A Study of Selected Maërl Beds in Irish Waters and their Potential for Sustainable Extraction

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ABSTRACT

Although maërl beds are both of economic importance and conservation interest, data on the distribution of beds and their associated communities are lacking in Irish waters. This report describes the spatial distribution and volume of the maërl resource (*Lithothamnion corallioides*, *Phymatolithon calcareum*) along the west coast of Ireland from Donegal to Cork.

Taking an average thickness of 2m (range: 0.1 – 3m) the current study estimates that the total national exploitable maërl bearing resource is of the order of 3 x 10^6 m^3 (see Section 2.2.2. page (22/23). The Report outlines guidelines for the exploitation of this natural resource, which because of its extremely low growth rate, cannot be considered a renewable resource in the strictest sense.

Area surveyed	3.7 x 10^6 m^2
Areas not included but believed to contain maërl	20 x 10^6 m^2
Estimated maërl bearing area:	57 x 10^6 m^2
Estimated average thickness of maërl	2m (range:0.1–3m)
Estimate volume of maërl bearing sediment	114 x 10^6 m^3
Of which 10% is maërl	11 x 10^6 m^3
Of which 25% is exploitable	3 x 10^6 m^3

Lithophyllum dentatum, a rare and beautiful maërl species from Co. Galway.

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1. Introduction

Maërl is thought to be a Breton term, originally used to describe both the live and dead algal gravels off the Brittany coast formed by unattached coralline algae. In European waters, these algal beds occur from the Mediterranean through to the Arctic (BOSENCE, 1983) but are best known in Brittany and Ireland. In Ireland and Britain, they are known to occur along the Atlantic coast of Ireland (KEARY, 1994), Scotland (FARROW, 1983) and in Cornwall (BOSENCE, 1980).

Collection of maërl has been carried out as early as the 17th century in Ireland and the 18th century in Cornwall (BRIAND, 1991). The main use was as a fertiliser on lime-poor soils. Although historical levels of extraction were quite high, present day extraction in Irish waters is small, at a licensed level of 5,000 tonnes per annum, compared to the French extraction of as much as 500,000 tonnes per annum (BRIAND, 1991). Recent usage of maërl or maërl-derived products is quite diverse, with BRIAND (1991) listing the following: soil amelioration, agricultural and horticultural fertiliser, animal fodder additive, acid water treatment, biological de-nitrification, drinking water potabilization, toxin elimination, and also mentions its use in pharmaceutical, cosmetics, nuclear and medical industries. Even so, the main use of maërl today still remains as a cheap bulk fertiliser in lime-poor soils to raise their pH (BLUNDEN *et al.*, 1997).

The wide variety of uses of maërl is as a result of the chemical composition, an aspect which has been studied by BLUNDEN *et al.* (1975, 1977), whilst a comparison of the chemical properties of maërl versus ground limestone has been carried out by BLUNDEN *et al.* (1997). Maërl is primarily composed of calcium and magnesium carbonate, and contains much higher proportions of magnesium, iron and other elements than ground limestone. Maërl also has a more porous nature, which may ensure a faster microbial breakdown if applied as a crushed material. Nevertheless, BLUNDEN *et al.* (1997) concluded that unless field trials could demonstrate a considerable advantage of the use of powdered maërl over powdered, and much cheaper limestone, that the use of maërl could not be justified for use as either a agricultural or horticultural fertiliser on the basis of its high cost. In contrast to this, KEARY (1994) pointed out that the lime-poor soils in the West of Ireland are often quite distant from a source of powdered limestone and that the local availability of a lime source may be of economic interest.

In recent years, much scientific and administrative attention has been directed to the preservation of biodiversity, culminating in various national and international legislative instruments. The two main maërl-bed forming species (*Lithothamnion corallioides*, *Phymatolithon calcareum*) have been included on international lists of habitats, which would merit protection or at least some form of management structure to preserve their inherent community and structural diversity. However, in common with many subtidal habitats and in contrast with many terrestrial habitats, very little is known of the actual level of maërl habitat biodiversity and aspects of community functioning.

In response to the apparent lack of information on maërl beds in Irish waters and in view of their potential economic significance, the Marine Institute, under its Operational Programme for Fisheries 1994-1999, funded a two-year study programme of maërl in Ireland.

The aims of this project were four-fold:

1. To document the spatial spread and total volume of the maërl resource in Irish waters.

2. To document the distribution of the maërl-bed forming species.

3. To assess and document the biodiversity of the maërl associated community in terms of fauna and flora.

4. To assess the environmental impacts of maërl extraction and propose guidelines for sustainable extraction of the resource.

The detailed results of this project are contained in two internal reports presented to the Marine Institute:

- ANON. (1996) details historical knowledge of the distribution of maërl beds in Irish waters and formed the basis of the mapping reported upon in the present document.
- ANON. (1998) presented the entire results of the study programme as a series of scientific studies.

The present document aims at summarising this information and at the same time ensuring access to the dispersed and often difficult to obtain scientific literature on the subject.

2. The Resource

2.1. The Distribution of Maërl Beds in Irish Waters

The older series of British Admiralty Charts frequently used the notation 'crl' (Figure 1) to indicate that the bottom consisted of calcareous material not definitely related to shells (SHEPARD *et al.*, 1949). This led KEARY (1994) to work on the hypothesis that, at least in Irish waters, these markings related to maërl deposits. This may however not always be the case, as DE GRAVE & WHITAKER (1997) discovered a polychaete (*Sabellaria alveolata*) reef at an Irish Sea location, which was indicated as 'crl' and was incorporated as an unconfirmed record by KEARY (1994). The latter (KEARY, 1994) made a distinction between reported/observed deposits and records solely based on 'crl' annotations. This distinction was also made by DE GRAVE & WHITAKER (1999a) who found that the unconfirmed category mainly lay in deeper, further offshore waters up to a depth of 100 m, whilst the deepest recorded live maërl bed in Irish waters is off the Aran Islands in 32 m of water (BRIAND, 1991). Although deep-water rhodoliths are well known in many world-wide locations, with the maximum depth of rhodolith growth being 60-70 m in the Canary Islands (MCMASTER & CONOVER, 1966), the possibility exists that some of these records refer to other types of biogenic structures. DE GRAVE & WHITAKER (1999a) consider that only 50-60% of 'crl' markings in Irish water corresponds to presently confirmed maërl beds.

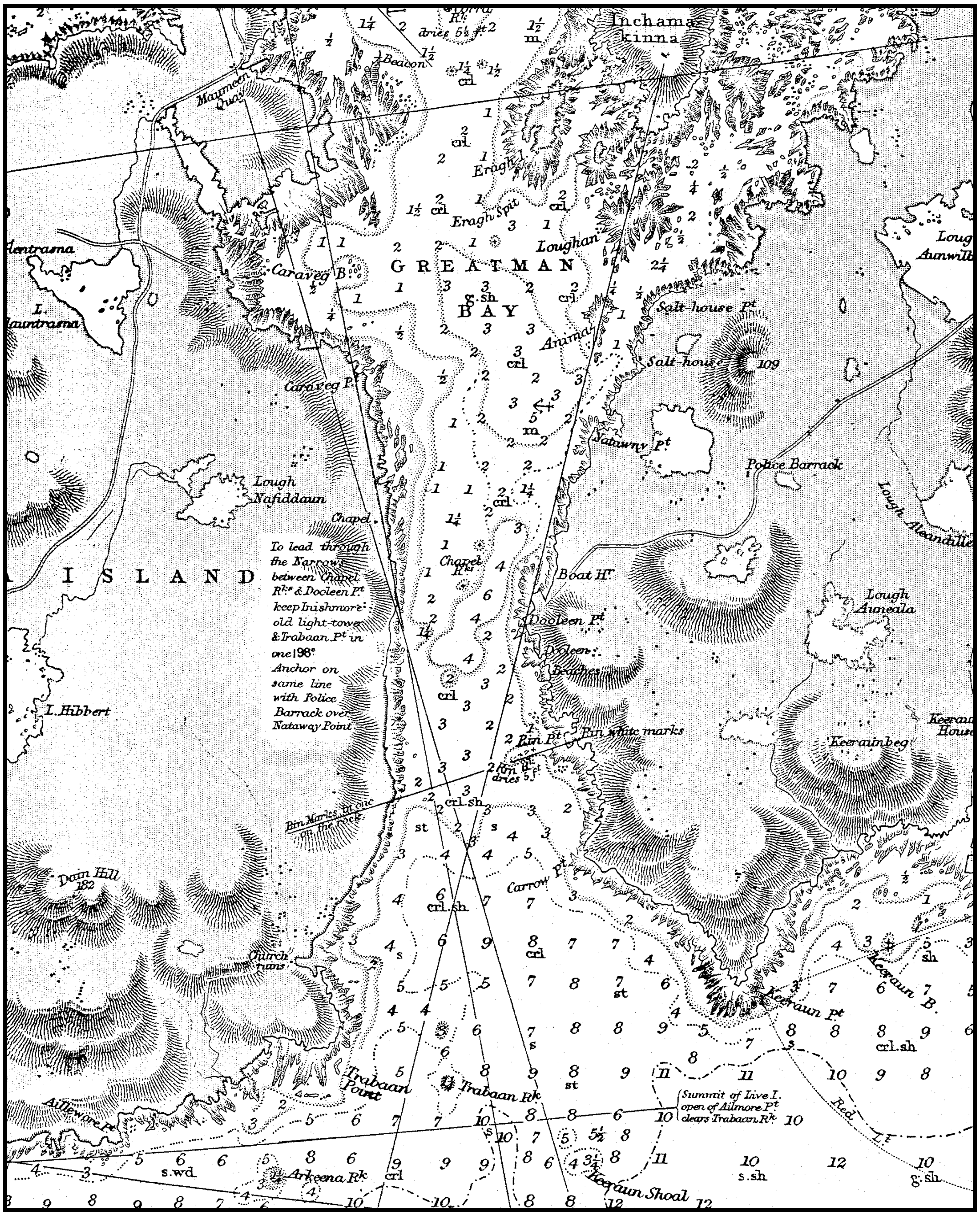


Figure 1. **Example of “crl” notations on British Admiralty Chart (Greatman Bay).**

The unconfirmed category occurs mainly around the Blasket Islands and in scattered locations from Galway Bay up to northern Donegal, details of the locations and depths can be found in ANON. (1996) and DE GRAVE & WHITAKER (1999a).

Confirmed records, based on more recent observations or confirmed older observations, are clustered in two areas, the largest in term of numbers of records encompasses Galway Bay and stretches further north along the Connemara coastline, with the other area being south-west Ireland (Figure 2, Table 1). The Galway-Connemara area holds 65-70% of all confirmed maërl beds in Irish waters, with the south-west region accounting for a further 20-25%. The remaining beds are situated along the Donegal coastline.

