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FISHERY-ASSOCIATED CHANGES IN THE WHELK *BUCCINUM UNDATUM* STOCK IN THE SOUTHWEST IRISH SEA, 1995 – 2003.

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ABSTRACT

The whelk fishery of the southwest Irish Sea had a turnover of approximately €18 million and employed 250 people directly and indirectly in catching and processing in 2003. In the nine years, 1995-2003 inclusive, whelk landings to Ireland from the southwest Irish Sea fluctuated between 3,800 and almost 10,000 tonnes(t) per year; from an estimated 5,000 – 15,000 boat-days annually. A collapse in landings was recorded in 1997 and again in the spring of 2004. The fishery is divided for assessment purposes into four sectors, the central two consisting largely of nursery area and the north and south extremities of the fishery populated by more older, larger and mature whelk. Logbooks were not completed by fishermen participating in this fishery which was, in theory, managed by size limit, but the regulations were not enforced. Boats fishing whelk made daily fishing trips and daily weights recorded by processors were used to estimate biomass in each of the sectors by depletion regressions. Total biomass fluctuated between 12,720 t in 1999 and 37,319 t in 2002. The estimates based on a full season's landings are used to compare the fishery from one year to the next and to supply weighting factors for other parameters of the population. Exploitation rates were lowest in one of the central sectors of the fishery (where they averaged 27% annually). At the southern extremity they averaged 39%. Depletion estimates based on landings records from approximately April to 15 June provided higher exploitation rates and lower biomass. The mortality coefficient Z, calculated from a catch curve, peaked in two years, 1998 and 2002, as did an index of recruitment. The age at full recruitment declined after 2000. Throughout nine years of documented history, one of the central sectors of the fishery assumed progressively greater dominance over the others, providing 77% of the landings from the entire fishery to its ports in 2003. Some sectoral changes to the whelk population may be irreversible: the oldest animals have been removed from the northern extremity of the fishery and while the whelks which are exploited at the southern end between 2000 and 2003 were similar in size to those exploited in the mid-1990s, their tonnage between 1999 and 2003 decreased from 47 to 4% of the landings in 1995. A substantial recruitment in 2001 or 2002 was followed by an increase in fishing effort of 42% between 2002 and 2003 and this is identified as the reason for the collapse in 2004.

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1. INTRODUCTION

Whelk have been harvested in the southwest Irish Sea from the mid-1960s, initially to supply a small niche market in the United Kingdom which probably did not exceed 100 t annually. The thin shelled form of the species is abundant in the south west Irish Sea where predators like large crustaceans are relatively scarce. In the 1990s, demand from the Far East, notably South Korea, expanded the fishery which, in 1995 and 1996, yielded approximately 6,000 t/annum. In the following two years landings fell below 4,000 t/annum, after which they gradually increased to more than 9,000 t in 2003 (Table 1). Early in 2004 the fishery abruptly collapsed, prompting this review of its history in an attempt to find an explanation.

Table 1. Landings (t) of whelk in Ireland, 1995 – 2003. (Source: Department of Communications, Marine and Natural Resources.) Italicised figures have been adjusted in accordance with data received from industry.

	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Carlingford								0.5	
Dundalk								0.5	
Total North of Dublin								**1**	
Skerries		35.0							
Howth	427.0	555.0	266.0	117.9	319.9	471.0	355.6	397.0	178.2
Dunlaoghaire	538.0	520.0	339.0	295.0	576.0	611.0	366.0	302.0	1,046.4
Greystones	76.6	0.6	28.0	15.0	103.7	25.0	79.5	14.0	80.0
Total Dublin	**1,041.6**	**1,075.6**	**633.0**	**427.9**	**999.6**	**1,107.0**	**801.1**	**713.0**	**1,304.6**
Arklow				891.8	371.0	327.0	350.0	343.0	754.0
Wicklow				1,655.0	2,388.0	2,120.0	4,349.0	6,226.0	5,344.2
Total Arklow and Wicklow	**1,406.0**	**2,453.0**	**1,784.0**	**2,546.8**	**2,759.0**	**2,447.0**	**4,699.0**	**6,569.0**	***7,639.0***
Total Courtown	**778.0**	**864.0**	**475.0**	**395.5**	**567.7**	**460.0**	**424.7**	**323.0**	**297.0**
Cahore Point	90.6	114.1				15.0			
Wexford	2,785.6	1,425.8	890.0	158.6	167.1	266.4	250.7	199.0	354.0
Rosalie	24.9	10.2	9.0	86.9	64.2	79.1	121.8	94.0	210.7
Carne				36.2		54.4			
Total Wexford	**2,901.1**	**1,550.1**	**899.0**	**281.7**	**231.2**	**414.8**	**372.6**	**293.0**	***644.0***
Kilmore			15.0	14.8	2.3	44.2	65.3		4.6
Fethard and Slade	4.3	14.8	11.0		0.6			0.5	
Dunmore East		525.1	45.0						
Duncannon						0.4			
Castletownbere									0.5
Schull						0.1			
Total Celtic Sea	**4.3**	**539.9**	**71.0**	**14.8**	**2.8**	**44.7**	**65.3**	**0.5**	**5.1**
Bantry						0.1			
Greencastle	18.6								
Burtonport							0.6		2.2
Greencastle							0.1		
Malin etc									670.0
FROM VI a	**18.6**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.7**	**0.0**	***672.2***
Totals SW Irish Sea	**6,126.7**	**5,942.7**	**3,791.0**	**3,651.9**	**4,557.5**	**4,428.8**	**6,297.4**	**7,898.0**	**9,884.6**

The whelk fishery is conducted within 5 nm of the coast for much of its north-south extent (Figure 1). The animals concentrate on banks of sand and aggregate, which are washed by strong north-south tidal currents. Aggregate banks in the northern half of the fishery extend further offshore and fishing takes place over these up to 10 nm from the coast.

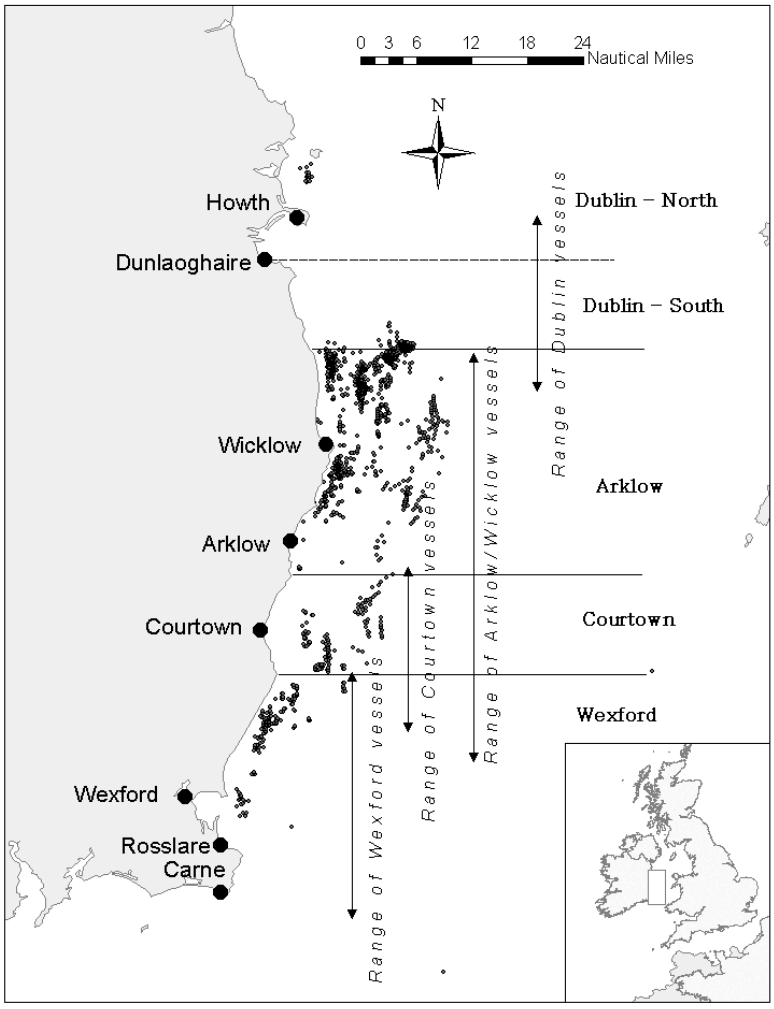

Figure 1. Outline map of whelk fishery of the southwest Irish Sea showing its approximate distribution, main landing places, sectoral divisions and range of vessels. The extent of the fishery is indicated by stippling (from Fahy *et al*., 2000).

In the early years of the last century, the south east coastline of Ireland supported a trawl fishery which was replaced by static gears and whelk is currently the principal species landed there. The fishery had an estimated turnover of €18 million in 2003 and employed 250 persons, directly and indirectly, in catching and processing.

The earlier history of this fishery has been described in Fahy *et al.* (1995 & 2000), the latter of these providing details of stock distribution, growth and size at maturity in addition to some details of Landings Per Unit Effort (LPUE) over a brief period. This account examines the stock structure within a longer time frame and in greater detail, up to and including 2003. The same sub-division of the fishery into four principal sectors from north to south, Dublin, Arklow, Courtown and Wexford, is also used in this investigation.

1.1 The Fishery

The number of vessels fishing whelk in the south west Irish Sea fishery fluctuated between 40 and 80 approximately since the mid-1990s. Whelk fishing boats range in size from less than 10 to 15 m in length. A number were not registered and the boats are essentially polyvalent. These factors complicate quantifying effort. Most boats were crewed by two men, with some one man operations. In addition some of the largest boats which were converted from trawling, are crewed by up to four people. An industry source in 2003 estimated that the average crew size was 2.5 men per vessel. The boats made daily fishing trips, setting out close to dawn and returning to port in the early afternoon.

Whelk fishing took place throughout the year, for an average of 315 to 338 days/annum in each of the sectors over the nine years documented (Table 2). Fishing usually commenced early in January and the first quartile (Q) of the landings was made within 80 – 100 days approximately; the second and third in less time. The first three quartiles required less fishing time in Wexford, averaging 152 days, than in the other three sectors where they averaged 215 – 242 days over the nine years 1995 – 2003 inclusive.

