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# A survey by hydraulic dredge of interstitial bivalves with commercial potential in Cill Chiaráin and Beirtreach buí Bays and along their connecting shoreline, Co Galway

**by**

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## SUMMARY

The shellfish co-operative, Comharchuman Sliogéisc Chonamara Teó (CSC) manages oyster and scallop in Beirtreach buí and Cill Chiaráin Bays, both of which are designated aquaculture areas. Cill Chiaráin is also a candidate Special Area of Conservation (cSAC). Various traditional fishing activities are carried on in the bays and CSC has rights to exploit clam species there.

The work described here is a survey of interstitial clam species by hydraulic dredge between November 2001 and January 2002. Investigations were restricted from some of the upper bay areas where surface bivalve management was in progress. Much of the remaining areas within the Bays proved unsuitable for hydraulic dredging by virtue of the nature of the substratum. The exposed parts of the lower bays and the intervening coastline where the substratum was coarse sand (maërl or shell sand) were suitable for hydraulic dredging but bedrock and loose boulders often proved obstacles to towing.

There was evidence of two assemblages of bivalves in the bays: one typified by *Venus verrucosa*, *Venerupis senegalensis* and *Tapes rhomboides*, all large and potentially valuable, occurred within maërl mixed with fine mud, the other whose most valuable components included *Ensis arcuatus* and *Spisula solida*, occurred in disintegrating maërl and in shell sand.

The bivalve fauna in the two bays appeared to be typified by relatively high diversity and low biomass – which is accentuated by recent natural mortalities of *Ensis arcuatus*, a dominant species - and this is likely to prove a challenge to marketing; the Irish market typically exploits small numbers of clam species simultaneously.

The terms of the licence under which CSC operates may provide opportunities to exploit clams within their designated area by means other than hydraulic dredging and these should be investigated. In view of the scientific values of the area and its status as a cSAC any plan to exploit its interstitial bivalves should be discussed with the relevant state agency.

## INTRODUCTION

Comharchuman Sliogéisc Chonamara Teó (CSC) is a shellfish co-operative which manages oyster and scallop fisheries in Beirtreach buí and Cill Chiaráin Bays, Co Galway. These activities occupy a relatively small proportion of the area over which CSC exercises jurisdiction (Whilde, 1973) and the co-operative also has rights to exploit clam populations within its boundaries. Cill Chiaráin Bay and Beirtreach buí Bays are designated aquaculture areas and the vicinity of Cill Chiaráin is of considerable interest for scientific and conservation reasons (Sides et al, 1994). Beirtreach buí Bay is an estuary although its substrata are not unlike those of the adjoining bay (Anon, 1983). In order to extend its current range of activities, CSC, with the assistance of Bord Iascaigh Mhara, Taighde Mara Teó and the Marine Institute, commissioned a survey of interstitial bivalves with a view to identifying species with commercial potential which might be exploited in a sustainable way. The survey was undertaken on the MFV Medway Venture between November 2001 and January 2002. The result is described here.

### The area

More scientific work is available on Cill Chiaráin than on Beirtreach buí Bay, by virtue of its greater scientific interest. However, occasional notes, written from the perspective of managing surface-living bivalves, to which no authorship can be attributed, are available on Beirtreach buí (Anon, 1983). A note on the escallop in Cill Chiaráin and surrounding areas was prepared by Gibson (1958). More general references to Cill Chiaráin are in Keegan (1974a), Sides *et al* (1994) and particularly in Deeny (1975) whose account of the geology and sedimentology of Cill Chiaráin Bay is heavily drawn on in this work.

Cill Chiaráin Bay is a narrow, 16 km long, indentation into the Connemara coastline on the northern shore of Galway Bay; it is 7 km wide at its maximum extent and its opening to the sea is 2 km across. The bay is cut into the western margin of the Main Galway Granite and the country rocks are granites with scattered basic intrusions in the form of dykes. The Galway Granite is in contact with Dalradian rocks (the Connemara series) just north of the bay's northern limit and with rocks of the South Connemara Series on Letermullen Island at the southern margin of the bay. The Connemara Series outcrops at a few localities along the bay's eastern limit.

The bay proper may be said to begin at a line joining the south tip of Birmore Island to the east tip of Dinish Island. Here, the 10 m isobath outlines the main channel leading into the bay. About 1.4 km south of Maan Island the channel divides, one branch running north and shallowing between Maan Island and Ardmore Point. The other branch runs north on the eastern side of Maan Island, reaching into the shallow depression of Casheen Bay. The most outstanding feature of the Bay is the Maan Island Deep, just north of Maan Island which trends north east to south west and is interpreted as a mini-Graben structure, formed by faulting in the basement rock.

The topography of the immediate hinterland is irregular and, except on the west, just north of Cill Chiaráin, is predominantly low lying blanket peat bog. Although there are numerous scattered small lakes, there are no major rivers draining into the Bay. Roches moutonèes and glacial striae show a preferred N.E. – S.W. orientation, as does the trend of the bay itself. Except for a small (200m long) sandy beach on the Ardmore peninsula, the shoreline is rocky and low lying. There are no cliffs. This description is taken from Deeny (1975) who also provided a wind rose which showed that dominant direction of the wind in the vicinity of Cill Chiaráin was westerly, although the dominant direction of winds exceeding 33 knots was from the south west.

The bathymetry of the Bay appears to be controlled by the (presumably ice eroded) basement rock topography. From a limited series of seismic profiles Deeny concluded that sediment had accumulated over the bay floor up to 7.5 m.

The overlying sediments are regarded as a temperate water, inshore, shelf, biogenic carbonate type which belongs to the FORAMOL (Foraminifera and Mollusc) association of Lees and Butler (1972). In the case of Cill Chiaráin Bay, the biogenic sediments may be considered as having an algal and a non-algal component.

Crustose coralline algae contribute to the sediments mainly through the species *Lithothamnium coralloides* and *Phymatolithon calcareum* – see also de Grave *et al* (2000) - hence the sediments have a high carbonate content, which contrasts with the igneous bedrock. *Lithothamnium* can occur in a variety of sizes, the largest (arbuscular) fragments possibly exceeding 3 cm longest axis, growing in an uncompacted arrangement and ranging to a small grain size as the coral breaks down. As a general rule, the larger the fragment of *Lithothamnium*, the greater its algal content. Keegan (1974a) maintained that the intertidal occurrence of living maërl was unique to Irish waters.

The non-algal component, also high in calcium carbonate, is composed of bivalve shell, barnacles, foraminifera, ostracods, echinoid spines and sponge spicules.

Non-carbonate grains derive from the igneous rocks which surround the bay and contribute to a silt-mud facies. Because the topography is of low relief and no major river discharges through it, these fine grains tend to accumulate in bay heads, close to shore.

Deeny (1975) listed mixed facies as his fourth category of sediments. The extent to which the above listed groups intermix, which is largely determined by the efficiency of transport by water current, determines the granulometry at any particular part of the bay. In Cill Chiaráin Bay, sediments tend to be transported shorewards. Deeny deduced this from his interpretation of ripples on the sediment surface.

## METHODS

### Gear and the collection of samples

The survey was conducted using a hydraulic dredge. The dredge body (cage) consisted of a metal frame measuring 1.45 m in length by 65 cm in width and 50 cm in height and covered in overlapping layers (one to three) of wire meshing which provided effective mesh openings of between one and three cm. . The forward end of the dredge body was open and it was equipped with a digging blade of 25 cm in width which projected downwards to a depth of 23 cm below the base of the dredge frame and in advance of it. Water was pumped from the vessel into the anterior frame of the dredge whence it was released downwards via jets on the roof plate of the anterior frame into the dredge mouth and upwards through the digging plate. The purpose of the combined effect of these jets was to fluidise the substratum and to wash interstitial bivalves out of it and into the dredge cage. On deck the volume of material in the dredge cage was estimated before the cage was opened at an end flap and its contents – the catch and associated materials – were spilled onto the deck where they were completely or partially sorted, depending on the quantity of materials in the dredge cage.

The hose which supplied water to the anterior dredge frame and digging plate was 30 m in length and its length was not altered during the survey. Towed gear performs most effectively at a depth which is one third the length of the warps hence, the dredge in this instance would have performed best at a depth of 10 m.

To standardise sampling, the dredge was towed for 5 minutes at each station. Sampling stations were selected from local knowledge and usually after a cursory inspection by depth sounding and visual examination to ascertain whether any obstacles to dredging were present, a precaution which was not always successful in identifying them.

GPS readings were noted at the commencement and conclusion of a tow. The minimum distance covered was calculated using the following formula (from Lordan *et al*, 2001):

$$D = 60 * \sqrt{(L_s - L_h) + (O_s - O_h)^2 * Cos\frac{(L_s + L_h)^2}{2}}$$

Where D was the distance moved (km), L, the latitude and O the longitude; the subscript s indicates the beginning of a tow and h its conclusion.

The characteristics of the substratum at each tow were inferred subjectively from the dredge contents.

When the dredge was taken aboard, and the back flap opened, the bivalves were manually separated from the remainder of the dredge spoil. The common species were identified, counted and measured. Less common species or animals which were not readily identified were retained in alcohol and identified, weighed and measured in the laboratory. Species are referred to according to the terminology of Hayward et al, 2000. When the dredge cage was filled with fine graded materials, a sub-sample of these was taken and sorted, the interstitial material being washed away using the deck hose. A standard sub-sampler was filled from the dredge contents; it consisted of a porous plastic box measuring 37*57*12 cm. Dredge contents from a total of 68 tows were analyzed in the course of the survey.

