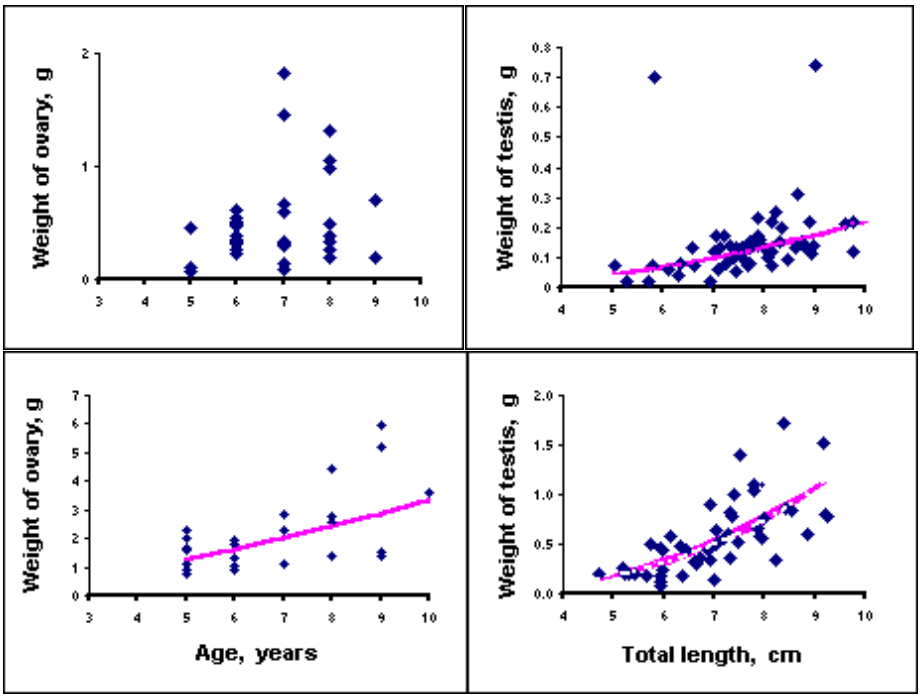

Fig.11 Variation in weight of ovary at different ages (left) and testis at different lengths (right) in January-February 1998 (top graphs) and October 1998 (bottom graphs).

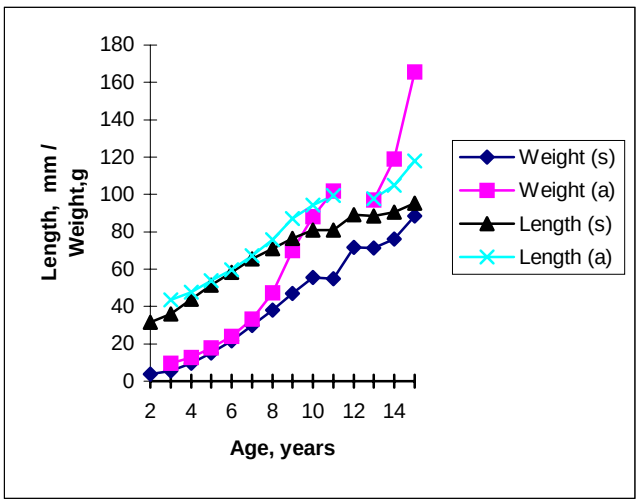

Fig. 12. Length and weight at age of whelk sampled in 1996 (material bulked) to illustrate relative changes as the year progresses, (a= autumn, s= spring).

In addition to the straightforward depletion of the resource by over-fishing a more insidious decline in the medium term is a possible consequence of the current exploitation pattern. Miloslavich *et al* (1994) examined the fecundity of two size groups of the related *Buccinum cyaneum* from the Sanguenay Fjord. They found that although the quality of the juvenile at hatching (in terms of size and biochemical content) did not vary significantly, the number of eggs and developing embryos within egg capsules increased with the size of the female. The implication of a similar development in the southwest Irish Sea is for lower fecundity in the remaining depleted stocklets.

The history of the South Carolina whelk fishery is likely to have some resonances for the British one. The traditional British *Buccinum undatum* fishery was centred on the ports of southeast England, up to 20 years ago (Hancock, 1967). Landings declined there and to ports in the eastern English Channel following a peak in the mid-1980s. Overall, British landings have fluctuated, reaching a very low level in 1990 but they increased in 1993, 1994 and reached a new peak in 1995, due to a reawakened interest in this species. Landings of whelk have taken place into various ports in England, Wales and Scotland and a larger number of landing places have recorded whelk catches (Nicholson *et al*, 1997). The market opportunities offered by the Far East are believed to be the stimulus for the revival of this fishery also.

The biology of *Buccinum undatum* predisposes it to form small isolated populations or stocklets and some of the characteristics of landings to different sectors indicate the existence of distinctive populations. There is still however, insufficient information to recognise how many are involved or how to definitively categorise them.

A variety of factors might influence growth rate. Mean length at age varied from one sector of the fishery to another and these differences were significant (Tables 4 and 5). A factor likely to influence mean length in this case is the density of animals on the seabed. Both Fahy *et al* (1995) and Mahon (1986) referred to the occurrence of skewed length frequency distributions. The animals might have been discarded so that the smaller, slower growing individuals came to dominate the landings at a later time (sorting of whelks has been practised at times throughout the fishery particularly when meat extraction was carried out manually) or because localised nursery areas support heavy densities of the animals thus creating a Lee phenomenon. It may not be a coincidence that the slowest growth rate (at Courtown) and the Lee phenomenon (Fahy *et al* 1995) were recorded from a sector which has high densities of the animals.

Length and age frequencies of whelk were most variable in the Dublin sector (Fig 3) which might indicate that various age ranges were available; in Wexford there were fewer juveniles and this observation (Figs 2 and 6) is supported by observations by one of us (E.F.) at sea. The Wexford sector would appear to have suffered the greatest loss of vessels (Table 14) and of landings (Table 1) since 1996, possibly pointing to a stock depletion although that does not appear obvious

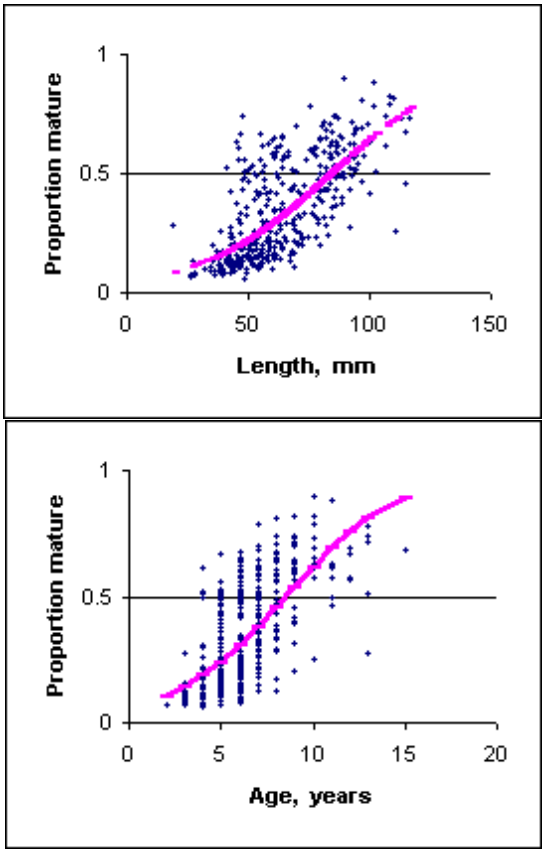

Fig. 13. Proportion of whelk to mature as indicated by the ratio of penis length to shell length expressed in terms of length and age (Wexford sector).

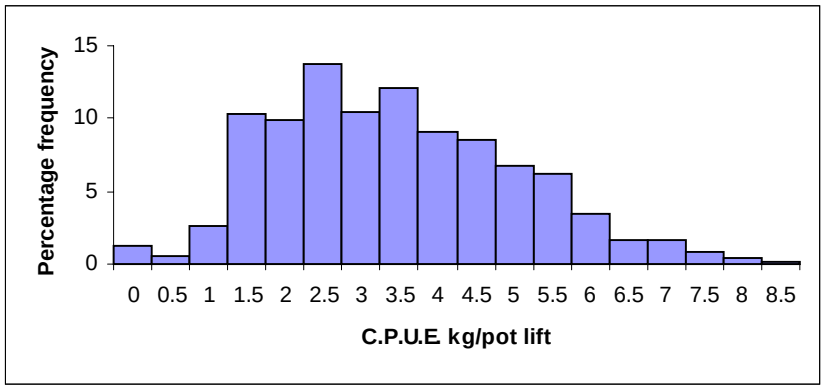

Fig. 14. Frequency distribution of catch per unit effort (kg/ pot lift), data used to map whelk abundance in the southwest Irish Sea.

from the cpue data presented (Fig 21). Whelk from the Wexford sector have similar maturation characteristics to those in Courtown (Table 8); faster growth in Wexford might be a consequence of lower density there and it is surmised that the stocklets in this sector might have their breeding grounds further north from which they are dispersed (possibly with the aid of tidal currents) over the southern part of the fishery.

Reaching estimates of absolute density in pot fisheries is difficult, particularly for whelks which display seasonal variations in feeding intensity (Martel *et al*, 1986; Fahy *et al*, 1995). Santarelli (1988) found this to be an obstacle to estimating population size using a depletion method. Himmelman *et al* (1993) showed that in the Gulf of St Lawrence the quantity of food contained in the stomach of the gastropod varies with season and substratum and whelk might also form associations with sea stars in the vicinity of bivalve concentrations and participate in their feeding activities. However if the constant catchability hypothesis, which is fundamental to the operation of, for instance, the de Lury method, does not operate throughout the year, it might be feasible to compare one year with another. Unfortunately that would be complicated by growth occurring in the residual stock between years and also possibly by local migrations facilitated by tidal currents. Kideys (1993) concluded that pots might provide good information on whelk density provided it could be interpreted using additional information. Valentinsson *et al* (1999) undertook such an estimate in enclosed waters off the Kattegat where the tidal amplitude is 0.2 m. Once fished down, they found whelk densities remained low when the area was fished again one year later. The conditions which prevailed for this experiment, however, are not those which occur in the south west Irish Sea. An additional complication in assessing total biomass by a depletion method which requires that an estimate of density in one area would be assumed to apply over a larger one, is the fact that within the fishery, whelk occur in discrete patches (Fahy, 1999).

Whelk densities shown in Fig 17 were prepared from fishermen's data rather than from a random survey of the area. Miller (1976) reviewed methods of estimating whelk density and counselled caution; using such methods as fishermen's surveys it was absolutely essential to have further knowledge before describing such information as absolute density This survey makes no claims to be other than an account of where whelk are harvested in quantity. However, ground adjoining the fished areas has been tested and the survey includes the results of another undertaken *by Bord Iascaigh Mhara* (BIM) in 1999 to locate additional ground, which proved unfruitful. Gowanlock (1926) and Hancock (1963) reported from tagging experiments that whelk movements are limited but Harvey *et al* (1987) showed that when pursued by a predator they could move at considerable speed. A similar result might be obtained when the animal pursued prey (Himmelman, 1988, McQuinn *et al*, 1988). Within limited areas, whelk would appear to congregate. According to fishermen in the southwest Irish Sea such places are usually characterised by strong currents and close isobaths.

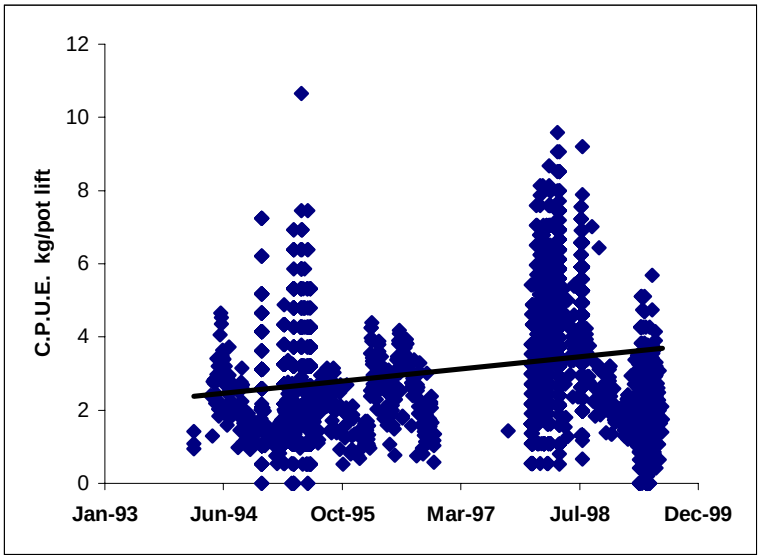

Fig. 15. Trend line added to data used to plot cpue in the whelk fishery of the southwest Irish Sea, 1994-1999.