Table 2. Analysis of the whelk fishing season in four sectors of the south west Irish Sea fishery 1995 - 2003 inclusive. The numbers refer to the days required to make a quartile, Q (25%) of the annual landings.

Sector Dublin

	Start date	Q1	Q2	Q3	**Q1-3**	Q4	Annual fishing days
1995	7-Jan-95	110	63	85	**258**	67	325
1996	23-Feb-96	115	115	45	**275**	24	299
1997	31-Jan-97	79	86	76	**241**	72	313
1998	19-Jan-98	23	65	93	**181**	155	336
1999	15-Jan-99	174	56	40	**270**	71	341
2000	12-Jan-00	112	50	55	**217**	127	344
2001	5-Jan-01	103	87	104	**294**	56	350
2002	6-Jan-02	99	52	78	**229**	118	347
2003	12-Jan-03	77	62	72	**211**	134	345
	Average	99	71	72	**242**	92	333
	St. dev.	40	21	22	**36**	43	17
	Coef. var	0.40	0.30	0.30	**0.15**	0.47	0.05

Sector Arklow

	Start date	Q1	Q2	Q3	**Q1-3**	Q4	Annual fishing days
1995	6-Jan-95	94	46	85	**225**	113	338
1996	23-Feb-96	72	51	78	**201**	111	312
1997	4-Jan-97	102	84	83	**269**	71	340
1998	18-Jan-98	61	64	54	**179**	132	311
1999	13-Jan-99	165	46	57	**268**	75	343
2000	12-Jan-00	70	84	65	**219**	125	344
2001	3-Jan-01	133	32	131	**296**	56	352
2002	6-Jan-02	95	76	58	**229**	122	351
2003	11-Jan-03	118	48	50	**216**	137	353
	Average	101	59	73	**234**	105	338
	St. dev.	33	19	25	**37**	30	16
	Coef. var	0.33	0.32	0.34	**0.16**	0.28	0.05

Sector Courtown

	Start date	Q1	Q2	Q3	**Q1-3**	Q4	Annual fishing days
1995	9-Jan-95	89	42	67	**198**	153	351
1996	23-Feb-96	49	71	70	**190**	120	310
1997	10-Jan-97	74	87	87	**248**	86	334
1998	29-Jan-98	54	58	48	**160**	140	300
1999	23-Jan-99	150	38	68	**256**	77	333
2000	4-Jan-00	82	65	74	**221**	131	352
2001	7-Jan-01	105	72	63	**240**	107	347
2002	8-Jan-02	108	70	46	**224**	109	333
2003	11-Jan-03	96	60	41	**197**	146	343
	Average	90	63	63	**215**	119	334
	St. dev.	31	15	15	**31**	26	18
	Coef. var	0.34	0.24	0.24	**0.15**	0.22	0.05

Sector Wexford

	Start date	Q1	Q2	Q3	**Q1-3**	Q4	Annual fishing days
1995	6-Jan-95	90	29	27	**146**	180	326
1996	10-Jan-96	84	41	40	**165**	178	343
1997	27-Jan-97	75	19	26	**120**	170	290
1998	18-Feb-98	74	23	40	**137**	143	280
1999	1-Jun-99	9	9	22	**40**	157	197
2000	18-Jan-00	101	36	53	**190**	144	334
2001	2-Jan-01	53	64	44	**161**	191	352
2002	7-Jan-02	116	57	35	**208**	149	357
2003	3-Jan-03	97	51	56	**204**	150	354
	Average	78	37	38	**152**	162	315
	St. dev.	31	18	12	**52**	18	52
	Coef. var	0.41	0.50	0.31	**0.34**	0.11	0.17

Vessels involved in this fishery do not complete logbooks so there were no records of their location, Catch Per Unit Effort (CPUE) or LPUE. The analysis of fishing effort undertaken here is essentially made through records of commercial transactions which are regarded as a reliable account of the quantity of whelk landed by a vessel in a single day. However, the payment dockets rarely referred to a named boat, so it was not always feasible to trace a consignment to the vessel which landed it.

Landings and their documentation.

Data obtained from the processors during the early 1990s when the fishery was expanding and before the collection of statistics had developed to the stage where all buyers were covered, frequently exceeded the returns reported by the government department responsible for the collection of these figures:

- in 1990, landings data abstracted from one dealer's records were 721% greater than recorded by the Government Department responsible for fisheries
- in 1991, abstracted data were 164% greater and in 1993 were 188% greater than in the official records
- in 1993, 248% more landings were abstracted from the same dealer's records for the Wexford Sector than were recorded in the official statistics.

By 1995 however, these problems had diminished and this analysis of the fishery commenced in that year, although 1996 is regarded as more comprehensively documented. In 2003 the Wexford and Arklow sectors were under-recorded by at least 25% and 10% respectively in the official statistics which were adjusted accordingly (Table 1, Figure 2). Figure 2 demonstrates the progressively increasing dominance of the Arklow sector over the others and the decline from the mid-1990s of the Wexford sector's contribution to the landings.

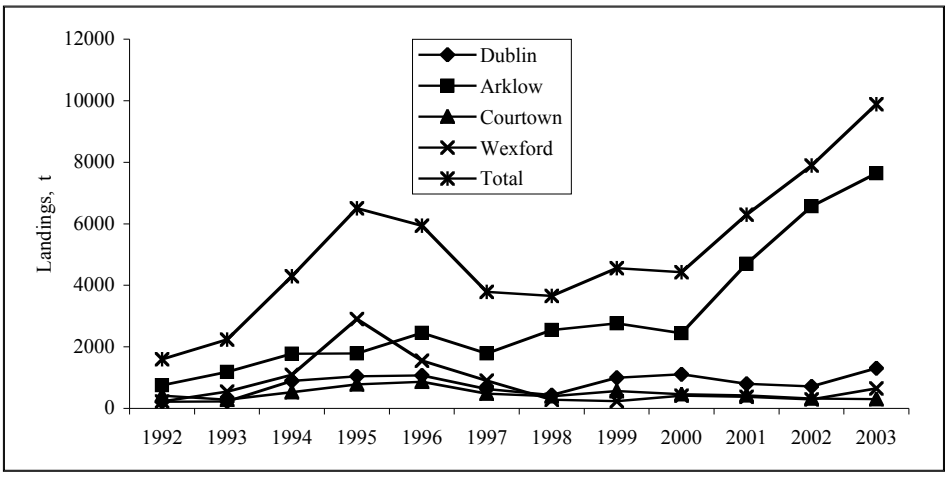

Figure 2. Landings to each sector of the southwest Irish Sea fishery, 1995 – 2003 (source, Department responsible for fisheries, some years modified by data obtained in this investigation).

Distribution of landings and effort

The whelk fishing fleet consists mainly of half-decked vessels of 10 to 15 m but there is some difference in the sub-sectors which supplied the two main processors: to generalise, daily landings to one of the principal buyers frequently averaged less than 60% of those sold to the other principal buyer. The records of Company B provided the majority of the data on which LPUEs were estimated.

Sample weights of daily consignments to processors were averaged in each sector from 1990 and the average consignment weights were divided into the total sectoral landings in each year to obtain an approximate number of fishing days (Figure 3).

Following its poorly documented early years, fishing effort expanded rapidly from approximately 2,000 boat days per year in 1993 to peak in 1995 at 15,000 boat days. Declining to less than 12,000 boat days in 1996, effort continued to reduce until 1998 after which it gradually increased to peak again in 2003 at approximately 11,000 fishing days. The early 1990s had been characterised by relatively large landings which were probably due to a combination of a few bigger vessels fishing down what was largely a virgin stock.

The number of boat days in this fishery underwent a similar trend to the landings data (Figure 2), declining from 1996 when the largest contributor to the effort was the Wexford sector, to 1998 and thereafter increasing to 2003 when Arklow was responsible for 76% of landings (Figure 3). Estimates of boat days in this fishery must however be regarded as an indication rather than an accurate measurement of effort because of differences between fleet components. There was an increase of 42% in fishing effort between 2002 and 2003, not the largest since 1995, but contemporaneous with the highest landings per vessel in that period.

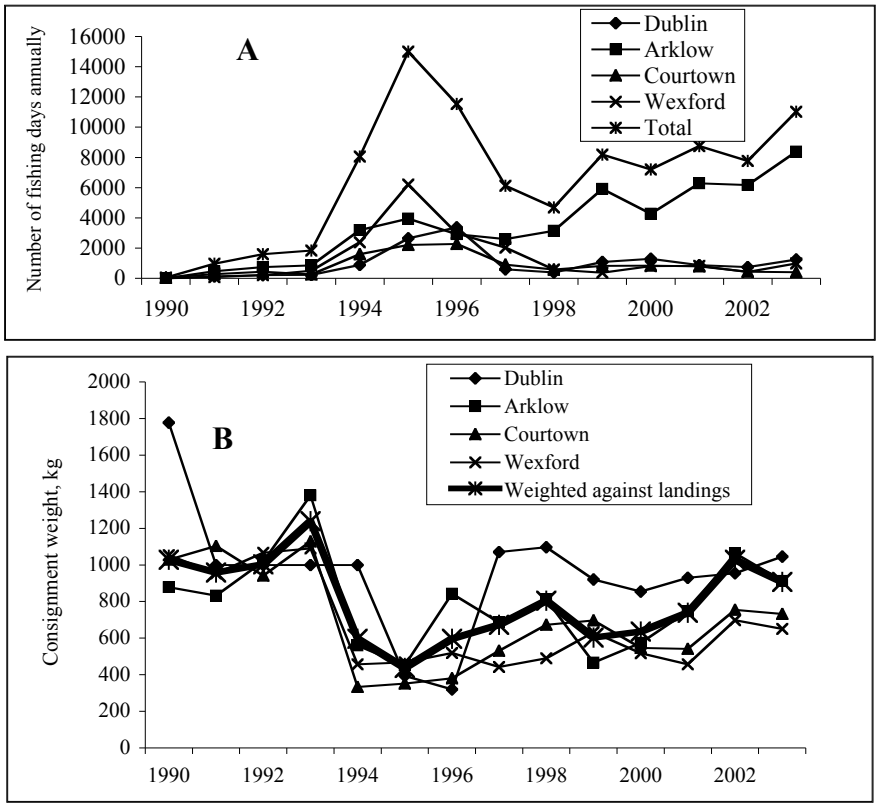

Figure 3. A, The number of boat (fishing) days/annum in each sector of the south west Irish Sea fishery and B, the average consignment weight in each sector/year from which A is derived.

