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SOME THICK SHELLED WHELK *BUCCINUM UNDATUM* CHARACTERISTICS AND FISHERIES IN IRELAND.

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ABSTRACT

Observations are presented on two whelk populations from the Cape grounds in Co. Donegal and the vicinity of Helvic Head Co. Waterford. Both co-exist with large populations of brown crab (*Cancer pagurus*) which is the likely explanation for their thick shells. In the south west Irish Sea (with which comparison is made) and in the Cape stocks, 83-88% of individuals were easily aged by reference to the operculum. Heavy calcification obscured structure in the case of Helvic animals and only 6% of these could be confidently aged. Helvic and south west Irish Sea whelk have similar $L\infty$, but both Helvic and Cape whelk have more rapid early growth than in the Irish Sea.

The density of whelk in the Helvic vicinity is insufficient to support a commercial fishery. The yield of whelk from other areas of the Celtic Sea is sporadic and slow to recover from exploitation. The Cape fishery shows signs of rapid depletion since most recent exploitation began there in 2003. The centrally situated sectors of the south west Irish Sea fishery are highly resilient and recover rapidly from heavy removals of biomass which can exceed 50% *per annum*.

Maturation appears to take place at a lower size and age in the Irish Sea than in the other two whelk stocks and this is tentatively proposed as the explanation for their lower productivity.

CONTENTS

INTRODUCTION

Whelk, *Buccinum undatum*, is one of Ireland's most economically important and voluminous inshore landings. In 2003, when exceptionally, almost 10,000 tonnes were registered, it was the heaviest landing for any shellfish (crustacean, mollusc) species taken only within 12 nm. The species probably occurs in all coastal areas, but it is abundant in the south west Irish Sea which provides most of the commercial fishery (Fahy *et al.*, 2005). The south west Irish Sea had three years (2001-2003) of good recruitments and the heaviest landings in any year since the fishery expanded in the mid-1990s took place in 2003. However the juveniles were rapidly harvested and landings slumped the following year. This prompted a search for additional supplies of the resource.

An exploratory survey, sponsored by Bord Iascaigh Mhara, Sofrimar of Kilmore Quay and the Marine Institute was conducted in the vicinity of Helvic Head in the second quarter of 2005. The objective of the investigation was to establish whether marketable quantities of whelk occurred in the area and the survey provided an opportunity to gather information on some of the biological characteristics of Celtic Sea whelk on which only occasional observations have been made (see, for example, Fahy *et al.*, 2000).

The south coast is better known for landings of brown crab (*Cancer pagurus*) than for whelk (Fahy *et al.*, 2005). In such circumstances whelk are typically heavily shelled, in contrast to the lighter and smoother shelled animals which are found in the Irish Sea where brown crab are less abundant (Meredith *et al.*, 2005).

The Cape grounds in Co. Donegal yield landings of cod (*Gadus morhua*) and brown crab among other species. In 2003, 672 tonnes of whelk were landed from this fishery (Figure 1) although annual landings were lower in the two following years. Data from the Celtic Sea show that whelk landings have been sporadic and since the south west Irish Sea fishery expanded in the mid- 1990s landings from both there and the Cape grounds have been small and irregular. The differing circumstances of whelk in the three areas considered here provide a context in which to compare their biological characteristics.

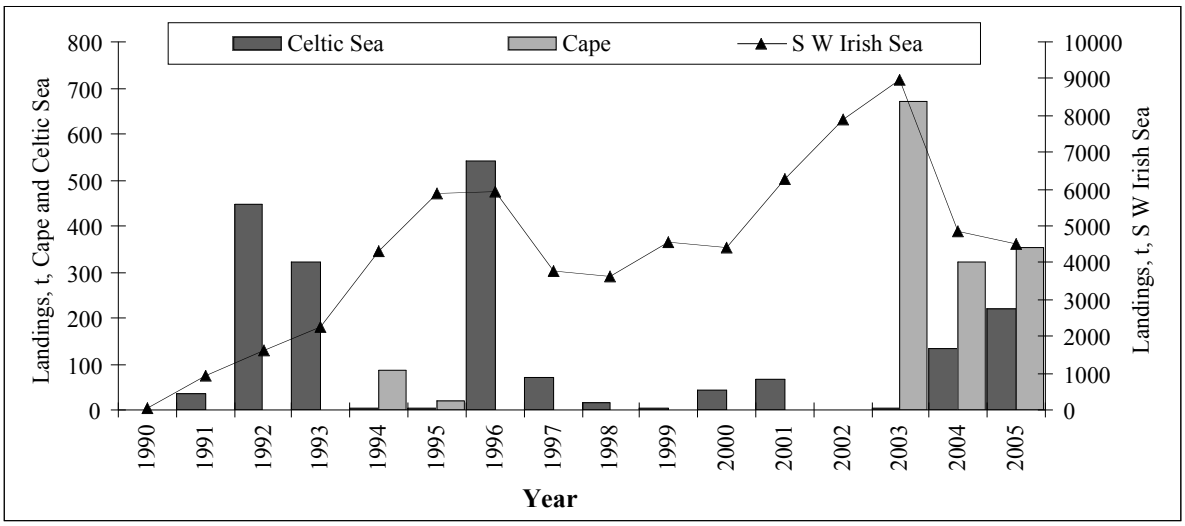
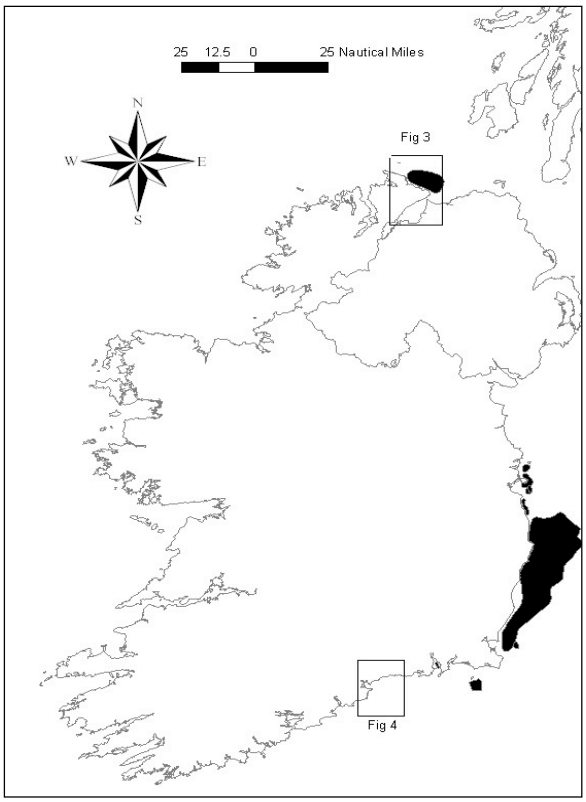