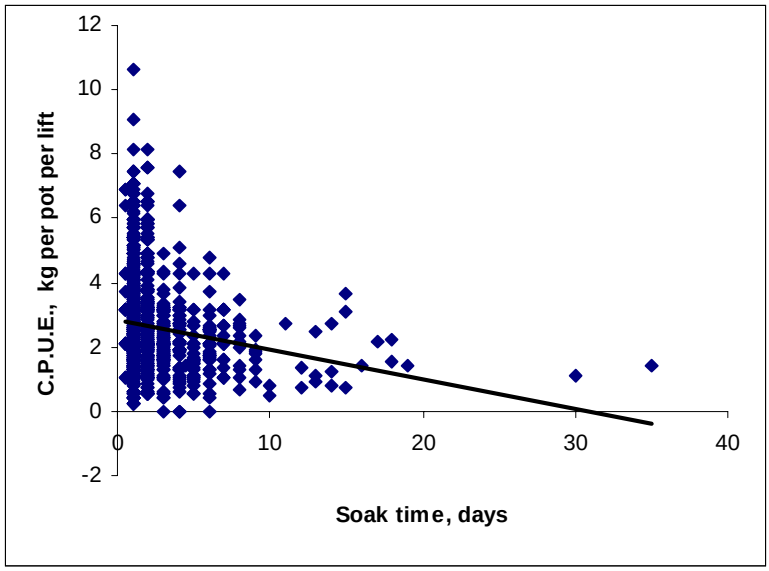

Fig. 16. Trend line added to data used to plot change in cpue against soak time in the whelk fishery of the south Irish Sea.

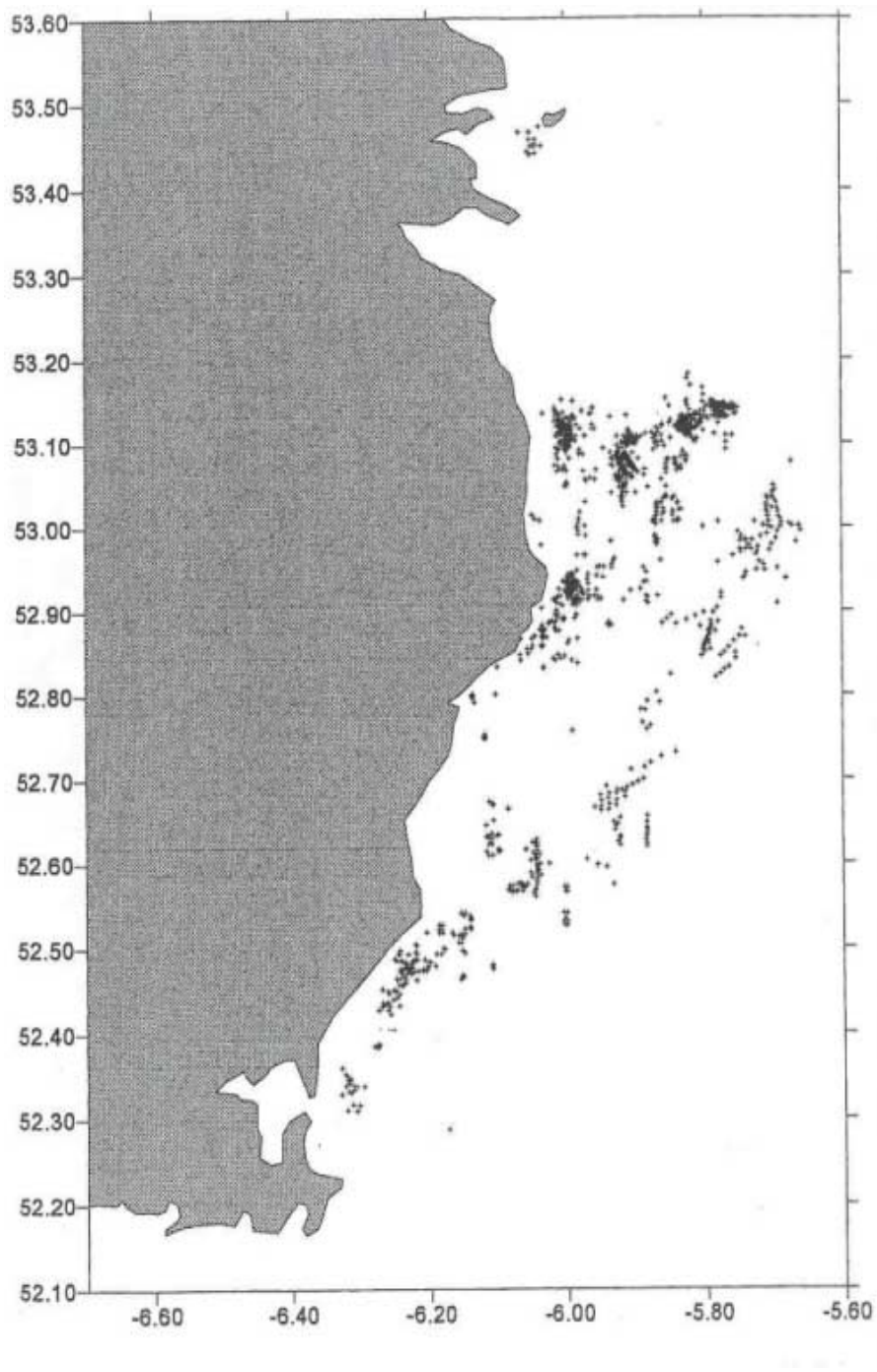

Fig. 17a. Relative whelk cpue distribution over the southwest Irish Sea fishery. Occurrence of data points.

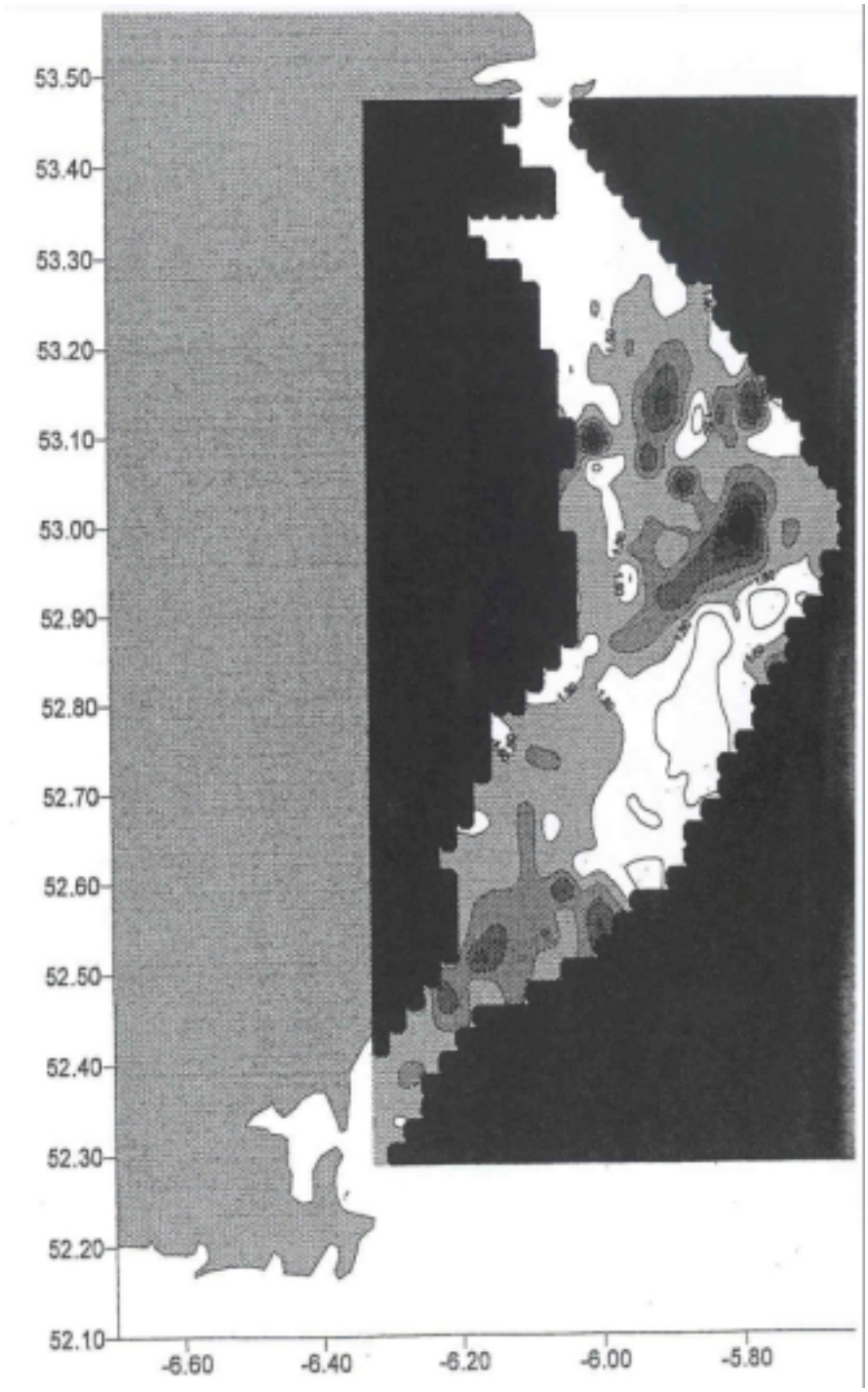

Fig.17b. Relative whelk cpue distribution over the southwest Irish Sea. Smoothed contours. The black areas indicate >6.5 kg per pot lift.

A range of conservation measures, such as those listed by Anderson *et al* (1993), are theoretically available to ensure sustainable management of a whelk fishery. The usual first step is however to regulate by size limit. Within European stocks of *Buccinum undatum* males and females tend to reach maturity at the same size although there may be considerable variation in this from one area to another (Valentinsson *et al*, 1999). Some differences between sectors occur (Table 8), the highest age and length at male maturation being recorded for Dublin (8.5 years and 83.2 mm) but elsewhere the outcome was fairly uniform (6.1-7.2 years and 63.2-67.6 mm). Gendron (1991) estimated the minimum size to ensure that immature animals be excluded from the catch and concluded the length of shell should be between 65 and 75 mm. Similar dimensions should apply in the case of the Irish Sea. Kideys *et al* (1993) also calculated that sexual maturity in Irish Sea whelk was reached at 60-70 mm length. Gendron (1991) considered that a conservation regime might be managed by covering pots with a suitable mesh size permitting the escape of animals smaller than the prescribed size limit. Such a measure is unlikely to make a great difference in the Irish Sea although escape holes of appropriate size are desirable. During active feeding whelk cram into pots so that the smaller ones become trapped among the larger and cannot reach the escape holes even if these were sufficiently large to permit their liberation. The effective use of escape holes requires that all bait contained in a pot is exhausted so that the animals attempt to get out before the pot is recovered. Enforcing such practices would be unrealistic although the provision of larger escape holes (of, say, 35 mm) might be efficacious and it could be justified on the actual length as opposed to the minimum length at maturity. The present investigations concentrated on the males, which were convenient to sample in a routine way, the ages and lengths at which 50% became mature being identified as the critical measurement.

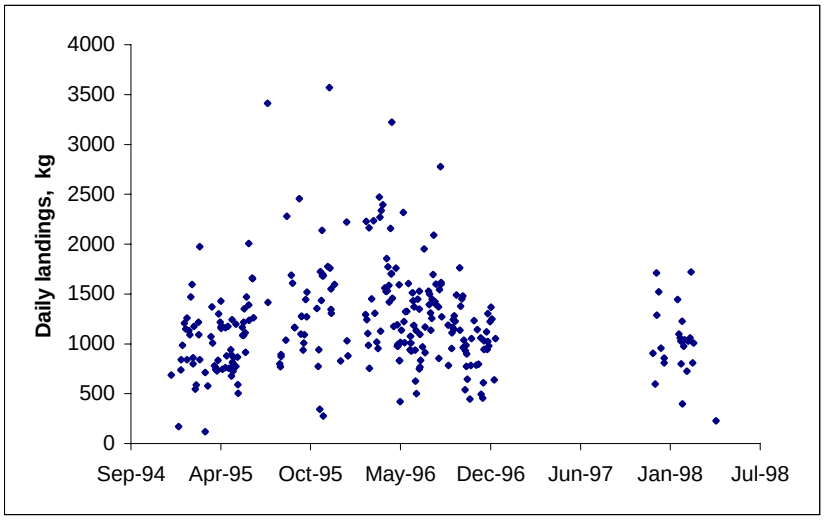

Fig. 18. Trend in daily landings (1994-1999) of a fisherman in the Dublin Sector.

