Irish Fisheries Investigations Number 14

THE DUNDALK COCKLE *CERASTODERMA EDULE* FISHERY IN 2003-2004

Edward Fahy[1], Jim Carroll[1] and Sean Murran[2]

[1]Fisheries Science Services, Marine Institute, Snugboro Road, Dublin 15.
[2]Department of Communications, Marine and Natural Resources, Howth, Co. Dublin.

ISSN: 0578 7467

ABSTRACT

A cockle fishery in Dundalk Bay has been infrequently documented since 1970. Cockle bearing sands and muds are 44.5 km^2 in extent. The bay, which is in an SPA and a cSAC also supports large numbers of overwintering birds, of particular relevance is the oystercatcher (*Haematopus ostralegus*). In 2003 and 2004 when an assessment of the fishery was undertaken, cockles ranged from 0 to 8+ years of age, but the vast majority were 0 and 1+ animals. Growth was rapid and 53% of asymptotic length (49.1 mm) was achieved at the first winter. In agreement with observations elsewhere, the density of the rapidly growing animals was very low. The estimated cockle biomass in spring 2004 was 1,654 tonnes comprising 143 million animals. A survey undertaken in spring 2004, suggested that spat falls contributing to the population may not have been evenly distributed throughout the Bay. Condition factor in 2003 and 2004 did not conform to an expected seasonal pattern, suggesting that some parts of the area supported better growth rates than others. Cockle landings from this fishery are of good quality. Cockle size is at the upper end of the range in Britain and Ireland and the majority of individuals landed by suction dredging were 1+ years old. Raked landings contained more 2+ cockles than suction-dredged ones. Damage to cockles discarded by suction dredging followed the pattern reported elsewhere and damage rates increased with the size of the animals. Some cockle landings have probably always been made in Dundalk Bay by picking and raking, but 2001 marked the beginning of an expansion of the dredge fishery, whose landings exceeded 200 tonnes in 2004. The necessity for controls and management of this fishery in the context of EU legislation and particularly within the constraints of the Habitats Directive is briefly examined.

TABLE OF CONTENTS

1. INTRODUCTION

Dundalk Bay is an area, of approximately 44.5 km^2 of cockle-bearing sand and mud flats, open to the east (Figure 1), which has from time to time briefly supported a fishery. It was first surveyed in 1972 by A. Meaney of the Resource Development Section of Bord Iascaigh Mhara in association with Seaco Ltd., a local company, who concluded that the potential for a commercial fishery was limited (Anon, 1972). Local interest in such a venture remained however and in 1986 Seaco Ltd., in association with SA Lenger B V (Holland) attempted harvesting using vessels from the Netherlands. The outcome was not commercially successful. An obvious source of competition for the cockle resource was over-wintering birds, particularly oystercatchers (*Haematopus ostralegus*). Douglas (1995) who gave estimates of predation, stated that between October and March 10,000 tons of commercial sized cockles are eaten by oystercatchers over-wintering in Dundalk Bay; McQuaid and Douglas (1990) had provided more conservative estimates of damage. Over-wintering bird populations had been monitored since the mid-1960s and their large numbers led McQuaid and Douglas (1990) to conclude that cockles which spatted there would be more advantageously harvested at an early stage for on-growing elsewhere. Alternatively, consideration was given to mariculturing cockles which might be gathered at small size and transplanted to a part of the Bay in which good growth rates had been recorded, where they would be reared under protective netting, a technique which proved problematical (Douglas, 1995).

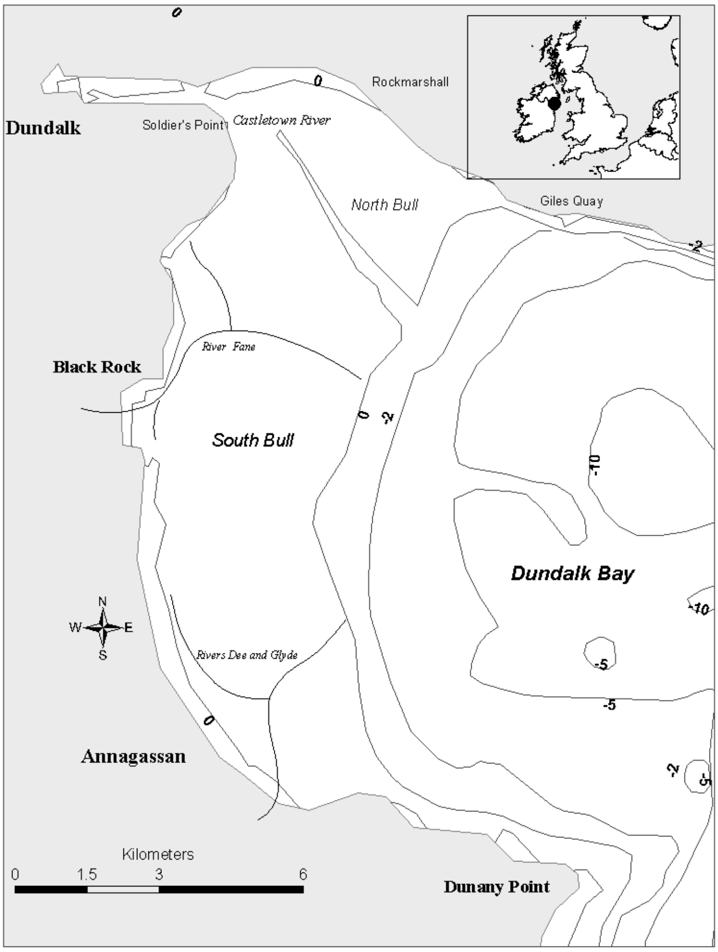


Figure 1. Dundalk Bay showing the main geographical features, place names referred to in the text and bathymetry.