**Data handling**

The presence of a species was recorded and the co-occurrence of any which occurred in five or more tows was calculated according to the methods of Fager (1957). First, the presence/absence and co-occurrence of species pairs were recorded throughout the series of samples. The totals were arranged in a 2*2 contingency table, set out as follows:

| Species 2 | Species 1 Present | Species 1 Absent | |
|---|---|---|---|
| Present | *a* | *b* | *a+b* |
| Absent | *c* | *d* | *c+d* |
| | *a+c* | *b+d* | *n=a+b+c+d* |

The table was drawn up so that Species 1 was more abundant than Species 2, i.e. (a+b)<(a+c). The corrected Chi-square value was calculated:

$$\chi^2 = \frac{n\left[|ad - bc| - \left(\frac{n}{2}\right)\right]^2}{(a+c)(b+d)(a+b)(c+d)}$$

where the letters are as in the above contingency table and (*ad-bc*) signifies placing the term in the positive form. When *ad* was greater than *bc* the association was positive; when *bc* was greater than *ad* the association was negative.

The coefficient of interspecific association (C*Sp*1*Sp*2) and its standard error, as devised by Cole (1949), were then calculated, different formulae being used depending on the size of the figures in the table. When $ad \geq bc$:

$$CSp1Sp2 = \frac{ad - bc}{(a+b)(b+d)} + or - \sqrt{\frac{(a+c)(c+d)}{n(a+b)(b+d)}}$$

The second set of circumstances, which covered the remainder of the associations encountered in the course of this survey, obtained where $bc > ad$ and $d \geq a$:

$$CSp1Sp2 = \frac{ad - bc}{(a+b)(a+c)} + or - \sqrt{\frac{(b+d)(c+d)}{n(a+b)(a+c)}}$$

**Granulometry**

Some analysis of sediments was carried out on samples which had been collected during an earlier survey of *Ensis arcuatus* in Cill Chiaráin Bay, in the vicinity of Inishmuskerry Island (Fahy *et al*, 2001). Eight samples were collected in the course of a diving survey. In the laboratory they were dried and the various grain sizes were separated by a series of sieves into the following grades (>16, >8, >4, >2, >1, >0.5, > 0.25, >0.125, >0.063 and < 0.063 mm) after which the fraction retained by each sieve size was weighed. The sieve measurements were expressed in the terms of Krumbein's phi scale where >16mm was phi –4; >1mm was 0 and >0.063 mm, 4. For computation purposes the class size mid-points were given arbitrary values (for example, material retained on the -4 phi sieve, was given an arbitrary class midpoint of –4.5, material retained on the 1 mm sieve was given an arbitrary class midpoint of –0.5 and material retained on the 0.063 sieve was given an arbitrary class value of 3.5 phi). The weight in each class was expressed as a percentage of the total weight in a sample which had been sieved. The following statistics were then calculated:

*Mean grain size*

$$\overline{X}_\phi = \frac{fm}{n}$$

where n = 100

*Sorting coefficient*

$$^{\lambda}\sigma_\phi = \frac{1}{100}.fm^2 - \overline{X}^2$$

*Skewness*

$$Sk\phi = \frac{\frac{1}{100}.fm^3 - \frac{3}{100}.\overline{X}.fm^2 + 2\overline{X}^3}{^{\lambda}\sigma_\phi}$$

## RESULTS

### Sample tows

Details of the dredge tows are summarised in Table 1 and the positions of the stations are shown in Fig 1. The minimum length of tow (the actual length might have in some cases been greater when the vessel deviated from a trajectory in order to avoid obstacles) ranged from 0 – 95 m but averaged only 27 m. The water depth of tow averaged approximately 5 m (at which the dredge was not performing most effectively); at the majority of stations the depth was less than that at which the dredge was rigged to perform best.

### Species sampled

Twenty six bivalve taxa were recorded in the course of the survey, the biomass and average weights of the most abundant being calculated (Table 2). Two species of *Lutraria* (*L. lutraria* and *L. angustior*) were recorded but they may not have been distinguished on every occasion. Members of the Nuculidae (nut shells) and *Parvicardium* sp or spp are too small to have any commercial interest and hence, their systematics were not further pursued.

The co-occurrences of the more common bivalves were sufficiently numerous to permit examination for inter-specific associations; there were 16 taxa (mostly species) resulting from 63 dredge tows. The taxa are set out in Table 3 (Pages 20 and 21); some of the numbers recorded refer to sub-samples rather than entire dredge contents and all taxa should more appropriately be recorded as present or absent for the calculation of associations.

The calculations of Chi-square from the presence, absence and co-occurrence of species pairs among the 63 dredge samples are set out in Table 4 (Pages 22 and 23): 27 species pairs had significant values for Chi-square and these are examined for their association values in Tables 5 – where the values are positive - and in Table 6 where the pairs are negatively associated. In both the values are calculated according to the appropriate formulae and the standard errors are also provided. In Fig 2 the associations among species pairs are set out diagrammatically.

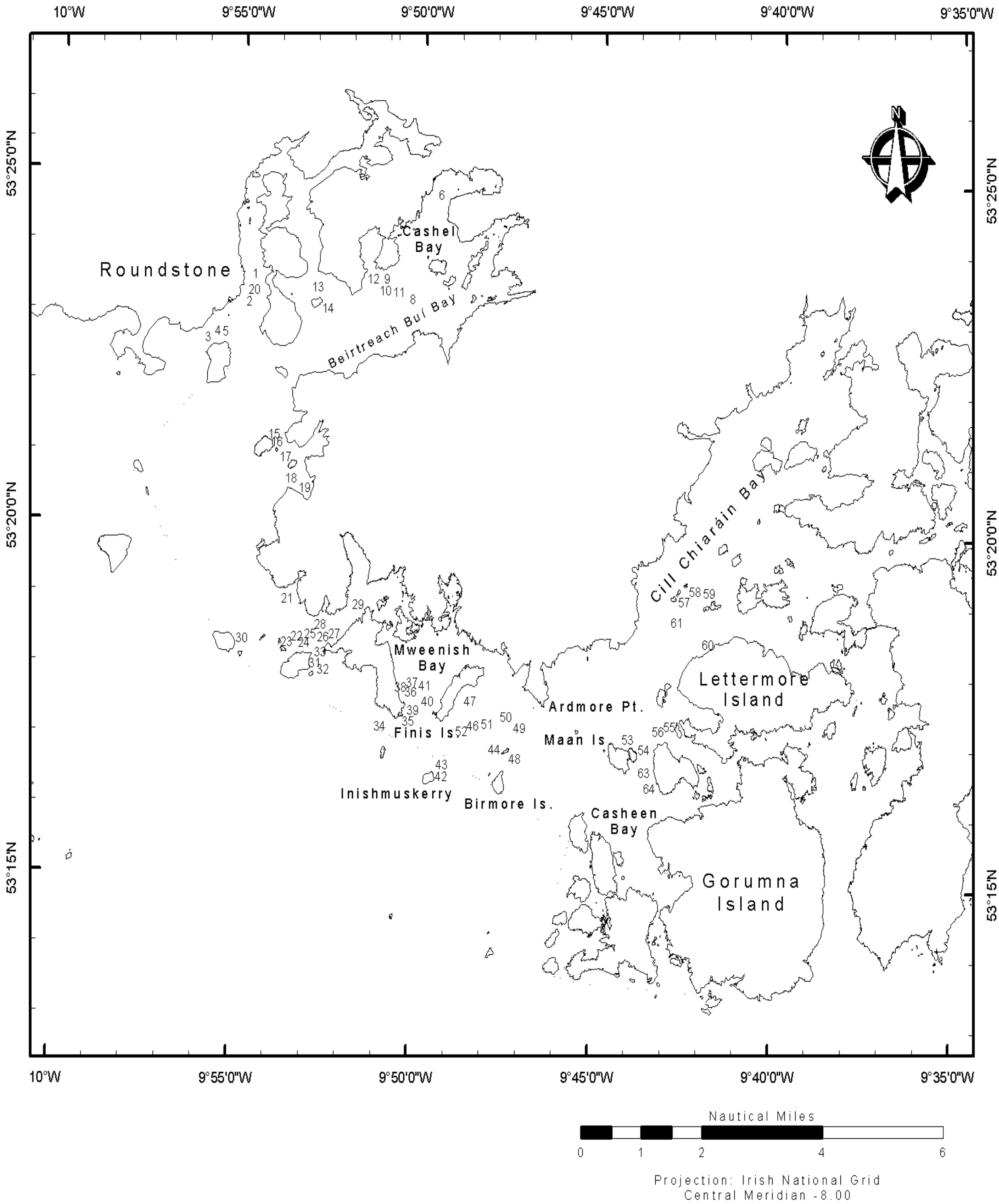


**Fig 1.** Map of the survey area showing the location of sample tows (numbered). The boundary of the co-operative, CSC, is included.

**Table 1.** Position of sampling stations and details of tows made in the survey of bivalves in Cill Chiarain Bay. Key 1: arbuscular *Lithothamnium*; 2, mud; 3, *Zostera*; 4, sand; 5, Large stones. N R = not recorded.