Location	Comments	References
Long Island Bay	Large area in inner part of bay	HISCOCK & HISCOCK (1980)
Roaringwater Bay	Scattered records	HISCOCK & HISCOCK (1980)
Dunmanus Bay	Single record	DE GRAVE & WHITAKER (1999a)
Bantry Bay	Scattered records of small aggregations, larger beds in Lonehort Point and Bank Harbour	DE GRAVE & WHITAKER (1999a)
Kenmare River	Few, scattered records	DE GRAVE & WHITAKER (1999a)
Galway Bay area	Numerous small aggregations and larger beds in both inner and outer parts of the bay; also numerous records in connecting bays	LEES *et al.* (1969), DEENY (1975), KÖNNECKER & KEEGAN (1983), MAGGS (1983), O'CONNOR *et al.* (1993), NUNN (1993)
Mannin Bay	Large bed	LEES *et al.* (1969), BOSENCE (1976)
Clifden Bay	Single record	LEES *et al.* (1969), GUNATILAKA (1977)
Kingstown Bay	Scattered records	LEES *et al.* (1969), GUNATILAKA (1977)
Streamstown Bay	Scattered records	LEES *et al.* (1969)
Off Connemara Coast	Scattered records	LEES *et al.* (1969)
Ballynakill Harbour	Single record	SOUTHERN (1915)
Killary Harbour	Scattered records	KEEGAN & MERCER (1986)
Clew Bay	Scattered records in inner and outer bays	SOUTHERN (1915)
Donegal Bay	Single small bed	DE GRAVE & WHITAKER (1999a)
Mulroy Bay	Scattered records, possibly larger bed present	NUNN (1993)

Table 1. Location details for confirmed maërl beds in Ireland, data compiled from ANON (1996) and DE GRAVE & WHITAKER (1999a).

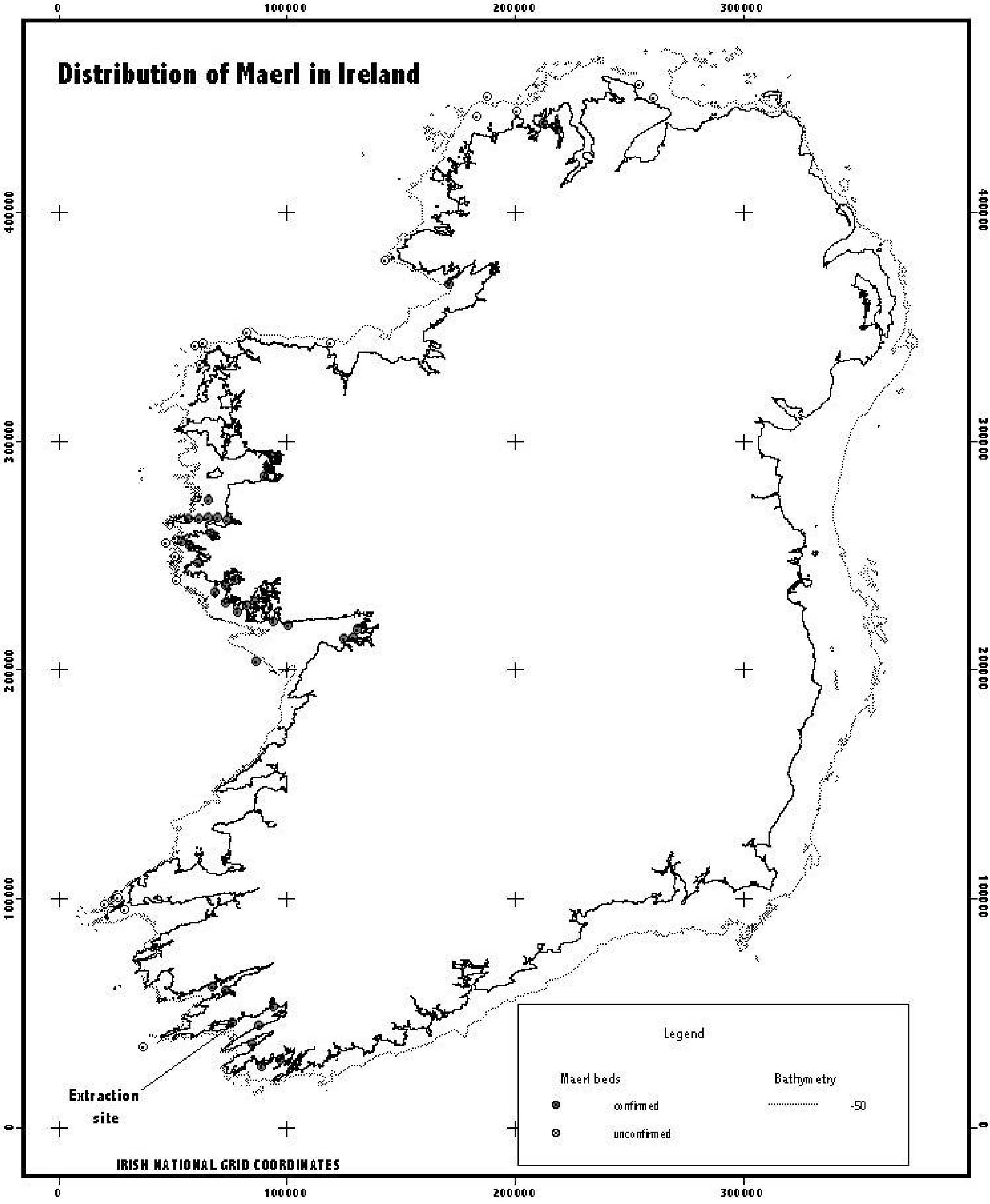


Figure 2: Distibution of maërl beds in Irish waters (excluding Northern Ireland). Diagram courtesy of G. Sutton, Coastal Resources Centre, NUI, Cork. (1999).

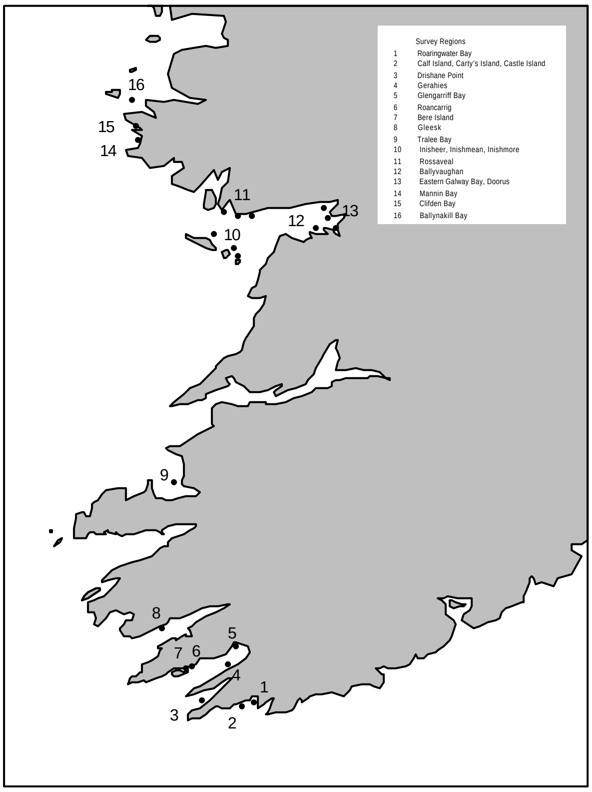


Figure 3. Roxann Survey Sites

In general, maërl beds are present along the Atlantic seaboard of Ireland, from Roaringwater Bay, Co. Cork to Mulroy Bay, Co. Donegal. This pattern repeats itself in Scotland and in France, where maërl beds are only present in the transparent, well-lit Atlantic waters. Other, 19th century or beginning of the 20th century records of maërl from East coast locations are reviewed by GUIRY (1978), these are best considered as isolated plants, perhaps originating from small, spatial aggregations and may not constitute maërl beds (DE GRAVE & WHITAKER, 1999a).

2.2. Quantification of the Resource

2.2.1. Resource Evaluation

During 1996-1998, a Roxann mapping survey (see CHIVERS *et al.*, 1987) was conducted on various maërl deposits. Roxann mapping has been successfully used during work of a similar nature (for recent examples see MAGORRIAN *et al.*, 1995 and PINN & ROBERTSON, 1998) and is the single, most useful tool for large-scale mapping of surface deposits in the marine environment. The general location of these deposits was determined from various publications and historic charts (ANON., 1996) and this survey sought to provide a more detailed delineation of the deposit areas.

Almost all the known maërl deposits lie along the west coast with the majority off counties Cork, Kerry and Galway. Deposits occur as far north as Donegal though many of these are in water depths greater than 30 m and have not been confirmed in recent times (see Section 2.1). It is difficult to quantify deposits as they vary in size from small to very large and it is sometimes unclear if the smaller deposits are in fact part of a larger one. However, it is likely that sizeable deposits occur in over 60 locations along the coastline from Cork to Donegal. Twenty-three locations were chosen for survey using criteria such as water depth, location, potential for commercial extraction and scientific merit. The chosen sites are listed in Table 2 and illustrated in Figure 3.

Large deposits not surveyed include Kilkieran Bay, Greatman Bay and the south-west Connemara coastline. These were omitted as it was considered exploitation was undesirable as these are proposed Natural Heritage Areas (pNHAs).

Area	Survey Sites
Long Island Bay, Co Cork	Roaringwater Bay, Calf, Carty's & Castle Islands
Dunmanus Bay, Co Cork	Drishane Point
Bantry Bay, Co Cork	Gerahies , Glengarriff Bay
	Roancarrig, Bere Island
Co Kerry	Gleesk, Kenmare River
Co Galway	Aran Islands, Inishmore, Inishmean, Inisheer
	Rossaveal, Ballyvaughan, Eastern Galway Bay, Doorus
Co Galway	Mannin Bay
Co Galway	Clifden Bay
Co Galway	Ballynakill (Inishbofin) Bay

Table 2. Roxann Survey Sites.

As part of the project a limited geophysical survey, using a Datasonics Chirp II sub-bottom profiler, was conducted on one deposit (Lonehort Point, Bantry Bay) to determine the thickness of maërl bearing sedimentary material overlying bedrock. The survey data together with unpublished estimates for other sites (J. WALSHE, pers. comm.) was then used to quantify the total national maërl deposit in terms of surface areas. By further assuming a nominal average deposit thickness it was possible to estimate volumes of maërl-bearing sediment for the entire coastline.

The seabed mapping was conducted with a Marine Micro Systems Groundmaster Roxann™ unit. This system classifies seabed material by means of parameters derived from the first and second echo returns from a 200 kHz depth sounder. Information from the first echo pulse is used to derive a parameter E1 which loosely represents the seabed hardness while information from the second echo return is used to derive E2, a measure of the seabed material roughness (CHIVERS *et al*., 1987). The combination of these two parameters is sufficient to characterise the physical properties of the seabed material.