Value of the landings

Data collected by the Government department responsible for fisheries are the basis of the values attributed here. Whelk had a first sale value of almost €6 m in 2003. Prices increased from the equivalent of €449 per tonne in 1992 to €662 per tonne in 2003. In 1996 the first sale price had been €656 per tonne but it fell the following year. In Figure 4 the average value of a day's fishing is compared with the consumer price index, the two having been standardised in 1992 when consignment sizes were larger (Figure 3). The values of a consignment in 2002 and 2003 were relatively speaking, the highest in the series since 1995.

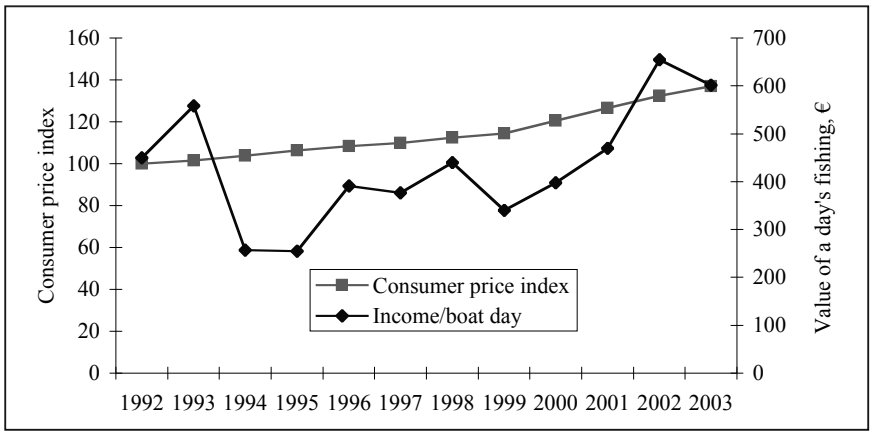

Figure 4. The value of a day's fishing per boat in the south west Irish Sea whelk fishery, 1992 – 2003 inclusive and the consumer price index (source: Central Statistics Office) for the same period. The base year in 1992 in both cases.

2. MATERIALS AND METHODS

Samples of the landings were collected throughout the fishing season each year (as in Fahy *et al.,* 1995 and 2000), from 1994 to 2003, with the exception of 1995 and 1997. The methods of Santarelli *et al.* (1985) were used to age individual whelk. The biological material collected and analysed earlier is revisited when the questions of seasonality of growth and recruitment in the fishery are addressed.

Data on which calculations of biomass were made were irregularly collected from one or other of the principal buyers throughout the 1990s until 2003. Two processors, Companies A and B, handled the majority of whelk landings from the south west Irish Sea since 1995 and records of one or both were available for all years since 1990, with the exception of 1994. In 1995 and 1996 data were collected from both companies and in 2001-2003 data were supplied electronically by both for the Arklow sector of the fishery.

Whelk are in theory managed by size limit and two substantially similar regulations establish size limits in the Irish Sea:

- the Whelk (Conservation of Stocks) Order, 2001 [S.I. 294 of 2001] has the effect of setting a size limit of approximately 50 mm length which approximates to the
- European Union's minimum length of 45 mm (Annex XII of regulation 850/98/EEC).

Neither was enforced however, so that landings of whelk to the southeast coast of Ireland were synonymous with catches.

Throughout these investigations, landings to a particular port were taken as evidence that a vessel was working in its vicinity. Daily landings were stacked on a pier where they were collected by the processor who subsequently weighed the consignment and made payment for it. For an average boat, an optimal day's fishing effort involved lifting and re-setting approximately 350 pots, although the effort might be curtailed by, for instance, unfavourable weather conditions. No allowance was made for a prolonged soak time resulting from bad weather which is likely to lose catch (Fahy *et al.*, 2000). Payments-inwards dockets issued by processors were taken as a measure of fishery performance. The average landing by a vessel for a day's fishing was obtained by the formula:

$$\sum L_{St} / N_{St}$$

where N is the number of consignments purchased by the processors from sector (or part of sector) S in time t (a year's fishing).

Daily landings were usually, although not always, higher at the beginning of a fishing season than in the following autumn making such data appropriate for calculating biomass size by depletion methods (King, 1995). Santarelli (1988) discussed the difficulties of using depletion methods because of variations in feeding intensity by whelk throughout the year. Fahy *et al.* (2000) surmised the approach might be a useful way to make comparisons on a year to year basis. The biomass of whelk present in a sector at the beginning of a fishing season was in the majority of cases estimated here from a large proportion of the total landings to that sector. These estimates were then

raised to the full landings of the sector. Similar calculations were also attempted for a shorter period in spring in order to compare exploitation rates over the entire season with those which took place in a brief period.

According to the formula

$$B_{St} = B_{Sx} - \sum L_{St}$$

B was the biomass removed, *x* was the commencement of the fishing year when the biomass was highest and *L* were the landings (=catches).

$$LPUE_{St} = qB_{Sx} - q\sum L_{St}$$

where q was the catchability coefficient, in this case the proportion of the whelk landings removed from a sector as a result of a single boat-day's effort.

$$B_{Sx} = LPUE_{Sx} \Big/ q$$

Values for B_{Sx} and q were obtained by regressing daily landings per vessel against cumulative landings within a fishing sector throughout a fishing year.

Length frequency distributions were obtained and a Log weight:Log length regression was carried out on samples from each sector/year to raise the numbers in the samples to numbers in landings. Two parameters were derived from these sectoral length frequencies: the percentage number of whelk below 50 mm in length which also contributed to a recruitment index, *R*:

$$R = \frac{\%<50mmLt_{St} * Biomass_{St}}{100}$$

Whelk >70 mm were regarded as fully mature and contributing to spawning. The spawning stock biomass (SSB) was defined as:

$$SSB = \%Weight > 70mm_{St} * Biomass_{St}$$

Age at full recruitment to the fishery was identified as the modal point in an age frequency distribution in a sector/year after the length frequency distribution had been allocated to ages by ALK. Log numbers at age were regressed against age in years to obtain a catch curve, the slope of the regression being interpreted as the coefficient of total mortality (*Z*).

Statistical packages used in this work were SPSS 11.0 and Microsoft Excel 9.0.

3. RESULTS

3.1 Growth and recruitment of whelk in the south west Irish Sea

As a preliminary to calculating the biomass from daily landings records, the growth and recruitment of whelk in the south west Irish Sea fishery were examined using all aged material from 1996 to 2003 inclusive. Recruitment of whelk to the south west Irish Sea fishery increased with age/size. No 0 group animals and only 2 1+ individuals were captured. Thereafter, whelk became progressively more abundant as another stria was added to the operculum and recruitment was considered full at 4 or 5 years old (Fahy *et al.*, 1995 & 2000). If growth and recruitment are contemporaneous, then the period at which recruitment occurs is likely to have a bearing on the estimation of biomass by depletion method. Santarelli *et al.* (1985) recognised that stria formation did not take place at the same time of year for all individuals but they suggested that between June and October was a likely period for it. They observed that length at a particular stria number was least in the fourth quarter of the year. In this case lengths of age groups in the range 3 – 9 years (the most abundant in the samples) were averaged and the averaged lengths of each age group in successive months were compared with each other and the increase or decrease in successive months recorded (Table 3).

Table 3. Difference in length (mm) in successive months of age groups 3-9 summarised for the period 1996 - 2003 inclusive.

Age	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals	No. sampled
3	-2.94	-0.85	2.49	-1.27	-2.04	-2.23	6.64	-3.25	2.64	-0.62	-4.43	5.86	0	1,686
4	-9.32	7.55	2.36	-1.65	0.41	-5.05	7.2	-1.04	2.91	-4.85	2.83	-1.35	0	4,222
5	-1.84	0.26	4.14	-2.86	-0.33	-2.1	5.6	-1.73	1.04	-2.59	2.49	-2.08	0	4,888
6	0.33	0.99	2.76	-2.92	1.21	-1.42	4.35	-1.56	-0.25	-2.33	-0.13	-1.03	0	3,366
7	4.41	2.03	2.54	-3.88	-0.18	1.98	2.28	-3.83	2.2	-2.29	-3.53	-1.73	0	1,713
8	-1.7	-1.07	0.69	-0.18	0.07	2.31	2.24	-6.16	0.1	2	-8.73	10.43	0	904
9		3.91	-1.76	2.62	-3.78	3.28	-0.59	-3.68	0.01	4.28	-14.92		-10.63	460
Totals	-11.06	12.82	13.22	-10.14	-4.64	-3.23	27.72	-21.25	8.65	-6.4	-26.42	10.1	-10.63	
No. sampled	1,385	1,621	1,488	1,239	2,991	999	2,522	1,635	796	1,334	626	603		

Individuals of age group 9 were absent from samples in December and January and the results did not show clear patterns applying to age groups or months. Most active growth took place in July. The second highest month for growth was March, followed by February and December. November, August, January and April registered the greatest negative growth. Negative growth would be associated with the formulation of striae (annuli) when the individuals which had completed a year's growth and were at their largest within that age group, became the smallest of the next age group.

Comparing the age frequencies of these groups throughout year (Figure 5), based on the sampled numbers in Table 3 (whose lengths were converted to weights using a logarithmic weight to length relationship where the intercept was –8.16 and the x increment 2.79), there are spikes of increase, most obvious among the pre-fully recruited age groups, in December, March and July, three of the months in which large increases in length were registered. A reduction in June also coincided with negative growth in that month although a larger reduction in October was not

similarly complemented with a reduction in average length. Most notable in Figure 5 is the increase in abundance of pre-fully recruited age groups in November and December and the corresponding reduction in post-fully recruited (4+) ones. Thus it appears that while some recruitment took place throughout the year, the most significant surge was in the fourth quarter.

Active growth and recruitment was likely to influence the outcome of an estimate of biomass by depletion methods. It was therefore desirable to replicate the exercise over a shorter time frame and as close to the beginning of the fishing year as possible.