While various attempts were made to capitalise on the potential of the cockle resource, two European Community Directives which are relevant to development in the Bay were enacted. Council Directive 79/409/EEC, the Birds Directive, designated Dundalk Bay an SPA (Special Protection Area), because of its international importance as an over-wintering area for migratory birds. The Directive sought to protect the environmental qualities of the Bay and to prevent disturbance of feeding birds. Council Directive 92/43/EEC, the Habitats Directive, also applies to the Bay which has been designated a cSAC (candidate Special Area of Conservation). Exactly how these directives (92/43/EEC weakens some of the provisions in 79/409/EEC) would affect the cockle fishery had yet to be discovered (Douglas, 1995). In its judgment of 7 September 2004 (Case C-127/02), the European Court, after considering a specific case of mechanical cockle dredging in the Waddenzee, concluded that the competent national authorities could authorise cockle extraction in an SAC, but only if they have made certain it will not adversely affect the integrity of the site.

In addition to the ventures described above some hand picking of cockles from the surface of the sand flats and some harvesting by rake at the northern and southern ends of the Bay may have been undertaken before 2001 but these activities were undocumented. The most recent expansion in fishing effort commenced in 2001 when three vessels dredged almost 9 tonnes of cockles from Dundalk Bay. The following year an estimated two or three boats and an artisanal rake fishery accounted for almost 169 tonnes; in 2003 the number of dredgers increased to between eight and ten and from these 287 tonnes were recorded. In 2004 landings of 201 tonnes were recorded (Table 1). Landings in the period 2002-2004 may have been under-declared by 25%. In the course of developing the recent fishery the season gradually extended to occupy the entire year although landings fell off during the spring when cockle condition declined after spawning.

Table 1. The Dundalk Bay cockle fishery 2001-2004 inclusive, with details of the boat dredge fishery. (source: DCMNR).

Year	Number of boats	Dredging season	Landings to dredgers (t)	Total landings (including rake) (t)
2001	3	August - December	9	9
2002	2 to 3	May - December	132	169
2003	8 to 10	January - December	262	287
2004 (until July)	20 to 21	January - March; June - December	201	201

In common with many Irish inshore fisheries, the Dundalk cockle resource attracted a rapid increase in fishing effort and generated conflict between different extraction methods, particularly the artisanal rake fishery and continuous delivery hydraulic dredgers (White Fish Authority, 1969). There was also concern that the fishery should be managed in a sustainable way. The Marine Institute was asked by the Department of Communications, Marine and Natural Resources to undertake an appraisal which involved a stock assessment and included an examination of the landings of the two main extraction methods and an evaluation of discarding by hydraulic dredgers.

2. MATERIALS AND METHODS

For practical purposes, the fishery is divided into two parts. The Castletown River divides the sand flats into the North Bull and the South Bull (Figure 1). The South Bull, which is approximately 20 km in length, might be sub-divided into northern and southern areas. Landing places are Dundalk at the north end of the Bay and Annagassan, a small pier to the south. Landings are attributed to these places because more precise data on their provenance were not always available. However, given the relatively small distance between them, it is possible that some of the South Bull landings into Dundalk may have come from the Annagassan vicinity.

Fourteen samples of landings from continuous delivery dredge were collected between 13 October 2003 and 29 October 2004. Discards from this method were collected by placing a net bag of 5mm mesh size over the outflow from a continuous feed suction dredge to collect cockles which had passed through the internal sieve; ten such samples were examined between 29 October 2003 and 18 August 2004. Samples from two landings consignments collected by rake in February and June 2004 were also analysed. A survey of cockle densities on the North Bull was undertaken between 25 March and 2 April and on the South Bull between 29 April and 10 June 2004. In these surveys cockles were removed by raking from $1m^2$ randomly-chosen quadrats over the extent of the mud and sand flats. Discrete cockle beds were not identified. A list of samples is provided in Table 2.

All biological material was removed to the laboratory where it was stored frozen until examined. All cockles were individually measured for length (to the nearest 0.1 mm) and weighed (to the nearest 0.1 gm). The number of annular rings on each was noted. The height and vertical ring positions of a sub-sample were measured in order to calculate a growth curve for the fishery. Damage to landed cockles by fishing gear had not been described as a problem in Dundalk Bay. However, damage to discarded animals beneath the landing size as a result of suction dredging has been a recognised source of mortality in fisheries of this kind. Discards were individually examined under magnification (X20) to establish any obvious damage which might have occurred in the course of capture and rejection.

Four vessels provided data on their fishing positions in 2003.

Statistical packages used in the course of the work were Microsoft Excel (Microsoft Office 2000) and SPSS 12.0.1. ArcMap was used to plot fishing and sampling positions in Dundalk Bay.

Table 2. Biological samples examined from the Dundalk cockle fishery, 2003 - 2004, in chronological order.

Code No.	Date	Location	**L**anding/**d**iscard/ **S**urvey	Gear type	Numbers sampled
3	13-Oct-03	Annagassan	L	Dredge	96
9	29-Oct-03	South Bull	d	Dredge	216
10	29-Oct-03	South Bull	d	Dredge	217
11	29-Oct-03	South Bull	d	Dredge	142
12	17-Dec-03	South Bull	d	Dredge	93
13	17-Dec-03	South Bull	d	Dredge	68
22	17-Dec-03	South Bull	L	Dredge	146
4	21-Jan-04	Annagassan	L	Dredge	302
5	13-Feb-04	Annagassan	L	Dredge	193
6	20-Feb-04	Annagassan	L	Dredge	162
7	20-Feb-04	North Bull	L	Rake	139
14	23-Feb-04	South Bull	d	Dredge	245
15	23-Feb-04	South Bull	d	Dredge	113
23	23-Feb-04	South Bull	L	Dredge	126
24	23-Feb-04	South Bull	L	Dredge	202
1	Spring 04	North Bull	S	Sample	507
2	Spring 04	South Bull	S	Sample	843
8	16-Jun-04	North Bull	L	Rake	410
16	30-Jun-04	South Bull	d	Dredge	190
17	30-Jul-04	South Bull	d	Dredge	147
25	30-Jul-04	South Bull	L	Dredge	102
18	18-Aug-04	South Bull	d	Dredge	234
26	18-Aug-04	South Bull	L	Dredge	178
19	29-Oct-04	South Bull	L	Dredge	1,229
20	29-Oct-04	South Bull	L	Dredge	188
21	29-Oct-04	South Bull	L	Dredge	94
				Total	6,582