Figure 1. Landings (tonnes) of whelk from the Cape grounds in Co. Donegal, the Celtic Sea and the south west Irish Sea.

Distribution of the fisheries

The location and extent of whelk fisheries in Irish coastal waters are approximately shown in Figure 2. More detail of the south west Irish Sea fishery which is divided into four sectors for sampling purposes is given in Fahy *et al.*, 2000 and 2005. Landing places for the Cape fishery are shown in Figure 3 and the area of investigation in the Helvic vicinity in Figure 4.



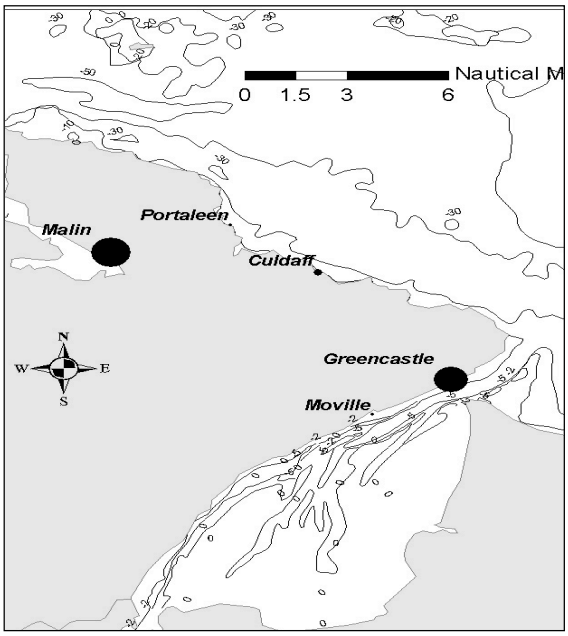
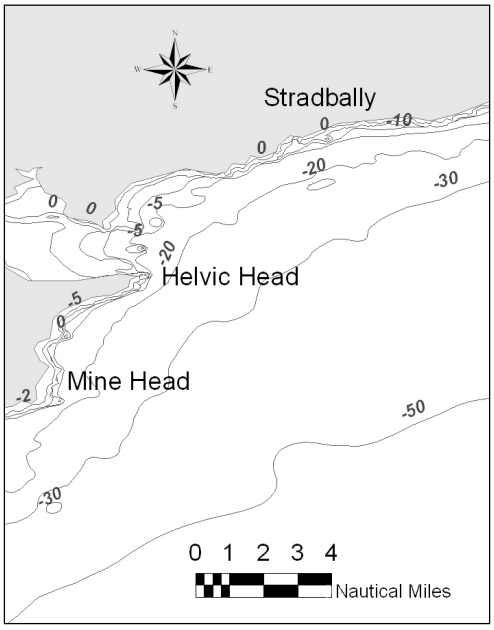


Figure 3. (Top) The vicinity of the Cape fishery. Symbol size represents relative importance of whelk landing places.

Figure 2. (Left)Whelk fisheries in Irish coastal waters, reproduced from Fahy *et al.* (in prep.). Figure 3 refers to the Cape grounds and Figure 4 the Helvic vicinity.



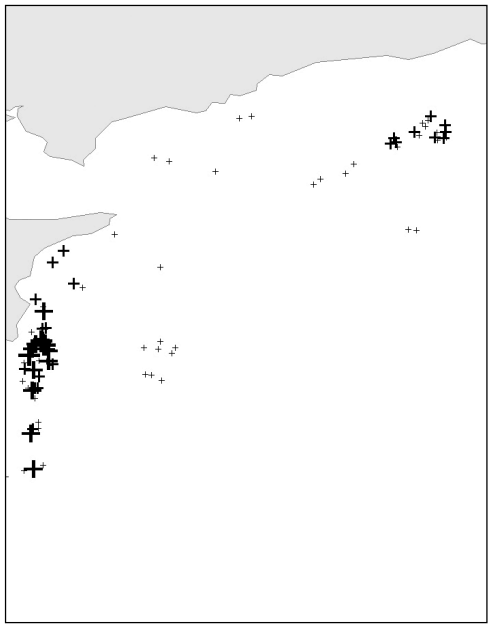


Figure 4. (Left) vicinity of the 2005 Helvic whelk survey. (Right) LPUE results, symbol size relative to success.