| Station number | Date | Start Latitude | Start Longitude | Length of tow (km) | Depth Start (m) | Depth Finish (m) | Substratum |
|---|---|---|---|---|---|---|---|
| 1 | Nov-01 | 52.3922 | 9.9102 | 0.095 | 4.6 | 4.6 | 1 |
| 2 | Nov-01 | 53.3857 | 9.9129 | 0.029 | 7.6 | 7.6 | 2 |
| 3 | Nov-01 | 53.3770 | 9.9315 | 0.005 | 4.1 | 5.5 | 4 |
| 4 | Nov-01 | 53.3785 | 9.9269 | 0.008 | 2.1 | 2.1 | 4 |
| 5 | Nov-01 | 53.3785 | 9.9234 | 0.014 | 2.2 | 2.2 | 3 |
| 6 | Nov-01 | 53.4121 | 9.8248 | N R | 2.3 | 4.6 | 1 |
| 7 | Nov-01 | 53.4023 | 9.8331 | 0.066 | 5.4 | 5.1 | 1;2 |
| 8 | Nov-01 | 53.3871 | 9.8371 | N. R. | 2.6 | 3.2 | 1;2 |
| 10 | Nov-01 | 53.3890 | 9.8499 | 0.050 | 4.8 | 10.0 | 2 |
| 11 | Nov-01 | 53.3888 | 9.8437 | 0.016 | 10.0 | 6.5 | 1;2 |
| 12 | Nov-01 | 53.3906 | 9.8554 | 0.050 | 2.5 | 3.0 | 1;2;3 |
| 13 | Nov-01 | 53.3895 | 9.8810 | 0.084 | 8.6 | 12.0 | |
| 15 | Nov-01 | 53.3534 | 9.8988 | 0.046 | 5.3 | 2.1 | 3;4 |
| 16 | Nov-01 | 53.3533 | 9.8991 | 0.019 | 4.8 | 4.4 | |
| 17 | Nov-01 | 53.3491 | 9.8943 | 0.008 | 8.2 | 7.4 | 4;5 |
| 18 | Nov-01 | 53.3442 | 9.8904 | 0.036 | 5.2 | 4.6 | 3;4 |
| 20 | Nov-01 | 53.3885 | 9.9105 | 0.030 | 7.6 | 7.8 | |
| 21 | Nov-01 | 53.3159 | 9.8922 | 0.020 | 9.6 | 9.8 | |
| 22 | Nov-01 | 53.3050 | 9.8867 | 0.021 | 5.4 | 5.6 | 4 |
| 23 | Nov-01 | 53.3056 | 9.8921 | 0.048 | 7.1 | 6.5 | |
| 24 | Nov-01 | 53.3054 | 9.8841 | 0.031 | 7.3 | 7.0 | |
| 26 | Nov-01 | 53.3088 | 9.8755 | 0.010 | 5.6 | 5.5 | |
| 27 | Nov-01 | 53.3077 | 9.8700 | 0.012 | 5.4 | 5.1 | 3 |
| 28 | Nov-01 | 53.3087 | 9.8777 | 0.024 | 6.2 | 6.1 | 3 |
| 29 | Nov-01 | 53.3148 | 9.8595 | 0.044 | 4.4 | 4.7 | |
| 30 | Nov-01 | 53.3062 | 9.9126 | 0.036 | 5.7 | 5.7 | 4 |
| 31 | Nov-01 | 53.3012 | 9.8771 | 0.019 | 2.0 | 2.4 | 4;5 |
| 33 | Nov-01 | 53.3017 | 9.8765 | 0.025 | 3.1 | 2.4 | 4 |
| 35 | Nov-01 | 53.2886 | 9.8357 | 0.024 | 5.2 | 5.2 | 4 |
| 36 | Nov-01 | 53.2951 | 9.8353 | 0.013 | 3.6 | 3.5 | 3 |
| 37 | Nov-01 | 53.2968 | 9.8318 | 0.013 | 4.5 | 5.7 | 4 |
| 38 | Nov-01 | 53.2944 | 9.8382 | 0.013 | 3.3 | 3.3 | |
| 39 | Nov-01 | 53.2892 | 9.8319 | 0.014 | 2.1 | 1.4 | 4 |
| 40 | Nov-01 | 53.2928 | 9.8263 | 0.001 | 2.4 | 2.6 | 4 |
| 41 | Nov-01 | 53.2961 | 9.8277 | 0.030 | 2.2 | 2.5 | |
| 42 | Nov-01 | 53.2755 | 9.8203 | 0.041 | 2.4 | 4.0 | 3;4;5 |
| 43 | Nov-01 | 53.2763 | 9.8191 | 0.011 | 4.4 | 5.2 | 4 |
| 44 | Nov-01 | 53.2814 | 9.7949 | 0.023 | 6.5 | 5.5 | 4 |
| 45 | Nov-01 | 53.2853 | 9.8097 | 0.061 | 6.3 | 5.8 | |
| 46 | Nov-01 | 53.2868 | 9.8051 | 0.040 | 7.0 | 7.1 | 4 |
| 47 | Nov-01 | 53.2926 | 9.8069 | 0.004 | 5.7 | 4.6 | |
| 48 | Nov-01 | 53.2793 | 9.7856 | 0.012 | 6.2 | 5.5 | |
| 50 | Nov-01 | 53.2892 | 9.7901 | 0.027 | 2.3 | 2.3 | 1 |
| 51 | Nov-01 | 53.2873 | 9.7988 | 0.009 | 4.1 | 3.8 | 1 |
| 52 | Nov-01 | 53.2854 | 9.8106 | 0.031 | 2.4 | 2.0 | |
| 53 | Nov-01 | 53.2845 | 9.7338 | 0.028 | 2.3 | 2.8 | 1;2;3 |
| 54 | Nov-01 | 53.2823 | 9.7263 | 0.021 | 2.7 | 3.1 | 1;2 |
| 55 | Nov-01 | 53.2878 | 9.7163 | 0.004 | 2.8 | 13.0 | 2 |
| 56 | Nov-01 | 53.2866 | 9.7190 | 0.015 | 3.5 | 3.5 | |
| 57 | Nov-01 | 0.0000 | 0.0000 | 0.000 | | | |
| 58 | Nov-01 | 53.3175 | 9.7089 | 0.018 | 2.9 | 2.4 | 1;3 |
| 59 | Nov-01 | 53.3199 | 9.7040 | 0.004 | 2.5 | 2.8 | |
| 60 | Nov-01 | 53.3074 | 9.6977 | 0.026 | 2.4 | 2.1 | 3 |
| 61 | Jan-02 | 53.2758 | 9.7260 | 0.017 | 2.9 | 1.7 | |
| 62 | Jan-02 | 56.2732 | 9.7233 | 0.036 | 6.5 | 1.9 | |
| 63 | Jan-02 | N R | N R | N R | | | |
| 64 | Jan-02 | N R | N R | N R | | | |
| 65 | Jan-02 | 53.2638 | 9.7505 | 0.034 | 2.3 | 3.3 | |
| 66 | Jan-02 | 53.2639 | 9.7447 | 0.003 | 4.0 | 3.9 | |
| 67 | Jan-02 | 53.2590 | 9.7346 | 0.047 | 2.1 | 1.9 | |
| 68 | Jan-02 | 53.2473 | 9.7175 | 0.050 | 5.4 | 5.9 | |
| | | | **Average** | **0.027** | **4.5** | **4.7** | |
| | | | **Maximum** | **0.095** | **10.0** | **13.0** | |
| | | | **Minimum** | **0.000** | **2.0** | **1.4** | |

**Table 2.** Bivalves recorded in the course of the Cill Chiarain survey, their total weight, and biomass in order, numbers and average individual weight. N R = not recorded.

| Identified in contingency table as | Taxon | Total weight (g) | Biomass in order | Numbers | Average weight (g) |
|---|---|---|---|---|---|
| D | *Ensis arcuatus* | 22,825 | 1 | 732 | 31.2 |
| | *Ensis siliqua* | 1,180 | 2 | 18 | 65.6 |
| N | *Venerupis senegalensis* | 884 | 3 | 73 | 12.1 |
| P | *Venus verrucosa* | 846 | 4 | 33 | 25.6 |
| B | *Dosinia exoleta* | 745 | 5 | 50 | 14.9 |
| L | *Tapes rhomboides* | 583 | 6 | 23 | 25.4 |
| J | *Spisula solida* | 515 | 7 | 43 | 12.0 |
| G | *Lutraria* spp | 276 | 8 | 7 | 39.4 |
| E | *Gari depressa* | 202 | 9 | 23 | 8.8 |
| I | *Acropagia crassa* | 165 | 10 | 11 | 15.0 |
| K | *Tapes aureus* | 129 | 11 | 30 | 4.3 |
| C | *Dosinia lupinus* | 107 | 12 | 22 | 4.8 |
| | *Glycymeris glycymeris* | 100 | 13 | 1 | 99.9 |
| O | *Chamelea gallina* | 67 | 14 | 21 | 3.2 |
| M | *Angulus squalidus* | 38 | 15 | 27 | 1.4 |
| | *Solecurtus scopula* | 23 | 16 | 2 | 11.7 |
| A | *Conchlodesma praetenue* | 14 | 17 | 20 | 0.7 |
| | *Mysia undata* | 5 | 18 | 1 | 5.0 |
| | *Clausinella fasciata* | 4 | 19 | 2 | 2.0 |
| | *Angulus tenuis* | 3 | 20 | 7 | 0.4 |
| | *Parvicardium spp.* | 1 | 21 | 5 | 0.2 |
| | *Moerella donacina* | 1 | 22 | 2 | 0.3 |
| | *Circomphalus casina* | N R | N R | N R | N R |
| F | *Gari fervensis* | N R | N R | N R | N R |
| | *Laevicardium crassum* | N R | N R | N R | N R |
| H | *Nucula sp or spp* | N R | N R | N R | N R |

## Sediment analysis

In the course of an investigation by diver of razor clam populations undertaken in a part of Cill Chiaráin Bay in 2000 and 2001, sediment samples were recovered from eight stations (Fahy *et al*, 2001) [their locations are noted here as in the earlier report]; their percentage frequencies are given in Table 7. The samples all came from close to the boundary of CSC and their locations are on the interconnecting shoreline between the two bays rather than within them. In retrospect, all, with the possible exception of the last (station 14, August 2001) which supported *Zostera marina*, are considered suitable for hydraulic dredging. *Ensis siliqua* frequented station 14, *E. arcuatus* was present at all of the others. The format for calculating the mean grain size and for calculating two of the values used to obtain the sorting coefficient and the coefficient for skewness are set out in Table 8 using the June 2000 sediment sample to illustrate the process. The other two characteristics of the samples set out on Table 7, the percentage fines (consisting of all grades of 2 or less on the phi scale) and the modal point on the phi scale are read from the frequency distributions in that Table.