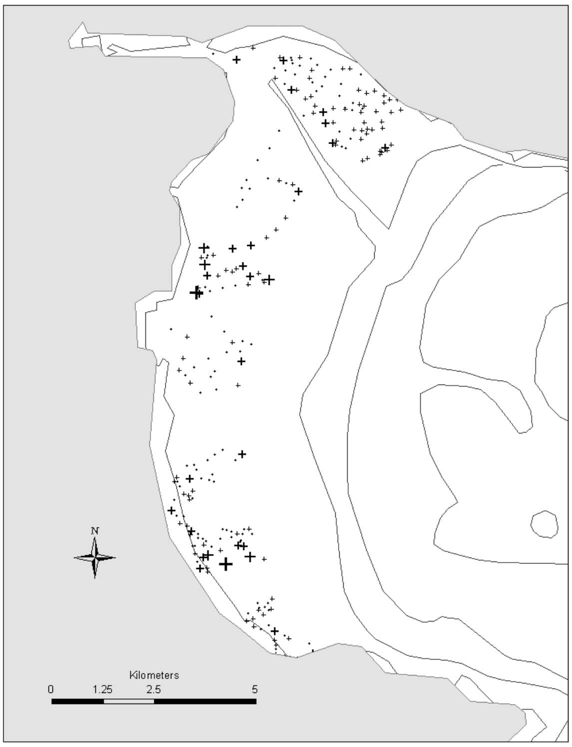
3. RESULTS

3.1 Distribution of the resource

Cockle was the dominant bivalve in Dundalk Bay, making up more than 99% of the biomass of bivalves on the mud and sand flats. A small tellin species and very occasional *Ensis arcuatus* were the only other species encountered. The distribution of quadrats sampled in Spring 2004 are shown in Figure 2 together with positions at which suction dredging had taken place the year before.

Figure 2. Locations at which quadrats were taken in the spring 2004 survey (small dots) and where suction dredging was reported by four vessels in 2003 (circles).

Numbers / m^2 were greater on the South Bull (4.3 ± 6.03 S.D., N=221) than on the North Bull (3.0 ± 6.9 S.D., N = 144) (Figure 3), while the contrary was true of weight: 38.0 g / m^2 ± 60.7 S.D. on the North Bull and 36.8 g/m^2 ± 46.8 S.D. on the south (Figure 4). Some of this difference can be explained by the average age of cockles: 0.93 years old on the North Bull (± 0.67 S.D., N=507) and 0.69 years old on the South Bull (±0.90 S.D., N=843) (Figure 5).



Clockwise from top left:

Figure 3. Numbers of cockles per m^2 surveyed in spring 2004 (size of symbol indicates relative abundance).

Figure 4. Weight of cockles per m^2 surveyed in spring 2004 (size of symbol indicates relative abundance).

Figure 5. Age of cockles per m^2 surveyed in spring 2004 (size of symbol indicates relative age).

All samples were hierarchically clustered on the basis of individuals' lengths and ages (Figures 6 and 7). In both cases there are two principal groupings, discards and landings. On the basis of age however, both beach surveys cluster in the same division as the discards.

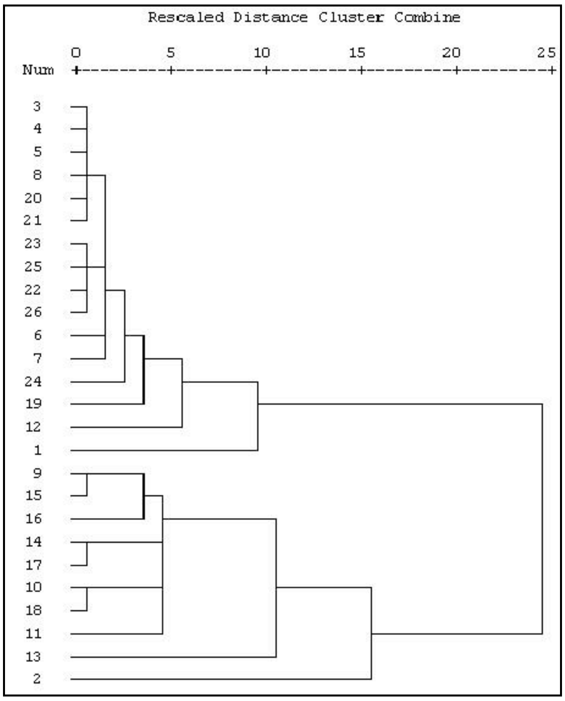


Figure 6. Hierarchical cluster analysis on the basis of length of all cockle samples from Dundalk Bay in 2003 and 2004. Numbers refer to sample codes in Table 2.