METHODS

Samples were obtained from Helvic grounds in whelk pots which were set in strings of 50, baited with brown crab and dogfish (*Scyliorhinus* spp). The gear was lifted on fourteen occasions between 21 May and 20 June 2005 and 90 strings of pots were emptied in the course of the survey. The intended soak time was 24 hours but, this was often prolonged by adverse weather conditions. Maximum soak time was 144 hours and the average was 54 hours.

The pots were set at depths ranging from 12 to 46 m (average 27.5 ± s.d. 8.9 m).

Samples of the Cape ground whelk were collected in 2003 and 2004 from a processor in Co. Donegal who also supplied details of daily landings weights. Time series of landings to named ports were used to estimate biomass by depletion method.

All biological material was frozen and later thawed in the laboratory. Total length, from the apex of the shell to the end of the siphonal canal (to the nearest mm below) and total weight (0.1 g) were noted as was the sex of an individual. Occasionally wet meat and shell weights were recorded separately. The penis length of some individuals was measured (nearest 0.1 mm) and the operculum was removed for estimation of age by the number of striae. Length growth coefficients were estimated from the von Bertalanffy equation (Ricker, 1975):

$$(1)\ \boldsymbol{Lt = L_{\infty}(1-exp[-k(t-t_0)])}$$

Where $\boldsymbol{L}$ is the length at age at time $\boldsymbol{t}$, $\boldsymbol{L_{\infty}}$ is the theoretical maximum length, $\boldsymbol{t_0}$ is the theoretical age at length zero and $\boldsymbol{k}$ is the growth coefficient. The values of $\boldsymbol{L_{\infty}}$, $\boldsymbol{t_0}$ and $\boldsymbol{k}$ were estimated by fitting a growth curve to the observed mean length at age data.

Age length keys (ALKs) were constructed to allocate whelk whose opercula could not be interpreted to an age group. Age at full recruitment and catch curves were estimated from the age distribution within collections from the Cape and Helvic grounds.

Males were considered mature when penis length achieved half or more of the total shell length. Within samples, the average length at which this occurred ($\boldsymbol{L_c}$) was estimated from the regression:

$$(2)\ \boldsymbol{Ln((1-P)/P)}\ \text{on}\ \boldsymbol{Lt}$$

Where $\boldsymbol{P}$ is the proportion of total length represented by length of the penis. Female maturation was estimated applying the same formula to the proportion at length in which the ovary ≥0.1 g.

RESULTS

The Cape fishery and the feasibility of a fishery at Helvic

Whelk landings from the Cape fishery were made into six places of which the largest were Malin and Greencastle (Figure 3). Effort had been expended by local processors to establish a commercial fishery in this area but the biomass in the vicinity of each named location showed a progressive year on year decline (Table 1). Depletion rates were rapid. Examples from Malin Head are shown in Figure 5 and are typical of all the calculated depletion rates for this fishery. Key indicators of the Cape fishery's progress are set out in Table 1. For the first two years, 2003 and 2004, biomass estimates were similar. At this stage fishers were probably exploring the distribution and range of whelk in their vicinities. Exploitation rates were high but they are not unusual for fisheries for this species (Fahy *et al.*, 2005). The fishing season (the period over which landings were registered by buyers) increased slightly after 2003; however, the number of days required to harvest 75% of landings in Co. Donegal declined in 2005, presumably as the fishery became better known.

Table 1. Observations on the exploitation of whelk in the Cape fishery.

	Biomass, tonnes		
	2003	2004	2005
Greencastle	523***		164***
Malin Head	526***	512***	93***
All Donegal	1,268***	1,218**	824***

<0.001**, <0.0001***

	% exploitation		
	2003	2004	2005
Greencastle	59		51
Malin Head	71	65	81
All Donegal	56	42	43

	Fishing days in year		
	2003	2004	2005
Greencastle	238	337	237
Malin Head	211	251	276
All Donegal	238	337	276

	Days to make 75% annual landings		
	2003	2004	2005
Greencastle	139	196	121
Malin Head	128	128	131
All Donegal	155	149	124

The main objective of the survey at Helvic was to ascertain whether whelk were present in commercial volume. The yield was estimated from the volume of a standard 40 kg plastic fish box filled by the catch per string of pots (virtually all whelk at Helvic were legally acceptable so no distinction is made between catches and landings). Yield ranged between 0 and 2 fish boxes (0-80 kg) per train of pots. In terms of yield the maximum was 1.6 kg per pot. The overall average was much lower: 0.34 ± s.d. 0.38 kg per pot. An average of 2 kg per pot lifted is regarded as commercially acceptable. Based on these results, there is no basis for a commercial fishery for whelk in the vicinity of Helvic Head.

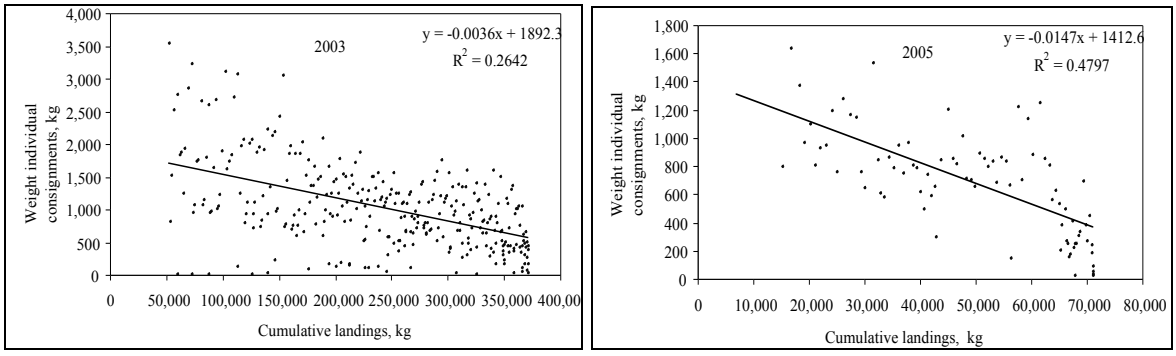


Figure 5. Depletion regressions from the Cape grounds, Malin Head vicinity, in 2003 and 2005.

