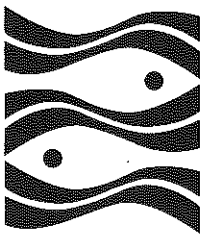
SERIES B (MARINE) No. 42 1995



IRISH FISHERIES INVESTIGATIONS

EDWARD FAHY, GARY YALLOWAY AND PAUL GLEESON

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Roinn na Mara
(Department of the Marine)

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by

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ABSTRACT

A small occasional fishery for whelk in the southern Irish Sea expanded in the early 1990s, particularly in 1993, to provide meat for the Far East. Between 1990 and 1993 the weight of whelk delivered by a fisherman to factory per day remained stable but the fishing effort increased by 44%. The quality of landings declined, increasing proportions of smaller whelk being retained. The most heavily fished populations apparently display a Lee effect.

An age at length key was prepared from 3,081 individuals and is used to transform length to age frequencies within the area of interest. The weight compositions of graded samples, abstracted from processors' financial accounts, were converted to population numbers. The age of full recruitment is reckoned to be five years over the area of interest although it may fall to four in the most intensely fished whelk patches.

A Thompson-Bell yield per recruit curve has F*max* at F=0.3. Only one fishery, at the northern fringes of the fishing area, has an F value (read from the catch curve) of less than this. F values of fisheries at the centre and south of the exploited area are all situated on the negative slope of the yield per recruit curve.

Male maturation occurs at a length of 70 - 80 mm in the least and 50 mm in the most exploited populations. Thus, a measure to protect broodstock would require a size limit of approximately 70 - 80 mm which would, coincidentally, approximate the size for maximum sustainable yield. It would also have a catastrophic effect on the existing fisheries. A size limit of 50 mm is already in force.

INTRODUCTION

A small inshore fishery for whelk has been in existence irregularly from the 1960s, supplying a small niche market in the United Kingdom. In the 1990s it expanded rapidly to provide whelk meat for the Far East. The fishery is pursued by a variety of craft; initially these were small half-decked vessels (less than 6 m in length) although more substantial boats (greater than 10 m in length) have become involved in the recent past. Whelk are fished with pots, plastic containers weighted with concrete and perforated with holes of 25 mm diameter. Three large processors, one in Co Wicklow, the others in Co Wexford, prepare the meat for export.

Whelk is a cold water, northern species ranging from 15 - 1,200 m depth. It is widely distributed, particularly on soft substrata; mature whelk move inshore and onto hard ground during the winter months to spawn (Martel et al, 1986). It is fished on all coasts but the majority of landings come from the southern Irish Sea (Fig 1). Although this fishery is gradually expanding northwards and offshore, it is carried out predominantly within 10 km of the coastline.

The rapid expansion of the Irish Sea whelk fishery and the landing of some very small material prompted conservation measures. In September 1994 a size limit was introduced for whelk. This paper contains details of the associated investigations intended to assess the fishery.

Statistics on the whelk fishery are poor and incomplete; available details have been tabulated below. Almost all landings are from the southern Irish Sea.

Status of the fishery

Information supplied by Bord Iascaigh Mhara identifies the principal current markets for Irish whelk as South Korea, Japan, the U.K. and Holland.

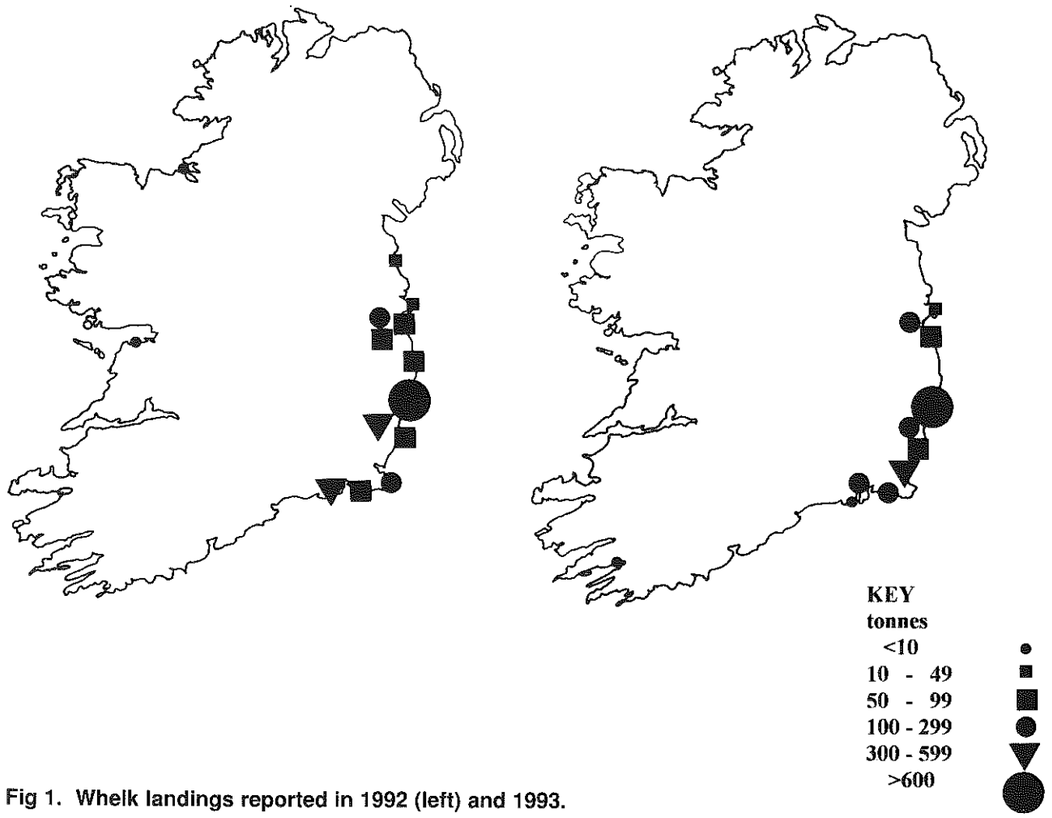

Fig 1. Whelk landings reported in 1992 (left) and 1993.

Year	Landings (tonnes)	Value (Ir£)	Price per tonne (Ir£)
1988	39	7,528	193
1989	40		
1990			
1991	959	364,674	380
1992	1,509	541,022	359
1993	6,000 (?)		

MATERIALS AND METHODS

There are two objectives to the work in hand: the first is to ascertain the status of the whelk stocks in the area of interest; the second is to prepare a management strategy for what has become a valuable fishery.

The first procedural detail to be considered is the choice of unit area in which to conduct investigations.

In his review of the subject, Caddy (1989) refers to the problems of applying stock assessment methodologies to semi-sedentary species where the sub-units of a population cannot be distinguished. In shellfish the structure and definition of unit stocks have been little discussed - this is particularly true of whelk - and a certain amount of mixing between adjacent stocks of *Buccinum undatum* may be assumed because the species is fairly mobile (Himmelman, 1988) and long lived. That notwithstanding, a conservative approach to assessment and management is appropriate particularly as *Buccinum* does not have a planktonic dispersal stage.

A major difficulty in establishing the stock-recruit relationship for this species, is identifying the limits of the population concerned. Caddy (1989) advises that such exercises should be undertaken by unit area - which could be as small as "a single shellfish bed" - and combined subsequently to provide a more general overview of the status of the species over a larger area. The largest spatial unit is the stock or genetically isolated population and, in decreasing order of dimension, the fishing ground and shellfish bed or, in this case, whelk patch. Within the southern Irish Sea, whelk appear to occur as large individuals at low density or as heavier concentrations of small animals. Something of Caddy's approach is adopted here: the principal landing places at which landings were made are regarded as collecting points for whelk harvested in their immediate vicinity. These are regarded as discrete biological units whose differences might however arise as a result of one or more of several potential reasons.