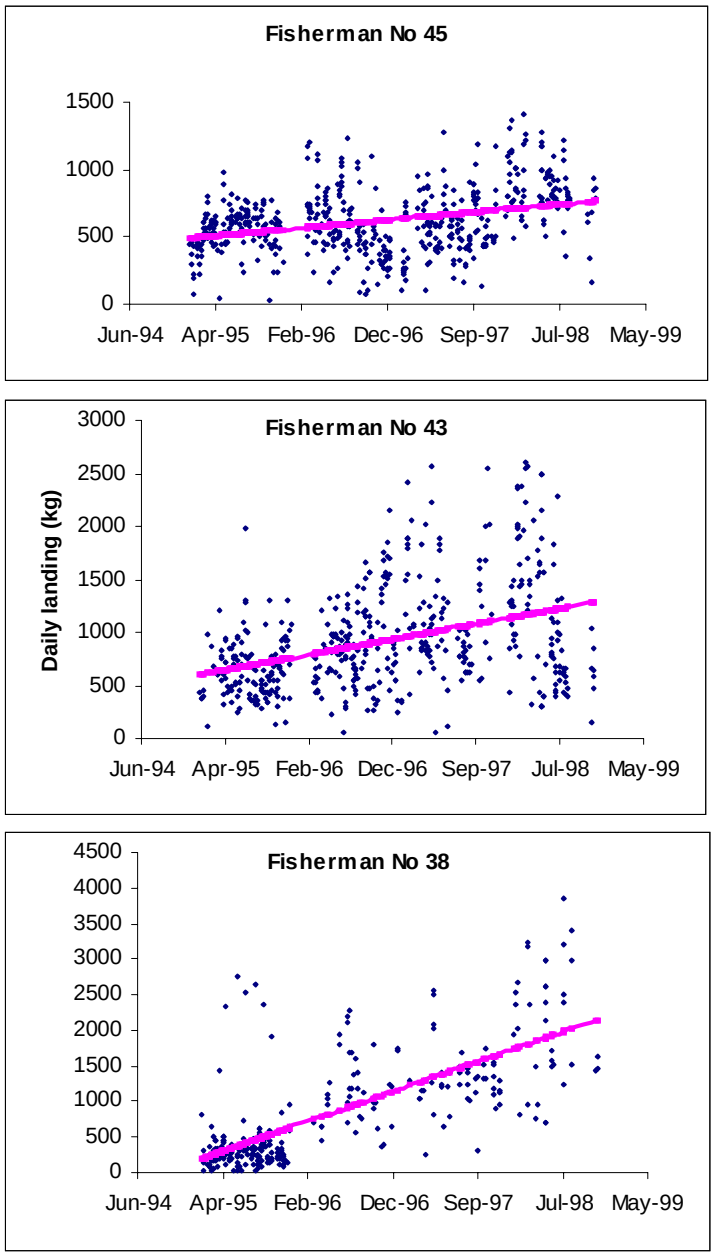

Fig. 19a. Trend in daily landings (1994-1999) of three fishermen in The Arklow sector. Correlations are shown where the data justify them.

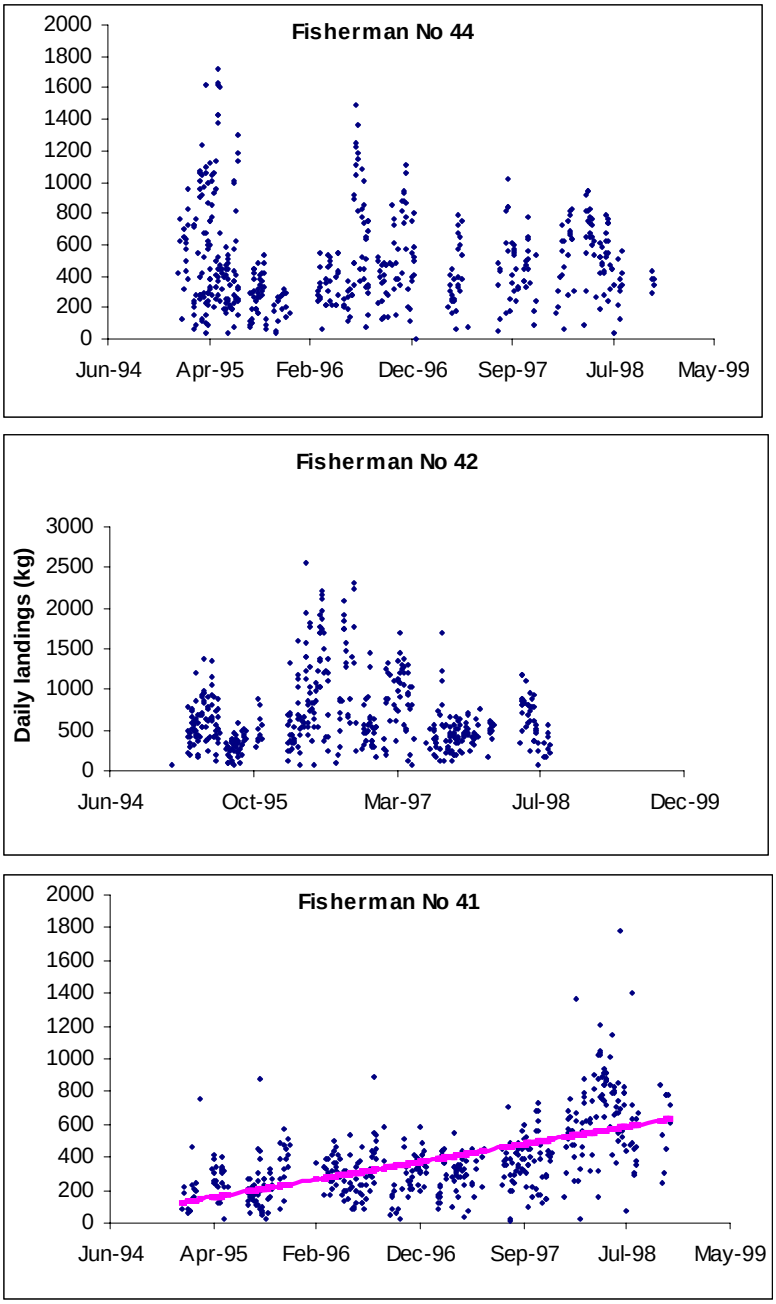

Fig. 19b. Trend in daily landings (1994-1999) of three fishermen in the Arklow sector (cont.).

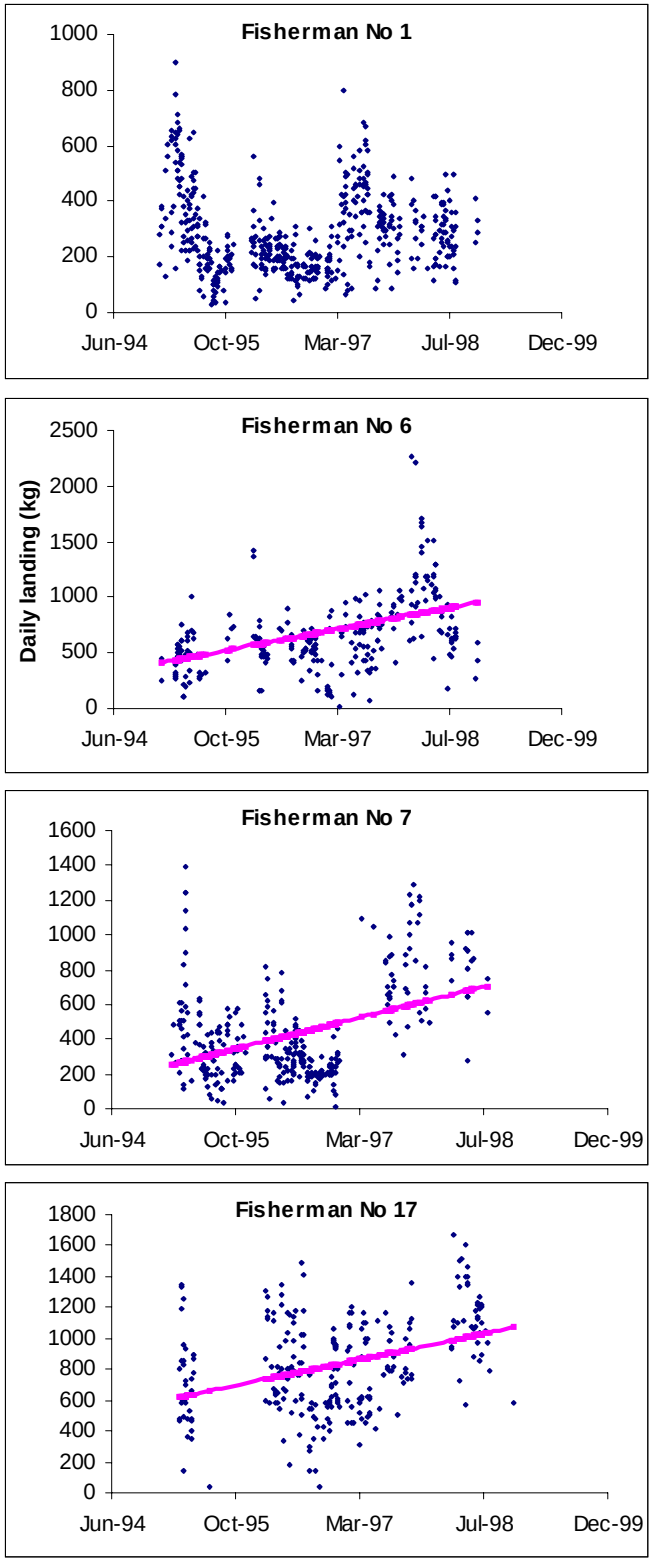

Fig. 20. Trend in daily landings (1994-1999) of four fishermen in the Courtown sector. Correlations shown where the data justify them.

The size limit of 50 mm, which was adopted for the southwest Irish Sea fishery in 1994, was, at the time regarded as a compromise, being smaller than justified by the biology of the species. Because whelk mature at a high age and size, it is necessary to make compromises of this kind in order to allow fisheries to operate (Gendron, 1991; Savard *et al*, 1994, Fahy *et al*, 1995; Velentinsson *et al*, 1999). In fact, the minimum length to permit spawning once by 50% of the population would be closer to 70 mm, which would mean a size limit of 35 mm maximum width. According to the data in Fig 13, less than 40% of male whelks at any site have matured at a length of 50 mm and it is important, for conservation reasons, to use a 50% maturity length, which can differ significantly from the length at first maturation. In the Dublin sector the minimum length should, by this reasoning, be 83 mm and the minimum width 41 mm. The difficulty presented where the animals mature at a variety of sizes/ages in small stocklets is acknowledged. Gendron (1992) suggested: "Because of geographical variability in the size at sexual maturity, different minimum catchable sizes should be established by partitioning the whole region into different sub-regions which are homogeneous in respect to the size at sexual maturity", a suggestion which is impractical in the present context.

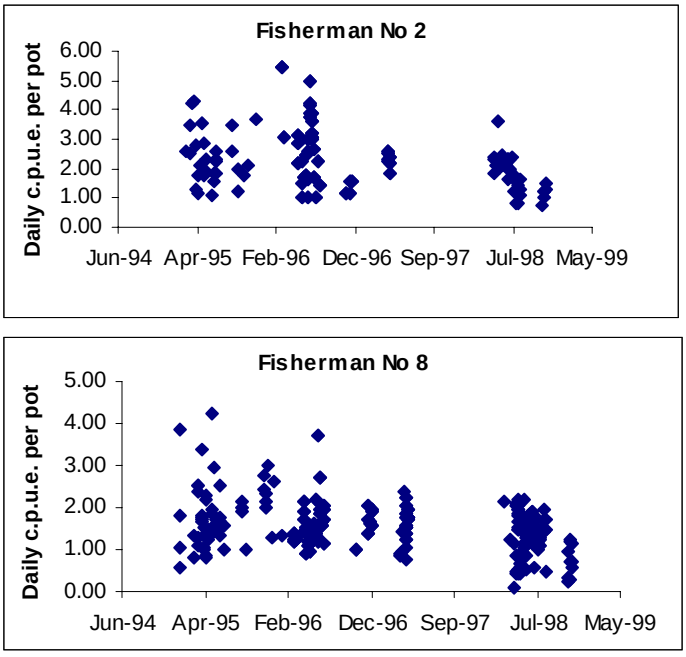

Fig. 21. Trend in daily landing (1994-1999) of two fishermen in the Wexford sector, corrected for increased pot numbers.