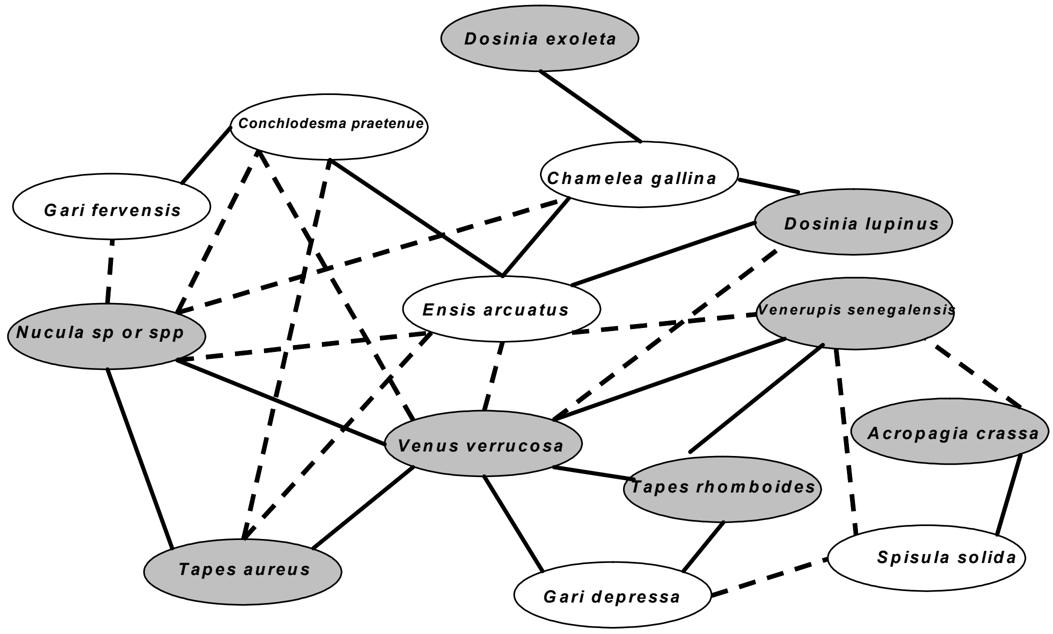


**Fig 2.** Associations among bivalve species whose presence or absence was recorded from 63 sample tows. Stippling identifies species which occurred in maërl/soft ground (substrate type 3 from Keegan, 1974a). Solid lines mark positive associations, broken lines, negative ones.

**Table 5.** Calculations of interspecific associations within the group where associations are positive.

| Species 1 | Species 2 | a | b | c | d | a+b | c+d | a+c | b+d | n | $X^2$ | ad | bc | ad/bc | Csp1sp2 | St error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | D | 16 | 7 | 16 | 24 | 23 | 40 | 32 | 31 | 63 | **3.99** | 384 | 112 | 3.43 | **0.4** | **0.2** |
| C | O | 12 | 9 | 11 | 31 | 21 | 42 | 23 | 40 | 63 | **4.53** | 372 | 99 | 3.76 | **0.3** | **0.1** |
| E | P | 7 | 6 | 10 | 40 | 13 | 50 | 17 | 46 | 63 | **4.40** | 280 | 60 | 4.67 | **0.4** | **0.2** |
| B | O | 16 | 5 | 17 | 25 | 21 | 42 | 33 | 30 | 63 | **5.80** | 400 | 85 | 4.71 | **0.5** | **0.2** |
| D | O | 16 | 5 | 16 | 26 | 21 | 42 | 32 | 31 | 63 | **6.68** | 416 | 80 | 5.20 | **0.5** | **0.2** |
| H | P | 7 | 5 | 10 | 41 | 12 | 51 | 17 | 46 | 63 | **5.56** | 287 | 50 | 5.74 | **0.4** | **0.2** |
| E | L | 5 | 4 | 8 | 46 | 9 | 54 | 13 | 50 | 63 | **5.53** | 230 | 32 | 7.19 | **0.4** | **0.2** |
| N | P | 13 | 4 | 14 | 32 | 17 | 46 | 27 | 36 | 63 | **8.94** | 416 | 56 | 7.43 | **0.6** | **0.2** |
| H | K | 6 | 6 | 6 | 45 | 12 | 51 | 12 | 51 | 63 | **6.90** | 270 | 36 | 7.50 | **0.4** | **0.1** |
| A | F | 5 | 4 | 5 | 49 | 9 | 54 | 10 | 53 | 63 | **9.16** | 245 | 20 | 12.25 | **0.5** | **0.1** |
| I | J | 3 | 2 | 5 | 53 | 5 | 58 | 8 | 55 | 63 | **6.82** | 159 | 10 | 15.90 | **0.5** | **0.2** |
| K | P | 9 | 3 | 8 | 43 | 12 | 51 | 17 | 46 | 63 | **14.47** | 387 | 24 | 16.13 | **0.7** | **0.2** |
| A | D | 9 | 0 | 23 | 31 | 9 | 54 | 32 | 31 | 63 | **8.00** | 279 | 0 | | **1.0** | **0.3** |
| L | N | 9 | 0 | 18 | 36 | 9 | 54 | 27 | 36 | 63 | **11.41** | 324 | 0 | | **1.0** | **0.3** |

## DISCUSSION

Keegan (1974b) presented a list of 119 species of bivalve from the shallow (<45 m) waters of Galway and Cill Chiaráin Bays. The occurrence of the species recorded in the course of the present work could be described in similar terms to those used to describe their frequency in the course of his paper. The majority were common although sometimes associated with a particular granulometry. Of the species listed here only *Solecurtus scopula* was described by Keegan as rare and that description would also apply to the dredge survey of Cill Chiaráin where only two specimens were recorded.

**Table 6.** Calculations of inter-specific associations where values are negative.

| Species 1 | Species 2 | a | b | c | d | a+b | c+d | a+c | b+d | n | X $^2$ | ad | bc | ad/bc | d>a | CSp1 Sp2 | St Error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E | J | 0 | 8 | 13 | 42 | 8 | 55 | 13 | 50 | 63 | **4.04** | 0 | 104 | 0.00 | | **-1.0** | **0.6** |
| A | H | 0 | 9 | 12 | 42 | 9 | 54 | 12 | 51 | 63 | **4.12** | 0 | 108 | 0.00 | | **-1.0** | **0.6** |
| A | K | 0 | 9 | 12 | 42 | 9 | 54 | 12 | 51 | 63 | **4.12** | 0 | 108 | 0.00 | | **-1.0** | **0.6** |
| F | H | 0 | 10 | 12 | 41 | 10 | 53 | 12 | 51 | 63 | **4.46** | 0 | 120 | 0.00 | | **-1.0** | **0.6** |
| A | P | 0 | 9 | 17 | 37 | 9 | 54 | 17 | 46 | 63 | **5.64** | 0 | 153 | 0.00 | | **-1.0** | **0.5** |
| I | N | 0 | 5 | 27 | 31 | 5 | 58 | 27 | 36 | 63 | **6.20** | 0 | 135 | 0.00 | | **-1.0** | **0.5** |
| D | K | 0 | 12 | 32 | 19 | 12 | 51 | 32 | 31 | 63 | **17.92** | 0 | 384 | 0.00 | | **-1.0** | **0.3** |
| D | H | 1 | 11 | 31 | 20 | 12 | 51 | 32 | 31 | 63 | **12.89** | 20 | 341 | 0.06 | 20.00 | **-0.8** | **0.3** |
| D | P | 2 | 15 | 30 | 16 | 17 | 46 | 32 | 31 | 63 | **16.41** | 32 | 450 | 0.07 | 8.00 | **-0.8** | **0.2** |
| H | O | 1 | 11 | 20 | 31 | 12 | 51 | 21 | 42 | 63 | **5.67** | 31 | 220 | 0.14 | 31.00 | **-0.8** | **0.4** |
| C | P | 2 | 15 | 21 | 25 | 17 | 46 | 23 | 40 | 63 | **7.70** | 50 | 315 | 0.16 | 12.50 | **-0.7** | **0.3** |
| J | N | 1 | 7 | 26 | 29 | 8 | 55 | 27 | 36 | 63 | **5.01** | 29 | 182 | 0.16 | 29.00 | **-0.7** | **0.4** |
| D | N | 9 | 18 | 23 | 13 | 27 | 36 | 32 | 31 | 63 | **7.05** | 117 | 414 | 0.28 | 1.44 | **-0.3** | **0.1** |

The only species of *Spisula* recorded during the survey was *S. solida* although Keegan (1974a) noted the presence of *S. elliptica* and Sides *et al* (1994) recorded *S. subtruncata*. Deeny (1975) provided a list of 13 interstitial species compiled from bivalve shell fragments occurring in the non-algal component of sediments in Cill Chiaráin Bay. It includes *Goodalia triangularis*, a species which has an offshore distribution down to 100 m and *Monacuta substriata* which is associated with the spines of sea urchins, neither of which was recorded in the recent survey, in addition to surface dwelling bivalves which were not of interest here.

Deeny (1975) described four sedimentary facies within Cill Chiaráin Bay: *Lithothamnium*, shell sand, silt mud and mixed facies. His definitions were based on the nature and origin of the materials and their inter-mixture, distribution and sorting by water current in relation to topography and depth. Deeny's mixed facies comprised a variety of sediment types depending on the contribution of sediment size and type to the mixture. The composition of mixed facies in any part of Cill Chiaráin Bay depended on their proximity to sources of the primary components. In his account of the macrofauna of maërl substrates on the west coast of Ireland, Keegan (1974a), listed 6 substrate types.