To ensure full repeatability and inter-compatibility the same unit and transducer assembly was used on all surveys. Navigation data was taken from a Sercel NR53 DGPS receiver. Survey lines were run at various spacings (20-500 m) depending on the location and the deposit extent. Data was generally logged at 1-second intervals on computer with Hypack survey software. All data were logged in its raw format to facilitate later re-calibration and evaluation.

Grab samples were taken for ground truthing with a hand-held Van Essen grab and subjected to a visual examination.

Calibration of the Roxann unit was achieved by data clustering of E1, E2 pairs, followed by correlation with grab samples and diver observations. This allowed the 'Roxann Squares' (i.e. ranges of E1, E2 values) associated with maërl and maërl-bearing substrata to be identified. A feature of maërl deposits is that they rarely occur in pure form and therefore a unique E1, E2 signature is generally not available. Varying amounts of muds, sands and shells are almost always present and the E1, E2 values are modified by the physical characteristics of these sediments.

In many instances it is the substratum containing maërl that is being mapped rather than the maërl itself. Hence calibration effectively consists of relating a substratum to E1, E2 ranges and then inferring maërl presence in the substratum through sample data.

The same Roxann Squares calibration data were found to be applicable in all the exposed sites where granular substrata were present. In the more sheltered, muddier and shallower sites a different calibration was required for each site.

Reliability of the system was found to be good particularly in water depths of 5 - 30m where consistent and repeatable mapping of the maërl-bearing substratum was observed. In water depths shallower than 5 m the system is less stable due to the nature of echo-sounder acoustics.

Roxann surveys were conducted at each of the locations listed in Table 2. Results for the main locations, where distinctive deposits were observed, are presented in the following sections as graphical plans showing the survey line tracks. All maps are shown with Irish National Grid coordinates and depth contours and coastline features have been digitised from Admiralty Charts. Maërl deposits or substrata containing maërl as classified by the Roxann system have been highlighted as thick lines. Full data sets for all the sites including grab sample locations and descriptions are contained in the main report text (ANON., 1998).

Roaringwater Bay, Co Cork (Figure 4)
The Roxann survey of this bay covered an area of approx. 7 km^2. Water depths relative to chart datum ranged from approx. 3 to 9m. Grab samples indicated a silty/sand substratum in the outer bay with soft mud in the shallower waters towards the head of the bay. Two types of maërl were observed in the grab samples, these were the branch-like *Lithothamnion corallioides* and the flat *Lithophyllum dentatum*. The Roxann data correlated well with the grab samples and maërl was recorded over an extensive area. The data did not enable delineation of areas with different types of maërl.

Calf Island, Carty's Island, Castle Island, Long Island Bay, Co Cork (Figure 5)
This survey was conducted in three areas adjacent to these islands. The survey covered areas of approx. 0.4 km by 1 km in water depths ranging from 3 - 15m. Subsequent processing of the data indicated patchy small deposits of maërl particularly close to the shoreline in the shallower waters. Grab samples from numerous deeper water locations within the areas contained sands and gravels in differing combinations, but no maërl was recorded.

Dunmanus Bay, Co Cork
This survey was conducted over an area of 3 km x 0.6 km off Drishane Point in Dunmanus Bay. Water depths ranged from 5 to 25 m. Data did not indicate maërl to

be present and due to poor weather no grab samples were collected. For track-plot refer to ANON. (1998).

Gerahies, Bantry Bay, Co Cork (Figure 6)

This survey was conducted in the bay off Gerahies. The survey covered an area of 2 km by 0.9 km in water depths ranging from 10 to 35 m. A heavy swell was present on the day leading to poor quality data. Grab samples proved difficult to acquire due to the weather conditions and the two successfully achieved contained stone and some maërl pieces. The data indicates patchy areas of maërl-bearing material extending to the south-west.

Roancarrig, Bantry Bay, Co Cork (Figure 6)

This survey was conducted between the northern shore of Roancarrigbeg and the mainland. The survey covered an area of 2 km by 1 km in water depths ranging from 3 to 30 m. Grab samples contained sand and gravel with small amounts of maërl. The data indicates patches of maërl in the shallower waters close to Roancarrigbeg and lying against the northern shoreline.

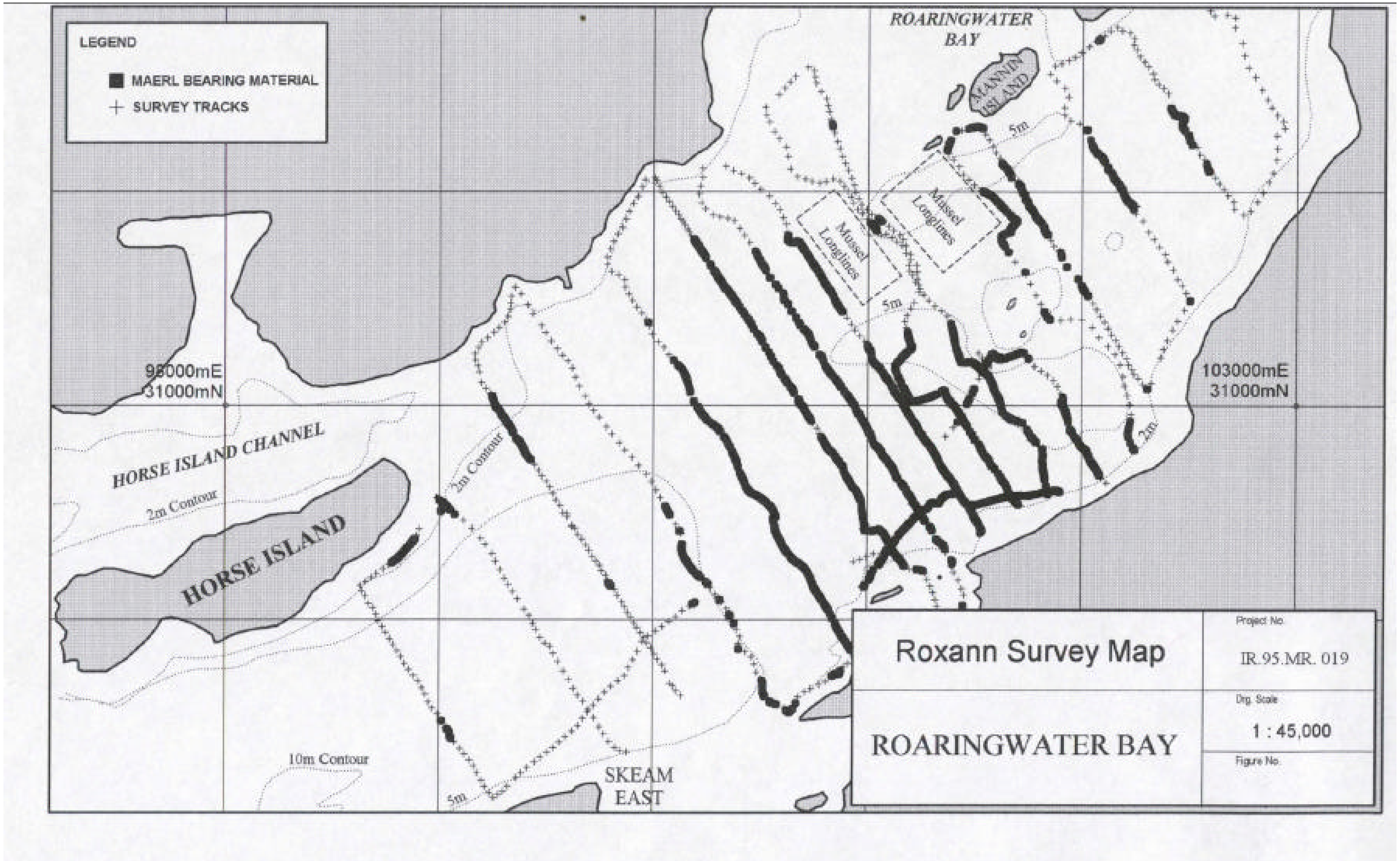


Figure 4: Roxann Survey Results (Roaringwater Bay).

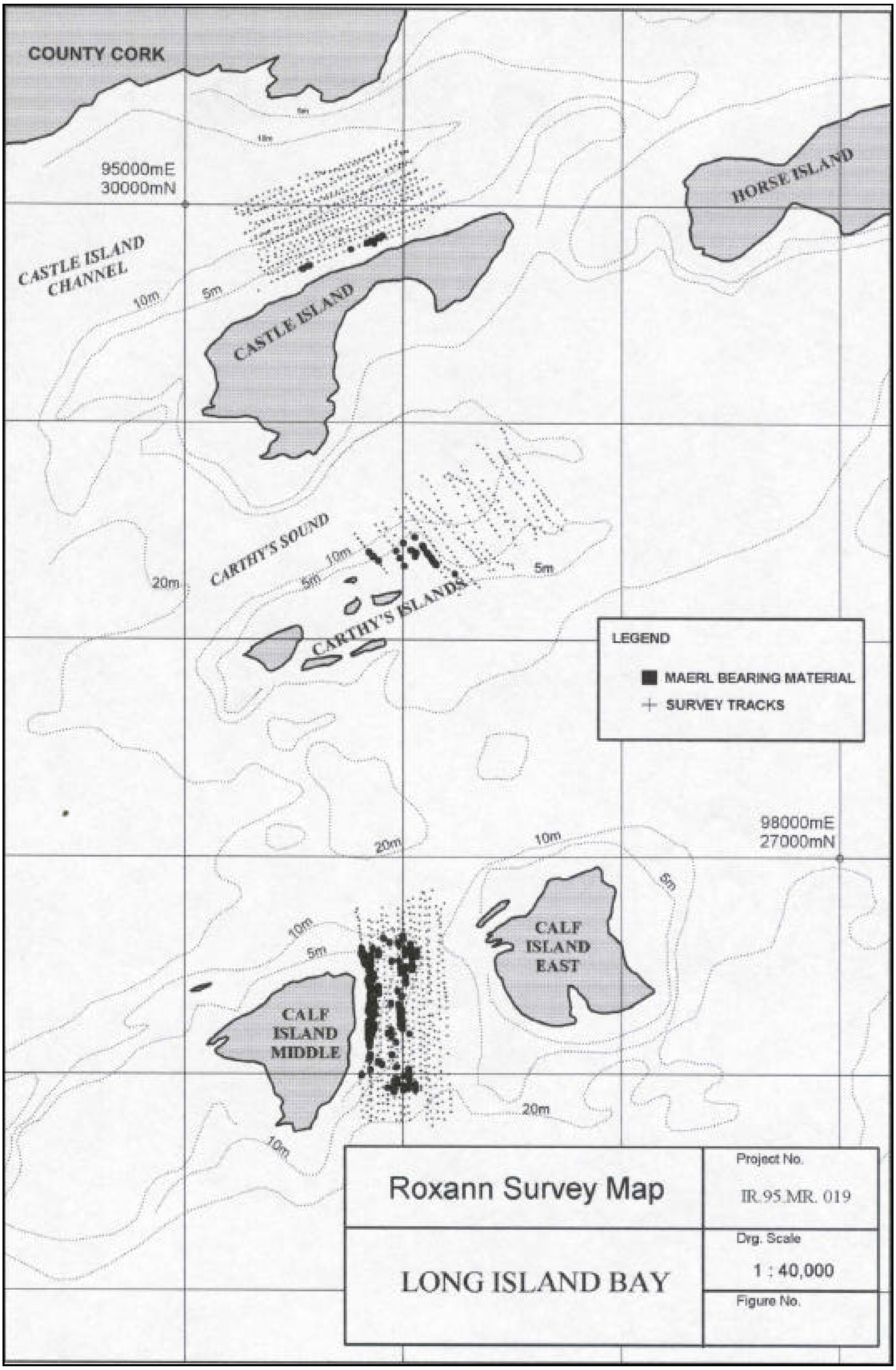


Figure 5. Roxann Survey Results (Long Island Bay).