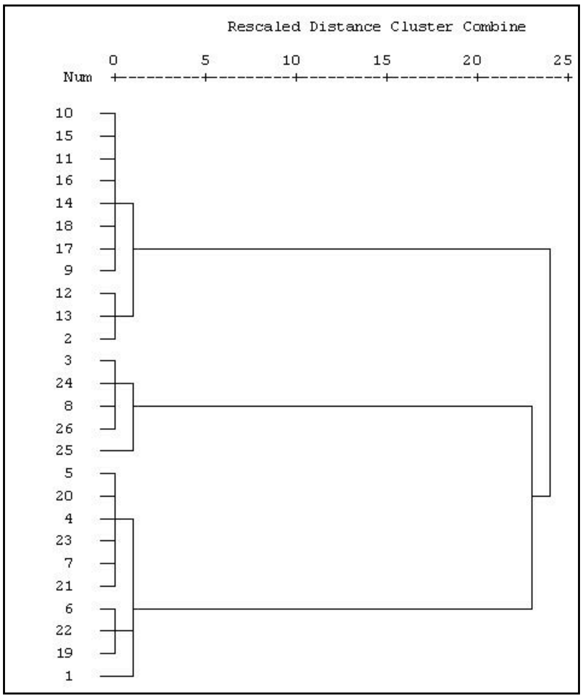


Figure 7. Hierarchical cluster analysis on the basis of age of all cockle samples from Dundalk Bay in 2003 and 2004. Numbers refer to sample codes in Table 2.

3.2 Size and age of cockles

Cockles sampled in the course of the investigation ranged between 5 and 56 mm in length and up to 8+ years old. The majority belonged to the 0 and 1+ year groups. The quality of cockles landed was high, ranging upwards from 28 mm in length and raked cockles were dominated by 2+ animals. Discards consisted mainly of 0 group cockles (Figure 8).

3.3 Growth

Growth calculations, based on the shell height, were undertaken for cockles on the South Bull from landings, discards and survey-sampled cockles. Shell height enabled a precise measurement of the distance between annuli. The relationship between shell height and length is shown in Figure 9. The formula which describes it is applied to the measured heights at annulus number, to convert height to length (Table 3). Lengths of animals aged by observed ring number are grouped in plus age groups. Mean lengths +/- 1 S.D. of plus groups and calculated lengths at age (from annulus position) +/- 1 S.D. are combined in Figure 10.

A growth curve was constructed using the calculated lengths at annulus number for years 1-5. Successive pairs of directly measured mean lengths at + lengths were averaged to obtain means at lengths 6 – 8 years. Estimates of asymptotic length ($Lt\infty$) and of the coefficient of catabolism (K) were made from the von Bertalanffy growth equation. $Lt\infty$ was 49.1 mm and the value for K was 0.4364; t0 was –0.3995.

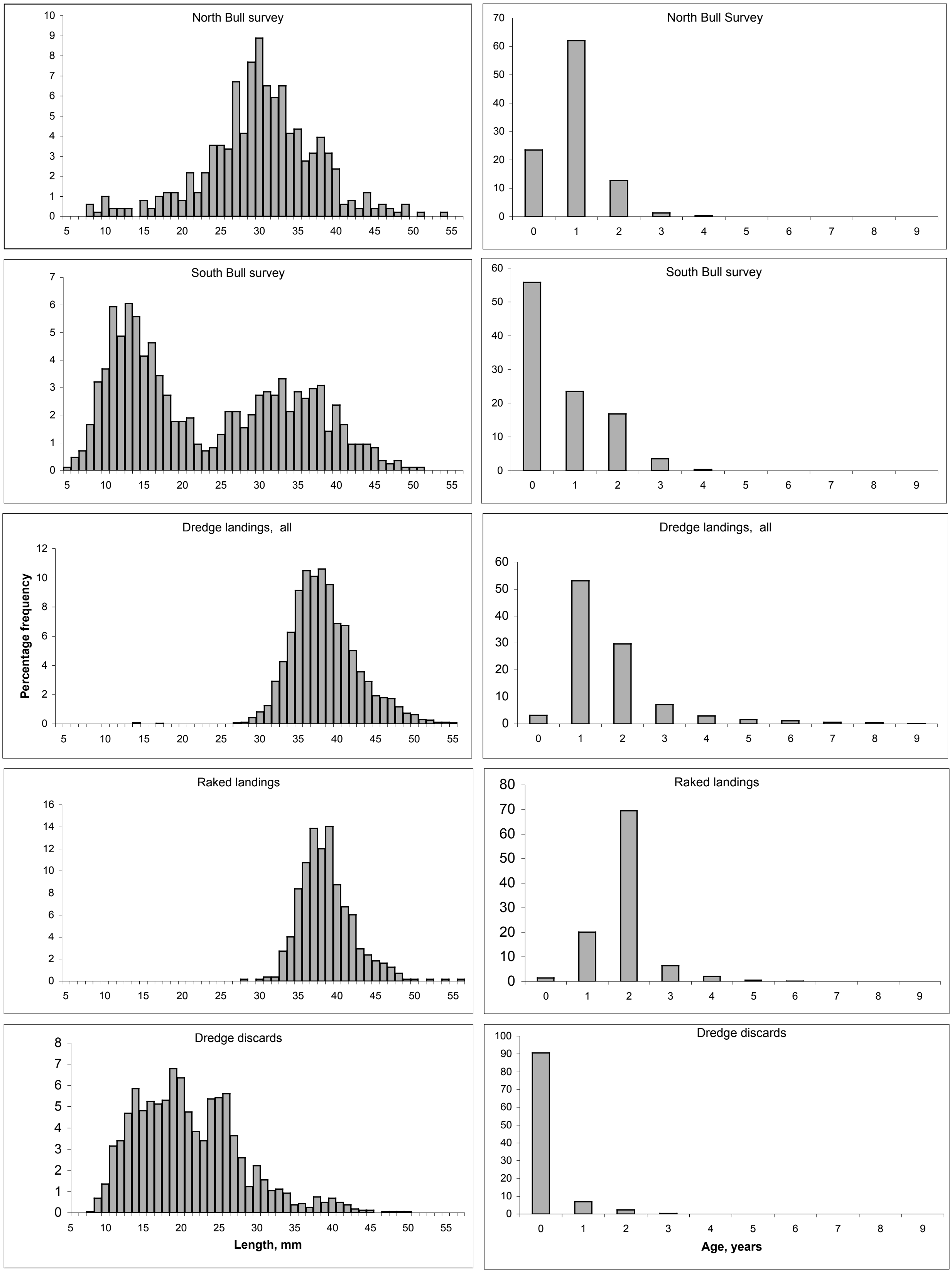


Figure 8. Length (left) and age (right) frequency distributions of cockles from Dundalk Bay in 2003 and 2004, grouped according to sample type.