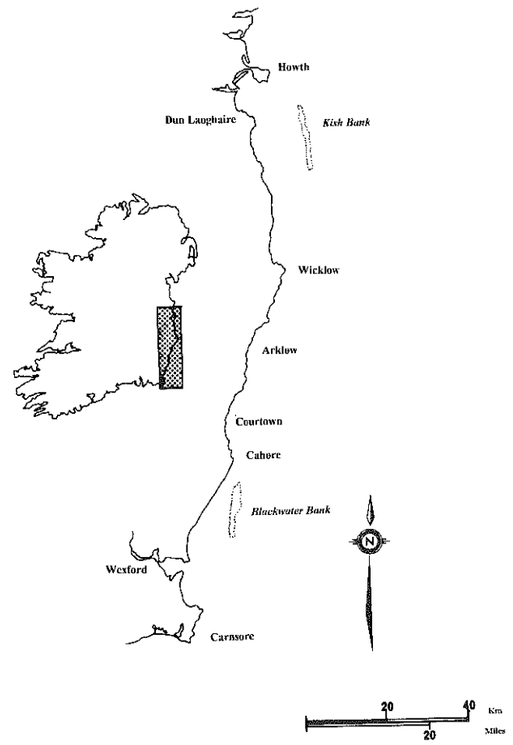

Fig 2. The study area, places referred to in the text marked. *Inset:* The area of interest shown on a map of Ireland.

Processors and landing places in Cos Wicklow and Wexford were visited in March, April and June 1994 to collect data on weight of landings, the size distributions of whelk captured and their grading prior to processing. Some trial potting for whelk was conducted out of Howth using the Department of the Marine's fast worker vessel *Lough Mask* with the specific purpose of collecting very small animals (those with one growth stria) which had not been encountered in the commercial landings. Two commercial whelk fishing boats were accompanied to sea in order to observe the fishing methods used and, particularly, to ascertain what grading and discarding practices were being operated.

Biological material, which included catches outside the principal area in which whelk are exploited (the study area), from north of Howth south to Carnsore (Fig 2), was located at the main processors. From March to August 1994, 44 samples were examined: some were brought in by the Department's Fishery Officers. Some graded landings in Table 1 were taken from the processing lines and their place of landing is not known; they were however brought in by trucks gathering up landings from the study area, the southern Irish Sea.

In the laboratory whelk were boiled in order to facilitate removal of the operculum from the foot. For convenience, the weights of the animals were noted when boiling had taken place. However, comparison of weights before and after boiling indicated that while the smallest whelks gained weight in the course of the

process, the larger specimens lost up to 30% (Fig 3). This distortion precluded the use of post-boiling weights as raising factors.

The following biological data were noted of material sampled in Table 1: length from the apex to the tip of the siphonal canal, to the nearest mm, and total weight, g. Opercula were removed for ageing purposes. Length of penis was measured in some samples.

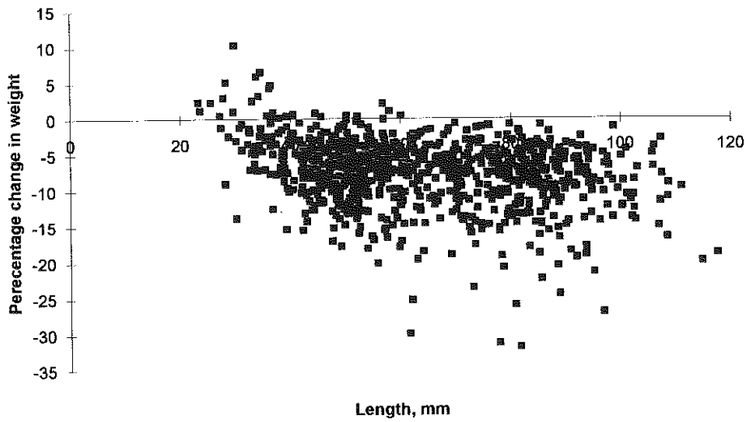

Fig. 3. Distortion in the weight of whelk after boiling.

The buying-in documentation to processors (Companies A and B), between January 1990 and January 1994 in the case of the former and from 1993 for the latter, was examined and the fishermen supplying them, their weights and the grade composition of individual consignments were abstracted. The majority of these consignments were traced to port of landing.

RESULTS

The development of the whelk fishery in recent years

The Irish Sea whelk fishery, was pursued on a small scale over many years, but expansion commenced in the mid 1980s and greatly accelerated in 1993, as is confirmed by the estimated landings and also by Fig 4. Within the study area the principal landing places are Courtown, Arklow, Wicklow, Wexford, Carne and, most recently, Dun Laoghaire and Howth whose catches have come from the Kish Bank and its vicinity. The overall weight of a consignment delivered to or collected by the processors has not altered greatly over the period although the fishing effort has increased (Table 2). (The number of pots in use was estimated after discussions with fishermen who have been engaged in the recent expansion of the trade). CPUE, expressed as kg of whelk per pot at three of the best documented ports, is shown as Fig 5. No particular trend is shown.

If the CPUE has remained relatively stable during the expansion of the whelk fishery, the average size of the individuals landed is reported to have declined although it is difficult to state this with precision other than to say that the landing of small whelk prompted this investigation.

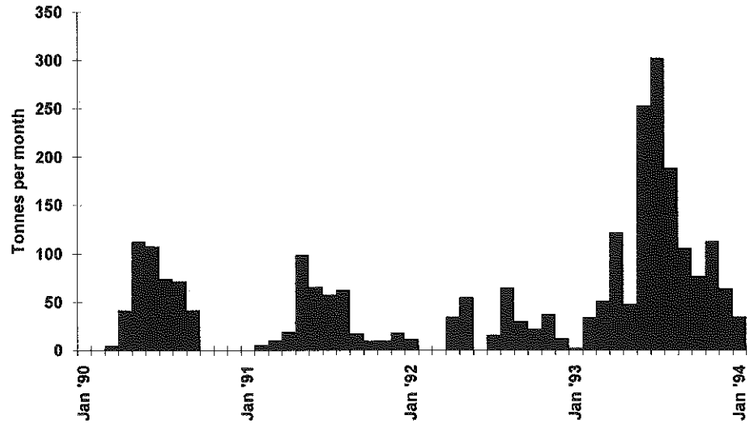

Fig 4. Whelk bought-in by Company A between January 1990 and January 1994.

Length frequencies in the Irish Sea whelk stocks

Length frequencies of whelk, biologically sampled from landing places in Wexford, Arklow, Courtown and Howth, are presented in Fig 6. Comparative data, derived however from small samples, were recorded in 1986 for three of the landing places considered here. In Fig 7 the earlier data from Arklow (Mahon, 1986), Courtown and Wexford (Connolly, 1986) are presented alongside the latest length frequencies for comparison.

At Arklow, Mahon's (1986) size range was 40-81 mm with a mode of approximately 50-55 mm. The latest one is not unlike this except that the mean size of capture appears to have increased slightly. At Courtown Connolly (1986) reported a length frequency of 36 - 70 mm, with a mode of between 50 and 60 mm. In comparison, the latest information on this fishery demonstrates a marked reduction in the length frequency of the landings. While it is not certain whether the earlier data represent catches or landings, they contain some small individuals and so are assumed not to have been sorted. In the case of Wexford Harbour, an earlier length frequency distribution suggests that the landings contained a higher proportion of larger whelk (Connolly, 1986). All samples from both Courtown and Wexford would have been acceptable to the market.

Graded landings

Following the dramatic increase in whelk landings from the southern Irish Sea in 1993 competition among buyers intensified and, in order to attract a better product, processors began to grade the material they bought-in, offering a better price for the larger grades. These sales transactions were scrutinized in order to ascertain whether any change in the size range of the purchase might be discerned.