Shell sculpture, age and growth

The shell of Irish Sea whelk is typically thin and smooth on its external surface. Cape and Helvic whelk are thicker with longitudinal ridges and Helvic animals have a heavier shell.

The numbers of whelk handled in the two collections from Helvic and the Cape grounds are set out in Table 2 where success at interpreting age is reported together with the sex ratio of the samples. Comparison is made with similar data from the four sectors of the south west Irish Sea fishery in 2004 and a summary of samples from the south west Irish Sea is also given.

Table 2. Samples from the Helvic and Cape grounds in 2005, compared with the south west Irish Sea fishery in 2004.

Location	Size of sample	Numbers aged	Percentage aged	Sex ratio (ff/mm)
Helvic, Waterford (2005)	3,567	206	6	1.2
Cape, Donegal (2003-2004)	1,122	965	86	1.3
Dublin sector, 2004	520	458	88	1.4
Arklow sector, 2004	3,330	2,775	83	1.2
Courtown sector, 2004	430	365	85	1.2
Wexford sector, 2004	626	527	84	1.3
All S W Irish Sea, 2004	4,906	4,125	84	1.2

Length distributions from the Cape fishery in 2003 and 2004 combined suggest a bimodal length frequency which differs markedly from that of Helvic whelk (Figure 6). In both stocks the animals become asymptotic at approximately 9 or 10 years of age. Growth is rapid in Helvic whelk and the length frequencies of ages 3, 4, 5 and 6 may be descried in the length frequency distribution of the samples.

Growth coefficients for the two fisheries, compared with whelk from the south west Irish Sea are:

	L_∞ mm	k	t_0
Cape	114	0.192	-0.435
Helvic	106	0.261	1.271
S.W. Irish Sea	106	0.133	-0.959

(the south west Irish Sea data were reported in Fahy *et al.*, 2000).

The calculated growth curves are shown on Figure 7. Thin shelled south west Irish Sea whelk have the lowest asymptotic length and Cape whelk the greatest; Helvic animals occupy an intermediate position.