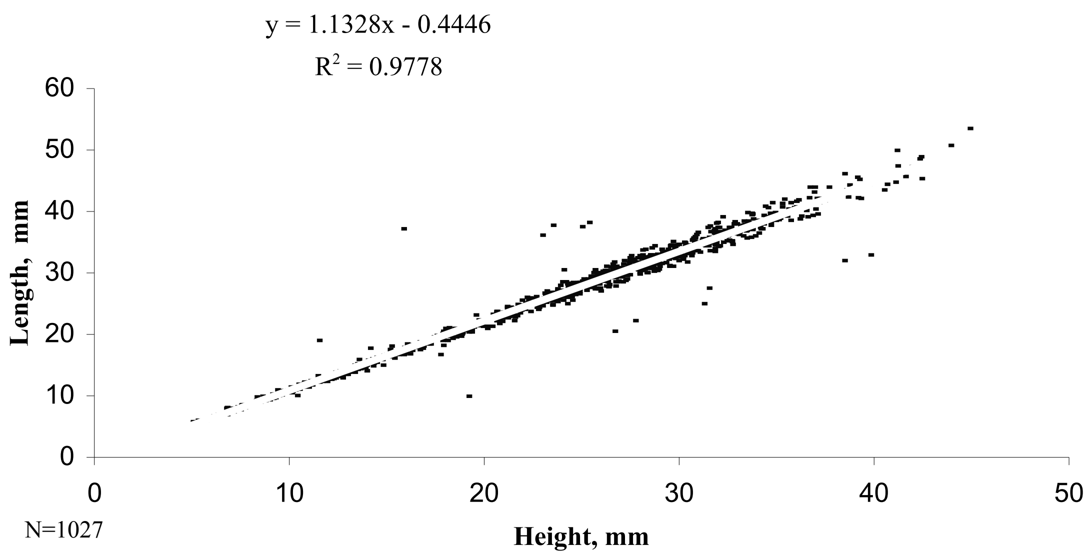


Figure 9. Length at height relationship in Dundalk Bay cockles in 2003 and 2004.

Table 3. Length at age derived from height at annulus position (bold) in the Dundalk cockle fishery. Plus lengths were measured directly.

Age	Height at age, mm Mean	St dev	Count
1	**23.4**	4.1	188
2	**31.9**	2.7	173
3	**34.2**	3.3	34
4	**36.4**	5.0	9
5	**38.1**	2.2	2

	Length at age, mm	At annulus position converted from height (bold)	
0+	18.3	6.7	2192
1	**25.9**	4.7	
1+	35.4	4.1	2496
2	**35.8**	3.1	
2+	38.8	4.7	1664
3	**38.4**	3.8	
3+	42.2	4.4	338
4	**40.9**	5.7	
4+	43.9	4.0	113
5	**42.9**	2.6	
5+	46.1	3.7	52
6+	47.4	3.4	39
7+	48.4	3.6	15
8+	49.7	3.1	12

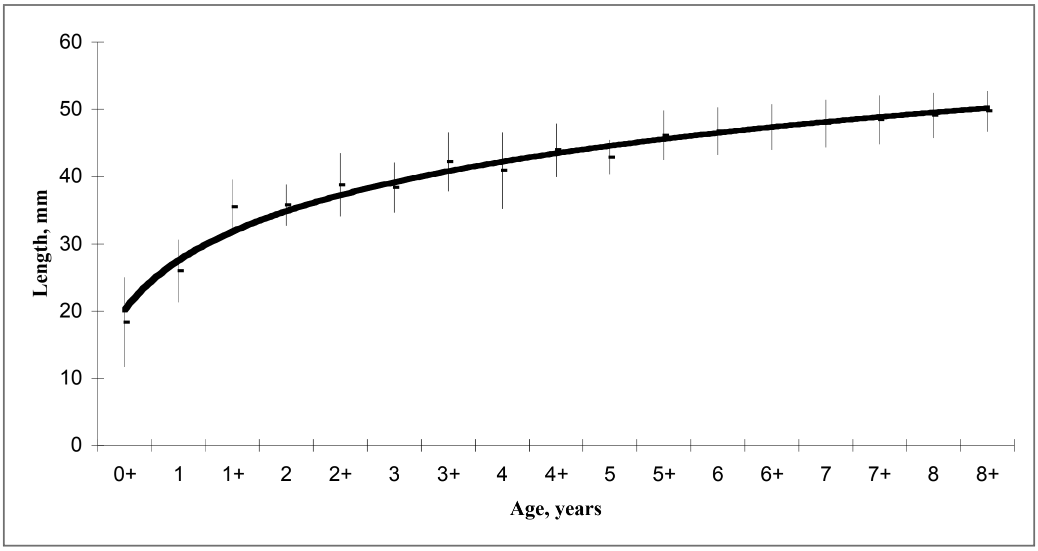


Figure10. Length at age (+/- 1 S.D.) of Dundalk Bay cockles.