In Company A, whelks are graded in numbers per lb (Fig 8). The frequency distribution of grades at three of the major landing places (Table 3) is similar to what is known of their size distribution from other sources (see below). However, in all cases the small grade predominates and its definition (Fig 8) is very wide. It was not considered worthwhile to pursue this source of information further.

Company B classified whelk in five grades: *Large, good, whelks, small* and *very small*.
The frequency distribution of these during 1993 is set out in Table 4. There are no definitions of these grades; allocation of bought-in material to them appears to have been subjective and there are strong indications that, over the period in question, the composition of the grades changed. For instance, at the end of June 1994, all of the grades were moved up one (so that the hitherto *small* became *whelks)*. A similar adjustment was reported for Company A. This fact, plus the gradual disappearance of *very small* as 1993 progressed (Table 4), might be indicative of an intake of progressively smaller material which, because of market forces and competition for landings, obliged the processors to revise their grading systems.

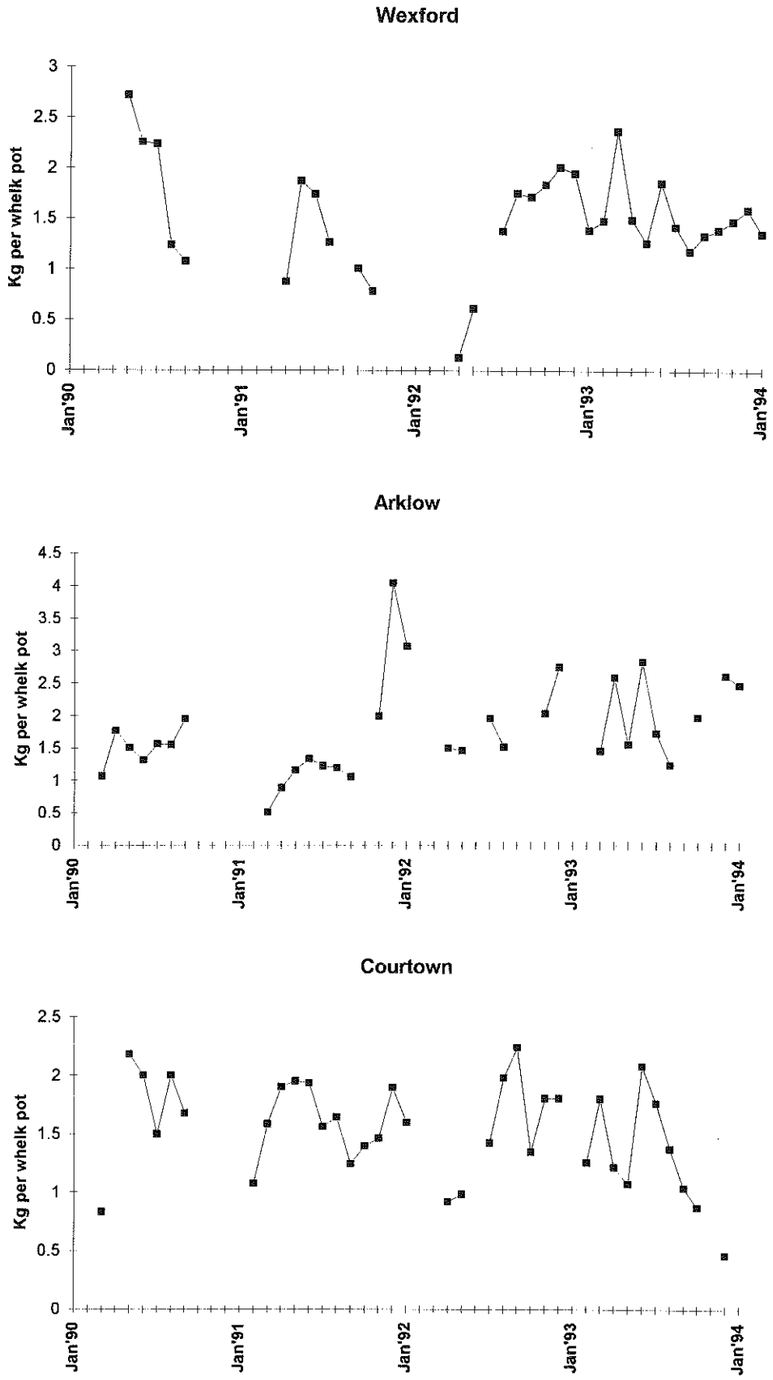

Fig 5. Catch per whelk pot reported from three landing places between January 1990 and January 1994.

No formal classification system was disclosed by Company B and, although buying-in documentation reveals that every kg of whelk purchased was attributed to a grade, it appears to have been a seletive process. The grades at Company B were sampled after their idenfication by staff. The *very small* grade in the purchasing documentation was occasionally accompanied by a note indicating it had been rejected in 1993 although material of this kind was not encountered in the course of field work; for which reason a reject sample (No 1 on Table 1) which originated elsewhere, was substituted for analysis.

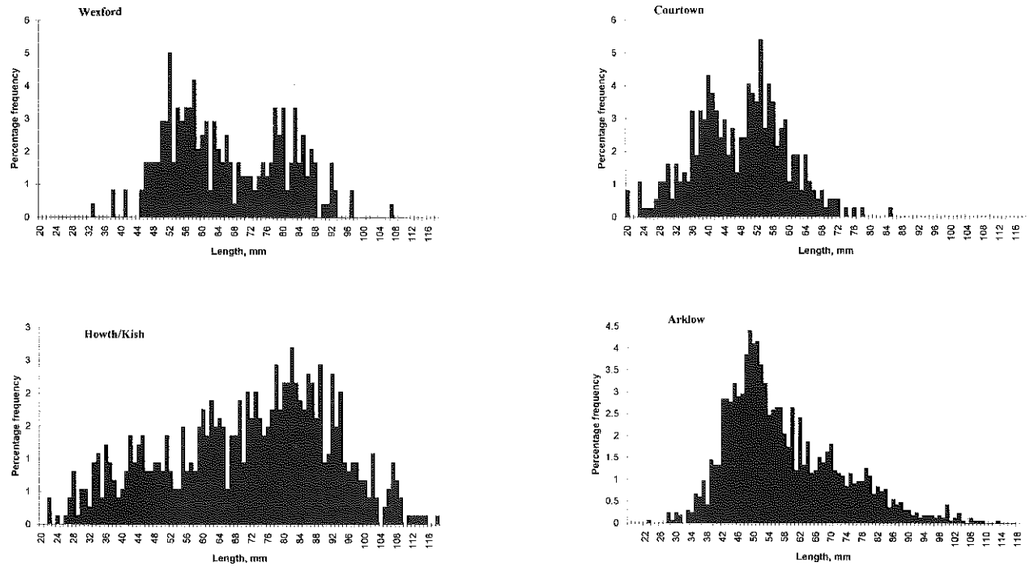

Fig 6. Sampled percentage length frequencies of whelk landed from four fishing areas in 1994.

Age at length data

Age was read as the number of opercular striae (Plate 1), after the methods of Santarelli and Gros (1985). Interpretation of opercular ornamentation was straightforward up to age 8 or 9 after which it became more difficult. No animal with only one stria was captured although efforts were made to obtain whelk smaller than 20 mm in length. While the pots in use throughout the fishery would have permitted the smallest whelk to escape, they invariably contained some individuals which were sufficiently small to get out but which were constrained by the numbers of larger animals from doing so.

Whelk is a cold water species which feeds most actively during the early spring and which becomes torpid during the warmer summer months (Martel et al, 1986). Hancock (1960) found most food consumed during April, the rate of intake dropping thereafter. Being attracted to baited pots, the rate of capture is related to feeding activity and the CPUE of whelk declines during the summer months (Hancock, 1967). Sales data provided a way of demonstrating the cyclical variation in feeding activity. The average weight of a consignment of whelk might indicate feeding activity and this appears to be cyclical (Fig 9). The opercular striae are formed in August and September, the warmest months when feeding activity is at its most sluggish. Virtually all of the whelk examined in the course of this work were sampled during the spring months, before the striae of the year would have formed. Thus, the age is read as the number of striae.