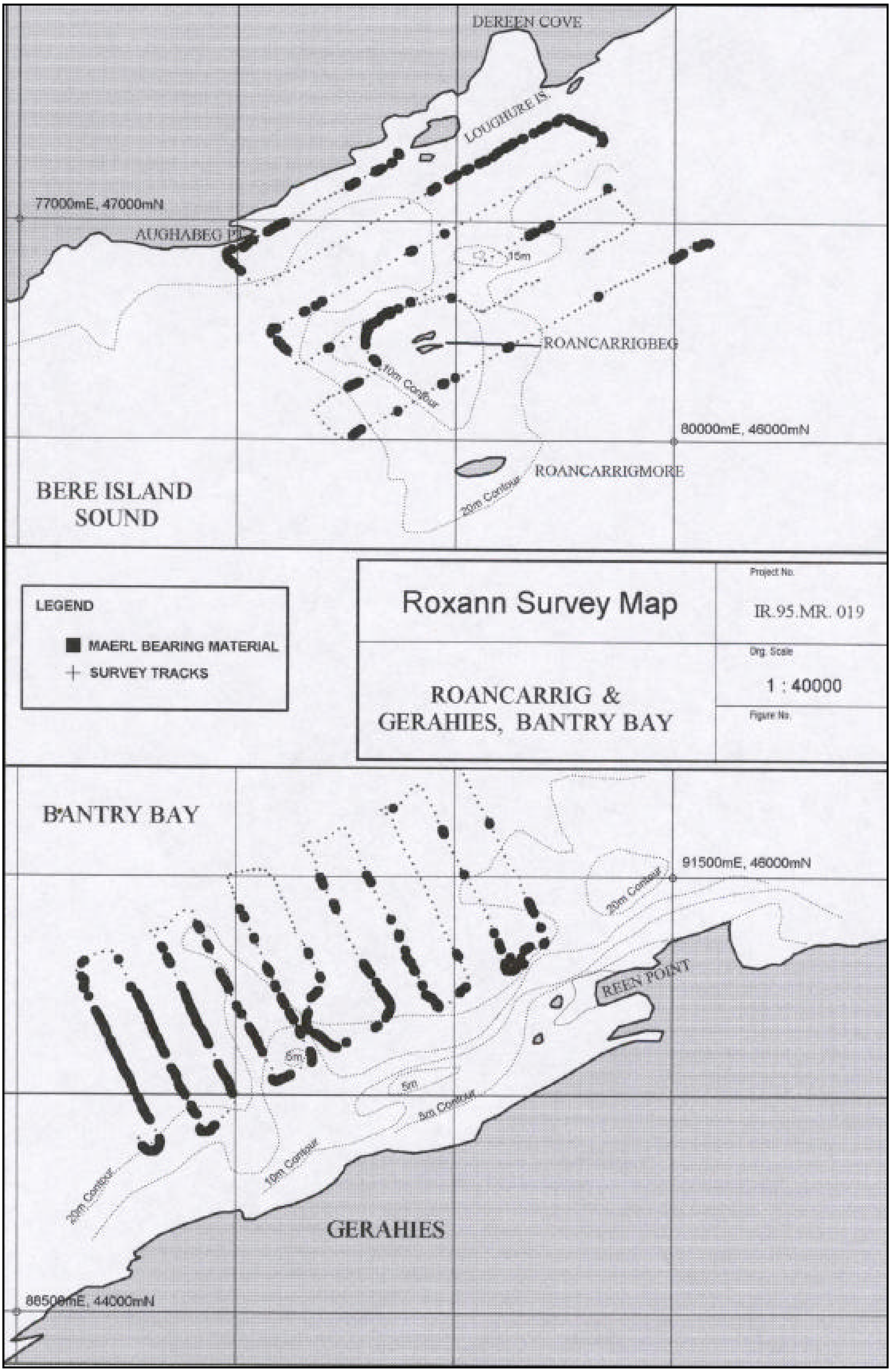


Figure 6. Roxann Survey Results (Roancarrig and Gerahies, Bantry Bay).

Glengarriff, Bantry Bay, Co Cork

A limited survey was conducted in Glengarriff Bay in an area 0.6 km x 0.4 km where a muddy deposit with occasional dead maërl pieces is known to exist. Water depths were 7 - 13m. Data showed a muddy seabed with no features. One sample was recovered containing mud but no maërl.

Bere Island, Bantry Bay, Co Cork

This survey was conducted at the site of a commercially worked deposit off the north eastern shoreline of Bere Island. The survey covered an area of 0.4 km x 0.9 km in water depths ranging from 3 - 11m. The Roxann surveys were conducted on the deposit during summer of 1996 soon after dredging works and showed a muddy substratum. This was due to a fine mud layer overlying the maërl deposit.

Geophysical profiling was conducted on this deposit with a Datasonics Chirp II sub-bottom profiler. Survey track lines were run at regular intervals across the deposit while towing the chirp fish alongside the vessel. Good data was obtained with the sub-bottom rock profile clearly evident at depths of 1 - 4m below the seabed. No significant internal layering was evident in the sub-bottom suggesting a uniform material to rock level. Grab sampling revealed this layer to be a mixture of maerl fragments and fines. The average bed thickness was found to be about 2m over the area of the deposit. Survey details are contained in ANON (1998).

Gleesk, Kenmare Bay, Co Kerry (Figure 7)

This survey was conducted between the shoreline and Illaunleagh island in waters of 5 - 20 m deep. The survey covered an area of 1.6 km x 0.3 km. Grab samples from various locations within the survey area contained maërl, sands, shell and silt in varying quantities.

Tralee Bay

A limited Roxann survey was conducted in Tralee Bay over an area of 0.3 km x 0.2 km. Water depths ranged from 10 - 12 m. Data indicated a muddy seabed with patchy maërl deposits. Samples contained mud with a small number of maërl pieces. For trackplot refer to ANON (1998).

Aran Islands, Galway Bay (Figure 8)

Extensive seabed maërl deposits are known to exist off the Aran Islands. Two large and two small areas were chosen for survey based on published data. The two larger areas lie to the northwest of Inisheer (5 km x 2.5 km) and Inishmaan (4.5 km x 4 km) respectively. Water depths ranged from 10 to 30 m. Results show the deposits to the NE of Inishmaan in the region of the Curran and Inishmaan Banks to be particularly extensive. Grab samples contained varying quantities of maërl sand and shell. Two smaller areas to the north of Inishmore were surveyed (1 km x 1 km; 1.5 km x 0.8 km) in water depths of 15 - 30m and 38 - 40m respectively. Results of these surveys are presented in Figure 9. Roxann data indicates a patchy maërl deposit in the area nearest to Inishmore though no maërl was found in the grab samples.

Ballyvaughan, Galway Bay (Figure 9)

An extensive area covering 3.5 km by 2 km was surveyed off Ballyvaughan, adjacent to Finvarra Point. Water depths ranged from 4m - 15m. Results indicate significant maërl deposits.

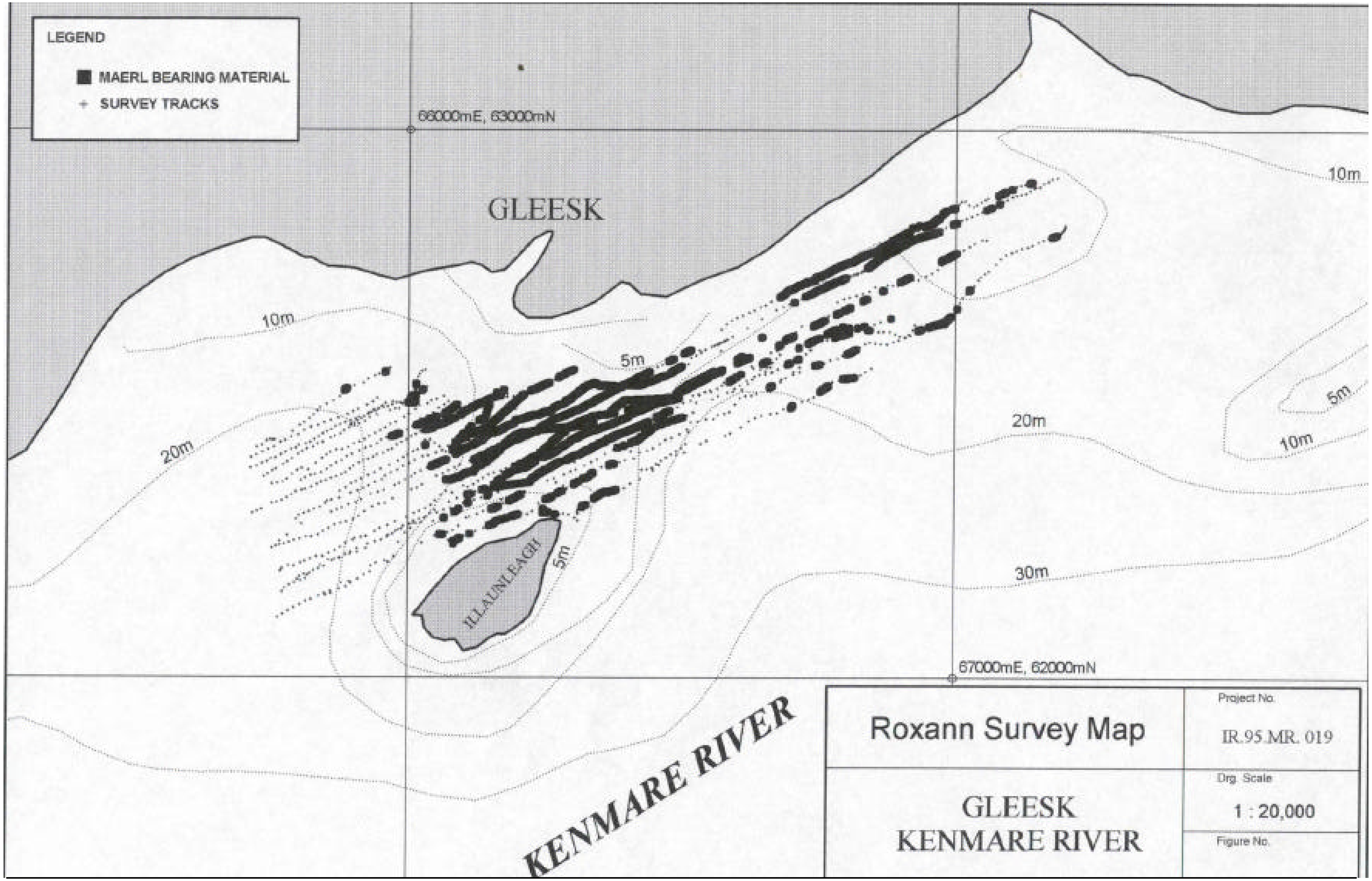


Figure 7. Roxann Survey Results (Gleesk).