In fact, observance of the 1994 size limit was poor (Table 16). In one sector almost half the annual landings (by number) were reckoned to be undersized following its introduction. The survival of the whelk fishery in the southwest Irish Sea is therefore regarded as fortuitous. Dependence on a single customer introduced fluctuations in demand for the product thus making the market

unstable and has discouraged fishermen from remaining in it. Indeed, the fishery is characterised by a high turnover in participants (Tables 11-14).

There are indications that stocklets responded to changes within the fishery. Reduction in effort as a result of fishermen leaving it is one. The heavy landings in 1996 were accompanied or immediately followed by an increase in the mortality coefficient (***Z***); a reduction in landings in the next assessment was accompanied by an improvement in ***Z*** (Table 15).

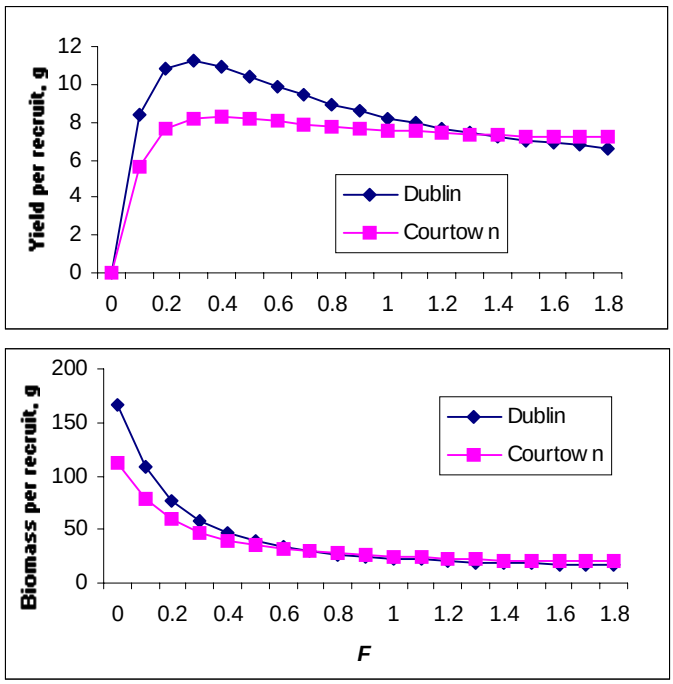

Fig. 22. Yield and biomass per recruit curves for whelk in the Dublin and Courtown sectors of the southwest Irish Sea fishery.

Ironically, the Codling and Rusk Banks which are reckoned to support the highest densities of whelk, have provided the greatest percentages of undersized landings (Table 16) yet, within the terms of this assessment, these stocklets would appear to be most resilient, responding in the Courtown sector to a reduction in fishing capacity with an increase in cpue (Fig 20). What occurred exactly in the Arklow sector is less clear because an increase in cpue there (Fig 19) might be explained by fishermen moving onto virgin ground.

The southwest Irish Sea whelk fishery is a valuable activity for the inshore fleet. At its peak in 1996 it supported 80 boats. The figure has halved since. This reduction in fishing effort has had a remedial effect but it is not a management measure. If the fishery is to survive into the future enforcement of the size regulation is a minimum requirement; enlargement of the size limit also requires consideration. Additional measures, such as those proposed by Anderson *et al* (1993), are also worthy of consideration.

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REFERENCES

Anderson, W D and A G Eversole (1984) Evolution of a *Busycon* fishery in the near shore South Atlantic Bight. *Journal of Shellfish Research* 4 (1): p 81.

Anderson, W D and A G Eversole (1988) Managing a predator: decline of an offshore *Busycon* fishery. *Journal of Shellfish Research* 7 (1): p 147

Anderson, W D and A G Eversole (1993) Over-exploitation and signs of recovery: analysis of an offshore whelk fishery. *Journal of Shellfish Research* 12 (1): 138

Cadée, G. C., J.P Boon, C.V Fischer,. B.P. Mensink, and C.C. ten Hallers-Tjabbes (1995) Why the whelk (*Buccinum undatum*) has become extinct in the Dutch Wadden Sea. *Netherlands Journal of Sea Research* 34: 337-339.

Duncan, S, C Gilling, G Hughes, S J Hawkins and R D M Nash (1989) The viability of establishing a whelk fishery in Manx waters Mimeo. Isle of Man. University of Liverpool.

Fahy, E (1999) Conflict between two inshore fisheries: for whelk (*Buccinum undatum*) and brown crab (*Cancer pagurus),* in the southwest Irish Sea. Paper delivered to the Third International Conference on Shellfish Restoration, Cork, Ireland, and September 1999.

Fahy, E and P Gleeson (1996) The Commerical exploitation of shrimp *Palaemon serratus* (Pennant) in Ireland. *Irish Fisheries Investigations* (New Series) (1): 28 pp.

Fahy, E, G Yalloway and P Gleeson (1995) Appraisal of the whelk *Buccinum undatum* fishery of the Southern Irish Sea with proposals for a management strategy. *Irish Fisheries Investigations,* Series B Marine 42: 26 pp.

Fitzsimons, M and J Mc Mahon (1999) Export and import trade in Irish seafood in 1998 and previous years. Mimeo. Bord Iascaigh Mhara.

Gendron, L (1991) Gestion de l'exploitation du buccin *Buccinum undatum* au Quebec: determination d'une taille minimale de capture. *Rapport Technical du Canadien Halieutique Aquatic* No 1833: 47 pp

Gendron, L (1992) Determination of the size at sexual maturity of the waved whelk *Buccinum undatum* Linnaeus, 1758, in the Gulf of St Lawrence, as a basis for the establishment of a minimum catchable size. *Journal of Shellfish Research* 11 (1): 1-7.

Gowanlock, J N (1926) Contribution to the study of marine gastropods II: the intertidal life of *Buccinum undatum*, a study in non-adaptation. Contributions to *Canadian Biology and Fisheries* 3: 169 – 177.

Gunnarson, K. and S. Einarsson (1995) Observations on the whelk populations (*Buccinum undatum*) in Breidifjördur, western Iceland. ICES C M 1995/K: 20

Hancock, D A (1963) Marking experiments with the commercial whelk (*Buccinum undatum*) ICNAF Special publication No 4: 176-187.

Hancock, D A (1967) Whelks Laboratory leaflet (New Series) 15. Ministry of Agriculture, Fisheries and Food, Burnham on Crouch, U.K.

Hancock, D A and A C Simpson (1962) Parameters of marine invertebrate populations. In: The exploitation of natural populations eds E D le Cren and M W Holdgate: 29 – 50.

Harvey, C, F X Garneau and J H Himmelman (1987) Chemodetection of the predatory seastar, *Lepasterias polaris*, by the whelk, *Buccinum undatum*. Marine Ecology Progress series 40: 79 – 86.

Herbst, S T (1995) The food lover's companion. Barron's Educational Services, New York.

Himmelman, J H (1988) Movement of whelks (*Buccinum undatum*) towards a baited trap. *Marine Biology* 97: 521 – 531.

Himmelman, J H and J R Hamel (1993) Diet, behaviour and reproduction of the whelk *Buccinum undatum* in the northern Gulf of St Lawrence, eastern Canada *Marine Biology* 116 (3): 423-430

Hylleberg, J (1991) Can gastropods be fought down by intensive fishing? A case story from Denmark 1910 Special publication Phuket Marine Biological Centre No 9: 113-116.

Jalbert, P, J H Himmelman, P Bélan and B Thomas (1989) Whelks (*Buccinum undatum*) and other subtidal invertebrate predators in the nothern Gulf of St Lawrence. *Canadian Naturalist* 116: 1 – 15.

Kideys, A E (1991) The ecology of the common whelk, *Buccinum undatum* L. off Douglas, Isle of Man, with particular reference to its ecological energetics. Mimeo. University of Liverpool.

Kideys, A E (1993) Estimation of the density of *Buccinum undatum* (Gastropoda) off Douglas, Isle of Man. *Helgoländer Meeresuntersuchungen* 47: 35 – 48.

Kideys, A E, R D M Nash and R G Hartnoll (1993) Reproductive cycle and energy cost of reproduction of the neogastropod *Buccinum undatum* in the Irish

Sea . *Journal of the Marine Biological Association of the United Kingdom* 73: 391 – 403.

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

Köie, M (1969) On the endoparasties of *Buccinum undatum* L with special reference to the Trematodes. *Ophelia* 6: 251 – 279.

Mahon, D (1986) The autecology of the Prosobranch mollusc *Buccinum undatum* L. with particular reference to its fishery potential B.Sc. thesis, University College, Dublin.

Martel, A, D H Larrivée, K R Klein and J H Himmelman (1986) Reproductive cycle and seasonal feeding activity of the neogastropod *Buccinum undatum Marine. Biology*. 92: 211-221

McQuinn, I H, L Gendron, J H Himmelman (1988) Area of attraction and effective area fished by a whelk (*Buccinum undatum*) trap under variable conditions. *Canadian Journal of Fisheries and Aquatic Science* 45: 2054 – 2060.

Miller, R J (1975) Density of the commercial spider crab, *Chionecetes opilio*, and calibration of effective area fished per trap usung bottom photography. *Journal of the Fisheries Research Board of Canada* 32: 761 – 768.

Miloslavich, P and L Dufresne (1994) The development and effect of female size on egg and juvenile production in the neogastropod *Buccinum cyaneum* from the Sanguenay Fjord. *Journal of Fisheries and Aquatic Sciences* 51 (12): 2866-2872.

Nicholson, G J & S M Evans (1997) Anthropogenic impacts on the stocks of the common whelk *Buccinum undatum* (l.) *Marine Environmental Research* 44 (3): 305-314

Nielsen, C (1975) Observations on *Buccinum undatum* L attacking bivalves and on prey responses, with a short review of attack methods of other Prosobranchs *Ophelia* 13: 87 – 108.

Ricker, W E (1975) Computation and interpretation of biological statistics of fish populations. *Bulletin of the Fisheries Research Board of Canada* 191: 382 pp

Robinson, I S (1979) The tidal dynamics of the Irish and Celtic Seas, *Journal of the Royal Astronomical Society* 56: 159 – 197.

Santarelli, L C (1988) Estimacion de la densidad poblacional de *Buccinum undatum* L (Gastropoda: Prosobranchia) per medio del modelo de extraccion sucesiva de DeLury *Anales del Instituto Cientifica del Mar y Limnologia del Universidad Autonoma Nacional de Mexico* 15 (1): 65-72

Santarelli, L and P Gros (1985) Dètermination de l'âge et de la croissance de *Buccinum undatum* L. (Gastropoda: Prosobranchia) à l'aide des isotopes stables de la coquille et de l'ornamentation operculaire. *Oceanologica Acta* 8: 221-229.

Santartelli, L and P Gros (1986) Exploitation du buccin dans le golf Normano-Breton. *La Peche maritime* 1986: 48 – 52.

Savard, L (ed) (1994) Rapport sur l'état des invertebrés en 1993: Crustacés et Molluscs des côtes du Quebec et crevette nordique de l'estuarie et de Golfe du Saint-Lautent. *Rapport Technical du Canadien Halieutique Aquatic*. No. 2257.

Ten Hallers-Tjabbes, C C, J M Everaarts, B P Mensink and J P Boon (1996) The decline of the North Sea whelk (*Buccinum undatum* L.) between 1970 and 1990: a natural or a human-induced event? *Marine Ecology* 17(1-3): 333-343.

Thomas, M L H and J H Himmelman (1988) Influence of predation on shell morphology of *Buccinum undatum* L. on Atlantic coast of Canada *Journal of Experimental Marine Biology and Ecology* 115: 221 – 236

Valentinsson, D A, F Sjodin, P R Jonsson, P Nilsson and C Wheatley (1999) Appraisal of the potential for a future fishery for whelks (*Buccinum undatum*) in Swedish waters: CPUE and biological aspects. *Fisheries Research.* 42: 215 – 227.

Vermeij, G J (1976) Interoceanic differences in vulnerability of shelled prey to crab predation. *Nature* (London) 260: 135 – 136

Table 1. Annual whelk landings (tonnes) from the immediate southwest Irish Sea with incidental landings from other ports adjoining.