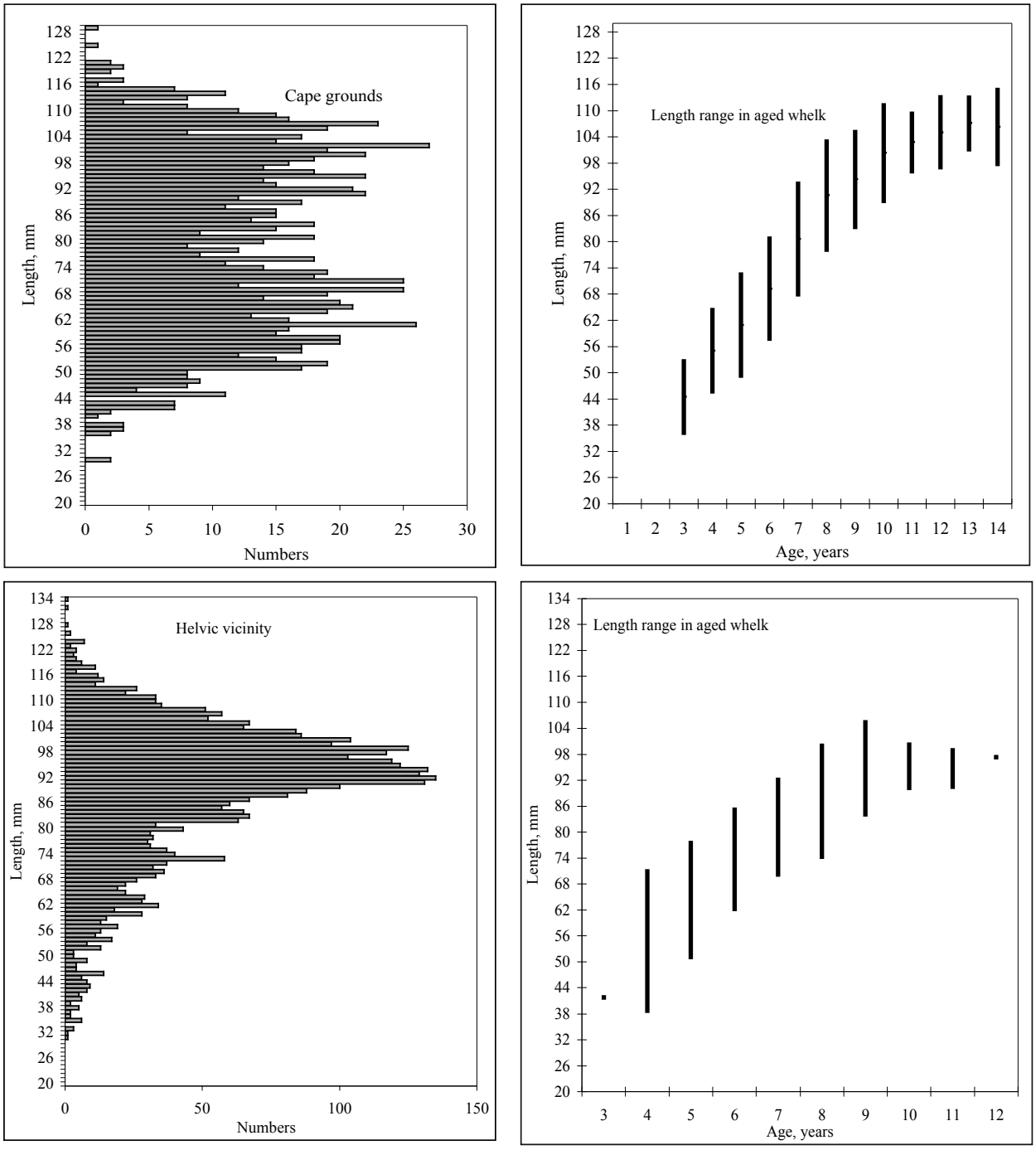


Figure 6. Length frequency (left) and mean ± 1 s.d. length at age of whelk from the Cape and Helvic areas.

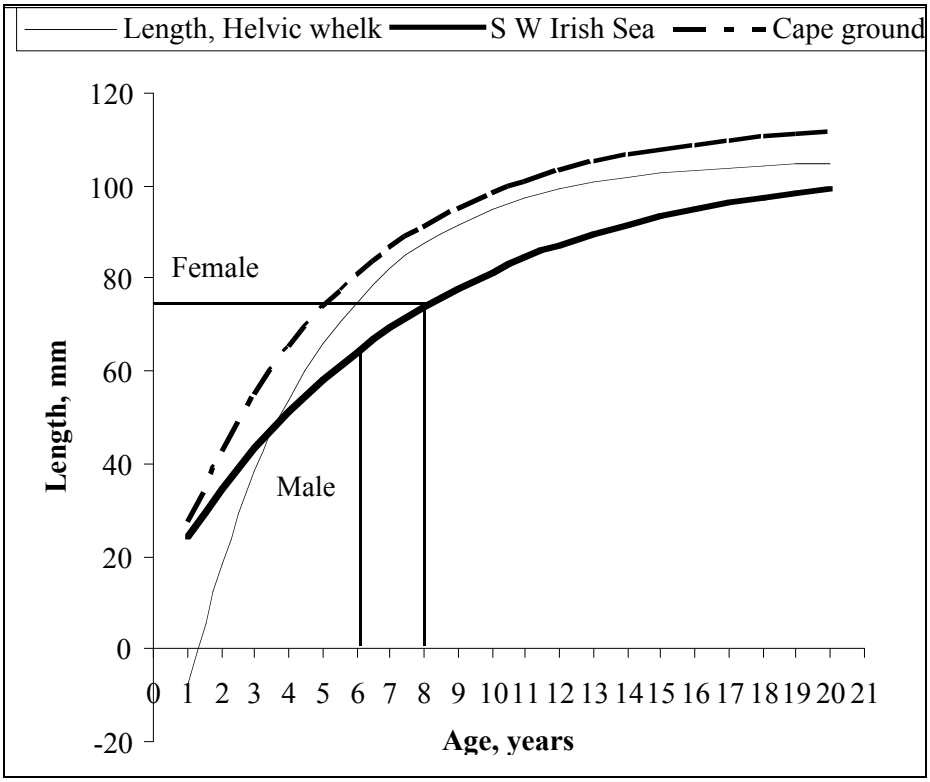


Figure 7. Calculated growth curves for Helvic, Cape and south west Irish Sea whelk. Mean length at 50% mature female whelk (those having ovaries ≥0.1 g) in the south west Irish Sea fishery and of 50% mature males (penis length ≥ 50% total length) in the Arklow sector of the south west Irish Sea fishery are indicated. Further explanation is to be found later in text.

Wet weight:length relationships and shell weight

Regressions of weight (g) on length (mm) provided the following outcome for the three groups of whelk:

	Cape	**Helvic**	**South west Irish Sea, 2004**
Intercept	-9.2303	-8.2815	-8.5219
X-variable	3.0110	2.8338	2.8629
R^2	0.9419	0.8932	0.9648
P	<0.0001	<0.0001	<0.0001
N	1,122	2,590	5,711

The curves drawn from this table are set out in Figure 8.

The Cape and south west Irish Sea populations of whelk have similar weights at length but those of the Helvic animals are heavier. Shell weight was expressed as a percentage of total weight in Irish Sea collections in 1996, 2000 and 2002. The relationship between the percentage weight accounted for by the shell declined as the animals increased in length (Figure 9 and Table 3). A significant correlation was not obtained for Helvic whelk whose percentage shell weight and length correlation, though not significant (P>0.05) however, did not have a downward tendency with increasing length.

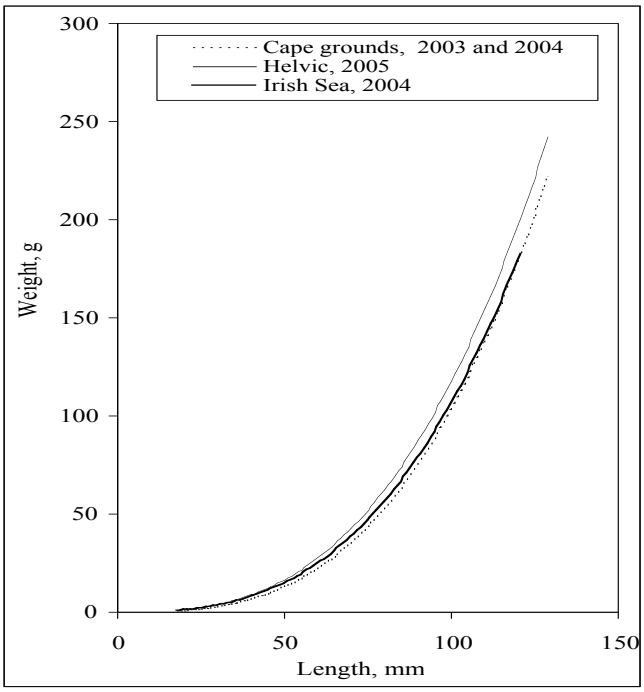


Figure 8. Weight at length relationships of whelk in the Cape, Helvic and south west Irish Sea whelk.