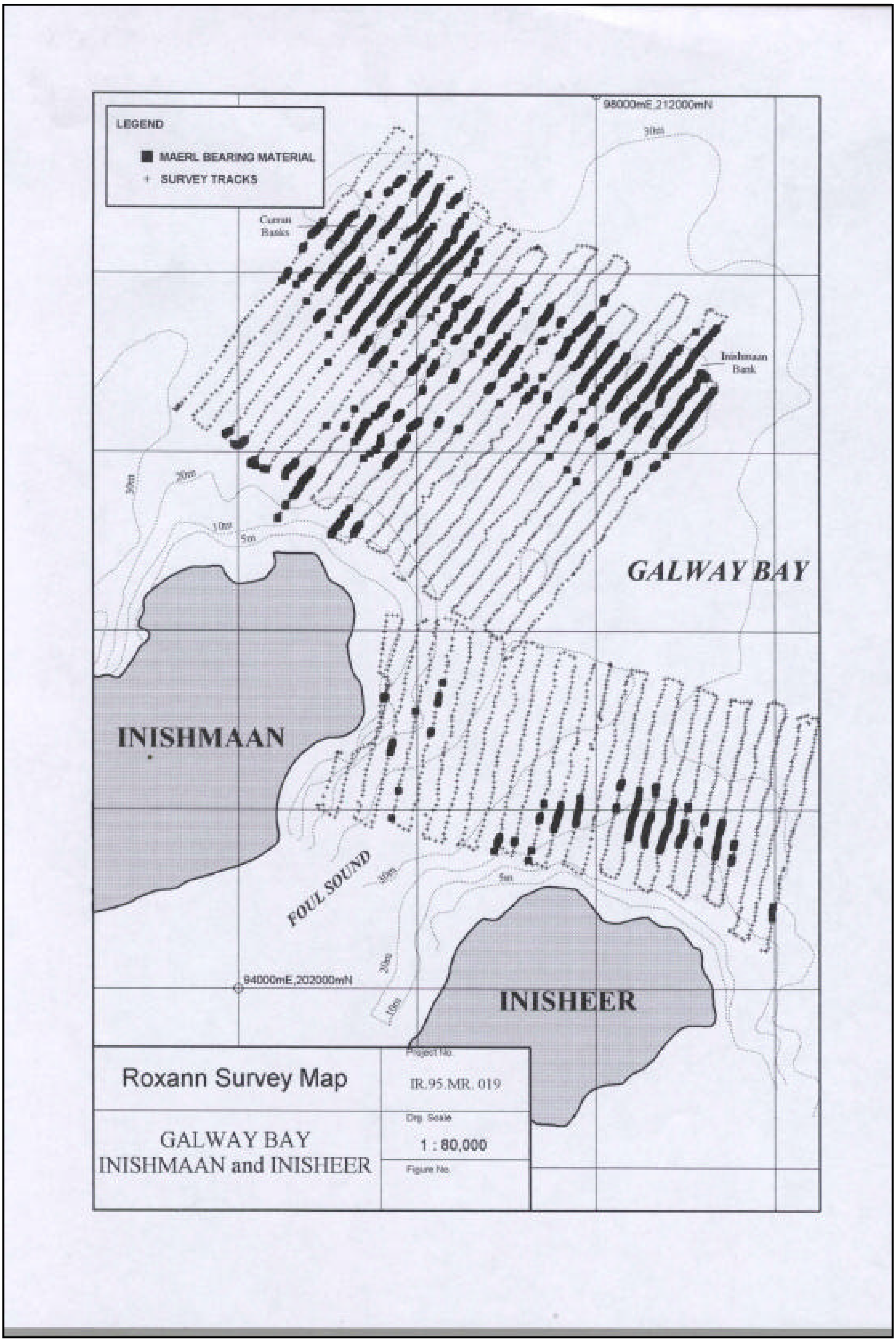


Figure 8. Roxann survey results (Inishmaan and Inisheer, Galway Bay).

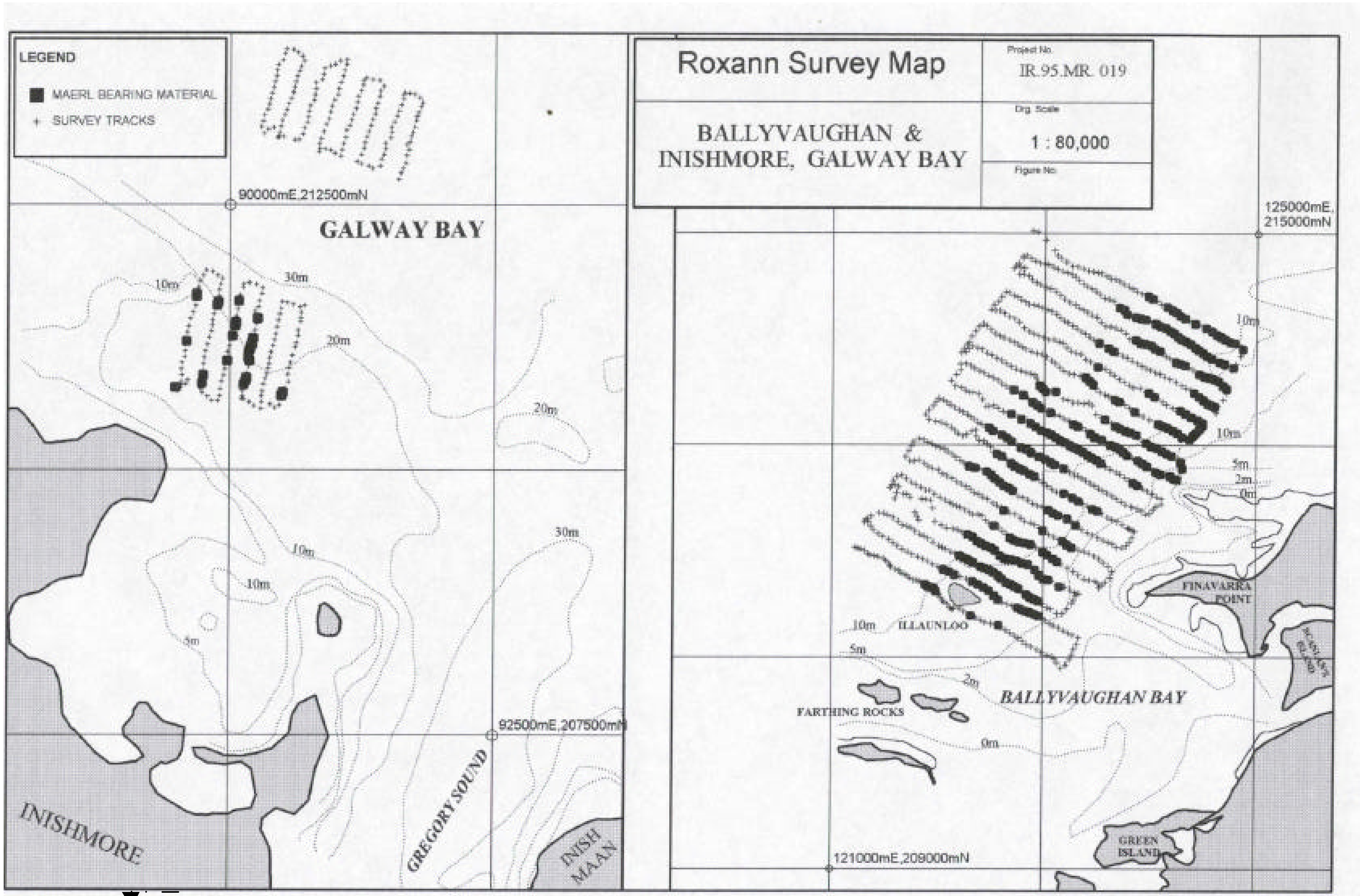


Figure 9. Roxann Survey Results (Inishmore and Ballyvaughan, Galway Bay).

Rossaveal, Galway Bay (Figure 10)
Three areas lying off Rossaveel Harbour were surveyed. The first smaller area lies to the west of the harbour entrance and covers approx. 1.5 km x 0.8 km in water depths of 10 - 20m. The second is a larger area of 3.7 km x 2.5 km and lies to the west of the harbour off Cashla Point with water depths ranging from 5 -30 m. The third area, 4.5 km x 4 km, lies to east of Cloghmore Point in water depths of 5 - 35m. Results indicate significant maërl deposits in two of the three areas.

Eastern Galway Bay (Figure 11)
This part of Galway Bay covering the North and South Bays has extensive maërl deposits. The survey covered an overall area approximating 9 km x 4 km in water depths ranging from 4 -15 m. The Roxann data indicates significant maërl deposits.

Doorus Strait, Galway Bay
Two small areas 0.6 km x 0.5 km were surveyed in waters that were generally less than 5 m. Data showed a muddy maërl deposit with a very small quantity of maërl recorded in the samples. For track-plot refer to ANON. (1998).

Mannin Bay, Co. Galway (Figure 12)
A large part of Mannin Bay was surveyed (2.4 km x 1.6 km) in water depths ranging from 2 - 12m. Roxann data, indicated significant amounts of maërl bearing material. Extensive grab sampling revealed a generally sandy substratum with varying quantities of maërl.

Clifden Bay, Co. Galway:
A small area in Clifden Bay was surveyed (0.7 km by 0.3 km). Water depths were generally 5 - 10m. Roxann data indicated a small area of maërl bearing material and grab samples confirmed a very muddy substratum with maërl pieces. For trackplot refer to ANON. (1998).

Inishbofin, Ballinakill Bay, Co. Galway (Figure 13):
An extensive area covering 7.5 km x 4.5 km was surveyed off Ballynakill Harbour towards Inishbofin Island. Water depths ranged from 10 - 53m. Results indicate scattered maërl deposits. Survey data showed an exposed rocky bottom over a wide area suggesting that this deposit is relatively thin, occurring between the rocky outcrops.