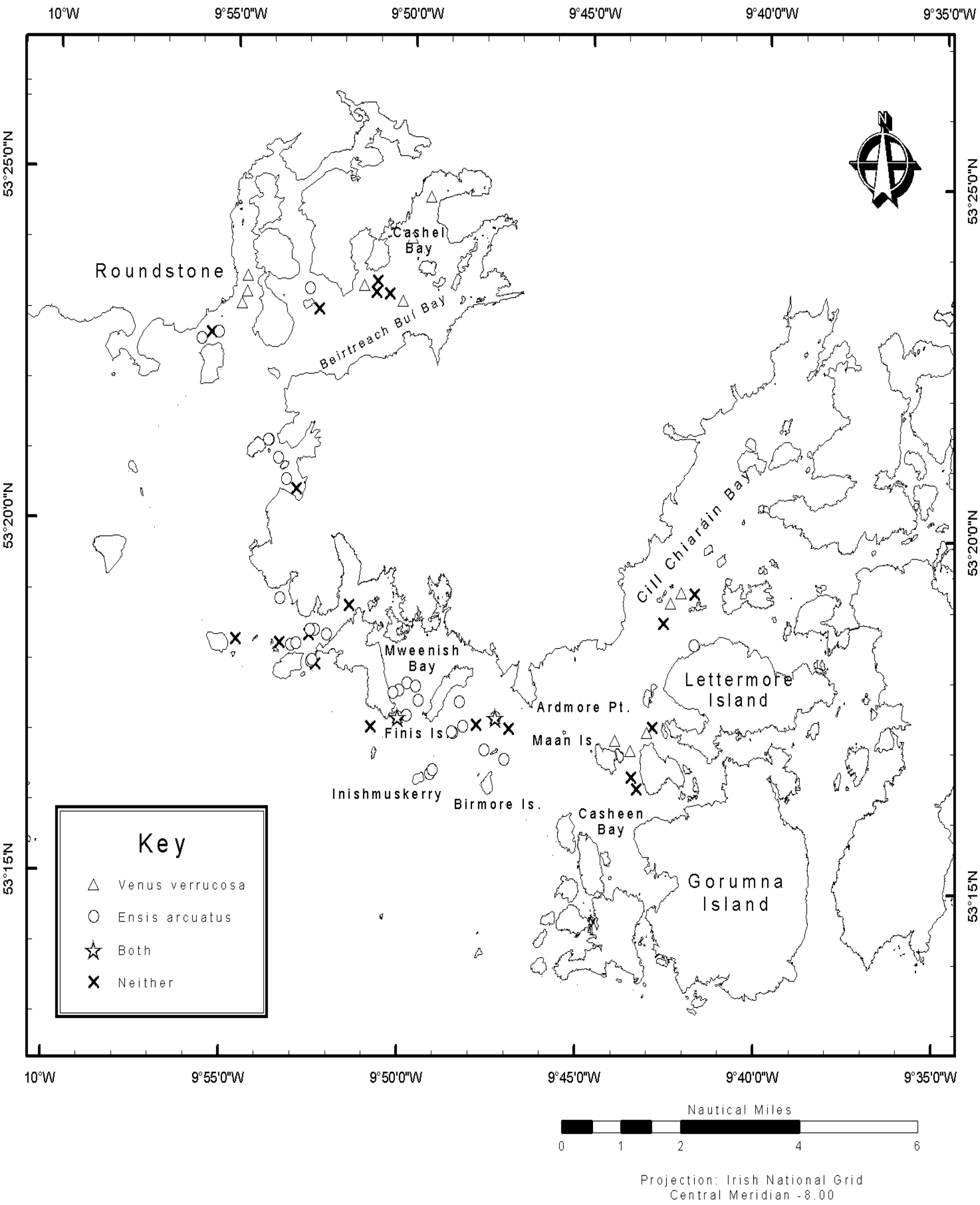


**Fig 3**. Stations at which *Ensis arcuatus* and *Venus verrucosa* were recorded.

His *Lithothamnium* zone he divided into two sub-groups, littoral and sub-littoral (substrates 1 and 2). His maërl and soft ground (substrate 3), covered by extensive *Zostera* beds, is an upper bay phenomenon while his substrate 4 (consisting of maërl associated with rock or rock-gravel) he encountered at 17 m, beyond the range of this survey. Keegan divided his substrate 5, consisting of maërl debris, into two sub-groups (considered together here). His group 6, consisting of maërl and muddy sand, was confined to certain locations and appears to be formed by the inter-actions of topography and current.

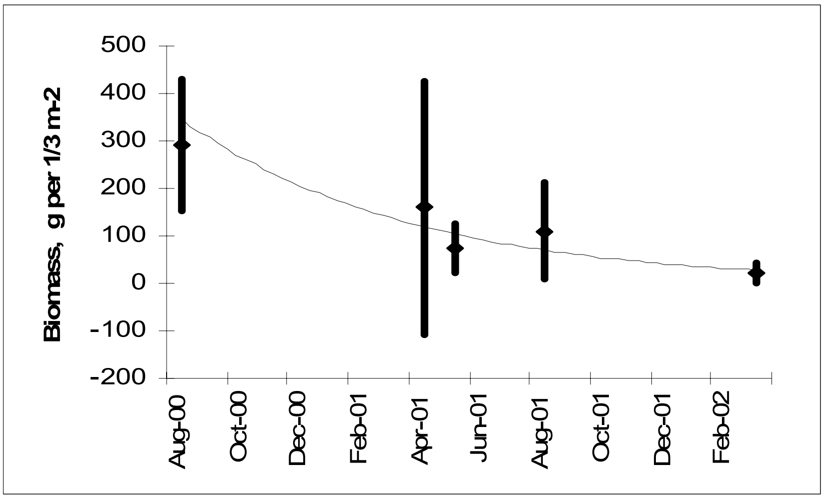


**Fig 4**. The biomass of *Ensis arcuatus* in the vicinity of Inishmuskerry Island at dates between August 2000 and March 2002; updated from Fahy *et al* (in press). Exponential trend line fitted.

Keegan (1974a) provided a large invertebrate species list associated with several of his substrate types and he used indicator species to characterise the substrates. Twelve of the fourteen bivalve species (for *Spisula elliptica* read *S. solida* in this work) whose significant associations are set out in Fig 2 are among Keegan's list. Two, *Chamelea gallina* and *Conchlodesma praetenue* were not considered by him. Two of the taxa, *Venus verrucosa* and the Nuculidae were reported by Keegan to be found only in maërl/soft ground (his type 3). According to Keegan five of the species recorded here occurred within two of the substrate types he listed, three in three and two in four.

If Keegan's observations on species associated with particular substrate types are applied to the current association analysis (Fig 2), bivalve species which can occur in maërl and soft substratum (type 3) have more positive than negative associations among them (group A in the text Table below); species which occur in sediments other than type 3, according to Keegan, (group B) have no positive association, and only one negative association, within that group. And animals in group A are more negatively than positively associated with those in group B.

| Groups | Associations among/between | Positive | Negative |
|---|---|---|---|
| A | Species/taxa occupying substratum type 3 - Keegan | 6 | 2 |
| B | Species/taxa occupying substrata other than 3 | 0 | 1 |
| C | Between groups A and B above | 4 | 6 |

**Table 7.** Sediment analysis of locations at which razor clams were recorded in Cill Chiarain Bay in 2000 and 2001. Percentage frequency of grades in sediment samples are shown above; the grade frequencies are expressed in terms of mm scale, Φ scale and m values. Mean grain size, skewness and sorting coefficient are set out below.

| Φ scale | mm scale | m values | Jun-00 No details | Aug-00 Stat 18 | Aug-00 Stat 2 | Aug-00 Stat 26 | Aug-00 Stat 27 | Aug-00 Stat 3 | Aug-00 Stat 7 | Aug-00 Stat 14 |
|---|---|---|---|---|---|---|---|---|---|---|
| -4 | >16 | -4.5 | 0.0 | 0.0 | 2.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0 |
| -3 | >8 | -3.5 | 0.0 | 0.5 | 7.2 | 0.0 | 0.0 | 0.3 | 0.7 | 0 |
| -2 | >4 | -2.5 | 0.9 | 1.6 | 9.3 | 0.0 | 13.9 | 1.7 | 2.2 | 0 |
| -1 | >2 | -1.5 | 2.0 | 5.2 | 14.3 | 1.3 | 32.8 | 8.1 | 10.7 | 1 |
| 0 | >1 | -0.5 | 32.2 | 21.2 | 39.7 | 8.4 | 27.7 | 47.0 | 50.9 | 3 |
| 1 | >0.5 | 0.5 | 53.4 | 43.5 | 24.6 | 38.8 | 20.3 | 42.2 | 31.0 | 5 |
| 2 | >0.25 | 1.5 | 9.6 | 21.4 | 1.4 | 33.7 | 4.0 | 0.7 | 2.4 | 8 |
| 3 | >0.125 | 2.5 | 1.8 | 6.0 | 0.7 | 17.4 | 1.1 | 0.1 | 1.4 | 75 |
| 4 | >0.063 | 3.5 | 0.1 | 0.6 | 0.2 | 0.4 | 0.1 | 0.0 | 0.5 | 8 |
| pan | <0.063 | 4.5 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0 |
| | | Totals | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100 |

| | Jun-00 No details | Aug-00 Stat 18 | Aug-00 Stat 2 | Aug-00 Stat 26 | Aug-00 Stat 27 | Aug-00 Stat 3 | Aug-00 Stat 7 | Aug-00 Stat 14 |
|---|---|---|---|---|---|---|---|---|
| Mean grain size | 0.245 | 0.472 | -0.838 | 1.088 | -0.784 | -0.185 | -0.244 | 2.283 |
| fm2 | 65.421 | 138.519 | 254.424 | 205.079 | 190.836 | 56.824 | 90.128 | 592.386 |
| fm3 | 45.244 | 138.291 | -697.130 | 406.849 | -291.364 | -61.464 | -41.691 | 1551.276 |
| Sorting coefficient | 0.59 | 1.16 | 1.84 | 0.87 | 1.29 | 0.53 | 0.84 | 0.71 |
| Skewness | 0.0 | -0.2 | -0.3 | -0.1 | 0.3 | -2.1 | 0.4 | -3.5 |
| % fines (</equal to 2 on Phi scale) | 11.5 | 28.1 | 2.3 | 51.5 | 5.3 | 0.8 | 4.5 | 91.7 |
| Modal point (Phi scale) | 1 | 1 | 0 | 1 | -1 | 0 | 0 | 3 |

Thus, there is evidence of species assemblages, within which some species have commercial potential, in Cill Chiaráin Bay. The evidence might be stronger had the sampling method been more precise. On occasion, by virtue of the difficult terrain, the hydraulic dredge behaved as a grab rather than a dredge because it moved only a very short distance; however, that was not always the case. O'Connor et al (1993) made a similar point in their characterisation of benthic communities in greater Galway Bay: that a dredge is likely to traverse different facies in a single tow thus obscuring the association between individual species and particular substrate types.