PORTS (Sectors in capitals)	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Greencastle		1			86	19				
Skerries							35			
Howth		18	12	24	466	427	555	266	118	320
Dunlaoghaire		68	109	116	362	538	520	339	295	576
Greystones		45	91	86	67	77	1	28	15	104
TOTAL DUBLIN		**131**	**212**	**225**	**894**	**1042**	**1076**	**633**	**428**	**1000**
Arklow (when given separately)		335	665	1185	1780				892	371
Wicklow (when given separately)		60	84						1655	2388
TOTAL ARKLOW		**395**	**749**	**1185**	**1780**	**1178**	**2453**	**1784**	**2547**	**2759**
TOTAL COURTOWN	**56**	**310**	**415**	**285**	**530**	**778**	**864**	**475**	**396**	**568**
Cahore Point		52	85	60	82	91	114			
Wexford				485	1008	2786	1426	890	159	167
Rosslare						25	10	9	87	64
Carne		29	140						36	
TOTAL WEXFORD		**81**	**225**	**545**	**1091**	**2901**	**1550**	**899**	**282**	**231**
Kilmore			81	128				15	15	2
Fethard and Slade		35	366	190		4	15	11		1
Dunmore East				3	4		525	45		
Grand Total (for the 4 sectors)	**56**	**917**	**1601**	**2240**	**4295**	**5899**	**5943**	**3791**	**3652**	**4558**
Average annual price per tonne (Ir£)	203	380	353	355	339	459	517	440	430	444

Table 2. Percentage age frequency distribution of whelk landed within four sectors of the southwest Irish Sea fishery.

Ages	Dublin	Arklow	Courtown	Wexford
2	1	0	1	0
3	5	5	7	4
4	9	22	26	12
5	**18**	**29**	**32**	**27**
6	**18**	21	19	20
7	15	12	8	16
8	12	6	4	8
9	8	3	2	5
10	6	1	1	3
11	3	0	0	1
12	3	0	0	1
13	1	0	0	1
14	1	0	0	1
15+	1	0	0	1
Totals	100	100	100	100
Numbers aged	**1,538**	**5,110**	**1,730**	**1,394**

Table. 3. Details of growth curves for whelk in the four fishery sectors together with the details of their calculation.

	Number of length		Growth coefficients			Ford-Walford plot
Sector	**at age points used**	**Age range**	$L\infty$	k	**t0**	**r2**
Dublin	9	3 to 11	101.6	0.1899	-0.4091	0.7410
Arklow	10	2 to 11	107.0	0.1541	-0.3908	0.7600
Courtown	7	3 to 9	116.1	0.0956	-1.3718	0.9890
Wexford	6	4 to 9	105.5	0.1474	-0.6991	0.9770
All Irish Sea	11	2 to 12	106.0	0.1330	-0.9586	0.9800

Table 4. Comparison by t test of mean lengths at age of whelk of four years old in the four fishery sectors.

Sector	Mean	Sd	variance	Number
Arklow	48.63	7.69	59.1361	1159
Dublin	44.14	8.56	73.2736	123
Courtown	46.44	7.85	61.6225	404
Wexford	56.81	7.21	51.9841	128

Values of *t*

		Arklow	Dublin	Courtown	Wexford
	Arklow		5.58	4.85	12.10
Values of *P*	**Dublin**	<0.001		2.66	12.07
	Courtown	<0.001	<0.01		13.87

Table 5. Comparison by t test of mean lengths at age of whelk of five years old in the four fishery sectors.

Sector	Mean	Sd	variance	Number
Arklow	53.63	8.57	73.4449	1484
Dublin	52.14	10.19	103.8361	252
Courtown	52.14	8.8	77.44	477
Wexford	60.72	9.34	87.2356	351

Values of *t*

		Arklow	Dublin	Courtown	Wexford
	Arklow		2.19	3.24	12.99
Values of *P*	**Dublin**	0.025<0.05		0.00	10.56
	Courtown	0.005<0.001	N.S.		13.39
	Wexford	<0.001	<0.001	<0.001	

Table 6. Regression of log total weight on log total length in whelk from four sectors of the fishery in the southwest Irish Sea (above) and the calculated weights (g) at selected lengths (below).

Sector	Dublin	Arklow	Courtown	Wexford
N	859	5,558	1,385	2,030
r2	0.9744	0.9463	0.9352	0.9486
slope	2.8295	2.8099	2.8642	2.8928
Intercept	-8.4187	-8.2967	-8.4805	-8.6201

Shell length, mm	Dublin	Arklow	Courtown	Wexford
45	10.5	11.0	11.3	10.9
65	29.7	31.0	32.3	31.7
85	63.5	65.8	69.7	68.8
100	100.6	103.9	111.0	110.2

Table 7. Regression of log total weight on log total length and log shell weight on log total length of two samples (g) from the Dublin sector (mm) and west of the Wexford sector (above) and calculated total and shell weights at three total lengths.

Sector	Dublin		West of Wexford	
	Total weight	Shell weight	Total weight	Shell weight
N	24	15	22	11
r2	0.9626	0.9302	0.9782	0.9463
x-variable	2.7445	2.6855	2.9833	3.3857
intercept	-8.0748	-8.6701	-8.9875	-11.546
	Calculated weights at three total lengths			
Lengths, mm				
65	29.4	12.7	32.0	13.3
85	61.4	26.1	71.3	33.0
100	96.0	40.3	115.7	57.2

Table 8. Mean age and length of male maturation in whelk from four sectors of the fishery in the southwest Irish Sea.

Sector	Mean age, years	r2	Mean length, mm	r2	No observations
Dublin	8.5	0.461	83.2	0.497	367
Arklow	7.2	0.110	67.6	0.196	986
Courtown	6.7	0.168	63.2	0.341	257
Wexford	6.1	0.218	65.6	0.333	528

Table 9. Sex ratio of whelk from the southwest Irish Sea (above) by month, all samples combined/ unit (below) by sector.

			Percentages		
Month	**Females**	**Males**	**Females**	**Males**	X^2
January	306	292	6.7	7.7	0.15
February	620	548	13.5	14.4	0.06
March					
April	471	324	10.3	8.5	0.30
May	546	360	11.9	9.5	0.51
June	607	592	13.2	15.5	0.40
July	564	384	12.3	10.1	0.40
August	368	332	8.0	8.7	0.06
September	462	400	10.1	10.5	0.02
October	618	550	14	15.1	0.07
November	23	26			
December					
Totals	**4,585**	**3,808**	**100**	**100**	**2.03**

OVERALL RATIO (f/m)= 1.204
There are 8 degrees of freedom; 15.5 is significant at this level

			Percentages		
Month	**Females**	**Males**	**Females**	**Males**	X^2
Dublin	621	525	12.4	12.6	0.00
Arklow	2946	2398	59.0	57.6	0.04
Courtown	862	715	17.3	17.2	0.00
Wexford	562	527	11.3	12.7	0.17
Totals	**4,991**	**4,165**	**100**	**100**	**0.21**

OVERALL RATIO (f/m)= 1.1983
There are 3 degrees of freedom; 7.8 is significant at this level

Table 10. Sources of information used in the survey of cpue

Sector	Port or vicinity	Period	Source	No records
Dublin	Howth	1999	1 fisherman	29
Arklow	Wicklow	1999	1 fisherman	10
	Codling Bank	1999	BIM	224
	Arklow	1994/95 and 1998	1 fisherman	2,438
	Arklow	1994 - 1998	1 fisherman	580
Courtown	Courtown	1999	1 fisherman	93
Wexford	Wexford	1999	4 fishermen	150
	Rosslare	1999	1 fisherman	29
		Total number of records		**3,524**

Table.11. Records of fishermen landing into the Dublin sector and selling to Company B in the period 1995-1998 inclusive.

Code	1995	1996	1997	1998	Number of years	Number of Observations
Fisherman No 1	1				1	40
Fisherman No 2	1	1			2	35
Fisherman No 3	1	1			2	75
Fisherman No 4	1	1			2	115
Fisherman No 5			1	1	2	157
Fisherman No 6		1	1	1	3	207
Fisherman No 7	1	1	1	1	4	44
Fisherman No 8	1	1	1	1	4	442
Totals	**6**	**6**	**4**	**4**		

Table. 12. Records of fishermen landing into the Arklow sector and selling to Company B in the period 1995-1998 inclusive.

Code	1995	1996	1997	1998	Number of years	No. observations
Fisherman No 1				1	1	15
Fisherman No 2				1	1	24
Fisherman No 3	1				1	30
Fisherman No 4	1				1	31
Fisherman No 7	1				1	36
Fisherman No 8			1		1	43
Fisherman No 10	1				1	49
Fisherman No 13				1	1	53
Fisherman No 17	1				1	90
Fisherman No 20	1				1	101
Fisherman No 21				1	1	107
Fisherman No 22		1			1	109
Fisherman No 23	1				1	133
Fisherman No 12			1	1	2	52
Fisherman No 14			1	1	2	59
Fisherman No 15			1	1	2	83
Fisherman No 16			1	1	2	87
Fisherman No 19			1	1	2	97
Fisherman No 24	1	1			2	136
Fisherman No 25			1	1	2	138
Fisherman No 27			1	1	2	159
Fisherman No 28	1	1			2	160
Fisherman No 30	1	1			2	196
Fisherman No 31			1	1	2	206
Fisherman No 32	1	1			2	216
Fisherman No 33			1	1	2	217
Fisherman No 34	1	1			2	233
Fisherman No 37			1	1	2	269
Fisherman No 9		1	1	1	3	46
Fisherman No 11		1	1	1	3	49
Fisherman No 18		1	1	1	3	95
Fisherman No 35		1	1	1	3	254
Fisherman No 39		1	1	1	3	342
Fisherman No 40		1	1	1	3	378
Fisherman No 5	1	1	1	1	4	35
Fisherman No 6	1	1	1	1	4	35
Fisherman No 26	1	1	1	1	4	155
Fisherman No 29	1	1	1	1	4	178
Fisherman No 36	1	1	1	1	4	265
Fisherman No 38	1	1	1	1	4	287
Fisherman No 41	1	1	1	1	4	483
Fisherman No 42	1	1	1	1	4	491
Fisherman No 43	1	1	1	1	4	498
Fisherman No 44	1	1	1	1	4	509
Fisherman No 45	1	1	1	1	4	566
Totals	**23**	**23**	**28**	**31**		

Table. 13. Records of fishermen landing into the Courtown sector and selling to Company B in the period 1995-1998 inclusive.

Code	1995	1996	1997	1998	No. years	No. observations
Fisherman No 13				1	1	7
Fisherman No 14	1				1	15
Fisherman No 4	1	1			2	71
Fisherman No 8	1	1			2	128
Fisherman No 10		1	1		2	129
Fisherman No 15			1	1	2	94
Fisherman No 2	1	1	1		3	260
Fisherman No 3		1	1	1	3	280
Fisherman No 5	1	1	1		3	357
Fisherman No 9	1	1	1		3	264
Fisherman No 11	1	1	1		3	197
Fisherman No 12	1	1	1		3	102
Fisherman No 1	1	1	1	1	4	198
Fisherman No 6	1	1	1	1	4	331
Fisherman No 7	1	1	1	1	4	529
Fisherman No 16	1	1	1	1	4	273
Fisherman No 17	1	1	1	1	4	147
Fisherman No 18	1	1	1	1	4	258
Totals	**14**	**15**	**14**	**9**		

Table 14. Records of fishermen landing into the Wexford sector and selling to Company B in the period 1995-1998 inclusive.

Code	1995	1996	1997	1998	No. years	No. observations
Fisherman No 1		1			1	35
Fisherman No 2				1	1	37
Fisherman No 3				1	1	41
Fisherman No 7			1		1	84
Fisherman No 4		1	1		2	55
Fisherman No 6	1	1			2	81
Fisherman No 8			1	1	2	104
Fisherman No 9		1	1	1	3	115
Fisherman No 5	1	1	1	1	4	68
Fisherman No 10	1	1	1	1	4	162
Fisherman No 11	1	1	1	1	4	206
Totals	**4**	**7**	**7**	**7**		

Table 15. Coefficients of mortality (**Z**) calculated from the catch curves for each year in which an assessment was undertaken.

	Sectors				
Year	**Dublin**	**Arklow**	**Courtown**	**Wexford**	**Averages**
1994	0.40	0.56	0.66	0.48	**0.53**
1995					
1996	0.26	0.48	0.64	0.40	**0.45**
1997	0.81	0.90	0.94	0.51	**0.79**
1998					
1999	0.24	0.68	0.88	0.62	**0.61**
Averages	**0.43**	**0.66**	**0.78**	**0.50**	

Table 16. Percentage undersized whelk (<50mm long), by number, landed in each fishery sector annually.