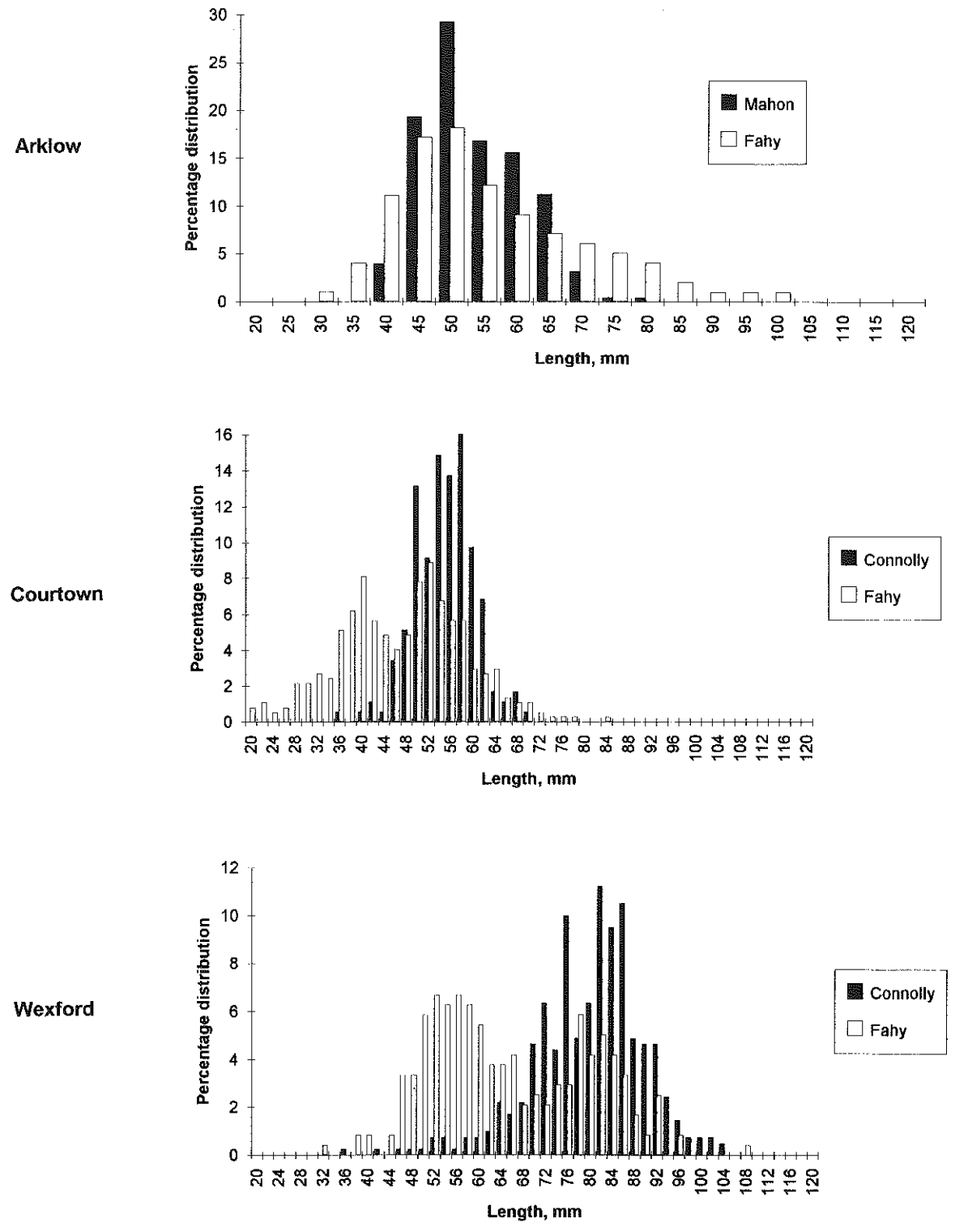

Fig 7. Length frequency data from Fig 6 compared with similar data from three fisheries in 1986.

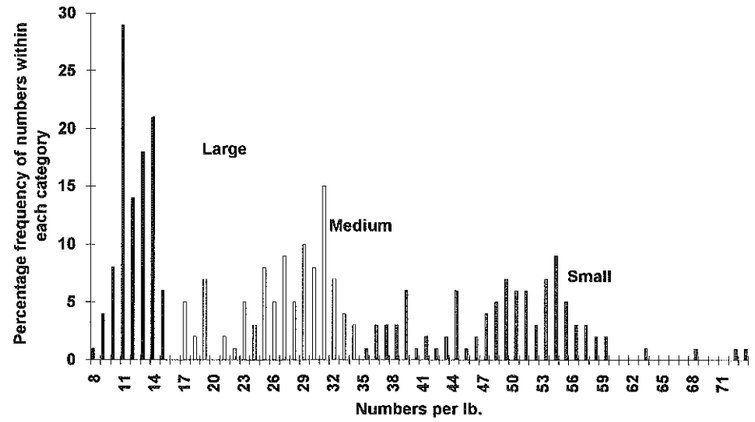

Fig 8. Commercial grading of whelk by Company A.

Age at length data were arranged in an age length key (Table 5) which was composed of 3,081 animals from the study area.

Whelk displaying the greatest longevity and highest growth rate came from the Howth/Kish fishery; the shortest lives and slowest growth were of whelk landed to Courtown. To test the suitability of the Irish Sea ALK for different fishing areas, the length frequency data for the two extremes, Courtown and Kish, were fed into the key which distributed the ages as shown in Table 6 ("calculated"). Chi-square tests compared the outcome with age frequencies derived from ageing these samples from the two fisheries ("observed") and the two interpretations were found not to be statistically different. It would thus appear that the key is capable of dealing with the range of populations contributing to the southern Irish Sea fisheries. This is thought to be the case because the same ALK accommodates predominantly older animals from some fisheries and younger ones from others, only a small percentage overlapping.

Growth

Von Bertalannfy growth curves were calculated for 13 of the largest samples and all displayed distinctive characteristics. Duncan et al (1989) considered that variations of this kind were indicative of discrete populations but they dealt with the Isle of Man which, at the time of their investigations, was relatively unfished. At least some of the differences among samples in the present work could be attributed to fishing practices and pressures. Heterogenous distribution might also play a part.

In Fig 10 a general growth curve for whelk from the area of interest is presented together with curves for whelk landed from the Kish and its vicinity and from the area around Courtown. The Kish curve is calculated from larger whelk and the Courtown one from smaller animals and there is little overlap between the two. The Courtown whelk patches are probably the most intensely fished in the southern Irish Sea. The older animals have apparently been removed from the Courtown samples and the survivors, after discarding, may show a Lee effect (Ricker 1975). Fig 11 provides a length frequency distribution of aged five year old whelk in the Irish Sea on which is super-imposed a length frequency distribution for Courtown, the latter - although it contains animals of comparable length at age to those in the general distribution - being apparently skewed to the lower end of the length range. Fishermen potting in this vicinity reported discarding up to 60% of their catches there in earlier years (pers. comm.) The Lee effect has been reported in whelk by Duncan et al (1989) and by Mahon (1986) in the Irish Sea whelk stocks. Reference to Table 5 and to Fig 11 shows why: whelk are extremely variable in size at any age. Discarding favours the smaller slower growing ones which, in time, make up an increasing proportion of a heavily fished stocklet.