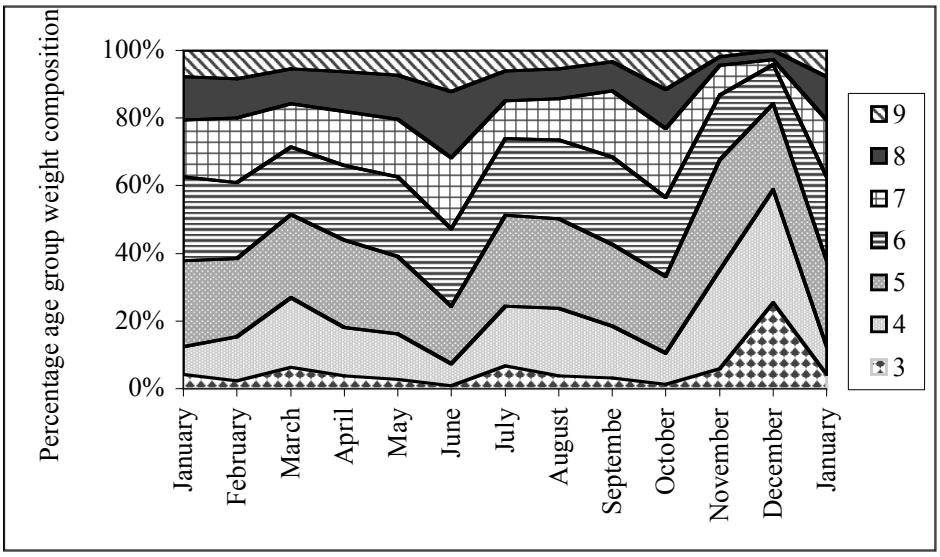

Figure 5. Percentage weight composition of age groups in the south west Irish Sea whelk fishery in each month, from samples examined between 1996 and 2003 inclusive.

3.2 Biomass estimates: 1, using records for the greater part or all of a season.
Only occasional depletion estimates of biomass, made from the daily landings data, were feasible before 1995, presumably because biomass removal was too insignificant in the early fishery to demonstrate the effect. Estimates were attempted for every sector every year after that, for each of the two processors separately and in combination, when data were available from both. The outcome of regressions in which $P<0.05$ are shown in Appendix 1. Where an estimate was feasible using the data from both companies combined, it was used in further analyses. Almost all data provided by the processors were used in the calculation of biomass. Only obviously bulked consignments that were an amalgamation of daily records (such as purchases from another processor or buyer) were excluded from consideration. Where there was an obviously gradual start to the fishery in a particular sector/year, the regression was calculated from the point when the fishery was considered to be fully operational (Figure 6).

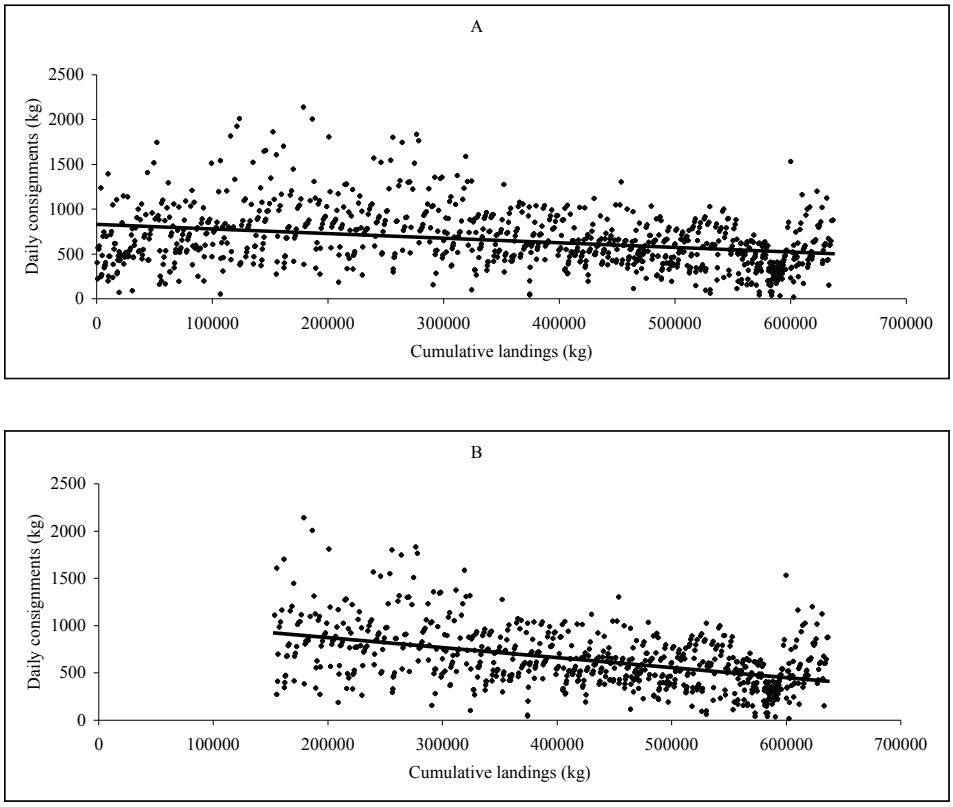

Figure 6. Depletion regression for whelk in the Wexford Sector in 2003, data provided by Company B. A shows the raw data which are transformed in B by the omission of the first 200 t of daily consignments which were made before the fishery was fully operational. N=772, R^2=0.2370, P<0.001.

In the case of the Arklow sector in 2002, three estimates were feasible (Figure 7). Company A's depletion regression yielded an estimate of 19,476 t biomass, Company B's 35,561 t and the two combined, 31,104 t. The difference in estimates by the two processors resulted from the whelk fishing fleet not being a homogenous entity.

The depletion regression for the Courtown sector in 2002 (data provided by Company B), appeared to indicate the participation of two fleet sectors with a different performance pattern, the larger or simply more effective boats fishing down the stock faster than the others. Were these to be separated, the two biomass estimates would probably resemble those of Companies A and B for the Arklow sector in 2002. It is understood that only Company B purchased Courtown landings in 2002 so that both fleet components contributed to that processor from the sector (Figure 8).

In 2001, the Arklow sector had a pulse of larger than usual recruitment to the fishery. Exceptional growth might also have contributed to the phenomenon. The records of Company B did not indicate any significant depletion in that year while estimates for Company A recorded a positive value for the slope of the regression (Figure 9).

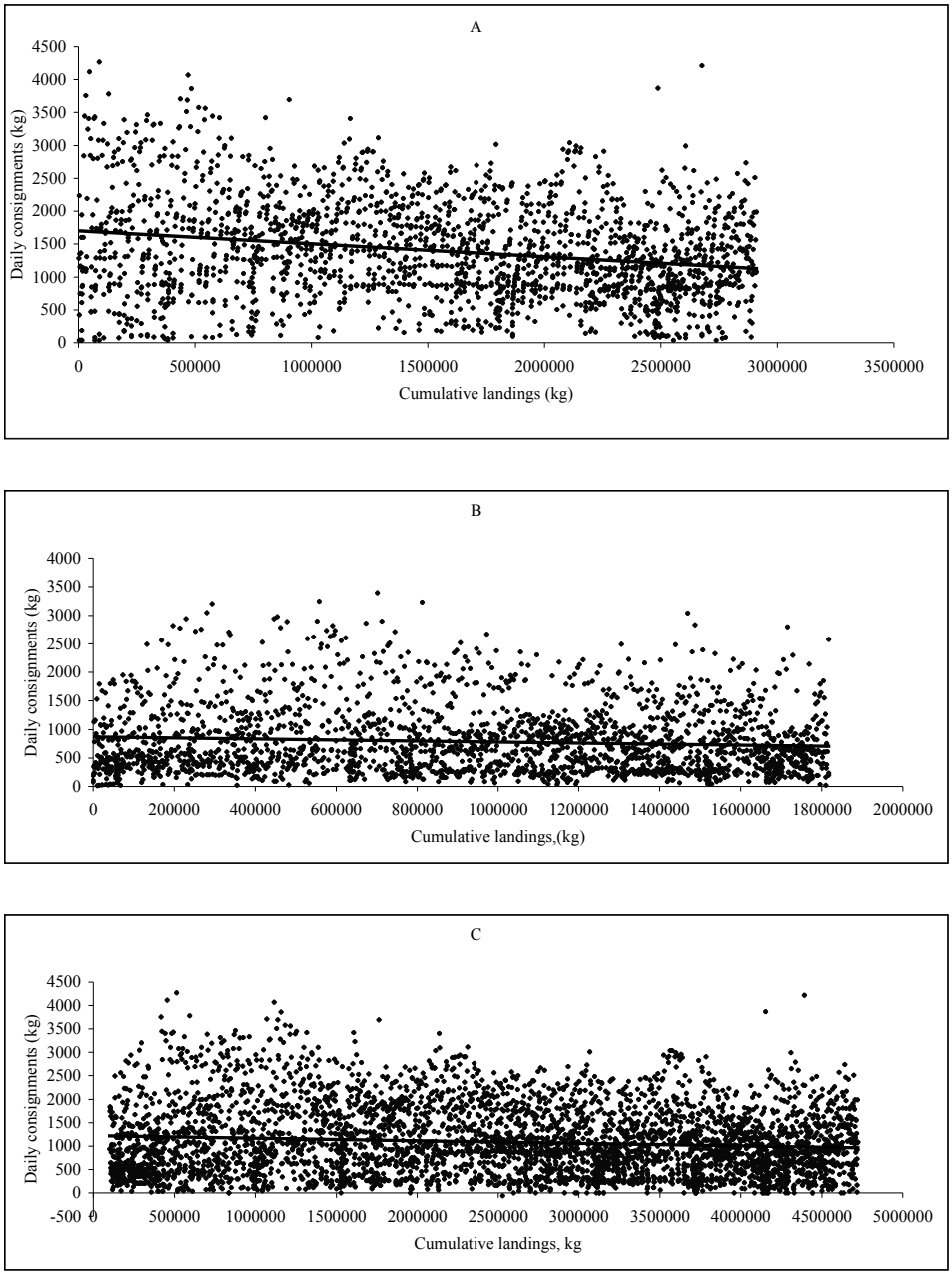

Figure 7. Depletion regressions on which the biomass of the Arklow sector in 2002 was estimated. A, Company A: N=2,085, R^2=0.0504, P<0.0001; B, Company B: N=2,322, R^2=0.0650, P<0.0001; C, Companies A and B combined: N=4,407, R^2=0.1010, P<0.0001.