3.4 Condition

Weight:length regressions for different parts of the Dundalk Bay fishery in different quarters are set out in Figure 11.

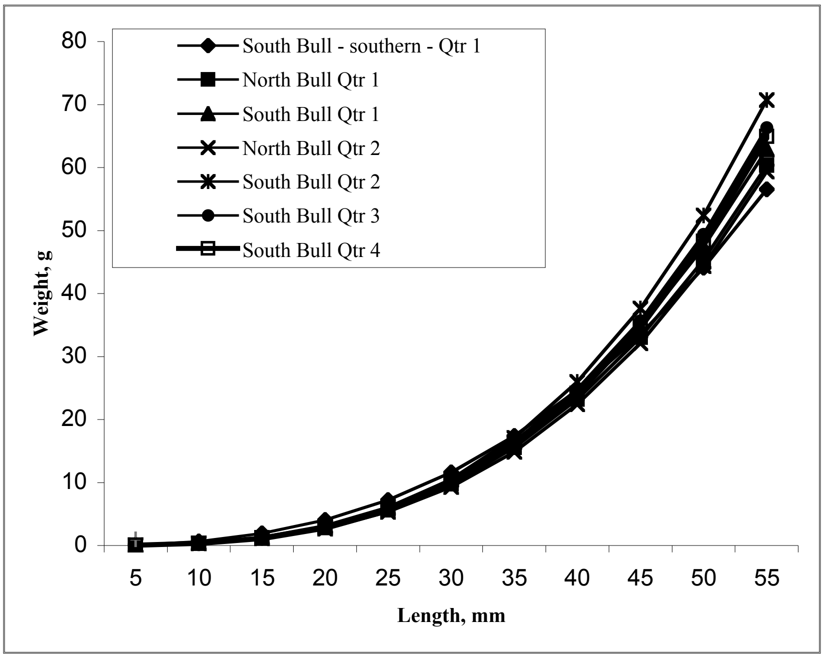


Figure 11. Weight at length of cockles from various areas of Dundalk Bay in different quarters of the year.

3.5 Mortality and catch curve

The cockle population of Dundalk Bay is short lived. Various categories of sample contained too few age groups to enable calculation of Z values from a catch curve. The landings from the South Bull did however: the value of Z was 0.7415 (r^2 = 0.9652, N = 9, P = 0.0003). Most of the other categories of sample (North and South Bull surveys and landings from the North Bull) had a more rapid decline in ascending age classes with indications that Z values ranged from 1.2 – 1.9.

3.6 Damage to discards

A total of 1,645 discarded cockles, were examined microscopically. Of these 20 were found to be chipped, 2 had a hole in one valve and 78 had a cracked valve. Twenty two individuals had a combination of two or more of the foregoing. The overall percentage with obvious structural damage to the shell was 7.42%.

Aggregating all types of damage under one heading, “smashed” which is current practice elsewhere, rates of damage increased with length of cockle (Table 4).

Table 4. Rates of obvious physical damage to cockle discards according to their length.

Length, mm	Numbers "smashed"	Total sample	% damage
10	2	85	2
15	9	389	2
20	11	459	2
25	21	383	4
30	32	183	14
35	22	63	29
40	17	43	33
45	6	13	38
50	2	4	50
Total	122	1,622	

4. DISCUSSION

Cockles occurred on the inner half approximately of the tidal plateau which rises inside the 0 m isolines of Dundalk Bay (Figures 1 and 2). The density of cockles was low in Spring 2004 but this has been the norm in all surveys in Dundalk Bay to date. A spring survey of the Dundalk fishery in 1972 was reported to yield between 10.8 and 40.9 cockles per m^2 (Anon, 1972), although quadrats which yielded nothing do not appear to have been included in these averages. McQuaid and Douglas (1990) reported 20 per m^2 in February and they remarked that the population density in Dundalk was lower than in the Wash or Burry Inlet (U.K.). They also observed that the cockle biomass is lowest in April. Cockle density is likely to be highest in September, before the depredations by over-wintering birds reduce the standing stock (Stillman, 2003).

The surveys of North and South Bulls revealed different age structures of their cockle populations which might be explained by the South Bull having been sampled at a later date in 2004, possibly after some spat settlement had occurred. The uneven distribution of an earlier spat fall might also have contributed to the outcome. Studies in the Wash cockle fisheries indicated that while tides and the location of larval release sites can influence the location of larval settlement and retention, the influence of wind can be considerably more important (Young *et al*, 1998). Young *et al* (1996) reviewed historical data on cockle recruitment which they examined in the context of easterly wind circulation in the months of April to July. The meterological data were available in a series of daily synoptic weather maps covering the British Isles and known as the Lamb series. Easterly Lamb circulation type was associated with better cockle settlements and the authors proposed that these served to retain larvae close to suitable settlement sites. The same should apply to Dundalk Bay, another east-facing cockle settlement area.

McQuaid and Douglas (1990) reported two spat falls annually in Dundalk Bay, one in May, the other in September-October. The relative contributions of these to the population is likely to influence the length at age. Montfort (1967) described a cockle population in the Ría de Vigo as also having two generations annually, arising from a slow growing autumn spat fall and a faster growing spring spat fall. No attempt was made to distinguish these cohorts in the current survey. The growth curve in Figure 10 was calculated on observations and no attempt was made to estimate the relative strength of cohorts which contributed to the observations.