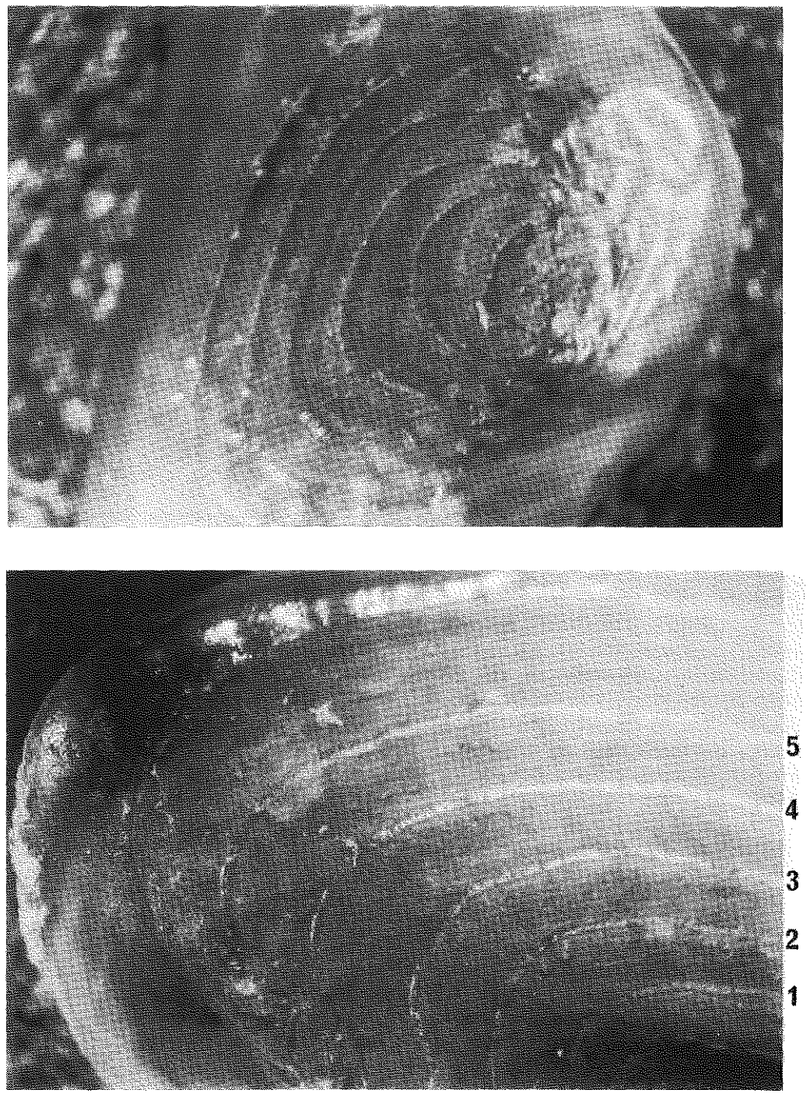

Plate 1. Opercular ornamentation in whelk: above, the distribution of striae on the operculum; below, the numbering of the opercular striae.

The von Bertalanffy growth parameters for the three curves are as follows:

	L_∞(mm)	k	t_0
Courtown	115.55	0.08	-1.77
Howth/Kish	121.72	0.13	0.28
"Southern Irish Sea"	121.66	0.11	-0.36

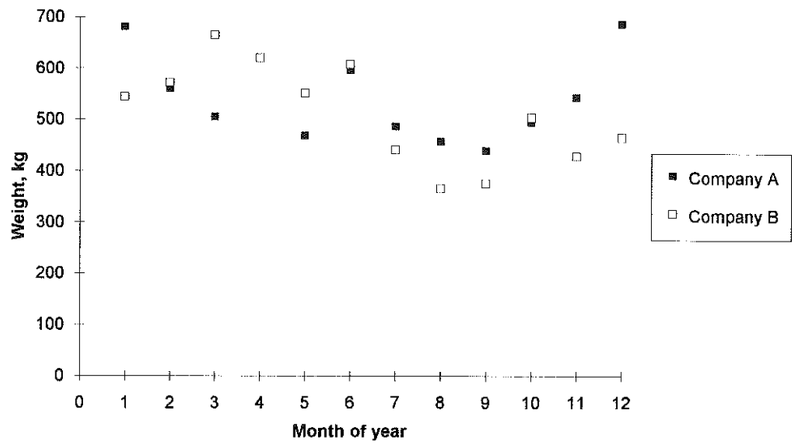

Fig 9. Average monthly weight of consignment delivered to processors: Company A, all data from January 1990 to January 1994 combined; Company B, 1993 only.

Raising factors

As in the case of the ALK, a single raising factor, derived from pre-boiling weights of whelk in the Irish Sea is used to convert sampled length to weight. The raw data are shown in Fig 12. Details of a log:log regression are: Intercept = -8.5651; Slope = 2.8631; N = 915; R^2 = 0.9759.

Fig 10. Calculated growth curves for whelk in the Irish Sea and at two fishing areas; symbols mark the raw data.

Estimation of mortality

Mortality was estimated by catch curve analysis for two sources of age distribution, one derived by applying the Irish Sea ALK to the size distributions sampled at the landing places in 1994, the other derived by ageing small samples of the grades and then raising them to the total graded landings for 1993. An example of raising graded landings to population numbers is shown in Table 7, comparative data for four landing places in Table 8.

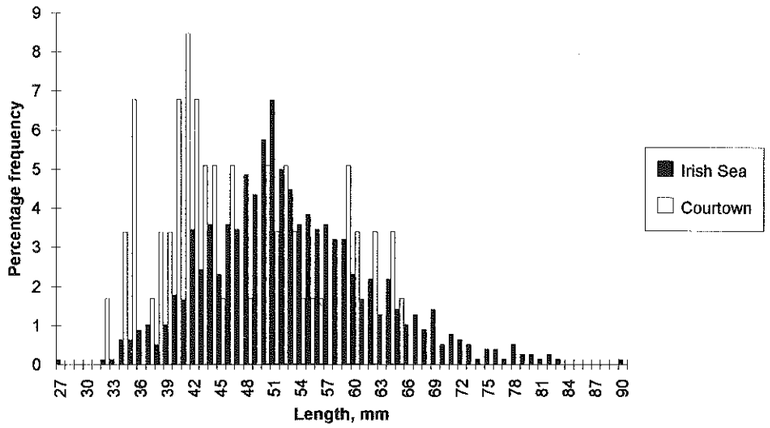

Fig 11. Length frequency distribution of all whelk aged five years from the study area compared with similar data from Courtown.

The data in Table 8 may be interpreted as a catch curve. The percentage age frequency distribution of all whelk aged in the course of these investigations is set out in Fig 13. If this is representative of the southern Irish Sea fishery, the age at full recruitment approximates to 5 years. From five to 14 years (the 15+ group being omitted), the decline in numbers was regressed against age. The total mortality coefficients (Z) are included on Table 8, together with the values of R^2 of the calculated slope of the line (logeN against ages 5-14). From these figures, the least exploited fishery is Howth. Courtown has the highest value of Z although the two methods of reaching its estimate provide different results. Arklow comes next, its ALK and graded samples are in closer agreement as are those calculated for Wexford.

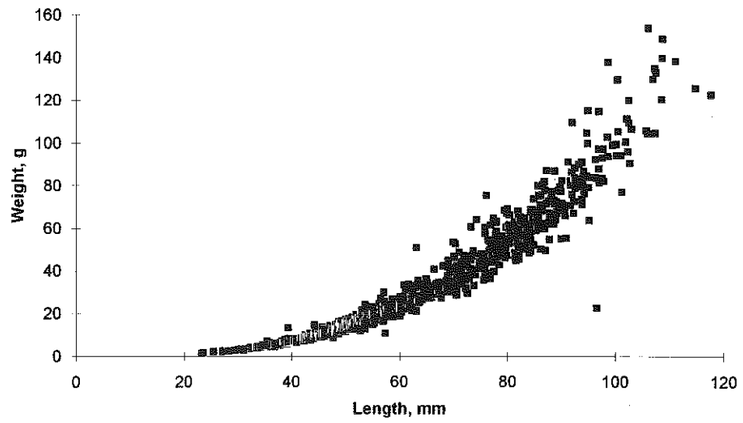

Fig 12. Weight at length relationship among whelk in the Irish Sea (N = 915).