Year	**Dublin**	**Arklow**	**Courtown**	**Wexford**	**Total**
1994	27.5	32.6	51.1	7.9	**31.4**
1995					
1996	4.6	27.5	47.6	12.0	**24.3**
1997	61.8	26.8	19.4	4.5	**32.7**
1998					
1999	12.3	33.8	48.9	1.6	**33.1**
Averages	**26.6**	**30.2**	**41.8**	**6.5**	

Appendix 1 Age at length key for whelk taken in the Dublin sector of the southwest Irish Sea fishery.

Length is measured in mm from the apex of the shell to the end of the siphonal canal

	Ages														
Length mm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Totals
18																0
19																0
20																0
21																0
22		4														4
23																0
24			1													1
25																0
26		2	1	1												4
27		1	3	1	1											6
28		2	5	1		1										9
29			3	1												4
30		2	4													6
31			3	2												5
32			2	3												5
33			4	3	1	1										9
34		1	3	3	2	2										11
35			1	3	2											6
36		1	6	6	3											16
37			3	5	4											12
38			7	4	1					1						13
39			3	3	4	2										12
40			1	2	7	4										14
41			2	7	9	2										20
42			1	8	5	3	1									18
43			2	9	10	4										25
44			2	6	11	7	1									27
45			1	6	10	6	3	1								27
46				7	8	4	3	1								23
47			1	5	10	4	2		1							23
48				5	14	3	2		1							25
49			1	6	7	5	2	1								22
50			1	2	12	4	4	1								24
51				1	11	3	3									18
52				4	14	6	4	2								30
53				3	4	8	3	3								21
54				1	10	7	4	1								23
55				1	13	6	5	1	1							27
56			2	1	1	6	7	5								22
57				2	7	5	3	4	1							22
58				2	8	8	1	2	1		1					23
59				3	6	5	6	3	1							24
60				2	5	7	4	3	1							22
61					6	7	5	3	2							23
62					4	7	6	1		1	1					20
63					3	9	2	1	1							16
64				2	6	8	4	4	4							28
65					2	10	6		1	1						20
66					3	4	2	2	1	2						14

67				5	5	1	3	1	1						16
68			1	5	5	2	1		2						16
69				5	5	9	2	1	1						23
70			1		6	1	3	1				1			13
71				3	9	4	1		1						18
72				1	3	5	2	1							12
73				2	2	5	3	1	1	1					15
74					2	4	4	4							14
75					3	5	3	2			1				14
76					2	2	4	3				1			12
77				1	1	6	5	5	1						19
78				2	3	4	6	2	1	1					19
79				1	2	4	2	3							12
80					6	5	5	1		2					19
81					5	4	1	4	2						16
82				1	3	11	8	1	3	1					28
83					3	2	6	4	1	2	1				19
84					3	2	9	2	1	1					18
85					2	3	6	3	1	3	2	1			21
86					1	5	9	6			2		1		24
87						2	4	5	4	3					18
88					1	4	2	6	1	1	1				16
89				1		6	2	3	4	2	3			1	22
90					3	3	2		1	1					10
91							3	3	7	1	2				16
92						2	4	6	3	4	3	2			24
93						2	1	4	4	2					13
94					2	2	3	2	2		3			1	15
95					2		1	3	1	1			1		9
96							1		1		1		1	1	5
97					1	1	2		2	1	4	1			12
98						2		1	2	2				2	9
99							1	1	1	1	2		1		7
100							2	2	4	1		1	1		11
101							1	1			2				4
102						1	1	4	5	4	1	1			17
103						1	1	1	1			1			5
104							1	1	1						3
105									1	1	1	1	1		5
106							1		2			1			4
107							1		2				1		4
108						1	2	1	1					2	7
109							1	1				1			3
110						1		2							3
111									1		2				3
112												2			2
113									1		1			1	3
114															0
115							1			2					3
116												1			1
117									1						1
118														1	1
119															0
120															0
Totals	13	63	123	251	238	195	160	108	74	40	32	15	7	9	1328

Appendix 2 Age at length key for whelk taken in the Arklow sector of the southwest Irish Sea fishery. *Length is measured in mm from the apex of the shell to the end of the siphonal canal*

	Ages															
Length mm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Totals
18																0
19		2														2
20																0
21			1													1
22																0
23			1													1
24																0
25		3														3
26			1	1												2
27		1	2													3
28		2	4	2												8
29		1	3	1												5
30		1	5	3												9
31		1	3	4		1			1							10
32			2	4	1											7
33		5	9	5												19
34			8	4	5											17
35			11	11		1										23
36		2	10	9	3	2										26
37		3	15	27	5	1										51
38			15	16	10											41
39			15	29	9	2	1									56
40		1	20	29	9	3	1	1	1							65
41			9	30	19	8										66
42		1	13	58	20	10	1									103
43		2	19	54	38	4	2		2							121
44			13	52	38	10	3									116
45			20	61	50	18	2	1				1				153
46			13	68	62	20	2									165
47		1	21	68	65	28	1	1	1							186
48		1	15	58	73	32	6	3								188
49			13	62	85	28	14	2	1							205
50			5	66	89	32	8	2	1							203
51			8	62	91	47	10	1	1							220
52			6	52	77	44	14	1	1	1						196
53			7	49	77	34	20	4		2						193
54		1	4	39	76	49	13	7								189
55			3	33	72	43	20	7				1				179
56			1	30	62	42	20	5	2							162
57			4	24	68	50	17	6								169
58			1	25	45	44	14	3	1	1						134
59			1	21	37	45	17	2	1							124
60			3	18	28	49	19	4	3							124
61				12	35	34	45	3	3	1						133
62				12	23	33	23	2	2							95
63			1	11	27	29	18	3	1	1						91
64				5	28	31	21	9	6							100
65				9	19	24	19	9	3		1					84
66				5	11	25	16	4	1	1						63

67			3	18	20	16	10	4	2						73
68			1	17	24	19	10	2		1					74
69			2	20	13	24	9	2							70
70			2	9	15	10	8	2	1						47
71		1	3	5	19	11	6	2	3						50
72				7	20	7	7	1	3						45
73			2	8	27	18	6	2							63
74			1	6	11	15	4	3	2						42
75				6	13	12	8	2							41
76				1	9	8	9	10	1						38
77			1	8	12	6	7	5	1						40
78			2	6	7	11	10	2	1						39
79				1	8	7	10	8	1						35
80			2	4	12	3	7	3	2						33
81				3	4	9	6	7	2						31
82			1	2	7	6	3	3	2						24
83				1	1	9	6	6	1	1					25
84					5	6	10	2	1						24
85				2	2	10	9	2	1						26
86					1	6	7	1	1					1	17
87			1	1	5	2	5	6	2				1		23
88					1	4	1	7		1					14
89					1	3	3	2	3						12
90					3	5	4		3					2	17
91				1	1	2	3	3				1			11
92						1	2		2	2				1	8
93					1	2	2	3	2	1			2		13
94						1	5	2							8
95					1	1	2		1						5
96						1	2	1	1	1	2				8
97					1					2					3
98				1				3							4
99				1			1	1		1	1				5
100							1	1				1	1	1	5
101															0
102								1	1						2
103						2			1	1					4
104							2				1				3
105						1	1								2
106						1	1		1		1		1	1	6
107												1			1
108								1		1	1				3
109												1			1
110									1	1					2
111															0
112															0
113												1			1
114													1		1
115															0
116															0
117															0
118															0
119															0
120															0
Totals	28	306	1150	1485	1067	586	267	132	50	14	8	5	6	6	5110

Appendix 3 Age at length key for whelk from the Courtown sector of the south west Irish Sea fishery.

Length is measured in mm from the apex of the shell to the end of the siphonal canal.

	Ages														
Length mm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Totals
18																0
19	1															0
20		1														1
21																0
22																0
23			4													4
24		1														1
25				1												1
26		1	1													2
27			2													2
28		1	4													5
29		2	1	1												4
30		1	6	1												8
31		1														1
32			6	1	1											8
33			4	7	1											12
34			3	3	3											9
35		1	6	5	3											15
36			9	14	5											28
37			2	12	2											16
38		2	6	14	6											28
39		1	5	24	3	1										34
40			11	25	9	5										50
41		2	8	17	19		2									48
42		1	5	16	18	2	1									43
43			3	19	18	2	1									43
44				20	13	2	1									36
45			2	18	12	12	1									45
46			1	15	22	9	3	1								51
47			4	13	10	7										34
48		1	1	22	25	8	3									60
49			5	20	29	7	1									62
50			5	15	21	12	3									56
51			3	14	22	12	5		1							57
52			5	12	26	12	1	1	1							58
53			2	18	26	11	4	1								62
54				7	24	13	3		1							48
55				8	39	11	6	1								65
56				28	20	11	3	2	1							65
57				6	18	19	3									46
58			1	9	8	15	3	2								38
59			1	5	17	15	5	1	1							45
60			1	3	8	13	5	3								33
61				5	14	12	8	2								41
62				3	10	12	3	2	1							31
63				2	3	8	3	1								17
64				1	6	5	2	2	1	1						18
65					6	7	3	1	1							18
66				2	8	4	2	4	2							22

67			4	6	4	6	2	1						23
68			1	2	9	2	3	1						18
69				3	2	5	2							12
70				3	4	3	1	1						12
71				3	4	4	3	1	1					16
72				3	4	5		2	1					15
73				1	4	1	3		1					10
74				2	3	3	1							9
75					1	1	1	1						4
76				1	1	3	2	1						8
77			1			1			1					3
78				1	3		1	1	1					7
79						2	2							4
80				1		3	1	3						8
81					3	2								5
82					1	1		1	1					4
83					1	1		1		1				4
84														0
85				2		1	1	2						6
86					1	1	1							3
87						2	1							3
88					2	1	2		1					6
89								1						1
90						1	1			1				3
91						1		1						2
92						1	1							2
93				1										1
94								1						1
95						1					1			2
96								1						1
97							1							1
98														0
99														0
100									1					1
101														0
102														0
103														0
104														0
105														0
106														0
107														0
108														0
109														0
110														0
111														0
112							1							1
113														0
114														0
115														0
116														0
117														0
118														0
119														0
120														0
Totals	16	117	412	504	294	127	55	30	9	2	1	0	0	0	1567

Appendix 4 Age at length key for whelk taken in the Wexford sector of the southwest Irish Sea fishery.

Length is measured in mm from the apex of the shell to the end of the siphonal canal

	Ages														
Length mm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Totals
18																0
19																0
20																0
21																0
22																0
23																0
24																0
25																0
26																0
27																0
28																0
29																0
30																0
31																0
32																0
33			1													1
34																0
35																0
36																0
37																0
38			2													2
39																0
40					1											1
41			3		1											4
42				1	2											3
43				2												2
44					1											1
45			2	3	3	1										9
46				5	5	1	1									12
47			1	3	7	2	1									14
48			2	3	7		1									13
49			2	4	6	2	2									16
50			1	5	6	1	1									14
51				7	12	8	2									29
52				8	14	8	3									33
53			1	11	16	6	1									35
54			2	7	16	9	2									36
55				9	13	11	3									36
56			1	7	21	7	3									39
57			1	7	17	7	5									37
58				9	13	10	5									37
59				4	11	8	5									28
60			1	5	20	9	2	2								39
61				5	17	8	3	1	1							35
62				4	16	5	4	2								31
63			1	3	14	13	4									35
64				2	10	3	6									21
65				1	8	9	4	1								23
66				2	7	15	4									28
67				2	3	11	6									22

68			3	11	9	3	2	1						29
69			1	12	12		3							28
70				4	10	9	2	1						26
71			3	5	6	4	2							20
72				8	9	7	2	1						27
73				5	13	9	2	1			1			31
74				7	9	5	6	2						29
75				6	6	6	4	1	1					24
76				6	9	6	4							25
77				3	8	8		1			1			21
78				3	7	5	8	1	1	1	1			27
79				3	7	4	4		1					19
80			1	2	7	5	1	2	1		1			20
81				2	3	5	2	2	1		1		1	17
82				2	3	8	4			1				18
83				2	3	6	6	2	1	1				1 22
84				1	2	5	5		1	1	1			16
85			1	1	2	3	3	1		2			1	14
86				1	1	5	6	2	2	1				18
87					4	5	3	3				1		16
88				1	1	4	3	3	2			1		15
89				1	2	2	1	1	2	1		1	1	12
90					2	1	2		1		1			7
91						3	4	2	1		1			11
92						2	2	4			2		1	11
93					1	1		1	2	1		2	1	9
94					2	3	1	1						7
95					1	1								2
96						1	1		1				1	4
97							1				1			1 3
98									1					1
99								1						1
100														1 1
101								1						1
102												1		1
103					2		1							3
104														0
105														0
106					1									1
107														0
108						1		1						2
109						1								1
110														0
111					1	1								2
112							1							1
113														0
114							1							1
115														0
116														0
117														0
118														0
119														0
120														0
Totals	21	128	353	297	197	93	37	19	9	11	6	6	3	1180