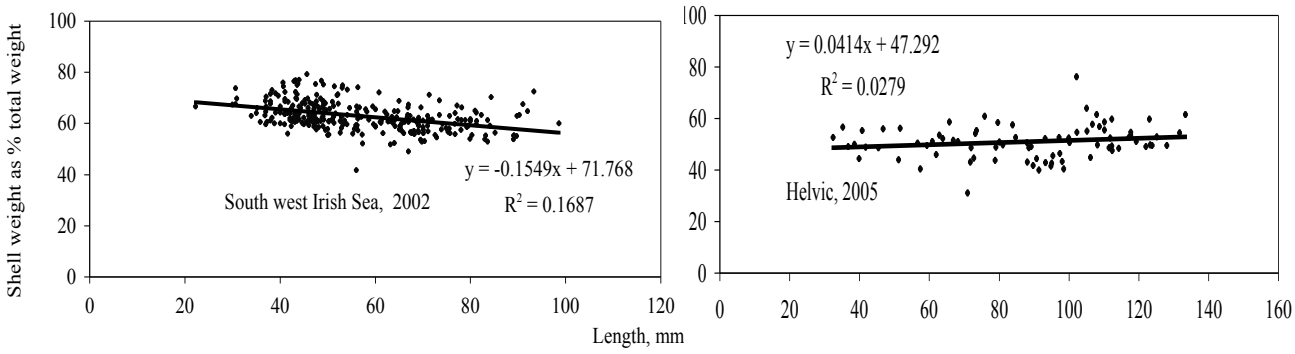


Figure 9. Shell weight as a percentage of total wet weight in Helvic and south west Irish Sea whelk.

Table 3. Correlation between shell weight as a percentage of total wet body weight and shell length.

	Irish Sea, 1996	**Irish Sea, 2000**	**Irish Sea, 2002**	**Helvic, 2005**
Average	47.5	63.2	62.9	50.9
S.D.	6.0	5.5	5.6	6.5
Max	87.1	77.1	79.2	76.3
Min	6.6	40.0	41.8	31.2
Intercept	54.2	71.9	71.8	47.3
X variable	-0.1242	-0.1578	-0.1549	0.0414
Number	1,670	220	293	82
R^2	0.0896	0.1653	0.1687	0.0279
P	<0.0001	<0.0001	<0.0001	0.1336
Significant?	Highly	Highly	Highly	No

Maturation

The length of the penis, expressed as a proportion of the total shell length, is the most convenient index of maturation and it was routinely measured in a sub-sample of whelk in the course of stock assessment work. The outcome of three regressions (formula 2), one for whelk from Helvic, one from the Cape grounds and one for whelk from the Irish Sea are compared in Figure 10.

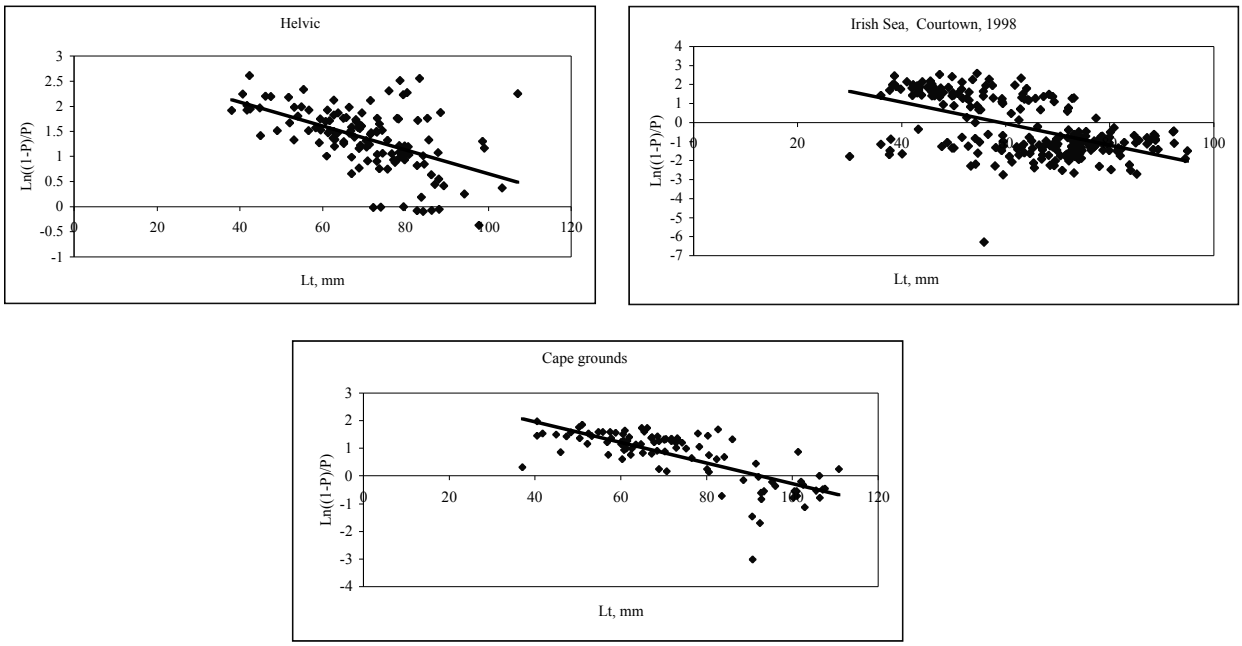


Figure 10. Regressions of P (penis length expressed as a proportion of total length) on total length.