It must be said that the selection criteria applied to the southern Irish Sea whelk fishery are not necessarily relevant in every case here. Indeed, the number of 4 year olds exceeded whelk aged five years in Arklow and Courtown. Recalculation of Z from four years for all gave fairly similar values although R^2 for Howth and Courtown (ALK) was considerably reduced.

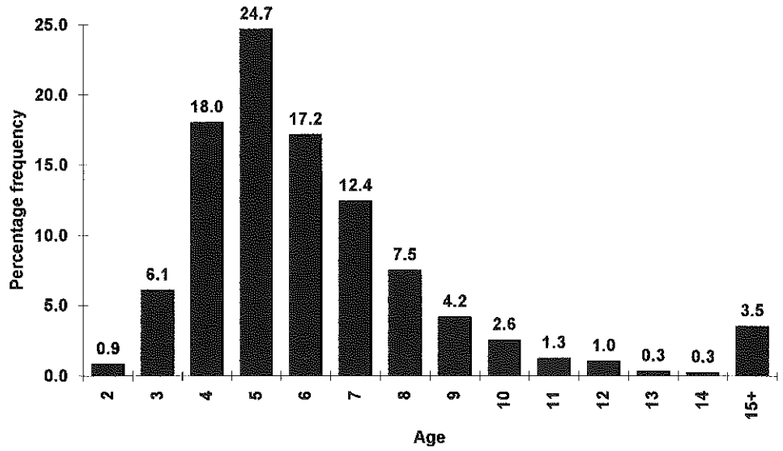

Fig 13. Age frequency distribution of whelk in landings from the Irish Sea (all samples).

Values of Z are similar, calculated after the application of ALK, in the Courtown and Arklow fisheries, from age five. However, the calculation of Z is only one way of interpreting population structure and it does not take pre-recruits into consideration: 26% of the biological samples from Arklow and 50% of the samples from Courtown were less than five years of age; these would not contribute to either catch curve beginning at age five.

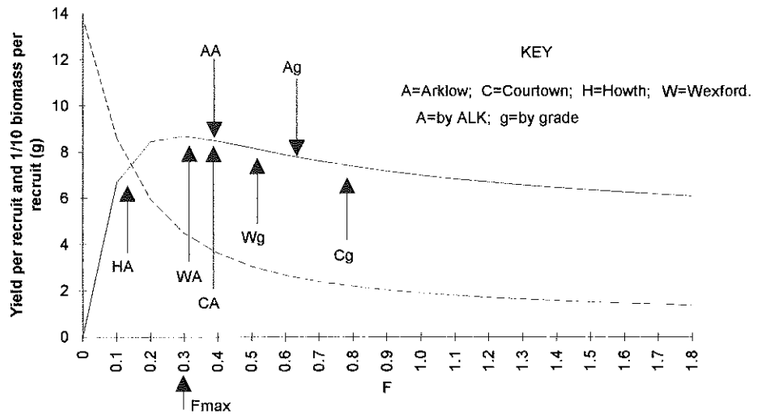

Fig 14. Yield and biomass per recruit curves for Irish Sea whelk, values for certain fisheries superimposed: A, Arklow; H, Howth and W, Wexford. A, by ALK; g, by grade.

Exploitation rate

The foregoing data are amalgamated in a Thompson-Bell yield per recruit curve (Table 9, Fig 14) on which are marked the values obtained for the four areas most closely examined here: Howth (Kish), Courtown, Arklow and Wexford. Only Howth is currently being exploited in a sub-optimal way (F=1.2). Courtown is furthest along the negative slope of the curve. Sub-optimal exploitation of the Howth/Kish fishery may owe more to its recent development than to the implementation of any management strategy. All of the other areas examined are currently displaying signs of over-fishing.

Maturation

The maturation of whelk was examined at two landing places, Howth and Arklow, the latter, fairly similar to Courtown, being representative of heavier exploitation. The most straightforward index of maturation is the length of the penis as a percentage of the total length of the shell. A value of 50% is assumed to mark maturity (Gendron, 1992).

In Fig 15 the mean value of the maturation index per mm length interval in male whelk is presented for Arklow and Howth. There is a lot of variability but the 50% index values are at approximately 70 mm at Arklow and 80 mm at Howth. Amalgamating all the raw data at 10 mm intervals, the indices of male maturity are not significantly greater at a shorter length at Arklow than at Howth (Table 10).

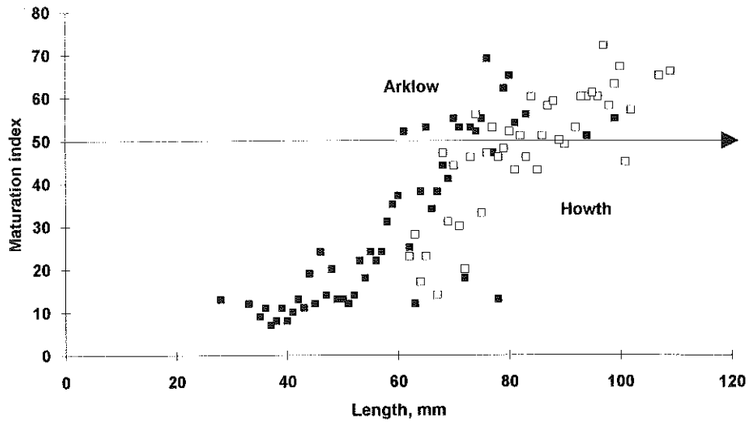

Fig 15. Average values of maturation index per mm for male whelk landed at Arklow and Howth; 50% maturation level marked.

DISCUSSION

DESIGN OF A MANAGEMENT STRATEGY

Even if it is unlikely to eliminate the resource - whelk being a low value fishery whose local exhaustion would most likely result in temporary cessation of fishing - heavy fishing pressure has undesirable consequences. These include reduction in the average size of catch and likely though unquantifiable diminution in stock fecundity. Either could contribute to the disruption and loss of markets. A fishery having a stable output and quality of product is desirable and managment should be directed to this end.

Low fecundity, aggregational behaviour, entirely benthic reproductive strategy, ease of capture and fast early growth make *Buccinum* a prime candidate for recruitment overfishing and predispose the fishery to a short life (Duncan et al, 1989).

Although the CPUE data on the whelk fisheries of the southern Irish Sea have held up well (Table 2) the averge size of individuals appears to have declined. Evidence for this is adduced from the comparison of length frequency data in 1986 with similar information in 1994. The distribution of whelk grades by Company B in 1993 might also be interpreted as containing rapidly increasing proportions of smaller animals. A Lee effect is well established in the most heavily exploited fisheries and these also have a slightly younger age at full recruitment (Table 8).

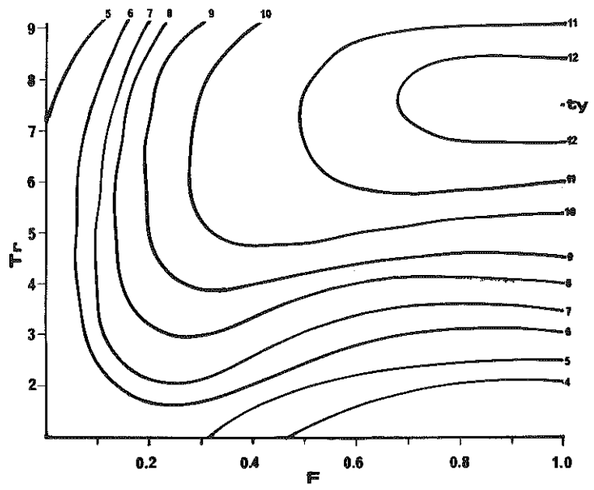

Fig 16. Yield per recruit isopleths for whelk in the southern Irish Sea. The Y axis indicates the age at recruitment to the fishery. The right vertical axis shows the yield (g) per recruit. F values are marked on the X axis. The maximum sustainable yield is marked Ty.