Appendix 5 Age composition of landings in 1999

STAGE 1 **Length frequencies (Percentages)**

Length	Dublin	Arklow	Courtown	Wexford
20	0	0.040749796	0	0
21	0.454545455	0.040749796	0	0
22	0	0	0	0
23	0	0.040749796	0	0
24	0	0.040749796	0	0
25	0	0.162999185	0	0
26	0	0.040749796	0.152905199	0
27	0.454545455	0.081499593	0	0
28	0	0.162999185	0	0
29	0	0.122249389	0.152905199	0
30	0.454545455	0.203748981	0.152905199	0
31	0	0.366748166	0.152905199	0
32	0	0.162999185	0	0
33	0	0.448247759	1.529051988	0
34	0	0.733496333	0.764525994	0
35	1.363636364	0.570497148	0.917431193	0
36	0.454545455	0.366748166	2.140672783	0
37	0	1.140994295	2.293577982	0
38	1.363636364	1.140994295	1.22324159	0
39	0.909090909	1.263243684	2.293577982	0
40	0.454545455	1.548492258	2.44648318	0
41	0.909090909	1.711491443	4.587155963	0
42	0.909090909	2.363488183	3.516819572	0
43	0	2.241238794	3.363914373	0
44	0.909090909	2.567237164	4.128440367	0
45	1.363636364	2.93398533	3.669724771	0
46	0.909090909	3.463732681	2.752293578	0.78125
47	0.909090909	3.178484108	4.281345566	0
48	0	3.382233089	4.740061162	0
49	0.454545455	3.2599837	3.669724771	0.78125
50	0.909090909	3.91198044	3.822629969	0
51	1.363636364	4.360228199	3.058103976	1.5625
52	0	3.993480033	3.669724771	0
53	0.909090909	3.015484923	3.822629969	1.5625
54	1.363636364	3.2599837	2.752293578	0
55	1.363636364	3.952730236	2.905198777	6.25
56	0.909090909	2.567237164	3.211009174	3.125
57	1.818181818	2.93398533	1.681957187	2.34375
58	0.454545455	2.322738386	1.681957187	2.34375
59	1.363636364	1.915240424	2.44648318	2.34375
60	1.818181818	1.915240424	2.140672783	3.125
61	1.363636364	1.792991035	1.834862385	2.34375
62	1.363636364	1.95599022	1.070336391	6.25
63	0	1.344743276	1.376146789	3.125

64	0.454545455	1.670741646	1.070336391	4.6875
65	0.454545455	1.874490628	0.764525994	3.90625
66	0.909090909	1.385493073	1.376146789	3.125
67	1.818181818	1.263243684	1.529051988	2.34375
68	0.909090909	1.466992665	1.22324159	5.46875
69	1.363636364	1.344743276	1.22324159	3.125
70	1.363636364	1.466992665	0.458715596	3.125
71	0.454545455	0.896495518	0.305810398	0.78125
72	0.909090909	0.855745721	1.22324159	3.125
73	0.454545455	1.059494703	0.917431193	2.34375
74	0.454545455	1.222493888	0.917431193	3.90625
75	0.909090909	0.937245314	0.152905199	3.90625
76	0.454545455	0.896495518	0.152905199	2.34375
77	0	1.181744091	0.152905199	3.90625
78	2.727272727	0.937245314	0.152905199	0.78125
79	0.454545455	0.814995925	0.152905199	2.34375
80	0.909090909	0.814995925	0.764525994	0.78125
81	0.454545455	0.733496333	0.458715596	0
82	2.727272727	0.488997555	0.152905199	2.34375
83	1.818181818	0.692746536	0.152905199	1.5625
84	0.454545455	0.611246944	0	3.125
85	4.090909091	0.692746536	0.152905199	1.5625
86	1.363636364	0.529747351	0.305810398	0.78125
87	1.363636364	0.570497148	0	0
88	2.272727273	0.32599837	0.305810398	1.5625
89	2.272727273	0.32599837	0.152905199	1.5625
90	1.818181818	0.285248574	0.305810398	0
91	2.727272727	0.244498778	0	0
92	5.454545455	0.040749796	0.152905199	0.78125
93	1.363636364	0.203748981	0.152905199	0
94	2.272727273	0.244498778	0.152905199	0.78125
95	0.909090909	0.081499593	0.152905199	0
96	1.818181818	0.162999185	0.152905199	0
97	1.818181818	0	0.152905199	0
98	2.727272727	0.081499593	0	0
99	2.727272727	0.081499593	0	0
100	2.727272727	0.122249389	0	0
101	1.818181818	0.040749796	0.152905199	0
102	2.727272727	0.040749796	0	0
103	1.363636364	0.040749796	0	0
104	1.363636364	0	0	0
105	0.454545455	0	0	0
106	1.363636364	0.040749796	0	0
107	0	0.081499593	0	0
108	0.454545455	0	0	0
109	0.454545455	0.040749796	0	0
110	1.363636364	0.081499593	0	0
111	0.909090909	0	0	0
112	0	0	0	0

113	0.454545455	0	0	0
114	0.454545455	0	0	0
115	0.454545455	0	0	0
116	0.454545455	0	0	0
117	0	0	0	0
118	0	0	0	0
119	0	0	0	0
120	0	0	0	0

STAGE 2 AVERAGE WEIGHTS - Averaged from 1994-1999 inclusive

Intercept	*-8.418714114*	*-8.296672477*	*-8.48047064*	*-8.620117861*
x-variable	*2.829476986*	*2.809901052*	*2.864181112*	*2.892827461*

Length	Dublin	Arklow	Courtown	Wexford
20	1.059335061	1.128668693	1.105004221	1.047094018
21	1.216152342	1.294512691	1.270731884	1.205820505
22	1.387244451	1.475284665	1.451844434	1.379518646
23	1.573173017	1.671557822	1.648973	1.568823398
24	1.774495326	1.88390043	1.862744828	1.774366632
25	1.991764548	2.112876078	2.093783464	1.996777276
26	2.225529931	2.359043907	2.342708937	2.236681457
27	2.47633699	2.622958817	2.610137912	2.494702621
28	2.744727669	2.905171665	2.89668384	2.771461648
29	3.031240501	3.206229442	3.202957093	3.067576957
30	3.336410746	3.526675434	3.529565088	3.383664605
31	3.660770525	3.867049377	3.877112401	3.720338374
32	4.004848942	4.227887597	4.246200877	4.078209855
33	4.369172197	4.609723138	4.637429731	4.457888531
34	4.754263692	5.013085886	5.051395636	4.859981843
35	5.160644131	5.438502685	5.488692815	5.285095265
36	5.588831611	5.886497436	5.949913121	5.733832362
37	6.039341713	6.357591206	6.435646115	6.206794854
38	6.512687579	6.852302313	6.946479135	6.704582673
39	7.009379989	7.371146421	7.482997369	7.227794014
40	7.529927439	7.914636619	8.045783915	7.777025388
41	8.074836204	8.483283499	8.635419843	8.352871667
42	8.644610405	9.077595234	9.252484255	8.955926133
43	9.23975207	9.698077644	9.897554336	9.586780517
44	9.860761194	10.34523427	10.57120541	10.24602504
45	10.50813579	11.01956641	11.27401097	10.93424846
46	11.18237195	11.72157324	12.00654277	11.6520381
47	11.88396387	12.45175179	12.76937083	12.39997988
48	12.61340396	13.21059707	13.56306346	13.17865836
49	13.37118279	13.99860208	14.38818738	13.98865677
50	14.15778923	14.81625785	15.24530767	14.83055704

51	14.97371045	15.66405355	16.13498786	15.70493982
52	15.81943194	16.54247647	17.05778995	16.61238453
53	16.69543758	17.45201208	18.01427444	17.55346936
54	17.60220966	18.3931441	19.00500038	18.52877132
55	18.54022895	19.36635449	20.03052537	19.53886624
56	19.50997465	20.37212355	21.09140564	20.58432884
57	20.51192453	21.41092988	22.18819601	21.66573267
58	21.54655488	22.4832505	23.32144998	22.78365023
59	22.61434056	23.58956082	24.49171973	23.93865293
60	23.71575506	24.7303347	25.69955615	25.13131111
61	24.85127048	25.90604447	26.94550884	26.3621941
62	26.02135759	27.11716096	28.23012619	27.63187018
63	27.22648586	28.36415356	29.55395535	28.94090667
64	28.46712344	29.64749019	30.91754229	30.28986989
65	29.74373724	30.96763739	32.32143177	31.6793252
66	31.05679291	32.3250603	33.76616744	33.10983701
67	32.4067549	33.7202227	35.25229178	34.58196881
68	33.79408645	35.15358705	36.78034617	36.09628316
69	35.21924961	36.62561447	38.35087089	37.65334174
70	36.68270529	38.13676483	39.96440515	39.25370533
71	38.18491326	39.68749671	41.62148708	40.89793385
72	39.72633217	41.27826746	43.32265379	42.58658636
73	41.30741956	42.9095332	45.06844135	44.32022108
74	42.9286319	44.58174883	46.85938481	46.09939538
75	44.59042459	46.29536811	48.69601826	47.92466584
76	46.29325198	48.05084359	50.57887477	49.79658822
77	48.03756739	49.84862671	52.50848646	51.71571749
78	49.82382313	51.68916775	54.48538453	53.68260783
79	51.65247051	53.57291592	56.51009919	55.69781265
80	53.52395983	55.50031929	58.58315977	57.76188463
81	55.43874044	57.47182488	60.70509467	59.87537565
82	57.39726074	59.48787866	62.8764314	62.03883689
83	59.39996817	61.54892552	65.09769658	64.25281879
84	61.44730926	63.65540935	67.36941597	66.51787106
85	63.53972959	65.80777301	69.69211447	68.83454272
86	65.67767387	68.00645837	72.06631611	71.20338208
87	67.8615859	70.2519063	74.49254411	73.62493675
88	70.09190862	72.54455669	76.97132086	76.09975368
89	72.36908408	74.8848485	79.50316791	78.62837912
90	74.69355348	77.27321972	82.08860604	81.21135868
91	77.06575718	79.7101074	84.72815521	83.8492373
92	79.48613471	82.19594768	87.42233462	86.54255926
93	81.95512478	84.7311758	90.17166266	89.29186823
94	84.47316526	87.31622607	92.976657	92.09770723
95	87.04069325	89.95153195	95.83783451	94.96061864
96	89.65814505	92.637526	98.75571135	97.88114425
97	92.32595617	95.37463991	101.7308029	100.8598252
98	95.04456135	98.16330454	104.7636239	103.8972021
99	97.81439456	101.0039499	107.8546883	106.9938149

100	100.635889	103.8970051	111.0045092	110.1502029
101	103.5094772	106.8428986	114.2135994	113.366905
102	106.4355909	109.8420579	117.4824705	116.6444594
103	109.4146611	112.8949096	120.8116338	119.9834037
104	112.447118	116.0018798	124.2015998	123.3842749
105	115.5333913	119.1633936	127.6528782	126.8476097
106	118.6739099	122.3798753	131.1659782	130.3739439
107	121.8691018	125.6517487	134.7414083	133.9638131
108	125.1193946	128.9794364	138.3796763	137.617752
109	128.4252152	132.3633606	142.0812894	141.336295
110	131.7869896	135.8039427	145.8467541	145.119976
111	135.2051434	139.3016033	149.6765764	148.9693282
112	138.6801012	142.8567622	153.5712616	152.8848844
113	142.2122874	146.4698387	157.5313143	156.8671768
114	145.8021254	150.1412512	161.5572386	160.9167372
115	149.4500381	153.8714175	165.649538	165.0340969
116	153.1564476	157.6607546	169.8087153	169.2197866
117	156.9217758	161.5096789	174.0352728	173.4743364
118	160.7464435	165.4186061	178.3297122	177.7982763
119	164.6308711	169.3879513	182.6925346	182.1921354
120	168.5754785	173.4181287	187.1242404	186.6564426