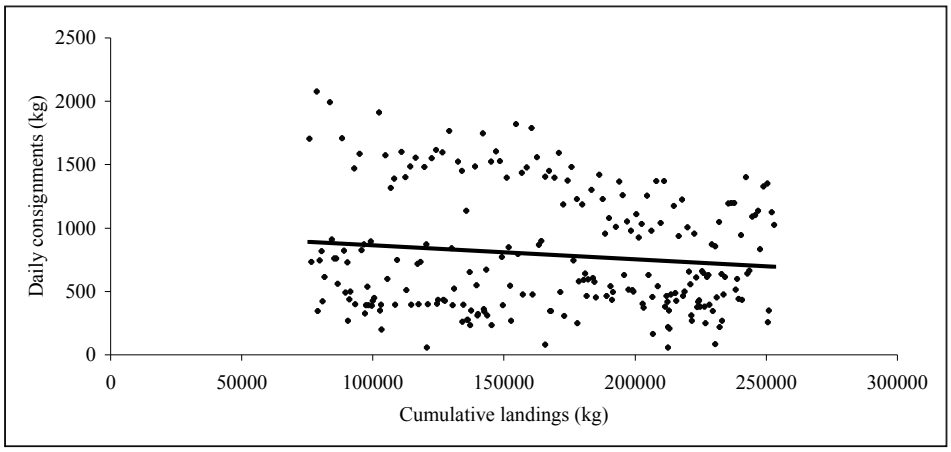

Figure 8. Depletion regression for the Courtown Sector in 2002 from data provided by Company B. N=227, R^2=0.0164, P=0.05.

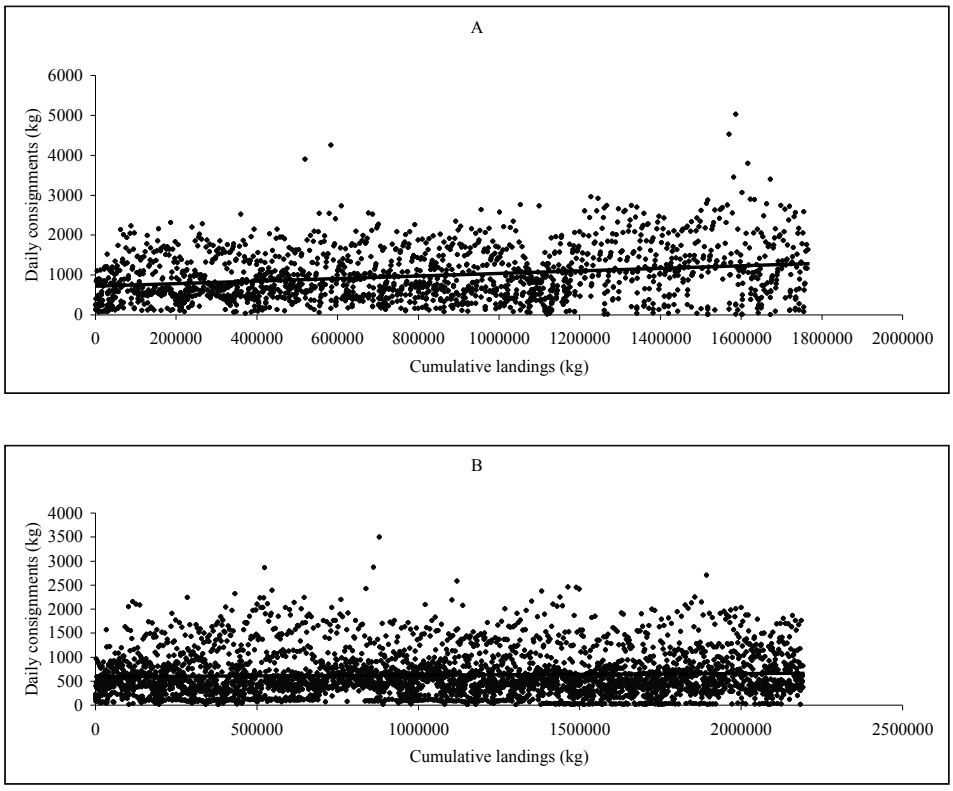

Figure 9. Depletion regressions for the Arklow sector in 2001. A, Company A, N=1,813, x=+0.0003; B, Company B, N=2,642, x=-0.0000067.

The outcome of all depletion regressions is summarised in Table 4 and in Figure 10 a number of these estimates which provided the basis for weighting various parameters in the fishery are set out. Some sector/year estimates in Table 4 are interpolated (all in 1997; Dublin 1999; Arklow 2001). The interpolated values for Arklow in 2001 may be a considerable underestimate of biomass in that sector/year. The estimate for the Dublin sector in 1995 is repeated in 1996 and the 2002 Dublin estimate is repeated the following year, as no values were available in 2003.

Table 4. Estimated biomass in each sector of the south west Irish Sea whelk fishery used as weighting factors for other parameters.

	Dublin	Arklow	Courtown	Wexford	Total
1990			**242**		242
1991			**1,624**	**174**	1,797
1992					
1993			**679**	**2,720**	3,399
1994					
1995	2,463	4,763	1,789	7,220	16,235
1996	**2,463**	10,398	**1,868**	8,675	23,404
1997	***1,648***	***11,461***	***1,249***	***4,622***	18,979
1998	**833**	**12,524**	**629**	**568**	14,555
1999	***3,413***	**7,439**	**1,498**	**370**	12,720
2000	**5,993**	**7,715**	**1,042**	**777**	15,527
2001	***4,937***	***19,409***	**1,664**	**1,849**	27,859
2002	**3,881**	31,104	**1,116**	**1,218**	37,319
2003	**3,881**	20,681	**1,069**	**1,003**	26,634
Average, from 1995	3,279	13,944	1,325	2,922	21,470

Key to fonts
Co A and Co B combined
Company B
Company A
previous year value used
interpolated

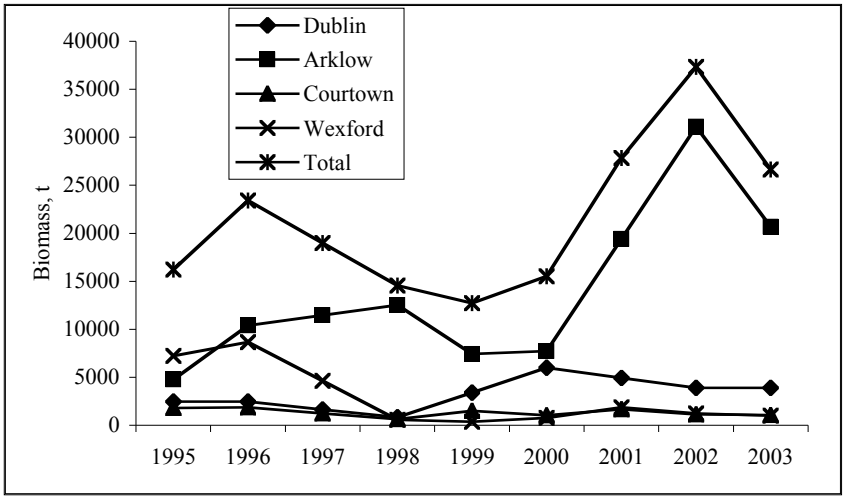

Figure 10. Biomass (t) in each and all sectors of the south west Irish Sea fishery from 1995 to 2003 (from Table 4).

3.3 Biomass estimates: 2, using records for the early season only.

These estimates whose details are summarised in Appendix 2, are for all years 1995 – 2003 inclusive which yielded significant regressions (P<0.05) per sector/year. Depletion regressions were attempted from the date at which the fishery was judged to be fully operational until 15 June, so as to precede the surge in growth and possibly recruitment in July.

All of the shorter time series provided estimates, which differed from those obtained from a full year's fishing. Closest correspondence was obtained between the two series for the Wexford sector in 1995. The majority of the other estimates for the short time series were smaller than those obtained from a full year's data.

3.4 Exploitation rates

Exploitation rate was calculated as the percentage of the biomass removed in landings in each sector/year (Table 5). The lowest exploitation rate for the period 1995-2003 was in the Arklow sector, the highest in Courtown and Wexford. The lowest variation in exploitation rates was recorded over the entire fishery, rather than in any one sector, suggesting that effort redistributed in response to the best fishing opportunities.

Table 5. Exploitation rates in the south west Irish Sea whelk fishery. The average is weighted by the biomass from 1995 to 2003 inclusive.

	Dublin	Arklow	Courtown	Wexford	Weighted average
1990			23		
1991			19	47	
1992					
1993			42	20	
1994					
1995	42	37	43	40	40
1996	44	24	46	18	25
1997	38	16	38	19	20
1998	51	20	63	50	25
1999	29	37	38	62	36
2000	18	32	44	53	29
2001	16	24	26	20	23
2002	18	21	29	24	21
2003	34	37	28	64	37
Average, from 1995	32	27	39	39	28
S.D.	13	8	12	20	6
Coef. var	0.40	0.29	0.31	0.52	0.23

3.5 Biological sampling

Fahy *et al.* (2000) in their assessment of the fishery presented the length frequencies of all whelk sampled from the south west Irish Sea between 1994 and 1999 inclusive. These data were up-dated for the period 2000-2003 inclusive and both are compared in Figure 11. All eight length frequencies were compared by one-way ANOVA with post-hoc testing by Fisher's least significant difference test. All were significantly different ($P<0.05$) with the following exceptions: Arklow 2000-2003 and Courtown 1994-1999; Wexford 1994-1999 and Wexford 2000-2003.

3.6 Percentage undersized and an index of recruitment

The percentage undersized whelk landed in each sector/year from 1994 are set out in Table 6. The incidence of undersized whelk in the landings was greatest in the central sectors of the fishery (Arklow and Courtown) and least in the Wexford sector. Greatest consistency (lowest coefficient of variation) was in the Arklow sector.

An index of recruitment *R* is set out in Table 7. Noteworthy among these data is the contribution of the Arklow sector to recruitment in 2002 (Figure 12). The index might have been higher in 2001 when no biomass estimate was feasible for this sector.