The growth rate of the Dundalk Bay cockle is relatively rapid. The animals develop fast and mature at 16 – 18 mm (McQuaid and Douglas, 1990). Cole (1956) reviewed growth rates in cockles from various parts of the United Kingdom and proposed there were inherent differences from place to place. Cockles from Barra in the Outer Hebrides were uniformly greater than 50 mm in length while those from the Burry Inlet, South Wales, rarely exceeded 30 mm. Cockles from Morecombe Bay, Lancashire, were intermediate. West *et al* (1979) described the cockles of Dublin Bay as having a $Lt\infty$ of close to 40 mm, conforming to the intermediate values. Dundalk Bay cockles belong to the upper end of the scale. Jessop (*pers. comm.*) suggested the low elevation of the sand flats in Dundalk Bay provided a longer feeding time for cockles than the higher elevation in parts of the Wash fishery. Their low density would also have contributed to better growth.

The cockle population of Dublin Bay in the early 1970s (West *et al*, 1979) was not unlike that of Dundalk Bay in 2004. In Dublin Bay the mean density was 9-13 cockles per m^2, the population was dominated by 0 and 1+ groups and the age ranged up to 9+. At 40 mm $Lt\infty$ was smaller than in Dundalk Bay.

Kristensen (1957) examined the interplay of density and growth in a cockle population in the Dutch Waddenzee and concluded, *inter alia*, that competition among cockles arises only where both the density and the extent of the population are considerable and the current velocity is low. Where few spat settle, growth is rapid and the maximum duration of life is long. The first of these conditions would appear to be satisfied in Dundalk Bay, but the longevity of the population there is likely to have been curtailed by bird predation. McQuaid and Douglas (1990) identified flatfish as important predators of small cockles but larger individuals (33-41 mm in length) were too big to be consumed by birds and these animals are likely to be predated only by fishermen.

Earlier cockle fisheries in Dundalk Bay appear to have been of small scale and brief duration. The current fishery may be the largest since 1970. Anon (1972) reported that 8 dredges (vessels) were in use in Dundalk Bay. Catch rates of 2 tonnes of cockle per hour were reported as theoretically feasible by suction dredging at that time. However, during this study in Dundalk Bay landings of 0.75 tonne per hour could be obtained, but landings were generally smaller. The boats could only gain access to the inner sand flats for three hours per high tide. Anon (1972) described the area swept by a suction dredge with a 60 cm blade as 1,115 m^2 per hour. Jessop (*pers. comm.*) observed that equivalent dredging speeds today would be 2.5-3.5 times greater. Given the low density of cockles within this fishery it is surprising that such methods were viable there. Anon (1972) reckoned that 54 cockles per m^2 was the minimum density required for suction dredging while 160 per m^2 was desirable. The latter quantities were rarely recorded, except possibly in very small areas. In the meantime improving technology is likely to have made lower densities economically viable and better growth would have contributed to this higher value.

Weight: length relationships for cockles originating in landings and surveys are set out graphically in Figure 11. Hancock and Franklin (1972) observed that seasonal changes occur annually in the meat content of cockles in Burry Inlet. Shell growth commenced early in May and was accompanied by a rapid increase in meat weight. By June the immediate weight loss due to spawning had been compensated for and the weight of meat increased until August, after which additional shell growth was negligible. In Dundalk Bay, a consistent seasonal trend in weight: length relationships was not established, suggesting that local variations in growing conditions might obscure a more general pattern.

Damage to discarded cockles is a problem which would, were the fishery actively managed, require more detailed consideration. The White Fish Authority (1969) stated that the amount of damage depends on terrain and operating skills. On coarse sand, little damage can result than in denser beds with more brittle shells. Estimates of 5 and 30% respectively were given.

Other than establishing that damage to discarded cockles occurred in accordance with a similar pattern elsewhere, the consequences of mechanical dredging were not investigated in Dundalk Bay. Damage levels are likely to vary from one boat to another. However, the lower density of the resource in Dundalk Bay is likely to result in repeated fishing over the same ground which is, in turn, likely to cause serial discarding of the same animals. Jessop (*pers. comm.*) pointed out that higher cockle densities can have an ameliorating effect on breakages, possibly by cushioning some individuals from the bars of the internal sieve.

In 2001, the management authority for the Wash cockle fishery introduced a breakage rate assessment. Bye law 3 of the managing Sea Fisheries Committee states "A certificate of approval will not be granted (to a vessel) if the instrument of fishing gear results in more than 10% by weight of the target species being smashed". "Smashed" means exhibiting evidence of chipping, breakage, cracking of the valves, holes in the valves or damage to the umbos. In fact, breakage is an extreme form of damage and experiments showed that animals which had been shocked or had damage to the soft tissues which were not recognisable were unlikely to survive for any length of time (30% of apparently undamaged cockles which had been handled had succumbed after a period of one month) (Jessop *pers. comm.*). Adequate assessment of mortality rates resulting from discarding is feasible only after the animals have been observed for a long period afterwards.

In addition to damaging the animals themselves, Piersma *et al*, (2001) examined the long term effects of mechanical cockle dredging in the Waddenzee and concluded that reworking the sediments resulted in the loss of fine grades which were put into suspension during the operation of the dredgers. Autumn storms were a likely mechanism of removal of these grades from the area altogether and negative feedback processes following these events prevented the accumulation of fine grains, which are conducive to bivalve settlement.

On 7 September 2004, The European Court [Grand Chamber, case C-127/02, Assessment of the implications of certain plans or projects for the protected site] considered the prosecution of fishing activities in areas designated under the Habitats Directive (92/43/EEC). The case in question considered mechanical cockle extraction in the Netherlands and its findings are directly relevant to the future existence of a cockle fishery in Dundalk Bay in the context of the conservation status of the area. The judgment found that a plan or project (in this case also cockle extraction) which is not directly connected with or necessary to the management of a site of this kind (whose purpose is nature conservation) is authorised only to the extent that it will not adversely affect the integrity of the site. Any activity which is carried on in such an area and which is not necessary for the management of the area (in this case for the purposes of nature conservation) must be subject to an appropriate assessment of its implications for the site's conservation objectives. If such an activity which is not connected to the necessity for management of the area is likely to undermine the site's conservation objectives, it must be considered to have a significant effect on the site. Under Article 6(3) of Directive 92/43/EEC, before a plan of extraction is approved, all aspects of it must be identified in the light of the best scientific knowledge available and its approval can take place only where no reasonable doubt remains that it will not adversely affect the integrity of the site.