A poor understanding of stock structure and location (the latter possibly changing in the short term because of the movement of sedimentary materials within the study area) rules out fishery closure as a management measure at this time. However, a size limit has been used for this species as a broodstock protection measure (Santarelli et al, 1986, Gendron, 1991). This was the precept for the introduction of a size limit for Irish whelk in September 1994 (Whelk (Conservation of stocks) Order, 1994; S.I. No 278 of 1994).

According to the newly introduced regulation, the size below which whelk should not be retained was set at 50 mm length from the apex of the shell to the end of the siphonal canal. The actual measurement used in the regulation is the maximum diameter of the shell (25 mm) which is approximately half the total length. A length of 50 mm corresponds with Hancock's (1967) statement on length at maturity in English populations. Duncan et al (1989) have pointed out that these populations were exploited, and, because there is great variability in length at maturation, a population from which larger animals had been removed would consist only of individuals which reach maturation at smaller dimensions. Mahon (1986) also observed that whelk in the vicinity of Courtown, the most heavily fished patches on the east Irish coast, matured at about 50 mm.

The selection of an optimal size limit is complicated by the facts that whelk appear to mature at different sizes under different exploitation regimes (Fig. 15) and that female whelk do not, once mature, breed in every successive year (Martel et al, 1986 on whelk in the Gulf of St Lawrence). Gendron (1992) showed that males mature at a smaller size than female whelk. Taking that into consideration, data emerging from this investigation suggest that a size limit of 70 - 80 mm would be more appropriate that the 50 mm which has been set. However, the introduction of a larger threshold size for capture would have grave implications for the survival of the fishery (Fig 6), a fact which was also recognized by Gendron (1991) and by Savard (1993), working on a similar regulation in Quebec. S.I. No 278 of 1994 therefore represents a minimal conservation requirement and further measures, including a larger size limit, may be necessary to safeguard a viable fishery.

There is clearly a necessity to monitor the consequences of a size limit. Isopleths drawn from the yield per recruit calculations (Fig. 16) indicate that a maximum yield of 12 g per recruit might be obtained from an infinite intensity of fishing effort if the age at recruitment were raised to 7.5 years which, incidentally, would coincide approximately with the larger size limit emerging from the investigations.

For the moment we conclude by paraphrasing the final statement of Santarelli et al (1986):

"The adoption of a market size (size limit) necessitates a discipline on the part of the fishermen who must, imperatively, reject any undersize whelk in the fishing areas...."

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Table 1. Characteristics of 44 samples of whelk examined in 1994.

Sample number	Where put ashore	Date	Nature of sample
3	Courtown	22-Mar	Ungraded landings
4	Cahore	23-Mar	Ungraded landings
13	DunLaoghaire	23-Mar	Ungraded landings
7	Malin Head	24-Mar	Ungraded landings
6	DunLaoghaire	24-Apr	Ungraded landings
5	Arklow	26-Apr	Ungraded landings
2	Carlingford	27-Apr	Ungraded landings
41	Portavogie	27-Apr	Ungraded landings
9	Howth	28-Apr	Ungraded landings
23	Wexford	28-Apr	Ungraded landings
1	Courtown	09-May	Discard
8	Howth	26-May	Ungraded landings
12	Arklow	07-Jun	Graded landings
28	Unknown	07-Jun	Graded landings
29	Unknown	07-Jun	Graded landings
10	Arklow	07-Jun	Ungraded landings
22	Unknown	07-Jun	Ungraded landings
24	Arklow	07-Jun	Ungraded landings
25	Unknown	07-Jun	Ungraded landings
32	Wicklow	07-Jun	Ungraded landings
38	Unknown	08-Jun	Graded landings
11	Wexford	08-Jun	Ungraded landings
15	Wexford	08-Jun	Ungraded landings
26	Arklow	08-Jun	Ungraded landings
31	Wexford	08-Jun	Ungraded landings
34	Arklow	08-Jun	Ungraded landings
36	Wexford	08-Jun	Ungraded landings
37	Courtown	08-Jun	Ungraded landings
16	Arklow	27-Jun	Graded landings
17	Arklow	27-Jun	Graded landings
40	Arklow	27-Jun	Ungraded landings
18	Arklow	28-Jun	Graded landings
21	Unknown	28-Jun	Graded landings
14	Howth	28-Jun	Ungraded landings
27	Arklow	28-Jun	Ungraded landings
33	Howth	28-Jun	Ungraded landings
35	Arklow	28-Jun	Ungraded landings
39	Arklow	28-Jun	Ungraded landings
30	Unknown	02-Aug	Graded landings
20	Howth	03-Aug	Ungraded landings
42	Unknown	22-Aug	Graded landings
43	Unknown	22-Aug	Graded landings
44	Unknown	22-Aug	Graded landings
19	Greystones	25-Aug	Ungraded landings

Table 2. Overall catch per effort indices for whelk bought in by Company A from January 1990 to January 1994 inclusive and by Company B in 1993.

Year	Kg/journey to factory	Pots fished per day	Kg/pot
Company A			
1990	477	250	1.91
1991	454	300	1.51
1992	475	300	1.58
1993	546	360	1.52
Company B			
1993	504	360	1.40

Table 3. Percentage frequency distribution of whelk bought-in from three landing places by Companies A and B.

	Large	Medium	Small
Company A			
Arklow	4	25	71
Courtown	4	20	77
Wexford	16	30	53

	Large	Good	Whelks	Small	Very small
Company B					
Arklow	0	9	22	65	5
Courtown	1	1	21	74	3
Wexford	15	11	24	49	1

Table 4. Percentage grading of consignments bought-in by Company B in 1993.

	Large	Good	Whelks	Small	Very small	all grades	Journeys to factory
Jan	2	1	1	65	31	2	88
Feb	3	3	2	51	41	2	60
Mar	2	12	12	49	27	2	69
Apr	12	6	21	60	0	12	389
May	13	8	30	49	1	12	454
Jun	7	5	26	61	1	25	819
Jul	4	4	24	68	0	15	681
Aug	5	1	25	67	2	8	458
Sept	2	4	21	73	0	5	281
Oct	2	15	48	36	0	7	287
Nov	2	43	17	38	0	5	238
Dec	0	29	30	41	0	4	180
Total	6	8	25	58	3		4,004

Table 5. Age at length key for whelk from the Irish Sea, from Howth to Carnsore. Length is measured in mm from the apex of the shell to the end of the siphonal canal.

Length, mm	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Totals
20	1														1
21	1														1
22	4	1													5
23	1	4													5
24	1	1													2
25			1												1
26	2	2	1												5
27	1	5	1	1											8
28	5	10	1		1										17
29	2	4	3												9
30	3	13													16
31	1	5	2		1										9
32		6	4	1											11
33		7	10	1	1										19
34	1	7	4	5	2										19
35		7	8	5											20
36	1	14	15	7											37
37		8	16	8											32
38	1	13	14	4											32
39	1	14	17	8	3										43
40		9	22	14	3										48
41	2	6	25	13	2										48
42		8	33	27	3	2									73
43		7	41	19	4										71
44	1	8	30	28	8	2									77
45		7	34	18	11	4	1								75
46		4	31	28	9	5	1								78
47		5	25	27	12	3		1							73
48		4	36	38	9	4		1							92
49		5	32	34	16	6	2		1						96
50		4	32	45	15	4	1								101
51			17	53	17	6		1							94
52		2	20	39	23	8	2								94
53		1	18	35	19	10	4								87
54			11	28	25	8	1								73
55		1	7	30	22	14	3	1							78
56		1	9	27	18	14	8	1							78
57			4	28	27	7	3	1							70
58			7	25	22	8	3	1	1						67
59			6	25	16	9	5	1							62
60			5	18	20	11	5	2							61
61			3	13	15	11	4	2							48
62			5	17	20	15	1	1	1	1					61
63		1	3	10	17	8	3	2		1					45
64			6	17	10	13	7	7	1						61
65			1	11	15	9	2	2	2						42