STAGE 3 **Weight distribution in sample for year**

Length	Dublin	Arklow	Courtown	Wexford
20	0	0.045993019	0	0
21	0.552796519	0.052751128	0	0
22	0	0	0	0
23	0	0.068115641	0	0
24	0	0.076768559	0	0
25	0	0.344397079	0	0
26	0	0.096130559	0.358212376	0
27	1.125607723	0.213770075	0	0
28	0	0.473540614	0	0
29	0	0.391959589	0.489748791	0
30	1.516550339	0.718556527	0.539688851	0
31	0	1.418233268	0.592830642	0
32	0	0.689142233	0	0
33	0	2.066298065	7.090871149	0
34	0	3.677080112	3.861923269	0
35	7.037241996	3.102650268	5.035497996	0
36	2.540378005	2.15886214	12.73681708	0
37	0	7.253975296	14.76065623	0
38	8.880937607	7.818437847	8.497222184	0
39	6.372163627	9.311554159	17.162838	0
40	3.422694291	12.25575353	19.68387502	0
41	7.340760186	14.51906711	39.61201763	0
42	7.858736732	21.45478906	32.53931772	0
43	0	21.73570784	33.29452529	0

44	8.964328358	26.55866988	43.64259113	0
45	14.32927608	32.3312462	41.37251733	0
46	10.16579268	40.60039631	33.04553057	9.103154767
47	10.80360352	39.57769519	54.67008917	0
48	0	44.68131854	64.28975037	0
49	6.077810359	45.63521459	52.80068764	10.9286381
50	12.87071749	57.96091091	58.27716999	0
51	20.41869607	68.29884801	49.34247051	24.53896847
52	0	66.06204948	62.59739429	0
53	15.17767052	52.62627931	68.86190534	27.42729588
54	24.00301318	59.96134996	52.30734049	0
55	25.28213038	76.54997497	58.19265781	122.117914
56	17.73634059	52.30007267	67.724697	64.32602761
57	37.29440824	62.81935418	37.31959573	50.77906095
58	9.793888581	52.22270899	39.2256804	53.39918024
59	30.83773713	45.17968047	59.91858038	56.10621781
60	43.11955465	47.36453671	55.01434037	78.53534723
61	33.8880961	46.44930548	49.44130062	61.78639241
62	35.48366944	53.04090164	30.2157314	172.6991886
63	0	38.14250478	40.67058076	90.44033335
64	12.93960156	49.53329657	33.09217064	141.9837651
65	13.51988056	58.04854605	24.71057475	123.7473641
66	28.2334481	44.78614712	46.4672029	103.4682407
67	58.92137255	42.59685834	53.90258682	81.05148939
68	30.72189677	51.57005434	44.99124914	197.4015485
69	48.02624947	49.2520488	46.9123803	117.6666929
70	50.02187085	55.94635428	18.33229594	122.6678292
71	17.35677875	35.57966291	12.72828351	31.95151082
72	36.11484742	35.32370076	52.99407191	133.0830824
73	18.7760998	45.46242311	41.3471939	103.8755182
74	19.5130145	54.50091544	42.9902613	180.0757632
75	40.53674962	43.39011681	7.445874351	187.2057259
76	21.04238726	43.07736589	7.7337729	116.7107536
77	0	58.90832007	8.02882056	202.0145214
78	135.883154	48.44543025	8.331098552	41.93953736
79	23.47839568	43.66170816	8.64068795	130.5417484
80	48.6581453	45.23253406	44.78834845	45.12647236
81	25.19942747	42.15537277	27.8463737	0
82	156.5379838	29.08942722	9.614133241	145.403524
83	107.9999421	42.63780497	9.953776235	100.3950294
84	27.93059512	38.90917442	0	207.8683471
85	259.9352574	45.58810682	10.65628662	107.553973
86	89.56046437	36.02624119	22.03862878	55.62764225
87	92.53852623	40.07851215	0	0
88	159.2997923	23.64940723	23.53863023	118.9058651
89	164.4751911	24.41233855	12.15644769	122.8568424
90	135.8064609	22.04207571	25.10354925	0
91	210.1793378	19.48902381	0	0
92	433.5607348	3.349468121	13.36732945	67.61137442

93	111.7569883	17.26389075	13.787716	0
94	191.9844665	21.34871053	14.21661422	71.95133377
95	79.12790296	7.331013199	14.65410314	0
96	163.0148092	15.09984124	15.10026167	0
97	167.8653749	0	15.55516864	0
98	259.21244	8.000269319	0	0
99	266.7665306	8.231780758	0	0
100	274.4615155	12.70134537	0	0
101	188.1990495	4.35382635	17.46385311	0
102	290.2788843	4.476041478	0	0
103	149.2018106	4.600444565	0	0
104	153.3369791	0	0	0
105	52.51517787	0	0	0
106	161.8280589	4.986954986	0	0
107	0	10.24056631	0	0
108	56.87245211	0	0	0
109	58.37509782	5.393779976	0	0
110	179.7095313	11.06796599	0	0
111	122.9137667	0	0	0
112	0	0	0	0
113	64.64194882	0	0	0
114	66.27369336	0	0	0
115	67.93183548	0	0	0
116	69.61656711	0	0	0
117	0	0	0	0
118	0	0	0	0
119	0	0	0	0
120	0	0	0	0
Total weights kg	**6.065547087**	**2.426145419**	**1.963676399**	**3.880873214**

STAGE 4 Insert landed weights

Landed weights for year (kg)	**999600**	**2759000**	**567700**	**231200**
Raising factors	**164799.6439**	**1137194.819**	**289100.5871**	**59574.22137**

STAGE 5 Numbers landed in each port

Length	Dublin	Arklow/Wicklow	Courtown	Wexford	TOTALS
20	0	46340.45717	0	0	46340.45717
21	74908.92905	46340.45717	0	0	121249.3862

22	0	0	0	0	0
23	0	46340.45717	0	0	46340.45717
24	0	46340.45717	0	0	46340.45717
25	0	185361.8287	0	0	185361.8287
26	0	46340.45717	44204.98274	0	90545.43991
27	74908.92905	92680.91433	0	0	167589.8434
28	0	185361.8287	0	0	185361.8287
29	0	139021.3715	44204.98274	0	183226.3542
30	74908.92905	231702.2858	44204.98274	0	350816.1976
31	0	417064.1145	44204.98274	0	461269.0972
32	0	185361.8287	0	0	185361.8287
33	0	509745.0288	442049.8274	0	951794.8562
34	0	834128.229	221024.9137	0	1055153.143
35	224726.7871	648766.4003	265229.8965	0	1138723.084
36	74908.92905	417064.1145	618869.7584	0	1110842.802
37	0	1297532.801	663074.7411	0	1960607.542
38	224726.7871	1297532.801	353639.8619	0	1875899.45
39	149817.8581	1436554.172	663074.7411	0	2249446.771
40	74908.92905	1760937.372	707279.7239	0	2543126.025
41	149817.8581	1946299.201	1326149.482	0	3422266.541
42	149817.8581	2687746.516	1016714.603	0	3854278.977
43	0	2548725.144	972509.6203	0	3521234.764
44	149817.8581	2919448.801	1193534.534	0	4262801.194
45	224726.7871	3336512.916	1060919.586	0	4622159.289
46	149817.8581	3938938.859	795689.6894	46542.36045	4930988.767
47	149817.8581	3614555.659	1237739.517	0	5002113.034
48	0	3846257.945	1370354.465	0	5216612.41
49	74908.92905	3707236.573	1060919.586	46542.36045	4889607.449
50	149817.8581	4448683.888	1105124.569	0	5703626.315
51	224726.7871	4958428.917	884099.6548	93084.7209	6160340.08
52	0	4541364.802	1060919.586	0	5602284.388
53	149817.8581	3429193.83	1105124.569	93084.7209	4777220.978
54	224726.7871	3707236.573	795689.6894	0	4727653.05
55	224726.7871	4495024.345	839894.6721	372338.8836	5931984.688
56	149817.8581	2919448.801	928304.6376	186169.4418	4183740.739
57	299635.7162	3336512.916	486254.8102	139627.0813	4262030.524
58	74908.92905	2641406.058	486254.8102	139627.0813	3342196.879
59	224726.7871	2178001.487	707279.7239	139627.0813	3249635.079
60	299635.7162	2178001.487	618869.7584	186169.4418	3282676.403
61	224726.7871	2038980.115	530459.7929	139627.0813	2933793.777
62	224726.7871	2224341.944	309434.8792	372338.8836	3130842.494
63	0	1529235.086	397844.8447	186169.4418	2113249.373
64	74908.92905	1899958.744	309434.8792	279254.1627	2563556.715
65	74908.92905	2131661.03	221024.9137	232711.8022	2660306.675
66	149817.8581	1575575.544	397844.8447	186169.4418	2309407.688
67	299635.7162	1436554.172	442049.8274	139627.0813	2317866.797
68	149817.8581	1668256.458	353639.8619	325796.5231	2497510.701
69	224726.7871	1529235.086	353639.8619	186169.4418	2293771.177
70	224726.7871	1668256.458	132614.9482	186169.4418	2211767.635

71	74908.92905	1019490.058	88409.96548	46542.36045	1229351.313
72	149817.8581	973149.6005	353639.8619	186169.4418	1662776.762
73	74908.92905	1204851.886	265229.8965	139627.0813	1684617.793
74	74908.92905	1390213.715	265229.8965	232711.8022	1963064.343
75	149817.8581	1065830.515	44204.98274	232711.8022	1492565.158
76	74908.92905	1019490.058	44204.98274	139627.0813	1278231.051
77	0	1343873.258	44204.98274	232711.8022	1620790.043
78	449453.5743	1065830.515	44204.98274	46542.36045	1606031.432
79	74908.92905	926809.1433	44204.98274	139627.0813	1185550.136
80	149817.8581	926809.1433	221024.9137	46542.36045	1344194.276
81	74908.92905	834128.229	132614.9482	0	1041652.106
82	449453.5743	556085.486	44204.98274	139627.0813	1189371.124
83	299635.7162	787787.7718	44204.98274	93084.7209	1224713.192
84	74908.92905	695106.8575	0	186169.4418	956185.2283
85	674180.3614	787787.7718	44204.98274	93084.7209	1599257.837
86	224726.7871	602425.9432	88409.96548	46542.36045	962105.0562
87	224726.7871	648766.4003	0	0	873493.1875
88	374544.6452	370723.6573	88409.96548	93084.7209	926762.9889
89	374544.6452	370723.6573	44204.98274	93084.7209	882558.0062
90	299635.7162	324383.2002	88409.96548	0	712428.8818
91	449453.5743	278042.743	0	0	727496.3173
92	898907.1485	46340.45717	44204.98274	46542.36045	1035994.949
93	224726.7871	231702.2858	44204.98274	0	500634.0557
94	374544.6452	278042.743	44204.98274	46542.36045	743334.7314
95	149817.8581	92680.91433	44204.98274	0	286703.7552
96	299635.7162	185361.8287	44204.98274	0	529202.5276
97	299635.7162	0	44204.98274	0	343840.6989
98	449453.5743	92680.91433	0	0	542134.4886
99	449453.5743	92680.91433	0	0	542134.4886
100	449453.5743	139021.3715	0	0	588474.9458
101	299635.7162	46340.45717	44204.98274	0	390181.1561
102	449453.5743	46340.45717	0	0	495794.0314
103	224726.7871	46340.45717	0	0	271067.2443
104	224726.7871	0	0	0	224726.7871
105	74908.92905	0	0	0	74908.92905
106	224726.7871	46340.45717	0	0	271067.2443
107	0	92680.91433	0	0	92680.91433
108	74908.92905	0	0	0	74908.92905
109	74908.92905	46340.45717	0	0	121249.3862
110	224726.7871	92680.91433	0	0	317407.7015
111	149817.8581	0	0	0	149817.8581
112	0	0	0	0	0
113	74908.92905	0	0	0	74908.92905
114	74908.92905	0	0	0	74908.92905
115	74908.92905	0	0	0	74908.92905
116	74908.92905	0	0	0	74908.92905
117	0	0	0	0	0
118	0	0	0	0	0
119	0	0	0	0	0

120	0	0	0	0	0
Totals	16405055.46	113719481.9	28910058.71	5957422.137	164992018.2
Numbers <50 mm	2022541.1	38416239.0	14145594.5	93084.7	54677459.3
Percentage < 50 mm	**12.3**	**33.8**	**48.9**	**1.6**	**33.1**