Mortality coefficients

Mortality coefficients (***Z***) were calculated for the entire Helvic collection in 2005 after it had been distributed among age groups by ALK in accordance with the limited age analysis. All of the Cape ground collections were similarly treated and the results of both are set out in Figure 11. Similar analyses of most of the four sectors of the Irish Sea fishery have been undertaken annually since 1994. Their averages, over a ten year period, are set out in Fahy *et al.*, 2005: the northern and southern ends of the south west Irish Sea fishery (the Dublin and Wexford sectors) have lower values, averaging at 0.48 and 0.52, while the central sectors, Arklow and Courtown have higher ones which averaged at 0.72 and 0.84 respectively. Where mortality coefficients are calculated from catch curves, recruitment can be influential and, in the case of the Irish Sea, the higher values are associated with nursery grounds. The Helvic grounds were not commercially exploited at the time of the 2005 survey. Full recruitment was assumed to have taken place at 5 years of age and mortality was high thereafter (***Z***=0.45) although complications in ageing this stock may have distorted this outcome. In contrast, exploitation is believed to have been heavy since the recent fishery developed on the Cape grounds but the value of ***Z*** was low at 0.28; full recruitment had occurred at age 5 in this fishery.

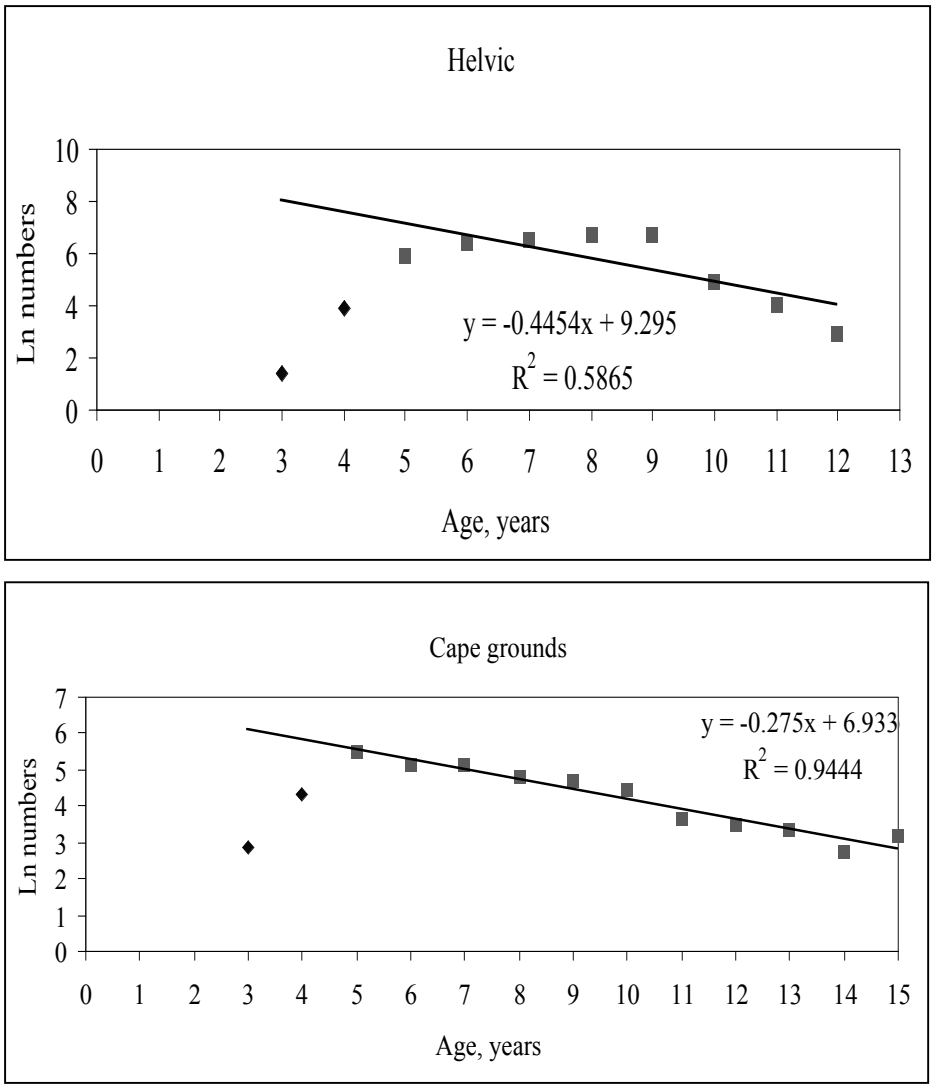


Figure 11. Catch curves and calculated mortality coefficient (Z) for the Helvic and Cape ground whelk.