The most valuable species with commercial potential which occurred within one substrate type according to Keegan (1974a) was *Venus verrucosa* which occupied the maërl/soft ground (his substratum 3). *Venus verrucosa* was negatively associated with *Ensis arcuatus* which is negatively associated with three additional species belonging to the maërl/soft ground group. The distribution of samples containing these species is set out in Fig 3 which demonstrates the discrete distribution patterns of the two.

The abundance of species recorded in the course of the survey was a consequence of the fishing method used. The dredge was not rigged to fish most effectively, which would have been at a depth of 10 m. Rock outcrops damaged its structure on occasion and large boulders blocked the entrance three times, effectively preventing the dredge from operating. Bay head muds and fine sands in which *Zostera marina* was rooted, were inimical to fishing by this method and the arbuscular form of *Lithothamnium* clogged the dredge cage. The dredge operated most effectively in sands which were either the shell sand facies or maërl debris or a mixture of them. These were situated in the vicinity of the entrance to the bay and its environs along the more exposed coastline (Fig 1). These areas are dominated by *Ensis arcuatus* on which some biological investigations have already been undertaken (Fahy *et al*, 2001).

**Table 8.** Template for calculating mean grain size, fm2 and fm3 in sediment samples, using the percentage frequency distribution of the sediment sample from June 2000.

| Φ scale | m | f | fm | m2 | fm2 | m3 | fm3 |
|---|---|---|---|---|---|---|---|
| **-4** | **-4.5** | 0.000 | 0.000 | 20.250 | 0.000 | -91.125 | 0.000 |
| **-3** | **-3.5** | 0.000 | 0.000 | 12.250 | 0.000 | -42.875 | 0.000 |
| **-2** | **-2.5** | 0.913 | -2.284 | 6.250 | 5.709 | -15.625 | -14.272 |
| **-1** | **-1.5** | 2.023 | -3.035 | 2.250 | 4.553 | -3.375 | -6.829 |
| **0** | **-0.5** | 32.166 | -16.083 | 0.250 | 8.041 | -0.125 | -4.021 |
| **1** | **0.5** | 53.428 | 26.714 | 0.250 | 13.357 | 0.125 | 6.679 |
| **2** | **1.5** | 9.585 | 14.377 | 2.250 | 21.566 | 3.375 | 32.349 |
| **3** | **2.5** | 1.815 | 4.538 | 6.250 | 11.345 | 15.625 | 28.363 |
| **4** | **3.5** | 0.069 | 0.243 | 12.250 | 0.850 | 42.875 | 2.974 |
| **5** | **4.5** | 0.000 | 0.000 | 20.250 | 0.000 | 91.125 | 0.000 |
| | | **Average =** | **0.245** | | **65.421** | | **45.244** |

Eight samples of sediment were recovered in the course of assessing razor clam populations at the entrance to Cill Chiaráin Bay in August 2000. Deeny (1975) observed that the largest volume of algae was contained in the coarsest fraction of *Lithothamnium*, which standard sieving techniques did not readily sort. For the same reason such fragments did not separate from interstitial bivalves in the course of hydraulic dredging; rather, they clogged the dredge cage making the apparatus inoperable. Below the 1 mm sieve mesh (0 on the phi scale), Deeny reported, algal content was minimal and it was this material which was most amenable to dredging. At the other extreme, as the percentage fines increased, there was a tendency for the substratum to become colonised *by Zostera marina* or to become simply an anoxic sticky mud which did not wash through the dredge and which was, anyway, unlikely to support bivalves.

Within the series of sediment samples analyzed here, the sorting coefficients are relatively low (when compared with the values provided by Deeny (1975). In seven of the eight samples, skewness is relatively low (the exception being Station 3 in August 2000 where there is a strong skew towards the coarser grain sizes, the minus end of the scale). The percentage fines is very variable and it may not always present a difficulty for hydraulic dredging. The modal points of the first seven samples which characterise sediments supporting *Ensis arcuatus*, are within the range –1 to 1 on the phi scale.

Given that the most suitable sediment for hydraulic dredging in Cill Chiaráin Bay contains *Ensis arcuatus*, which was also the most abundant species sampled in the course of the work, a note on its current status is appropriate.

The biology of *Ensis arcuatus* was investigated in, among other locations, outer Cill Chiaráin Bay (Fahy *et al*, 2001). The species occurs in relatively (when compared with *Ensis siliqua* in the Irish Sea) small patches in the lee of reefs and rocks which protect them from the Atlantic swell. Population work by divers was directed at establishing the biomass of razor clams in a "clam bed" (i.e. a local concentration of the animals) in the lee of Inishmuskerry.

The following March (2001) a mortality of *Ensis arcuatus* was reported from the vicinity. At the same time razor clam deaths were also reported from other parts of the region (Fahy *et al*, in press). In the course of the survey described here, patches of razor clams containing large numbers of freshly dead but undamaged shells (cursorily estimated at 50 - 75 % of the bed's numbers) were encountered throughout the area surveyed. A further quantitative assessment of the bed at Inishmuskerry in March 2002 revealed that the biomass had further slightly, but not significantly, declined in the interim (Fig 4 –updated from Fahy *et al*, in press). For the moment, the reduced mortalities of razor clams reported in 2002 appear to have stabilised but the consequences of the phenomenon, whose cause is not know, have been severe and, in view of the growth rates of the species, the beds are likely to require in excess of ten years to re-establish their biomass in 2000.

Council Directive 92/43/EEC on the conservation of natural habitats and wild fauna and flora came into force in 1992. Under its terms Cill Chairáin Bay was designated as a marine candidate Special Area of Conservation (cSAC) by virtue of its special scientific interest. This status does not forbid fish harvesting and aquaculture but it restricts activities which are likely to conflict with the conservation status of a designated area. It is expected that sustainable extraction of resources would be permitted under the aegis of a conservation plan of a marine SAC (O'Beirne, Pers.comm.)

Upper Cill Chiaráin Bay and some areas of the mid-bay are reserved for the management of oyster and scallop, for which reasons hydraulic dredging was not permitted there. For much of the remaining area, the nature of the substratum made dredging unworkable and it was only in the most exposed parts of the lower bay and along the open coastline that shell sand and maërl provided limited opportunities for the dredge to operate.

The CSC manages oyster and scallop fisheries in a disciplined and sustained way and thus, it is a framework in which the sustainable extraction of other bivalve species might be envisaged. Under its aegis alternative methods of harvesting bivalves might be given consideration.

Our initial survey of interstitial bivalves (the infauna) of Cill Chiaráin and Beirtreach buí Bays reveals they could be described as having a high diversity and low biomass. In recent years the fishing industry has concentrated on harvesting and supplying markets with one or two bivalve species at a time. *Ensis arcuatus* would have been a suitable candidate species for this approach by virtue of its relative abundance but recent mortalities have reduced its importance and its biomass in 2000 is unlikely to be restored for a further decade. In order to provide a sustainable fishery in these circumstances, consideration should be given to simultaneously marketing a number of bivalve species which are available at lower densities rather than concentrating on a single species only.

Co-ordinated Local Aquaculture Management Systems (C.L.A.M.S.) is a consultative system embracing state agencies, local authorities and certain technically trained individuals whose purpose is to assemble and evaluate relevant data concerned with the use of the coastal zone. Its purpose is to facilitate and promote use of the inshore by multiple users through the resolution of local conflicts. C.L.A.M.S. is not a licensing agency, nor is it concerned with regulation or enforcement of law. An overview has been prepared for Cill Chiaráin Bay which catalogues a range of activities carried out there and proposes how they should be carried on in an integrated manner. There is no mention within it of hydraulic dredging. Dúchas, the state agency charged with identifying and overseeing SACs, is however a consultee to the Cill Chiaráin C.L.A.M.S. committee, although it is not a member of the group.

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Table 3. Numbers of bivalve taxa recorded during a dredge survey of Cill Chiarain Bay in November 2001 and January 2002. Species further considered in the calculation of inter-specific association are indicated by upper case letters.