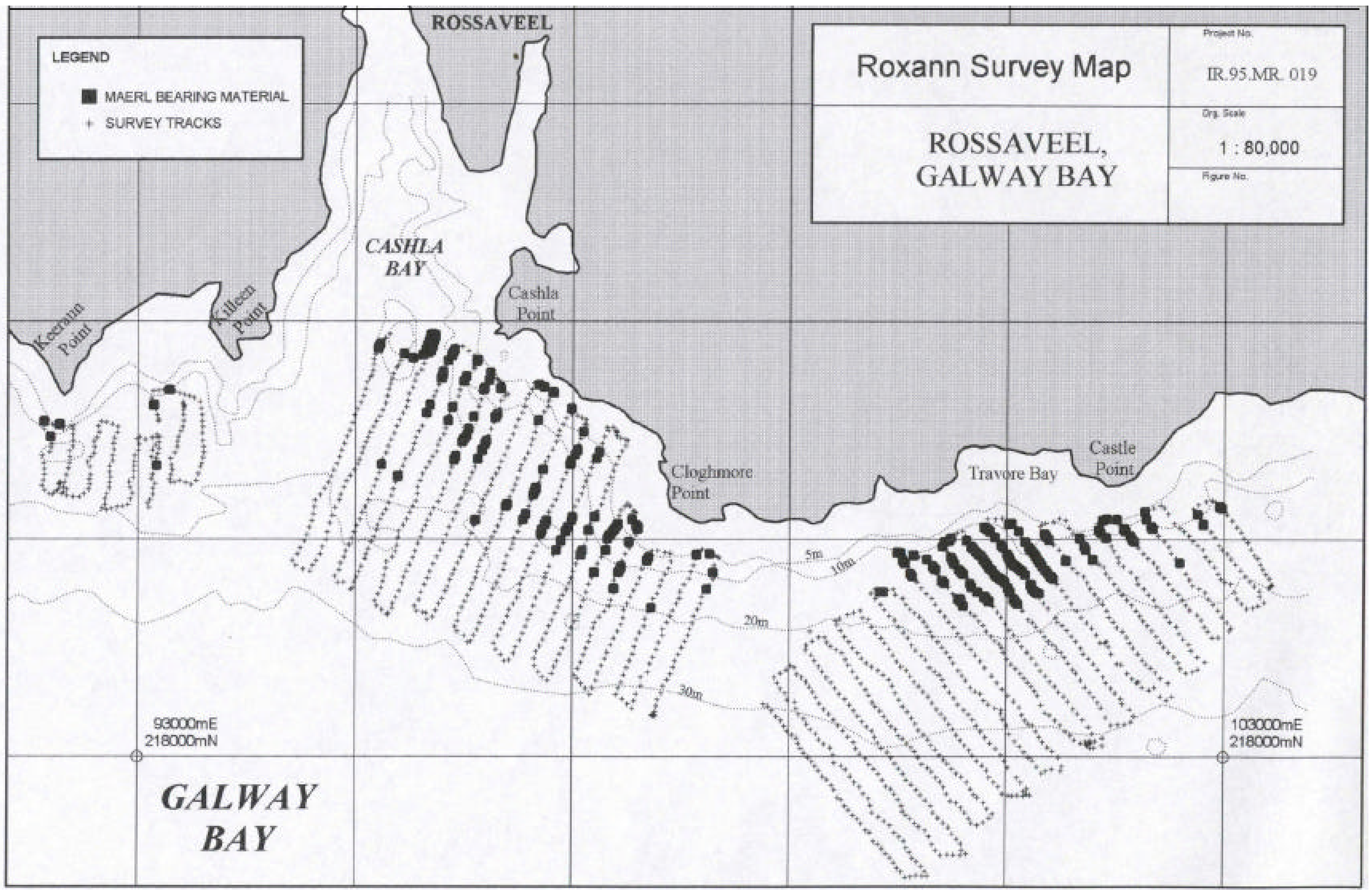


Figure 10. Roxann Survey Results (Rossaveel, Galway Bay).

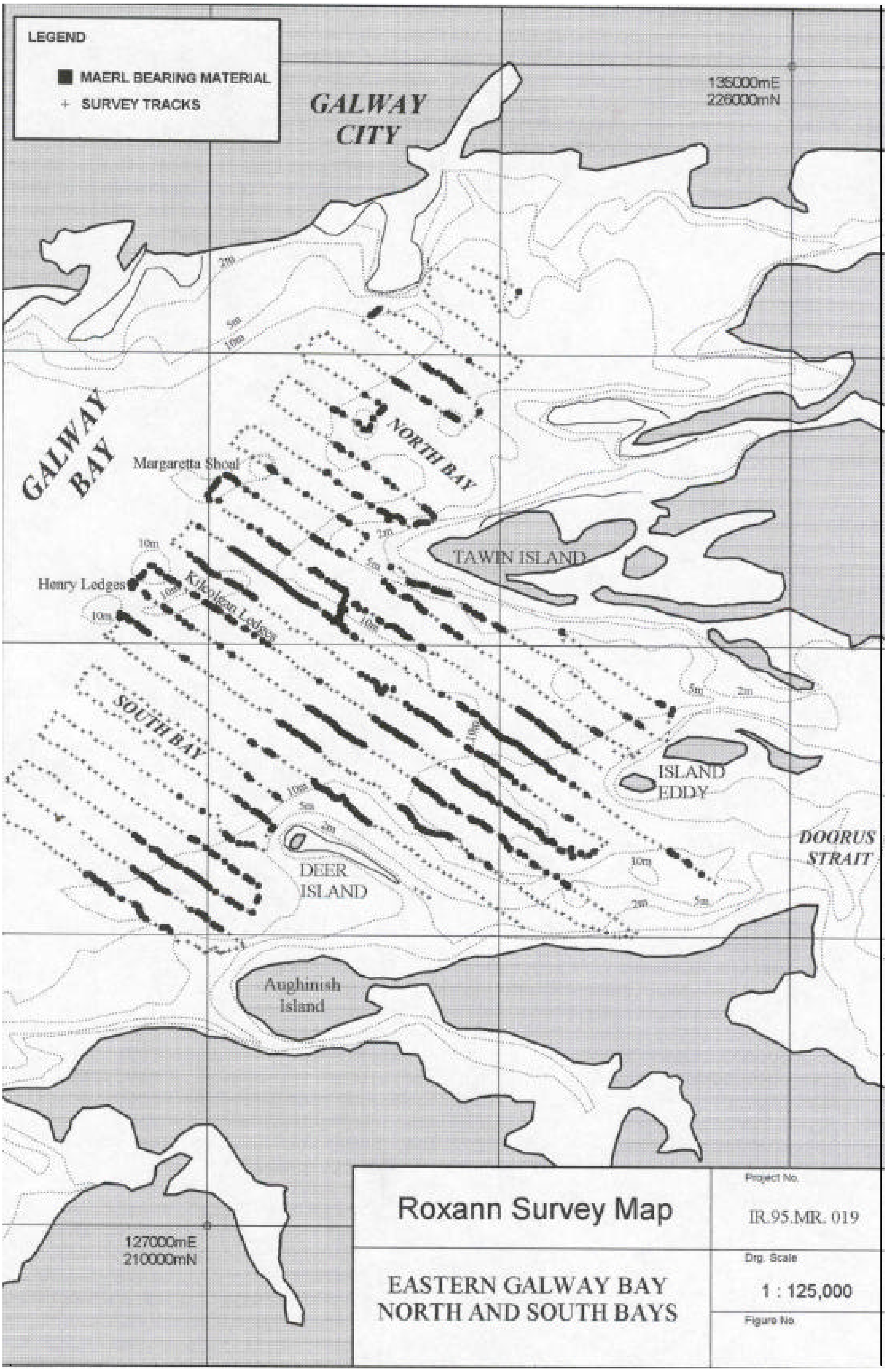


Figure 11. Roxann Survey Results (North and South bays, Galway Bay).

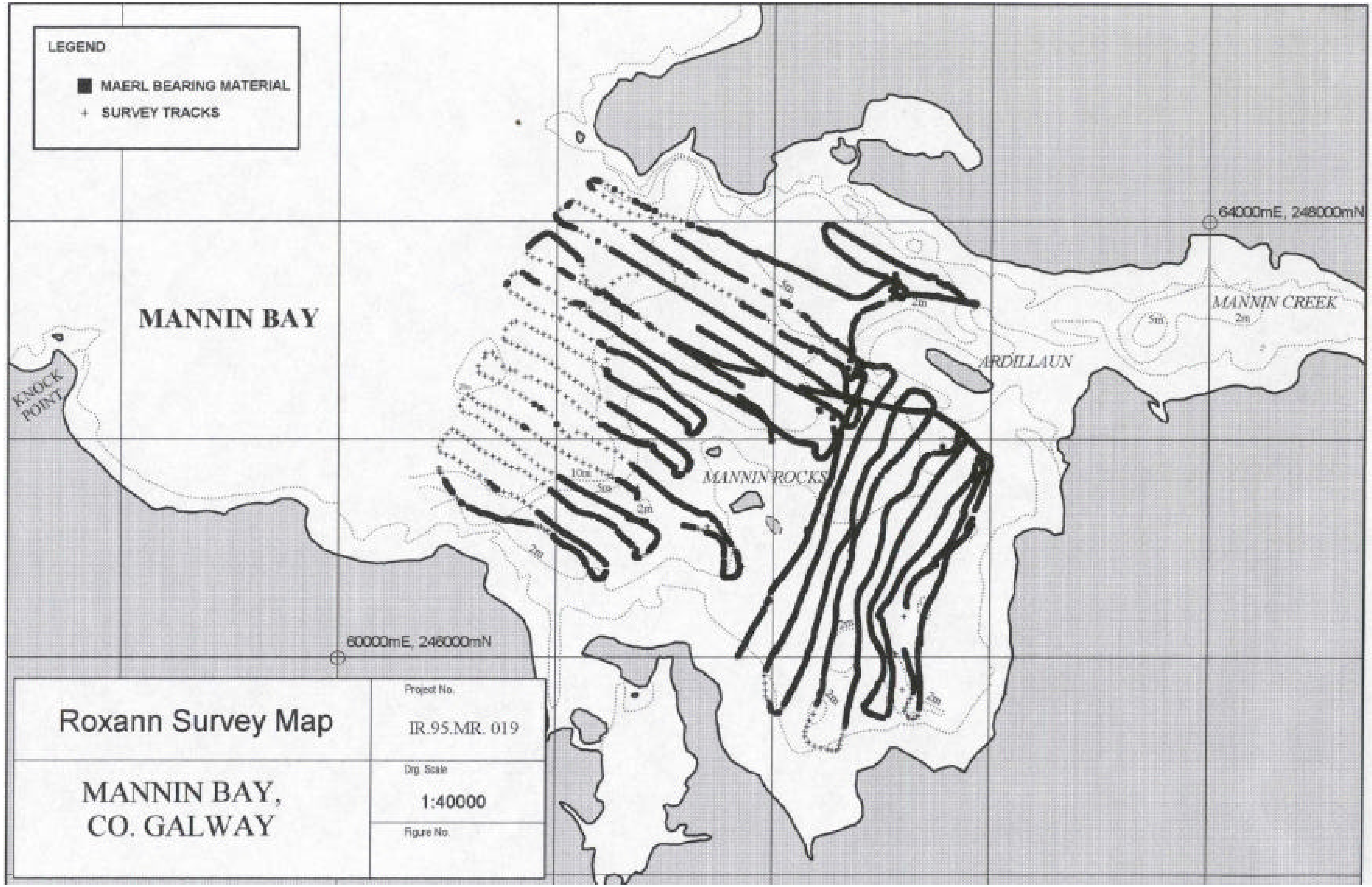


Figure 12. Roxann Survey Results (Mannin Bay).