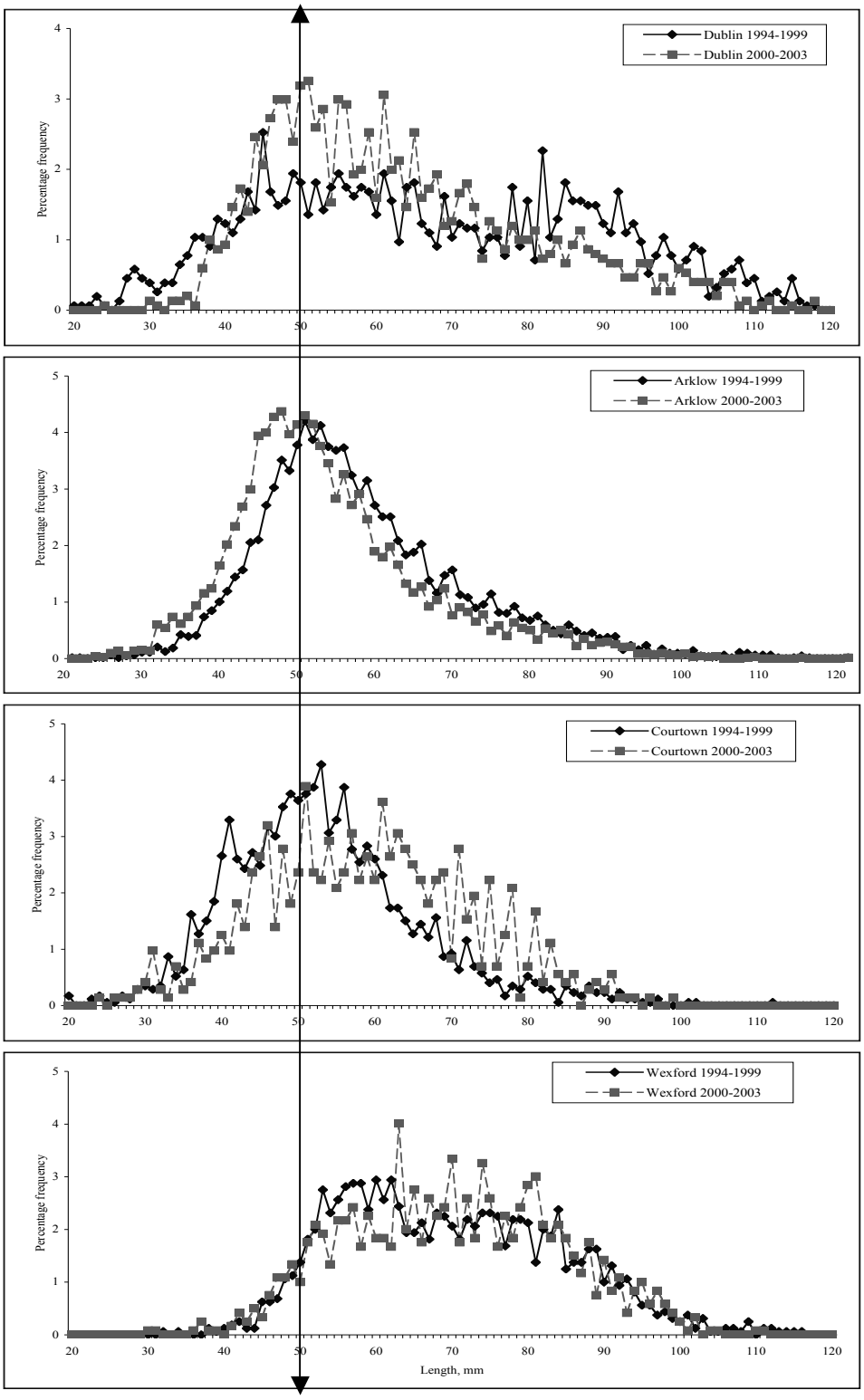

Figure 11. Length frequency distributions of all whelk sampled in the four sectors of the south west Irish Sea fishery in the periods 1994-1999 inclusive and 2000-2003 inclusive. The vertical arrow represents the size limit. Average lengths of whelk in each sector in each of the two periods are: Dublin, 67.75 and 62.46, Arklow 56.76 and 52.95, Courtown 53.03 and 58.31 and Wexford 69.36 and 70.07 mm.

Table 6. Percentage undersized whelk in each sector of the south west Irish Sea fishery. The average is weighted by the biomass from 1995 to 2003 inclusive.

	Dublin	Arklow	Courtown	Wexford	Weighted average
1994	27.5	32.6	51.1	7.9	
1995	***16.1***	***30.1***	***49.4***	***10.0***	***21.1***
1996	4.6	27.5	47.6	12.0	20.9
1997	***13.9***	***35.3***	***34.4***	***9.8***	***27.2***
1998	23.2	43.1	21.1	7.6	39.6
1999	12.3	33.8	48.9	8.8	29.1
2000	9.7	40.0	48.9	8.8	27.3
2001	24.4	36.1	16.3	5.7	30.8
2002	47.0	47.4	37.8	1.7	45.6
2003	23.1	43.1	21.1	7.6	38.0
Average (from 1994)	20.2	36.9	37.7	8.0	31.1
S.D.	11.3	6.0	13.0	2.6	7.9
Coef. var	0.56	0.16	0.34	0.33	0.26

Interpolated

Table 7. An index of recruitment to the whelk fishery of the south west Irish Sea. The average is weighted by the biomass from 1995 to 2003 inclusive.

	Dublin	Arklow	Courtown	Wexford	Total
1995	395	1,431	883	718	3,428
1996	113	2,860	889	1,041	4,903
1997	229	4,046	429	453	5,157
1998	193	5,398	133	43	5,767
1999	420	2,515	732	33	3,699
2000	581	3,086	510	68	4,245
2001	1,205	7,007	271	105	8,588
2002	1,824	14,743	422	21	17,010
2,003	896	8,914	226	76	10,112
Average	651	5,555	499	284	6,990
S.D.	564	4,179	280	371	4,373
Coef. var	0.87	0.75	0.56	1.31	0.63

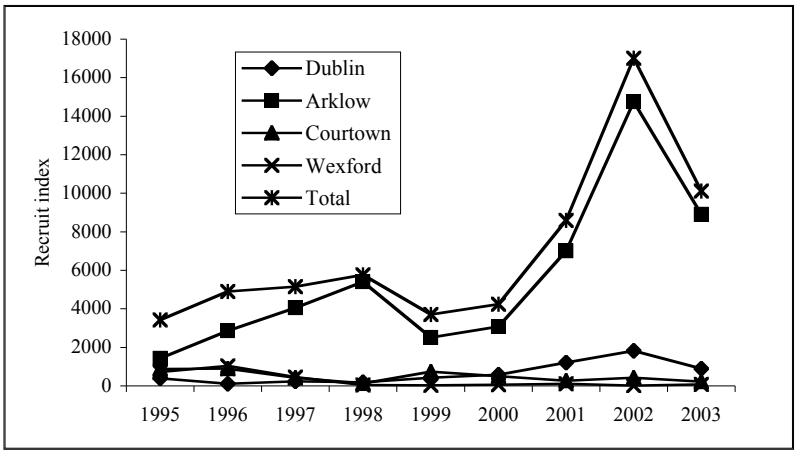

Figure 12. An index of recruitment for whelk to each sector of the fishery, 1995 – 2003. Averages weighted against sectoral biomass.

3.7 Age at full recruitment and mortality coefficient *Z*.

Age at full recruitment altered over the ten years in which the fishery was monitored (Table 8, Figure 13). Over the eight years in which records were collected, the greatest consistency was shown in the Arklow and Courtown sectors and the largest variability occurred in Dublin. The weighted average displayed a marked decline from 2001.

Although there was variability among sectors (Table 9), the weighted average *Z* value had two peaks, in 1998 and 2002; both coincided with peaks of recruitment (Figure 12). Thus, mortality coefficient *Z* indicated either the rate of depletion of the older age groups in a stock or the rate of recruitment; *Z* and *R* correlated highly significantly (Figure 15), indicating the heavy dependence of this fishery on newly recruited whelk.

Table 8. Age at full recruitment of whelk in each sector of the south west Irish Sea fishery. The average is weighted by the biomass from 1995 to 2003 inclusive.

	Dublin	Arklow	Courtown	Wexford	Weighted average
1994	6.5	5.0	5.0	5.0	
1995	***5.8***	***5.0***	***5.0***	***5.3***	5.2
1996	5.0	5.0	5.0	5.5	5.2
1997	***6.3***	***5.0***	***5.0***	***6.0***	5.4
1998	7.5	5.0	5.0	6.5	5.2
1999	8.0	5.0	4.5	6.0	5.8
2000	6.0	5.0	4.5	8.0	5.5
2001	4.0	4.0	4.0	5.0	4.1
2002	4.0	4.0	4.0	5.0	4.0
2003	4.0	4.0	4.5	5.0	4.1
Average (from 1994)	5.7	4.7	4.7	5.7	4.9
S.D.	1.4	0.5	0.4	1.0	0.7
Coef. var	0.25	0.10	0.09	0.17	0.14

Interpolated

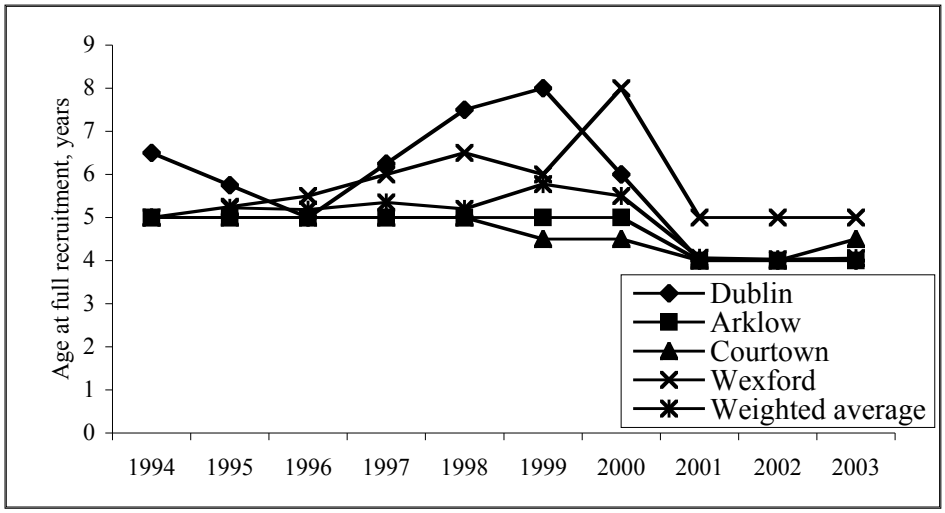

Figure 13. Age at full recruitment of whelk to each sector of the fishery, 1995 – 2003. Averages weighted against sectoral biomass.