| | | | | | | A | B | C | D | | E | F | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station number | *Angulus tenuis* | *Astarte sulcata* | *Parvicardium* spp | *Circomphalus casina* | *Clausinella fasciata* | *Conchlodesma praetenue* | *Dosinia exoleta* | *Dosinia lupinus* | *Ensis arcuatus* | *Ensis siliqua* | *Gari depressa* | *Gari fervensis* | *Glycymeris glycymeris* |
| 1 | | | | | | | | | | | | | |
| 2 | | | | | | | 8 | 3 | | | | | |
| 3 | | | | | | | 5 | 5 | 72 | | | | |
| 4 | | | | | | | | | | | | | |
| 5 | | | | | | | | 1 | 15 | | 1 | | |
| 6 | | | | | | | | | | | | | |
| 7 | | | | | | | 1 | | | | | | |
| 8 | | | 3 | | | | 1 | | | | 1 | | |
| 10 | | | | | | | | 1 | | | | | |
| 11 | | | | | | | 1 | | | | | | |
| 12 | | | | | | | | | | | | | |
| 13 | | | 1 | | | | | | 4 | | | | |
| 15 | | | | | | 1 | 4 | 2 | 7 | | | 3 | |
| 16 | | | 1 | | | 6 | | | 8 | | | 2 | |
| 17 | | | | | | | 8 | 1 | 9 | | | | |
| 18 | | | | | | | 1 | | 3 | | | | |
| 20 | | | | | | | 1 | | | | 1 | | |
| 21 | | | | | | | | 1 | 1 | | | | |
| 22 | | | | | | | 2 | | 79 | | | | |
| 23 | | | | | | | 8 | 1 | | | | | |
| 24 | | | | | | | 23 | | 4 | 16 | | | |
| 26 | | | | | | | 10 | 2 | 6 | | | | |
| 27 | | | | | | | | 2 | 4 | | | 1 | |
| 28 | | | | | | 2 | 4 | 3 | 9 | | 1 | 3 | |
| 29 | | 1 | | | | | | | | | | | |
| 30 | | | | *1* | | | 3 | 1 | | | | | 1 |
| 31 | | | | | | 1 | | | 16 | | | 1 | |
| 33 | | | | | | | | 1 | 51 | | | | |
| 35 | | | | | | | 2 | 4 | 12 | | | | |
| 36 | 4 | | | | | | | 2 | 8 | | | | |
| 37 | | | | | | | | | 5 | | | | |
| 38 | | | | | | | | 1 | 49 | 7 | | | |
| 39 | | | | | | | | | 17 | | | | |
| 40 | | | | | | | 7 | 1 | 24 | | | | |
| 41 | | | | | | 1 | 3 | | 28 | | | | |
| 42 | 2 | | | | | 4 | | 4 | 10 | | 5 | | |
| 43 | 1 | | | | | 1 | 5 | | 72 | | | | |
| 44 | | | | | | | 110 | 24 | 76 | | 3 | | |
| 45 | | | | | | | 1 | | 1 | 1 | | | |
| 46 | | | | | | | 3 | | 1 | | | 2 | |
| 47 | | | | | | 2 | 5 | | 91 | | | 3 | |
| 48 | | | | | | 2 | 23 | 32 | 13 | | | | |
| 50 | | | | | 2 | | 1 | | 1 | | 1 | | |
| 51 | | | | | | | | | | | | | |
| 52 | | | | | | | 1 | | 88 | | | | |
| 53 | | | | | | | | | | | 2 | | |
| 54 | | | | | | | | | | | 1 | | |
| 55 | | | | | | | 2 | | | | | | |
| 56 | | | | | | | 12 | | | | | | |
| 57 | | | | | | | | | | | | | |
| 58 | | | | | | | 1 | | | | | 1 | |
| 59 | | | | | | | | | | | | 2 | |
| 60 | | | | | | | | | 5 | | | | |
| 61 | | | | | | | | | | | | | |
| 62 | | | | *1* | | | 5 | 1 | | | | 1 | |
| 63 | | | | | | | | | | | | | |
| 64 | | | | | | | 7 | | | | 6 | | |
| 65 | | | | | | | 8 | | 10 | | 3 | | |
| 66 | | | | | | | | 1 | | | | | |
| 67 | | | | | | | | 1 | 7 | | | | |
| 68 | | | | | | | 18 | | | | 6 | | |
| | **7** | **1** | **5** | **2** | **2** | **20** | **294** | **95** | **806** | **24** | **31** | **19** | **1** |

(Cont. Table 3)

| | G | | | H | I | | J | K | L | M | N | O | P | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Laevicardium crassum* | *Lutraria spp* | *Moerella donacina* | *Mysia undata* | *Nucula sp or spp* | *Acropagia crassa* | *Solecurtus scopula* | *Spisula solida* | *Tapes aureus* | *Tapes rhomboides* | *Angulus squalidus* | *Venerupis senegalensis* | *Chamelea gallina* | *Venus verrucosa* | TOTAL |
| | | | | | | | | 1 | 2 | | 5 | | 2 | **10** |
| | | | | 10 | | | | 5 | | | 4 | 6 | 1 | **37** |
| 1 | | | | | | | | | | | | 13 | | **96** |
| | | | | 2 | | | | | | | | | | **2** |
| | | | | | | | | | | | 16 | 7 | | **40** |
| | | | | | | | | 8 | | 2 | 39 | | 3 | **52** |
| | | | | | | | | | | | 4 | | 1 | **6** |
| | | | | 1 | | | | 3 | 1 | | 5 | | 4 | **19** |
| | | | | | | | | | | | 1 | | | **2** |
| | | | | | | | | | | | | | | **1** |
| | | | | 2 | | | | | | | 1 | | 2 | **5** |
| | | | | 1 | 1 | | | | | | | | | **7** |
| | | | | | | | | | 1 | 1 | 2 | 6 | | **27** |
| | 1 | | | | | | 1 | | | | 3 | 1 | | **23** |
| | 1 | | | | | | | | | | | 2 | | **21** |
| | | | | | | | | | | | | | | **4** |
| | | | | 3 | | | | | 1 | | 1 | | 4 | **11** |
| | | | | | | | | | | | | | | **2** |
| | 2 | | | | | | 10 | | | | | 1 | | **94** |
| | | | | | | | | | | | | | | **9** |
| | 3 | | | | | | | | | | | | | **46** |
| | 1 | | | | | | | | | | | 3 | | **22** |
| | | 1 | | | | | | | | | | | | **8** |
| | | | | | | | | | | 7 | | | | **29** |
| | | | | | | | | | | 1 | | | | **2** |
| 1 | | | | | 2 | 1 | 2 | | | | | 3 | | **15** |
| | | | | | | | | | | | 1 | | | **19** |
| | | | | | | | 1 | | | | | | | **53** |
| | | | | | | | 10 | | | | | | 1 | **29** |
| | | 1 | | | | | | | | | 2 | 2 | | **19** |
| | | | | | | | | | | | 1 | | | **6** |
| | 1 | | | | | | | | | 2 | | 3 | | **63** |
| | | | | | 3 | | 4 | | | | | | | **24** |
| | | | | | 1 | | 7 | | | | | 1 | | **41** |
| | | | | | 4 | | | | | | | 1 | | **37** |
| | | | | | | | | | | | | | | **25** |
| | | | | | | | | | | 1 | | 4 | | **84** |
| | 1 | | | | | | | | | 1 | 3 | | | **218** |
| | | | | | | | | | | | | | | **3** |
| | | | | | | | | | | | | | | **6** |
| | | | 1 | | | | 9 | | | | | 8 | | **119** |
| | | | | | | 1 | | | 1 | | 1 | 2 | | **75** |
| | | | | | | | | | 4 | | 4 | 2 | 2 | **17** |
| | 1 | | | | | | | | 2 | | 5 | 6 | | **14** |
| | | | | | | | | | | | | 1 | | **90** |
| | | | | 7 | | | | 8 | | | 2 | | 2 | **21** |
| | | | | | | | | | | | 2 | | 5 | **8** |
| | | | | 4 | | | | | | | 1 | | | **7** |
| | 1 | | | 1 | | | | 1 | | | 2 | | 1 | **18** |
| | | | | 1 | | | | | | | | | | **1** |
| | | | | | | | | 2 | | | | 1 | 4 | **9** |
| | | | | | | | | | | | 5 | | 1 | **8** |
| | | | | | | | | | | | | | | **5** |
| | | | | | | | | 1 | | | | | | **1** |
| | | | | | | | | | | 12 | 1 | 11 | | **32** |
| | 2 | | | 2 | | | | 2 | | | | | 4 | **10** |
| | 1 | | | | | | | 3 | 3 | | 2 | | | **22** |
| | 3 | | | | | | | 5 | 7 | | 11 | | 2 | **49** |
| | | | | 2 | | | | 1 | | | | | | **4** |
| | | | | | | | | | | | | | | **8** |
| | | | | | | | | | | | | | 7 | **31** |
| **2** | **18** | **2** | **1** | **36** | **11** | **2** | **44** | **40** | **22** | **27** | **124** | **84** | **46** | **1766** |

**Table 4**. Prepartions for calculations of inter-specific associations.
The first two columns contain species 1 and 2 which are those taxa in Table 3 labelled with an upper case letter.