Continued overleaf

Table 5 — Continued

Length, mm	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Totals
66				8	11	6	2	1	3						31
67			1	10	13	7	6	1	2						40
68				7	12	9	4	2	2						36
69			9	11	7	16	6	3	1	1					54
70				4	13	12	6	4				1			40
71				6	16	11	2		1						36
72				5	5	10	7	2	3		1				33
73				4	9	8	7	2	2	1					33
74				1	7	6	8	4	2						28
75				3	5	11	6	4	1		1				31
76				3	5	6	8	4							26
77				1	5	11	5	6	2		1				31
78				4	6	8	13	2	1	3					37
79			1	2	5	11	11	6	2	2					40
80				2	11	5	11	4	1						34
81				1	5	11	2	3	2		1				25
82				2	4	12	12	3	3	1	1				38
83				1	5	7	10	5	3	2	2				35
84					4	3	10	3	4	1			1	1	27
85			1		2	9	5	5		2	1	1			26
86					1	8	7	6	1		2		1	1	27
87					1	4	6	5	7	3			1		27
88						4	2	6	2	1	3				18
89				1		4	4	3	2	3	3			1	21
90					4	3	2	1	2						12
91						4	2	1	5	1					13
92						1	7	5	1	4	2	2		1	23
93						1	2	5	3	2					13
94					1	1	2	1	2	1	3		2	1	14
95					1		1	3	2	1	3		1		12
96							1		1		3			2	7
97						1	1	1	1					1	5
98						1		2	1	1	1			1	7
99											2				2
100							2	1	4	2		1		1	11
101							1				1				2
102								2	3	1		1			7
103						2		1	1			1			5
104											1				1
105												1			1
106										1	1	1	1		4
107										2			1		3
108							1	1		1				1	4
109									1						1
110											1		1	1	3
111									1						1
112												1			1
113												1		1	2
114													1	1	2
115										1					1
116												1		1	2
117													1	1	2
118														1	1
Totals	29	194	572	783	544	394	238	132	81	40	34	12	11	17	3081

Table 6. Comparison of the age distribution of whelk from a fast growing and a slow growing population (Kish and Courtown). The ages have been read directly from the opercula (observed) and the individuals have been distributed among age groups by the Irish Sea ALK (calculated).

	Ages														
	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total
Fast	***Numbers***														
ALK	9	34	66	100	101	106	85	54	39	22	17	6	5	7	651
Observation	12	36	57	97	113	98	86	64	40	23	18	7	0	0	651
Slow															
ALK	8	48	89	96	49	24	8	3	1						326
Observation	11	36	82	98	61	27	11								326
Fast	***As percentages for calculation of Chi-square***												**Chi square**		
ALK	6.6	10.1	15.4	15.5	16.3	13.1	8.3	6.0	8.8				1.11		
Observation	7.4	8.8	14.9	17.4	15.1	13.2	9.8	6.1	7.4				Not significant		
Slow															
ALK	17.2	27.3	29.4	15.0	11.0								1.51		
Observation	14.4	25.2	30.1	18.7	11.7								Not significant		

Table 7. Graded landings from Wexford , raised to population numbers.

GRADE ANALYSIS

Age	Very small	Small	Whelk	Good	Large
2	12	4			
3	40	49	1		
4	40	168	13	6	1
5	20	159	33	18	10
6	4	58	30	19	24
7		21	22	18	32
8		4	14	13	27
9		2	6	8	15
10			3	5	9
11			1	3	3
12			1	4	3
13				1	1
14				1	1
15+				1	1
Totals	116	465	124	97	127
Weight of sample (kg)	0.651	5.228	3.852	4.455	6.493
Weight of landings	**577**	**31654**	**15785**	**6997**	**9576**
Raising factor	886	6055	4098	1571	1475

RAISED SAMPLE

Age						TOTALS ('000)
2	10636	24219	0	0	0	35
3	35453	296681	4098	0	0	336
4	35453	1017191	53272	9424	1475	1117
5	17727	962698	135230	28271	14748	1159
6	3545	351173	122936	29841	35396	543
7	0	127149	90153	28271	47194	293
8	0	24219	57370	20418	39820	142
9	0	12109	24587	12565	22122	71
10	0	0	12294	7853	13273	33
11	0	0	4098	4712	4424	13
12	0	0	4098	6282	4424	15
13	0	0	0	1571	1475	3
14	0	0	0	1571	1475	3
15+	0	0	0	1571	1475	3

Table 8. Percentage age frequencies from three landing places derived from the graded landings of Company B and from sorting of sampled material by ALK.

	by grades			by ALK			
Ages	Wexford	Arklow	Courtown	Wexford	Arklow	Courtown	Howth
4	33	37	38	10	21	31	10
5	34	36	37	24	30	35	16
6	16	15	15	22	20	19	16
7	9	7	6	18	13	9	17
8	4	2	2	13	7	4	14
9	2	1	1	7	4	1	9
10	1	0	0	3	2	1	7
11	0	0	0	2	1	0	4
12	0	0	0	1	1	0	4
13	0	0	0	0	0	0	1
14	0	0	0	0	0	0	1
Mortality coefficient from 5 years							
Z	0.68	0.79	0.97	0.51	0.58	0.58	0.32
r2	0.98	0.98	0.98	0.96	0.99	0.91	0.91
Mortality coefficient from 4 years							
Z	0.65	0.77	0.93	0.43	0.53	0.57	0.26
r2	0.98	0.98	0.98	0.86	0.96	0.92	0.78

Table 9. Calculations at Fmax of a Thompson-Bell yield per recruit curve for Irish Sea whelk. Fully recruited F = 0.3, M = 0.2.

AGE	Wt/age	PR	Za	e-Za	Na	Ba (g)	D (Nos)	Ca (Nos)	Ya (g)
2	3.10	0.05	0.22	0.81	1000	3100	193	13	42
3	6.20	0.25	0.28	0.76	807	5001	194	53	328
4	11.20	0.75	0.43	0.65	613	6861	212	112	1258
5	16.40	1.00	0.50	0.61	401	6568	158	95	1551
6	23.70	1.00	0.50	0.61	243	5757	96	57	1359
7	33.40	1.00	0.50	0.61	147	4921	58	35	1162
8	44.20	1.00	0.50	0.61	89	3950	35	21	933
9	51.50	1.00	0.50	0.61	54	2792	21	13	659
10	60.80	1.00	0.50	0.61	33	1999	13	8	472
11	72.30	1.00	0.50	0.61	20	1442	8	5	340
12	76.30	1.00	0.50	0.61	12	923	5	3	218
13	96.30	1.00	0.50	0.61	7	706	3	2	167
14	85.30	1.00	0.50	0.61	4	380	2	1	90
15+	153.90	1.00	0.50	0.61	3	415	1	1	98
Totals						44815	998	418	8675

Table 10. Comparison of indices of male maturity from Arklow and Howth

	Arklow			Howth				
Length range (mm)	Mean value	Variance	Observations	Mean value	Variance	Observations	t	*P*
30 - 39	9.7	3.9	6					
40 - 49	14.4	25.2	10					
50 - 59	21.5	57.4	10					
60 - 69	37.4	147.2	10	26.1	118.8	8	2.07	N.S.
70 - 79	47.7	325.1	10	42.3	124.7	10	0.81	N.S.
80 - 89	58.3	34.3	3	51.3	38.7	10	1.80	N.S.
90 - 99	53.0	8.0	2	59.6	40.8	9	2.25	N.S.
100 - 109	55.0	_	_	60.0	86.0	5		

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