The necessity to comply with these requirements imposes recurring obligations on the managers of a fishery such as Dundalk Bay which would require an annual assessment of the cockle biomass, an estimate of the number of birds likely to over-winter there and the determination of a Total Allowable Catch which reserves an adequate spawning stock biomass from potential landings.

On the basis of actual bird counts and various estimates of cockle consumption McQuaid and Douglas (1990) calculated that between October/November and March oystercatchers in Dundalk might consume 1,400 tonnes of cockles in Dundalk Bay. The calculated cockle biomass in the Bay in Spring 2004, was 1,645 tonnes made up of 143 million animals. How typical these estimates are it is not possible to say but, considering that the surveys were conducted in Spring, following a season's fishing and after migratory birds had left the area, there would probably have been some small surplus for harvest the following autumn once the requirements of the SAC had been satisfied.

Techniques for making the calculation necessary for the co-existence of fisheries and bird populations are available. Stillman *et al* (2003) developed a behaviour-based model which advised how to manage shellfisheries to maintain bird populations which feed on them while at the same time as taking a harvest of bivalves. Such a model however requires the systematic collection of data on bird numbers, shellfish density and climatic data. The continuance of a cockle fishery in Dundalk Bay will require the on-going collection of a variety of data in order to satisfy the demands of the Habitats Directive.

5. ACKNOWLEDGEMENTS

Sincere thanks are offered to the following who contributed samples and data to the investigations in Dundalk Bay: Brian Polly, James O'Hagen, Val Ward, Joey Murtagh, Laurence Doyle, Martin Hoey, Pat and Mary Power and Brian Grew. Damien Toner and Ian Lawler of BIM provided information and helpful advice and Kevin Concannon and Ken Hamilton, fishery officers of the Department of Communications, Marine and Natural Resources gave practical assistance with surveys and the collection of data. Trevor Alcorn of the Marine Institute provided advice and guidance on the use of ArcMap and he calculated areas within the Dundalk fishery. Ron Jessop, of the Eastern Sea Fisheries Joint Committee, Research Officer on the Wash cockle fishery and Mark Norman of Taighde Mara Téo, kindly commented on the MS.

6. REFERENCES

Anon 1972 A survey of the cockle (*Cardium edule* L) stocks in Dundalk Bay, Ireland, April 1972. Bord Iascaigh Mhara, Resource development section. Mimeo.

Cole, H. A. 1956 A preliminary study of growth rate in cockles (*Cardium edule* L.) in relation to commercial exploitation. Journal du Conseil, ICES **22**: 77 – 90.

Douglas, D. J. 1995 Investigation into the feasibility of establishing a commercially viable high density/low intensity cockle (*Cerastoderma* (*Cardium*) *edule* (L)) culture facility in Dundalk Bay: 75 pp Ryland Research Ltd. Omeath. Mimeo.

Hancock, D. A. and Franklin, A. 1972 Seasonal changes in the condition of the edible cockle (*Cardium edule* L.). Journal of Animal Ecology **41**: 567 – 579.

Jessop, R. [Eastern Sea Fisheries Joint Committee, Norfolk] (*pers. comm.*) Cockle discard mortality study. Kristensen, I. 1957 Differences in density and growth in a cockle population in the Dutch Wadden Sea Archives Néerlandaises de Zoologie **12**: 351 – 453.

McQuaid, S. and Douglas D. J. 1990 The potential for a cockle (*Cerastoderma* (*Cardium*) *edule* (L) fishery in north Co Louth. Carlingford Lough Marine Laboratory Bulletin No **5**: 24 pp mimeo.

Montfort, A. F. 1967 Edad y crecimiento de *Cardium edule* de la ría de Vigo. Investigaciones Pesqueras **31** (2) : 361-382.

Piersma, T., Koolhaas, A., Dekinga, A., Beukema, J. J., Dekker, R. and Essink, K. 2001 Long term indirect effects of mechanical cockle dredging on intertidal bivalve stocks in the Wadden Sea. Journal of Applied Ecology **38**: 976 – 990.

Stillman, R. A., West, A. B., Goss-Custard, J. D., Caldow, R. W. G., McGroarty, S., Le V Ditdurell, S. E. A., Yates, M. G., Atkinson, P. W., Clark, N. A., Bell, M. C., Dare, P. J. and Mander, M. 2003 An individual behaviour-based model can predict shorebird mortality using routinely collected shellfishery data. Journal of Applied Ecology, **40**: 1090-1101.

West, A. B., Partridge, J. K. and Lovitt, A. 1979 The cockle *Cerastoderma edule* (L) on the south Bull, Dublin Bay: population parameters and fishery potential. Irish Fisheries Investigations Series B (Marine) No **20**: 18 pp.

White Fish Authority 1969. Continuous delivery dredge for cockles. Research and Development Bulletin No. **25** (2): 4pp.

Young, E. F., Bigg, G. R. and Grant, A. 1996 A statistical study of environmental influences on bivalve recruitment in the Wash, England. Marine Ecology Progress Series, **143**: 121 – 129.

Young, E. F., Bigg, G. R., Grant, A., Walker, P. and Brown, J. 1998 A modelling study of environmental influences on bivalve settlement in the Wash, England. Marine Ecology Progress Series. 172: 197 – 214.