Table 9. Mortality coefficient (Z) for each sector of the south west Irish Sea fishery from 1994. The average is weighted by the biomass from 1995 to 2003 inclusive.

	Dublin	Arklow	Courtown	Wexford	Weighted average
1994	0.40	0.56	0.66	0.48	
1995	***0.33***	***0.52***	***0.65***	***0.44***	0.47
1996	0.26	0.48	0.64	0.40	0.44
1997	***0.35***	***0.68***	***0.74***	***0.41***	0.59
1998	0.43	0.88	0.84	0.42	0.83
1999	0.24	0.68	0.88	0.62	0.58
2000	0.46	0.68	0.86	0.21	0.58
2001	0.62	0.77	0.83	0.60	0.73
2002	0.82	1.03	1.33	0.82	1.01
2003	0.90	0.88	1.00	0.77	0.88
Average (from 1994)	0.48	0.72	0.84	0.52	0.68
S.D.	0.22	0.17	0.20	0.18	0.18
Coef. var	0.45	0.23	0.23	0.34	0.27

Interpolated

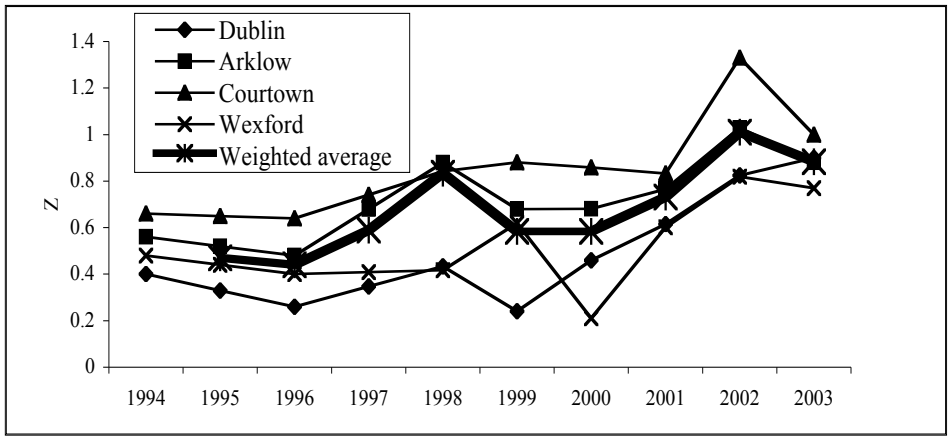

Figure 14. Mortality coefficient (*Z*) of whelk in each sector of the fishery, 1995 – 2003. Averages weighted against sectoral biomass.

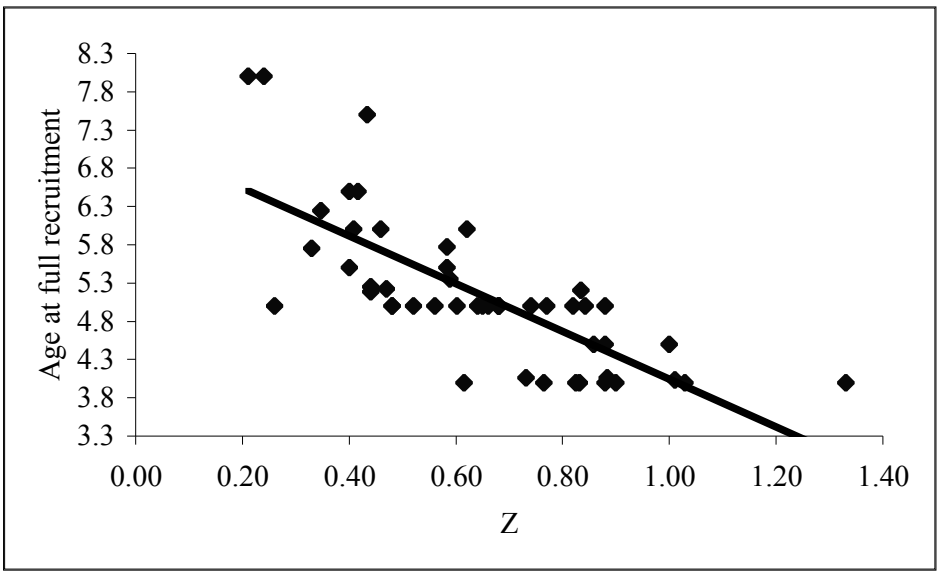

Figure 15. Correlation between age at full recruitment and values of *Z* in the fishery; weighted averages are included (N=49, R^2=0.5604, *P*<0.001).

3.8 Spawning stock biomass

Overall spawning stock biomass (SSB) declined until 1999 and then recovered and increased until 2001 when it again fell (Table 10). The total SSB in 1996, *c.*11,000 t is slightly lower than in 2001 (*c.*12,000 t). The SSB of the Wexford sector may have declined irreversibly although its contribution to actual spawning within this fishery is questionable. The high value of SSB in the Dublin sector in 2000 is questionable in view of the general comments made on sampling within this sector.

Table 10. Spawning stock biomass in the south west Irish Sea fishery.

	Dublin	Arklow	Courtown	Wexford	Total
1995	1,970	1,929	358	4,512	8,770
1996	1,872	3,535	598	5,205	11,210
1997	1,376	4,413	362	2,588	8,739
1998	758	5,385	164	295	6,602
1999	1,502	2,604	644	252	5,001
2000	4,735	3,240	261	692	8,927
2001	3,110	6,599	799	1,646	12,154
2002	1,514	7,465	603	865	10,446
2003	1,708	7,238	460	692	10,098
Average	2,060	4,712	472	1,861	9,105
S.D.	1,183	2,056	204	1,856	2,233
Coef. var	0.57	0.44	0.43	1.00	0.25

4. DISCUSSION

The biomass estimates, which serve to provide a framework in which various parameters may be quantified are indicative rather than a precise history of the fishery, since the mid-1990s. Estimates of biomass based on a complete fishing season are necessarily too high because growth and recruitment continued while landings were being made. The exploitation rates from the short time series up to 15 June tended to be higher than those calculated over an entire season in the course of which growth and recruitment would have reduced them. Closest agreement was obtained between the short season and full season estimates for the Wexford sector in 1995. Growth was likely to be less significant in this sector where the majority of individuals had reached asymptotic length (Figure 11) while the shorter fishing season in Wexford (Table 2) meant that a larger proportion of the consignments preceded recruitment in December than in other sectors (Figure 5).

All of the length frequency distributions of landings from the south west Irish Sea to the various sectors in two periods, 1994-1999 and 2000-2003, with the exception of Dublin 1994-1999 (Figure 11) were unimodal. The modes which approximately coincided with the superimposed vertical size limit arrow, signalled a large juvenile content. The Dublin length frequency distribution had a similar but lower mode in the period 1994-1999. This subsequently increased but its second mode in the vicinity of 90 mm consisted of older whelk, which had probably been fished out since. In the first assessment 8% of these whelk were aged 15+ (Fahy *et al.*, 1995) and animals of these dimensions generally occurred at lower densities than smaller and younger whelk. The Dublin sector is thought to contain two population types which is the reason for a proposed sub-division of the sector into north and south (Figure 1). Large whelk frequented the north but, to the south, the ground merges into that of the Arklow/Wicklow sand and aggregate banks which provide extensive nursery areas for the species. The Dublin sector supplied very different length frequency distributions from one year to the next (Fahy *et al.*, 2000). In other respects it also displayed greater diversity than the other sectors (percentage undersized (Table 6), age at full recruitment (Table 8) and mortality coefficient Z (Table 9)). There is a case for re-allocating some proportion of the Dublin to the Arklow sector but this is not feasible with the documentation available.

In Arklow, the length frequency of the landings declined in 2000-2003. Average length fell from 56.76 mm to 52.95 mm, a significant shift in size in view of the quantities of whelk landed into the Arklow ports.

The length frequency of the Arklow landings in 2000-2003 was not statistically different from that of Courtown in 1994-1999. Both sectors traditionally made heavy landings of sub-legal sized whelk. In the early 1990s whelks caught in the vicinity of Courtown displayed a Lee phenomenon: stunted growth caused either by over-crowding or by selective discarding (Fahy *et al.*, 1995 & 2000). Sandwiched between Arklow and Wexford, the Courtown sector is the smallest of the four. Its landings displayed similarity with landings into Arklow although in recent years the whelk from this sector have, unlike those in the Arklow and Dublin sectors, increased in size, suggesting that boats landing into this port might have sourced whelk from the southern end of the sector or even the northern Wexford one. There is no obvious trend in landings from Courtown.

The Wexford sector was the only one whose length frequencies in the two periods have not differed statistically. It was also unique in the small percentage of undersize whelk present in its landings. It is not feasible to state from where recruitment to this sector originates, but it was certainly not within it. It is questionable whether mature animals in this sector contributed to the spawning stock of the south west Irish Sea whelk fishery as it is currently known. Wexford sector whelks are all thin shelled, typical of the south west Irish Sea fisheries, so that they had not immigrated from the patches of heavy shelled whelks which occur further south in the Celtic Sea. They might have been displaced from further north by strong tidal currents which rolled them southwards from the Arklow and Courtown sand and aggregate banks.

Some significant and probably irreversible changes in sectoral performance occurred during the nine year documented history of this fishery. The Dublin sector provided a stable yield (Figure 2) although the characteristics and possibly the provenance of its landings changed to a greater extent than in any of the other three sectors. The increase in biomass in the Dublin sector recorded in 2000 (Figure 10) was more likely to have taken place an the southern rather than the northern end of this sector and it may represent greater penetration of the Arklow sector grounds by boats berthed in Dublin ports.

Arklow received 20% of the recorded landings from the south west Irish Sea fishery in 1995: landings increased slightly in 1996 and remained stable until 2000 after which they steadily rose. A significant factor in this rise is the larger size and greater mobility of some Arklow vessels which had a longer range than any others in the whelk fleet (Figure 1). A proportion of Arklow landings was likely to have originated outside the boundary of that sector shown in Figure 1 although for the majority, Arklow and Wicklow were probably the nearest landing places. In 2002 the Arklow sector accounted for 83% of whelk landings from the southwest Irish Sea.