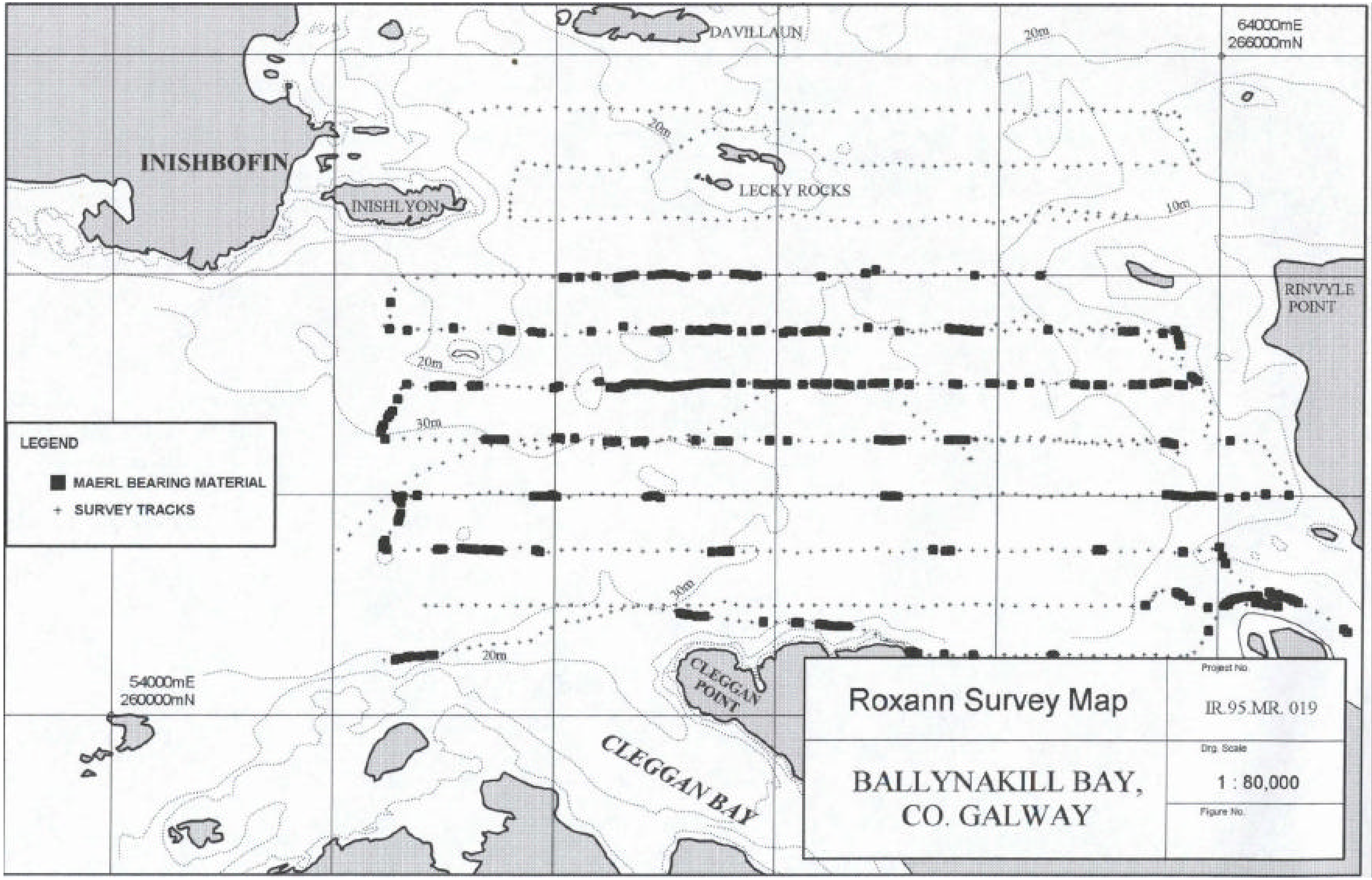


Figure 13. Roxann Survey Results (Ballynakill Bay).

2.2.2 Estimate of Deposit Extent

From the results of the survey work it has been possible to estimate the extent of the maërl bearing substrata within the areas surveyed. Table 3 lists the deposits and their associated surface area computed from the Roxann maps. The combined total area is seen to exceed 37 x 10^6 m^2, the greater part of which is due to the Eastern Galway Bay and Aran Island deposits. Areas not included in the survey, such as the Connemara coastline and the coastline northwards to Donegal, are estimated to have a combined surface area of at least 20 x 10^6 m^2 (ANON, 1996). These areas include Kilkieran and Greatman bays. This gives an estimated overall nationwide resource area of approximately 57 x 10^6 m^2.

Survey Sites	Area of Deposit (m^2 x 10^6)
Roaringwater Bay, Co. Cork	2.90
Calf Island, Co. Cork	0.02
Carty's Island, Co. Cork	0.02
Castle Island, Co. Cork	0.01
Drishane Point, Co. Cork	0.01
Gerahies , Co. Cork	0.40
Roanccarrig, Co. Cork	0.20
Bere Island, Co. Cork	0.14
Gleesk, Co. Kerry	0.11
Tralee Bay, Co. Kerry	0.14
Inisheer, Co. Galway	1.00
Inishmaan, Co. Galway	4.00
Inishmore, Co. Galway	0.05
Rossaveal, Co. Galway	0.01
Rossaveal, Co. Galway	1.00
Rossaveal, Co. Galway	1.50
Ballyvaughan, Co. Clare	2.40
Eastern Galway Bay, Co. Galway	20.0
Doorus Straight, Co. Galway	0.50
Mannin Bay, Co. Galway	2.00
Clifden Bay, Co. Galway	0.05
Ballynakill Bay, Co. Galway	1.00
Total	**37.46**

Table 3. Surface areas of maërl deposits within survey areas.

Little information is available on individual deposit thicknesses. This may vary considerably from less than 0.3m in exposed areas overlying bedrock to several metres where beds have formed in more sheltered regions. **In the absence of specific geophysical data at the majority of deposits it is only possible to guess at the overall volume of the resource. Taking an average thickness of 2m (estimated range 0.1m – 3m), the estimated total national maërl-bearing sediment resource volume is of the order 114 x 10^6 m^3.**

The actual quantity of maërl within any individual deposit will depend on its concentration as a percentage of the substratum. Typical values from samples collected during this study range from 5 - 50%. In some areas, such as Kilkieran Bay, concentrations of up to 90% have been recorded (DEENY, 1975). If an average of 10% is assumed then the total maërl resource estimate is 11 x 10^6 m^3. Not all of the deposits will be suitable for extraction as many are in sensitive coastal locations and of particular scientific merit. It is conceivable that only 25% of all deposits are suited to commercial exploitation giving an estimated national resource estimate of the order of 3×10^6 m^3 (Table 4).

Area surveyed	3.7×10^6 m^2
Areas not included but believed to contain maërl	20×10^6 m^2
Estimated maërl bearing area:	57×10^6 m^2
Estimated average thickness of maërl	2m (range: 0.1 – 3m)
Estimate volume of maërl bearing sediment	114×10^6 m^3
Of which 10% is maërl	11×10^6 m^3
Of which 25% is exploitable	3×10^6 m^3

Table 4. Estimate of exploitable quantities of maërl in Irish coastal waters.

.

Location	***Lithothamnion corallioides***	***Phymatolithon calcareum***	***Lithophyllum dentatum***	***Lithophyllum fasciculatum***	***Lithothamnion glaciale***
Carreroe		✚			
Finavarra		✚			
Kilkieran Pier	✚		✚	✚	
Kilkieran Bay	✚				
Killary Harbour					✚
Kingstown Bay	✚	✚	✚	✚	
Kinvarra Bay	✚		✚	✚	
Mannin Bay			✚	✚	
Roaringwater Bay	✚		✚		
Ardgroom	✚		✚		
Streamstown		✚			✚
Clifden		✚			✚

Table 5. Distribution of maërl species at various Irish locations.

2.3. Species Composition of the Resource

2.3.1. Taxonomy and General Distribution

The term maërl refers to accumulations of coralline algae characterised by calcified cell walls that form a rigid plant body. Living maërl is pink due to its particular combination of photosynthetic pigments. Coralline algae are divided into two general types: the erect geniculate (bent abruptly, knee-like) coralline types; and the non-geniculate encrusting types. It is the former that include the maërl-forming species.

All of the maërl-forming species found in the Ireland belong to the Division Rhodophycota, Order Corallinales, and the Family Corallinaceae. The seven species of interest to the present study fall into two of the seven subfamilies recognised by WOELKERLING (1988), namely the Lithophylloideae and Melobesioideae. Detailed information on the ecology and distribution of maërl species can be consulted in IRVINE & CHAMBERLAIN (1994). The names of species and the nomenclatural authority names used here follow this latter work. A summary of the distributions of particular species collected during this investigation is given in Table 5.

Subfamily Lithophylloideae
The basic features of species belonging to this subfamily include:

- Some cells of contiguous vegetative filaments are joined by secondary pit-connections.
- Cell fusions are absent or rare.
- Tetrasporangia and bisporangia lack apical plugs and are borne within uniporate conceptacles.

Only the genus *Lithophyllum* is maërl-forming in Ireland.

Genus *Lithophyllum*
Three apparently vary rare species of the genus are maërl-forming in Ireland:

Lithophyllum dentatum (Kützing) Foslie (Figure 14a) is rarely found in Counties Cork, Galway and Mayo, but has not been reported from Britain. It is also reported south to Spain and commonly from the eastern and western Mediterranean. Its precise relationship to the much commoner crustose species *Lithophyllum incrustans* Philippi remains to be established (see page 32) and the extremely rare *Lithothamnion agaricicforme* (Pallas) Foslie.

Lithophyllum fasciculatum (Lamarck) Foslie has been reported for Counties Cork, Galway and Mayo. IRVINE & CHAMBERLAIN (1994: 73) comment that “Material supporting a number of old records for Scotland, Wales and Co. Waterford has not been available for study.” The species is thus otherwise otherwise known only from Brittany. There are difficulties associated with Lamark’s *Nullipora fasciculata*, the basionym, which will need to be addressed in a separate, comprehensive taxonomic study. JOHNSTON (1842) appears to be the first author to apply Lamark’s name to the Irish plants. COTTON (1912) used the same name for beds at Clew Bay and Roundstone, where it was locally known as “Wild Coral”.