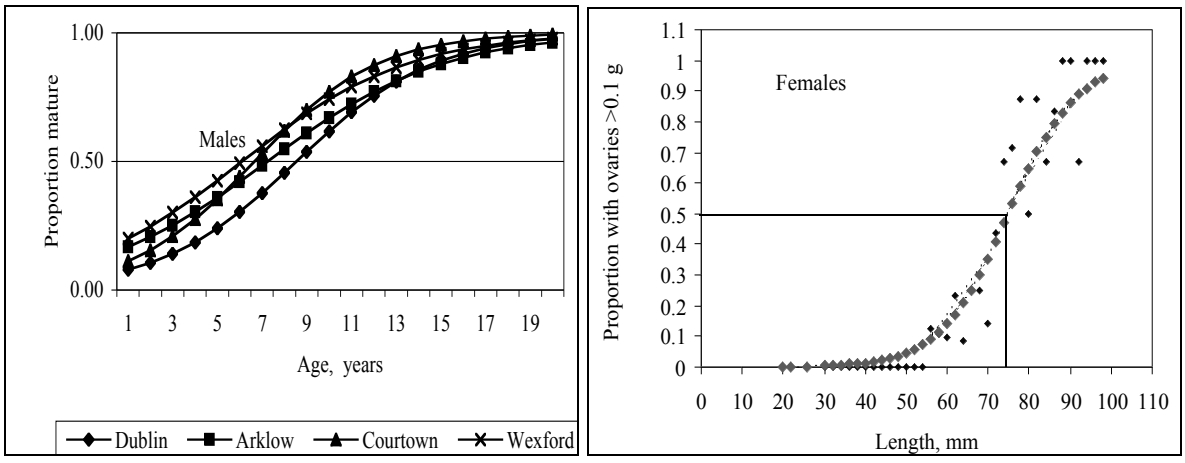


Figure 12. Ogives of male maturation in four sectors and of female maturation for the south west Irish Sea fishery.

DISCUSSION

Buccinum undatum is widely distributed geographically from low tide level to approximately 200m depth on both sides of the Atlantic, from Canada south to New Jersey in North America and in Europe from Norway to south west France. The shell structure probably alters in response to a variety of factors which include latitude, environment, the sex of the individual and predation pressure. Such statements have been made about a number of gastropod species and Thomas *et al.* (1988) related shell thickness in *Buccinum* to the occurrence of large decapod predators in Canada. Irish inshore waters support morphologically easily distinguishable stocks of whelk and the more heavily armoured ones co-occur with high densities of brown crab (Fahy *et al.*, 2002, 2004, 2005) so the established association between the two applies in the cases of Helvic and the Cape grounds also. However, Thomas *et al.* (1988) did not associate lower size at maturation with the absence of crustacean predators although this would appear to be the case for the Irish whelk stocks examined here.

Kideys *et al.* (1993) reported the onset of maturation in Irish Sea whelk at between 60 and 70 mm total length and similar results were obtained for the south west Irish Sea (Fahy *et al.*, 2000) which are reproduced here in Figure 12 for comparison. A single ogive for females in the entire fishery places the point of 50% maturity at 75 mm (corresponding to 8 years of age) (Figure 7). Four ogives for males, from each sector of the fishery place the age at 50% maturity at 64-75 mm, corresponding to 6-8 years.

It was not feasible to construct ogives for male maturation on either the Helvic or the Cape grounds but regressions of the proportion of total length represented by penis length on total length (Figure 10) suggest the males in both stocks reach maturity at greater length and age than in the Irish Sea. This tentative finding should be corroborated by more detailed anatomical examination but, if sustained, it provides a possible explanation for the poor regenerative capacity of the Cape and Helvic stocks.

Few juvenile whelk were encountered on the Helvic or Cape grounds and it is likely that nursery areas were not fished in either location. Catch curves (Figure 11) suggest that the mortality coefficient is low on the Cape grounds ($\boldsymbol{Z}$ = 0.45); possibly higher in Helvic although the latter was an unexploited stock. In the case of Helvic however, few age interpretations were possible (Table 2) and the construction of catch curves is subjective, depending on the age at which full recruitment is assumed to take place; a value of 5 years (which would be high in the south west Irish Sea fishery) would have resulted in a lower value for $\boldsymbol{Z}$ in Helvic. The Arklow and Courtown sectors of the south west Irish Sea have values of $\boldsymbol{Z}$ ranging from 0.84 to 0.72 whereas the Wexford sector which is a "growing-on" rather than a nursery area supporting few juveniles, had a 10 year average value of $\boldsymbol{Z}$ = 0.52. In the absence of more detailed information there are two potential explanations for the population structure on the Cape and Helvic grounds: either they are on-growing areas, such as the Wexford sector, or they are populated by whelk with a low regenerative capacity and longer survival capability.

A feature of whelk from the south west Irish Sea fishery is their high fecundity. Exploitation rates within the central nursery areas (sectors Arklow and Courtown) can result in the removal of >50% of the biomass annually (Fahy *et al.,* 2005) but the stocks are resilient and quickly recover despite heavy removals of undersized individuals. "Thick shelled" stocks

on the other hand are quickly depleted and they have a slow rate of recovery; this is well illustrated in Figure 1 which provides landings data for two of the three areas discussed.

This comparison of three whelk stocks is superficial. While it is possible to separate them on the basis of maturation and shell sculpture into two groups more detailed examination may well result in greater characterisation.

Acknowledgements
Richard Tobin and his crew on the MFV Ellen Marian collected the samples from Helvic Head. The survey was jointly financed by the Marine Institute, Sofrimar, Kilmore Quay and Bord Iascaigh Mhara whose local inshore facilitator John Hickey provided advice and practical assistance with the logistics of the operation. Landings data and samples of whelk from the Cape grounds in Co. Donegal were provided by the staff and management at Errigal Fish in Carrick, Co. Donegal.

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