| Species 1 | Species 2 | a | b | c | d | a+b | c+d | a+c | b+d | n |
|---|---|---|---|---|---|---|---|---|---|---|
| E | G | 3 | 9 | 10 | 41 | 12 | 51 | 13 | 50 | 63 |
| E | H | 3 | 9 | 10 | 41 | 12 | 51 | 13 | 50 | 63 |
| G | J | 2 | 6 | 10 | 45 | 8 | 55 | 12 | 51 | 63 |
| G | M | 2 | 6 | 10 | 45 | 8 | 55 | 12 | 51 | 63 |
| M | N | 4 | 4 | 23 | 32 | 8 | 55 | 27 | 36 | 63 |
| C | F | 4 | 6 | 19 | 34 | 10 | 53 | 23 | 40 | 63 |
| B | I | 3 | 2 | 30 | 28 | 5 | 58 | 33 | 30 | 63 |
| E | M | 2 | 6 | 11 | 44 | 8 | 55 | 13 | 50 | 63 |
| F | N | 5 | 5 | 22 | 31 | 10 | 53 | 27 | 36 | 63 |
| A | C | 4 | 5 | 19 | 35 | 9 | 54 | 23 | 40 | 63 |
| B | F | 6 | 4 | 27 | 26 | 10 | 53 | 33 | 30 | 63 |
| H | L | 2 | 7 | 10 | 44 | 9 | 54 | 12 | 51 | 63 |
| A | L | 2 | 7 | 7 | 47 | 9 | 54 | 9 | 54 | 63 |
| G | N | 6 | 6 | 21 | 30 | 12 | 51 | 27 | 36 | 63 |
| B | J | 5 | 3 | 28 | 27 | 8 | 55 | 33 | 30 | 63 |
| B | M | 5 | 3 | 28 | 27 | 8 | 55 | 33 | 30 | 63 |
| B | C | 13 | 10 | 20 | 20 | 23 | 40 | 33 | 30 | 63 |
| F | J | 2 | 6 | 8 | 47 | 8 | 55 | 10 | 53 | 63 |
| D | G | 7 | 5 | 25 | 26 | 12 | 51 | 32 | 31 | 63 |
| A | N | 4 | 5 | 23 | 31 | 9 | 54 | 27 | 36 | 63 |
| N | O | 9 | 12 | 18 | 24 | 21 | 42 | 27 | 36 | 63 |
| A | I | 1 | 4 | 8 | 50 | 5 | 58 | 9 | 54 | 63 |
| C | I | 2 | 3 | 21 | 37 | 5 | 58 | 23 | 40 | 63 |
| A | E | 2 | 7 | 11 | 43 | 9 | 54 | 13 | 50 | 63 |
| D | M | 5 | 3 | 27 | 28 | 8 | 55 | 32 | 31 | 63 |
| B | P | 10 | 7 | 23 | 23 | 17 | 46 | 33 | 30 | 63 |
| L | O | 4 | 5 | 17 | 37 | 9 | 54 | 21 | 42 | 63 |
| A | J | 2 | 6 | 7 | 48 | 8 | 55 | 9 | 54 | 63 |
| B | E | 8 | 5 | 25 | 25 | 13 | 50 | 33 | 30 | 63 |
| C | J | 4 | 4 | 19 | 36 | 8 | 55 | 23 | 40 | 63 |
| B | K | 6 | 6 | 27 | 24 | 12 | 51 | 33 | 30 | 63 |
| G | P | 3 | 9 | 14 | 37 | 12 | 51 | 17 | 46 | 63 |
| H | I | 1 | 4 | 11 | 47 | 5 | 58 | 12 | 51 | 63 |
| A | B | 6 | 3 | 27 | 27 | 9 | 54 | 33 | 30 | 63 |
| C | G | 4 | 8 | 19 | 32 | 12 | 51 | 23 | 40 | 63 |
| G | H | 2 | 10 | 10 | 41 | 12 | 51 | 12 | 51 | 63 |
| M | O | 4 | 4 | 17 | 38 | 8 | 55 | 21 | 42 | 63 |
| L | M | 1 | 7 | 8 | 47 | 8 | 55 | 9 | 54 | 63 |
| G | L | 3 | 6 | 9 | 45 | 9 | 54 | 12 | 51 | 63 |
| B | G | 8 | 4 | 25 | 26 | 12 | 51 | 33 | 30 | 63 |
| C | E | 4 | 9 | 19 | 31 | 13 | 50 | 23 | 40 | 63 |
| E | K | 4 | 8 | 9 | 42 | 12 | 51 | 13 | 50 | 63 |
| I | O | 3 | 2 | 18 | 40 | 5 | 58 | 21 | 42 | 63 |
| B | N | 13 | 14 | 20 | 16 | 27 | 36 | 33 | 30 | 63 |
| F | O | 5 | 5 | 16 | 37 | 10 | 53 | 21 | 42 | 63 |
| B | D | 19 | 13 | 14 | 17 | 32 | 31 | 33 | 30 | 63 |
| H | N | 7 | 5 | 20 | 31 | 12 | 51 | 27 | 36 | 63 |
| D | I | 4 | 1 | 28 | 30 | 5 | 58 | 32 | 31 | 63 |
| F | L | 1 | 8 | 9 | 45 | 9 | 54 | 10 | 53 | 63 |
| F | P | 2 | 8 | 15 | 38 | 10 | 53 | 17 | 46 | 63 |
| D | F | 7 | 3 | 25 | 28 | 10 | 53 | 32 | 31 | 63 |
| K | M | 1 | 7 | 11 | 44 | 8 | 55 | 12 | 51 | 63 |
| G | K | 4 | 8 | 8 | 43 | 12 | 51 | 12 | 51 | 63 |
| G | O | 6 | 6 | 15 | 36 | 12 | 51 | 21 | 42 | 63 |
| A | G | 1 | 8 | 11 | 43 | 9 | 54 | 12 | 51 | 63 |
| B | H | 5 | 7 | 28 | 23 | 12 | 51 | 33 | 30 | 63 |
| E | N | 8 | 5 | 19 | 31 | 13 | 50 | 27 | 36 | 63 |
| F | G | 1 | 9 | 11 | 42 | 10 | 53 | 12 | 51 | 63 |
| F | K | 1 | 9 | 11 | 42 | 10 | 53 | 12 | 51 | 63 |
| C | M | 5 | 3 | 18 | 37 | 8 | 55 | 23 | 40 | 63 |
| C | N | 8 | 15 | 19 | 21 | 23 | 40 | 27 | 36 | 63 |
| F | M | 3 | 5 | 7 | 48 | 8 | 55 | 10 | 53 | 63 |

Cont. Table. 4

| Species 1 | Species 2 | a | b | c | d | a+b | c+d | a+c | b+d | n |
|---|---|---|---|---|---|---|---|---|---|---|
| B | L | 7 | 2 | 26 | 28 | 9 | 54 | 33 | 30 | 63 |
| D | E | 5 | 8 | 27 | 23 | 13 | 50 | 32 | 31 | 63 |
| E | F | 1 | 9 | 12 | 41 | 10 | 53 | 13 | 50 | 63 |
| C | L | 2 | 7 | 21 | 33 | 9 | 54 | 23 | 40 | 63 |
| J | P | 1 | 7 | 16 | 39 | 8 | 55 | 17 | 46 | 63 |
| M | P | 1 | 7 | 16 | 39 | 8 | 55 | 17 | 46 | 63 |
| A | M | 3 | 5 | 6 | 49 | 8 | 55 | 9 | 54 | 63 |
| J | O | 5 | 3 | 16 | 39 | 8 | 55 | 21 | 42 | 63 |
| D | L | 3 | 6 | 29 | 25 | 9 | 54 | 32 | 31 | 63 |
| K | N | 8 | 4 | 19 | 32 | 12 | 51 | 27 | 36 | 63 |
| I | M | 0 | 5 | 8 | 50 | 5 | 58 | 8 | 55 | 63 |
| I | L | 0 | 5 | 9 | 49 | 5 | 58 | 9 | 54 | 63 |
| K | L | 4 | 5 | 8 | 46 | 9 | 54 | 12 | 51 | 63 |
| F | I | 0 | 5 | 10 | 48 | 5 | 58 | 10 | 53 | 63 |
| L | P | 5 | 4 | 12 | 42 | 9 | 54 | 17 | 46 | 63 |
| K | O | 2 | 10 | 19 | 32 | 12 | 51 | 21 | 42 | 63 |
| J | M | 0 | 8 | 8 | 47 | 8 | 55 | 8 | 55 | 63 |
| I | K | 0 | 5 | 12 | 46 | 5 | 58 | 12 | 51 | 63 |
| G | I | 0 | 5 | 12 | 46 | 5 | 58 | 12 | 51 | 63 |
| E | I | 0 | 5 | 13 | 45 | 5 | 58 | 13 | 50 | 63 |
| J | L | 0 | 8 | 9 | 46 | 8 | 55 | 9 | 54 | 63 |
| D | J | 7 | 1 | 25 | 30 | 8 | 55 | 32 | 31 | 63 |
| E | O | 2 | 11 | 19 | 31 | 13 | 50 | 21 | 42 | 63 |
| O | P | 3 | 14 | 18 | 28 | 17 | 46 | 21 | 42 | 63 |
| A | O | 6 | 3 | 15 | 39 | 9 | 54 | 21 | 42 | 63 |
| C | H | 2 | 10 | 21 | 30 | 12 | 51 | 23 | 40 | 63 |
| C | K | 2 | 10 | 21 | 30 | 12 | 51 | 23 | 40 | 63 |
| I | P | 0 | 5 | 17 | 41 | 5 | 58 | 17 | 46 | 63 |
| J | K | 0 | 8 | 12 | 43 | 8 | 55 | 12 | 51 | 63 |
| H | J | 0 | 8 | 12 | 43 | 8 | 55 | 12 | 51 | 63 |
| H | M | 0 | 8 | 12 | 43 | 8 | 55 | 12 | 51 | 63 |
| C | D | 16 | 7 | 16 | 24 | 23 | 40 | 32 | 31 | 63 |
| E | J | 0 | 8 | 13 | 42 | 8 | 55 | 13 | 50 | 63 |
| A | H | 0 | 9 | 12 | 42 | 9 | 54 | 12 | 51 | 63 |
| A | K | 0 | 9 | 12 | 42 | 9 | 54 | 12 | 51 | 63 |
| E | P | 7 | 6 | 10 | 40 | 13 | 50 | 17 | 46 | 63 |
| F | H | 0 | 10 | 12 | 41 | 10 | 53 | 12 | 51 | 63 |
| C | O | 12 | 9 | 11 | 31 | 21 | 42 | 23 | 40 | 63 |
| J | N | 1 | 7 | 26 | 29 | 8 | 55 | 27 | 36 | 63 |
| E | L | 5 | 4 | 8 | 46 | 9 | 54 | 13 | 50 | 63 |
| H | P | 7 | 5 | 10 | 41 | 12 | 51 | 17 | 46 | 63 |
| A | P | 0 | 9 | 17 | 37 | 9 | 54 | 17 | 46 | 63 |
| H | O | 1 | 11 | 20 | 31 | 12 | 51 | 21 | 42 | 63 |
| B | O | 16 | 5 | 17 | 25 | 21 | 42 | 33 | 30 | 63 |
| I | N | 0 | 5 | 27 | 31 | 5 | 58 | 27 | 36 | 63 |
| D | O | 16 | 5 | 16 | 26 | 21 | 42 | 32 | 31 | 63 |
| I | J | 3 | 2 | 5 | 53 | 5 | 58 | 8 | 55 | 63 |
| H | K | 6 | 6 | 6 | 45 | 12 | 51 | 12 | 51 | 63 |
| D | N | 9 | 18 | 23 | 13 | 27 | 36 | 32 | 31 | 63 |
| C | P | 2 | 15 | 21 | 25 | 17 | 46 | 23 | 40 | 63 |
| A | D | 9 | 0 | 23 | 31 | 9 | 54 | 32 | 31 | 63 |
| N | P | 13 | 4 | 14 | 32 | 17 | 46 | 27 | 36 | 63 |
| A | F | 5 | 4 | 5 | 49 | 9 | 54 | 10 | 53 | 63 |
| L | N | 9 | 0 | 18 | 36 | 9 | 54 | 27 | 36 | 63 |
| D | H | 1 | 11 | 31 | 20 | 12 | 51 | 32 | 31 | 63 |
| K | P | 9 | 3 | 8 | 43 | 12 | 51 | 17 | 46 | 63 |
| D | P | 2 | 15 | 30 | 16 | 17 | 46 | 32 | 31 | 63 |
| D | K | 0 | 12 | 32 | 19 | 12 | 51 | 32 | 31 | 63 |