In 1995, landings to ports in the Wexford sector outweighed those of any other sector. Thereafter they declined in each successive year until 1998 when they stabilised at between 230 and 415 t annually until 2003, when they again increased slightly to 644 t.

Sectoral characteristics strongly influenced the value of various parameters of the whelk stock and their patterns of exploitation. The larger/older animals in part of the Dublin and all of the Wexford sectors had heavier rates of exploitation than those in the centre sectors i.e. Arklow and Courtown. The centre sectors of the fishery also produced a larger number of undersized animals than its northern or southern extremities. The recruitment which was recorded in 2002 (Table 7), was one of the largest in the series which might alternatively have taken place in the previous year when the biomass of the Arklow sector could not be estimated. Over the nine years covered by this assessment, the Arklow sector accounted for 80% of recruitment within the south west Irish Sea.

The apparent collapse in the fishery which took place early in 2004 had a similar consequence to what occurred in 1997 following record landings in 1995 and 1996 when a number of vessels sought alternative target species. Inquiring into its causes, the two years to compare are 1996 and 2003. The estimated total biomass was fairly similar in both years (23,404 t in 1996, 26,634 t in 2003 – Table 4) and the SSB was

heavier in 1996 than in 2003 (11,210 t in 1996, 10,098 t in 2003 – Table 10). In 1996 the status of the south west Irish Sea fishery was quite different: much of the SSB was in the Wexford sector where it may not have been contributing to the regeneration of the south west Irish Sea fishery. The index of recruitment in 2003 was twice as great as in 1996 (Table 7) and that is a positive indicator to the future. In two other important aspects the fishery differed in these two years. In 2003, the age at full recruitment was more than one year lower than in 1996 (Table 8, Figure 12) and the mortality coefficient *Z* was twice as great (Table 9, Figure 14).

The development of the southwest Irish Sea fishery over its nine best documented years consisted of the working down of older whelk populations at its north and south extremities and of progressively greater targeting of juvenile whelk in the centre sectors which are the principle nursery grounds for the entire fishery. Fishing effort has varied in accordance with the biomass, reaching a peak of approximately 15,000 fishing days in 1995 (Figure 3). A lower number of fishing days in 2003 (approximately 11,000) may have been influenced by greater operational efficiencies in the meantime. The largest recorded profit per boat-day since the best documented history of the fishery commenced in 1995 was in 2002 (Figure 4), assuming that other things remained equal and that the size of the vessels was the same during the period. In 1997, the number of boat-days annually in the fishery declined although some individual vessels continued to make increasing landings from 1995 to mid-1998 (Fahy *et al.*, 2000) but this trend was not reflected in the landings to sector data. Biomass is probably the main determinant of fishing effort in the south west Irish Sea but other factors such as price were likely to be a strong influence on fishing effort.

Since records began the tendency to exploit smaller and younger whelk has intensified over this fishery. Heavy recruitments in 2001/2002, most marked in the Arklow sector, may be the basis on which the population will again expand. The large recruitment was however immediately followed by an expansion in fishing effort so that much will depend on the extent to which these juveniles have already been removed.

5. ACKNOWLEDGEMENTS

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Appendix 1: Outcome of depletion regressions based on a full fishing year

Source of data	Year	Sector	Landings (t)	Number of data points	Sample Estimate R^2 biomass	*P*	Landings in sample estimate (kg)	Sample estimate Biomass (kg)	Catchability Coefficient q	Estimated biomass (t)
Co A	1990	Courtown	56	393	0.019987	0.0050	403,956	1,747,853	0.0007	242
Co A	1991	Courtown	310	461	0.19851	0.0024	508,654	2,663,889	0.0005	1,624
Co A	1991	Wexford	81	44	0.15573	0.0080	41,951	90,036	0.0144	174
Co A	1993	Courtown	285	474	0.067068	<0.0001	534,645	1,273,403	0.0012	679
Co A	1993	Wexford	545	1241	0.014528	<0.0001	1,352,158	6,747,761	0.0002	2,720
A+B	1995	Dublin	1,042	519	0.020892351	<0.001	204,276	482,846	0.0011	2,463
A+B	1995	Arklow	1,178	3118	0.0136	<0.0001	1,405,832	4,763,268	0.0001	4,764
Co A	1995	Arklow	1,178	994	0.0799	0.0117	476,336	1,157,900	0.0005	3,418
A+B	1995	Courtown	778	1299	0.064324198	<0.05	457,666	1,052,610	0.0004	1,789
Co A	1995	Courtown	778	59	0.112183785	<0.01	60,203	119,189	0.0097	1,540
Co B	1995	Courtown	778	1206	0.106838674	<0.001	397,463	786,658	0.0006	1,540
A+B	1995	Wexford	2,901	1406	0.066921187	<0.05	657,313	1,635,904	0.0004	7,220
Co A	1995	Wexford	2,901	994	0.079963405	<0.0001	476,336	1,157,900	0.0005	7,052
Co B	1995	Wexford	2,901	412	0.182657637	<0.0001	180,977	299,888	0.0023	4,807
A+B	1996	Arklow	2,453	2177	0.014178437	<0.0001	1,835,391	7,780,260	0.0001	10,398
Co A	1996	Arklow	2,453	994	0.02795584	<0.0001	1,040,351	3,488,516	0.0004	8,225
Co B	1996	Arklow	2,453	722	0.06514	<0.0001	795,040	1,455,709	0.0008	4,491
Co B	1996	Courtown	864	1201	0.073139925	<0.0001	456,013	985,896	0.0005	1,868
A+B	1996	Wexford	1,550	1197	0.0118571	<0.0001	620,799	3,474,544	0.0002	8,675
Co A	1996	Wexford	1,550	842	0.0148377	0.0004	451,318	2,294,015	0.0003	7,879
Co B	1998	Dublin	428	241	0.107997899	<0.0001	264,352	514,425	0.0030	833
Co B	1998	Arklow	2,547	1963	0.010656	<0.0001	1,592,578	7,831,207	0.0012	12,524
Co B	1998	Courtown	396	262	0.156353	<0.0001	222,620	353,746	0.0032	629
Co B	1998	Wexford	282	168	0.028221	<0.05	236,101	475,609	0.0018	568
Co B	1999	Arklow	2,759	905	0.065100279	<0.0001	421,990	1,137,865	0.0005	7,439
Co B	1999	Courtown	568	252	0.119716872	<0.0001	175,496	462,780	0.0019	1,498
Co B	1999	Wexford	231	156	0.312762743	<0.0001	98,600	158,048	0.0063	370
Co B	2000	Dublin	1,107	415	0.117070956	<0.0001	199,614	1,080,688	0.0014	5,993
Co B	2000	Arklow	2,447	1686	0.01553025	<0.0001	1,486,789	4,687,307	0.0002	7,715
Co B	2000	Courtown	460	439	0.070133308	<0.0001	291,228	660,005	0.0011	1,042
Co B	2000	Wexford	415	426	0.125338643	<0.0001	314,433	588,395	0.0014	777
Co B	2001	Courtown	425	405	0.016388923	<0.01	320,127	1,253,316	0.0005	1,664
Co B	2001	Wexford	373	473	0.017262802	<0.01	215,979	1,070,559	0.0005	1,849
Co B	2002	Dublin	713	463	0.017688	0.0040	420,593	2,289,338	0.0004	3,881
Co B	2002	Arklow	6,569	2322	0.006463	<0.0001	1,817,048	9,836,495	0.0001	35,561
A+B	2002	Arklow	6,569	4275	0.010110553	<0.0001	4,722,333	22,359,965	0.0001	31,104
Co A	2002	Arklow	6,569	2085	0.0504	<0.0001	2,911,475	8,632,035	0.0002	19,476
Co B	2002	Courtown	323	227	0.015408	0.0500	253,089	874,595	0.0011	1,116
Co B	2002	Wexford	293	408	0.23152	<0.0001	149,249	620,291	0.0022	1,218
A+B	2003	Arklow	7,639	7331	0.0368057	<0.0001	6,686,094	18,101,142	0.0001	20,681
Co A	2003	Arklow	7,639	2907	0.04946435	<0.0001	3,048,327	7,924,599	0.0002	19,859
Co B	2003	Arklow	7,639	2481	0.016207	<0.0001	1,639,387	5,703,842	0.0001	26,578
Co B	2003	Courtown	297	379	0.026188	0.0016	277,545	999,314	0.0003	1,069
Co B	2003	Wexford	644	772	0.236977	<0.0001	644,226	1,003,315	0.0005	1,003

Appendix 2: Outcome of depletion regressions based on the year up to 15 June

Source of data	Year	Sector	Landings (t)	Number of data points	Sample Estimate R^2 biomass	*P*	Landings in sample estimate (kg)	Sample estimate Biomass (kg)	Catchability Coefficient q	Estimated biomass (t)
Co B	2000	Dublin	1,107	65	0.1274	0.0035	199,614	439,000	0.0057	2,435
A+B	1995	Arklow	4,764	586	0.0223	0.0003	498,000	1,322,000	0.0003	12,647
Co B	1997	Arklow	1,784	281	0.0245	0.0085	499,955	1,005,181	0.0012	3,587
Co B	1998	Arklow	2,547	778	0.1387	0.0001	906,000	2,977,000	0.0004	8,368
A+B	2003	Arklow	7,639	2,384	0.0051	0.0005	2,495,750	16,949,509	0.0001	51,879
Co B	1998	Courtown	864	115	0.2481	0.0002	210,000	662,000	0.0008	2,724
Co B	1996	Courtown	396	472	0.1725	0.0075	143,000	303,000	0.0040	838
A+B	1995	Wexford	2,901	711	0.0481	<0.0001	533,000	1,141,000	0.0006	6,210

Source of data	Year	Sector	Start date for regression	Exploitation rate (%)
Co B	2000	Dublin	26-May	45
A+B	1995	Arklow	30-Apr	38
Co B	1997	Arklow	17-Apr	50
Co B	1998	Arklow	20-Feb	30
A+B	2003	Arklow	11-Apr	15
Co B	1998	Courtown	23-Feb	32
Co B	1996	Courtown	21-Mar	47
A+B	1995	Wexford	10-Apr	47