Lithophyllum hibernicum Foslie is known only from three nineteenth-century collections, all from Ireland and including Ballynakill Harbour and Roundstone Bay, both in Co. Galway. It is a poorly described and understood species, and populations may not be currently extant; in addition, the plants described may not have been alive when collected. Morphologically similar specimens were found during the course of the project at one location in Kilkieran Bay, but their identity remains doubtful. It resembles *Lithophyllum fasciculatum* externally but its internal structure differs noticeably (Irvine & Chamberlain, 1994: 75).

Subfamily Melobesioideae
Characteristics of species belonging to the subfamily Melobesioideae include:

- Some cells of contiguous vegetative filaments, joined by cell fusions.
- Secondary pit connections absent or rare.
- Tetra/bisporangia with apical plugs and borne within multiporate conceptacles.

Three genera of the subfamily are potentially maërl-forming in Ireland: *Lithothamnion*, *Phymatolithon* and *Mesophyllum.*

Genus *Lithothamnion*
Two species of the genus are maërl-forming in Ireland:

Lithothamnion corallioides P.L.Crouan & H.M.Crouan is widely distributed in Ireland, Britain, and Brittany, France (Figure 14b), but generally on western coasts. It is very variable in form and is easily confused with *Phymatolithon calcareum.*

Lithothamnion glaciale Kjellman is a cold-water species found from Arctic Russia south to Ireland and Britain, the Western Baltic and the USA (to Massachusetts), Greenland, Japan and China. It was considered not to occur south of Northern Ireland, but an encrusting form was found at Killary Harbour Co. Galway in 1986 (KEEGAN & MERCER, 1986). During the course of the present project, specimens were found at Killary Harbour and Streamstown Bay. This may be a major bed-forming species in north-west Ireland (J. Hall-Spencer, pers. comm.), but no samples were available for study.

Genus *Phymatolithon* (Figure 14c)
A single species is maërl-forming in Ireland:

Phymatolithon calcareum (Pallas) W.H.Adey & D.L.McKibben is recorded from Norway and the weatern Baltic south to Spain, and in the western and eastern Mediterranean.

Genus *Mesophyllum*
A single species may be maërl-forming in Ireland:

Putative specimens of *Mesophyllum lichenoides* in its free-living form are preserved at the Natural History Museum in London (BM) collected in the nineteenth century from Roundstone Bay. Further collections were sought at this location but none were found. Detailed comparisons between these early collections, *Lithophyllum agariciformis,* and recent *Lithophyllum dentatum* collections are required.

General distribution and identification

Lithothamnion. corallioides and *P. calcareum* are the most common of the Irish maërl bed-forming species and contribute most of the maërl biomass in Greater Galway Bay. Both species are listed under Annex V of the European Union Habitats and Species Directive as being subject to management procedures. The species provide a unique habitat for other plants and animals, some of which are endemic to the maërl.

Identification to species level of the major bed-forming species, including the very common *L. corallioides* and *P. calcareum* is extremely difficult. It cannot be carried out in the field and involves a time-consuming process of decalcification and sectioning. Sterile material cannot always be identified to species and representatives of the Melobesoideae are only fertile in winter. Since maërl beds are made up very large numbers of plants, identification of single specimens cannot be said to represent the entire bed.

Species composition of particular beds also seems to shift from one species to another over time. Consequently, is not practically possible to characterise beds by species.

2.3.2. Additional Project Records

Site Description

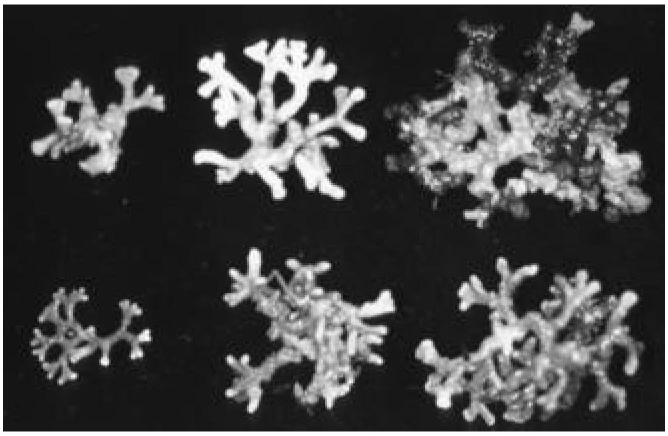
Carreroe:	1 m. Snorkled from shore. Thick beds of dead and live *P. calcareum* to shore
Finavarra:	3m. Shore dive. Scattered discs of *P. calcareum*
Kilkieran Pier:	2-3 m. Scattered plants of 3 spp. with filamentous turf. Very finely branched *L. corallioides*
Kilkieran Bay:	Boat dive to 15m. Mainly dead *L. corallioides*. Open branched flattened growth form.
Killary Harbour:	2-3m. Scattered dead *Lithophyllum* and encrusting *L. glaciale* on muddy bottom
Kingstown Bay:	50 cm. In seagrasss and to low tide
Kinvarra Bay:	Patches covered in balls of *Falkenbergia*, and some with even cover of *L. fasciculatum*
Mannin Bay:	Shore dive
Roaringwater Bay:	3 m. On soft mud. Unusually large beds of *L. dentatum*

Species	Dark	Green	Light
Lithothamnion corallioides	1.07	0.72	0.65
Lithophyllum dentatum	1.76	1.51	1.23
Lithophyllum fasciculatum	1.97	1.74	1.47
Phymatolithon calcareum	1.38	1.24	0.62

Table 6. Mean growth rates (mm/annum) of four maërl species under three conditions of illumination including dark, green and light categories.

(a) Lithophyllum dentatum (Kützing) Foslie

(b) Lithothamnion coralliodes (P.L.Crouan & H.MCrouan) P.L.Crouan & H.MCrouan



(c) Phymatolithon calcareum (Pallas) W.H.Adey et D.L.McKibbin

Figure 14. Maërl specimens from various locations in Ireland.
(a) Roundstone Bay, Co. Galway; (b) and (c) Galway Bay.
Photographs courtesy of the Irish Seaweed Industry Organisation.

2.4. Growth Rates, Morphology and Reproduction of Maërl Bed Forming Species.

Size and morphology

Size is defined here as maximum axial length. It is a quick and easy measurement in the laboratory and in the field. This study suggests that rhodoliths at Mannin and Kingstown Bays tend to be small (maximum axial length) in more wave-exposed locations between beds and within beds. Conversely, large plants occur at more sheltered locations between beds and within beds. The result is to be expected since plants are likely to experience more frequent breakage and erosion in more wave-exposed beds. Plant size therefore appears to be a reliable and sensitive morphological character to classify beds.

Shape

BOSENCE (1976) considered whether plant shape reflected wave-exposure, but his study was inconclusive. Rhodoliths are commonly divided into three shape-classes: spheroid, ellipsoid and discoid. Rhodolith shape was predominantly spheroid. This was not related to exposure to wave action at Mannin or Kingstown Bay. Plants growing in an unusually strong current such as Streamstown Bay have a discoid morphology. Plant shape is influenced by other factors besides water action, two such factors included size and species. Plants that were smaller than the mean sample size at Kingstown Bay and Mannin Bay have a more spheroidal habit than larger plants at both beds. Plants that were smaller were more irregular possibly due to erosion or age. Members of the Lithophylloideae (Figure 14a) tend to be more spheroidal than the Melobesoideae sampled, possibly due to the different internal structure of the two species (SNEED & FOLK, 1958).

Branching density was more variable within beds than between beds. Plants were more openly branched at sheltered locations within beds than exposed locations. Conversely, they had a more densely branched habit where exposed, but variation was not significant between beds.

Reproduction and population dynamics

No conceptacles were found on *Lithophyllum. fasciculatum* throughout the year. Conceptacles were found on *Lithophyllum. dentatum*, *Lithothamnion. corallioides* and *Phymatolithon calcareum* during the winter months, but all the conceptacles were tetrasporangial. This suggests that no sexual reproduction takes place. The most important method of propagation appears to be vegetative. *Litophyllum. dentatum* conceptacles were found for the first time in Ireland, all were tetrasporangial and uniporate.

Growth

Growth experiments were conducted in the field and in the laboratory on all four principal Irish maërl species (*Lithophyllum dentatum, Lithophyllum fasciculatum, Lithothamnion corallioides and Phymatolithon calcareum*) and analysed using ANOVA (Table 6). The two main bed-forming species, *Lithothamnion corallioides* and *Phymatolithon. calcareum* grow more slowly than the rarer species of the sub-family Lithophylloideae. Plants were tested in both dark and light conditions, in the field and in the laboratory. It is possible that the slower-growing but more widespread plants have a higher reproductive potential, or are more suited to Irish conditions than their faster-growing but rarer counterparts.

3. Biodiversity

3.1. Introduction

In contrast to many subtidal sedimentary habitats, maërl beds are highly three dimensional due to the large interstitial cavities being formed by the inter-locking thalli and the fact that maërl beds can be of a considerable thickness, frequently in excess of one metre. This is thought to cause a high species level diversity, but also a high functional diversity in terms of trophic groups and ecological types. Maërl beds are composed of several inter-grading sedimentary facies (CABIOCH, 1968; BOSENCE, 1976) ranging from pure maërl banks, often up to one metre thick in Irish water, to mixed maërl debris facies, in which varying proportions of mud, sand and shell debris are present. This high spatial heterogeneity combined with the three dimensionality creates numerous micro-habitats preventing resource monopolisation by a few, dominating species (GRALL & GLÉMAREC, 1997). Furthermore, maërl beds can be constructed by different species of coralline algae, some of which exhibit different architectural complexities. The effect of this differential structural complexity on the faunal and floral communities has only been recently addressed. Although both the fauna and flora of maërl beds has yet to be fully compared and contrasted with other subtidal habitats in a qualitative manner, it is assumed that maërl beds hold a high level of biodiversity.

To illustrate the high level of biodiversity of maërl associated communities, the example of the gammaridean Amphipoda can be used. This is one of the few animal groups of which the taxonomy and distribution in Irish waters is well documented (COSTELLO *et al.*, 1990). The comparison is restricted to benthic marine gammridean amphipods in families with at least 5 species and found within the 200m depth contour. The maërl study sites of DE GRAVE (1999) harbour just over a quarter of all gammaridean amphipods known in Irish waters. Compared to the other study sites in Table 7 which each cover a range of different sedimentary and epiphytic habitats, this is quite a high percentage and compares favourable with other sites, such as Strangford Lough and Cork Harbour, both being considerably larger in area than Mannin Bay.

Locality	**Number of species**	**Percentage of Irish fauna**
Dublin Bay	92	51.11
Lough Hyne	78	43.33
Clare Isl. Survey	68	37.78
Belfast Lough	56	31.11
Carnsore Point	55	30.55
Strangford Lough	49	27.20
Mannin Bay maërl	48	26.67
Cork Harbour	38	21.11

Table 7. Comparison of number of species of gammaridean Ampiphoda in various Irish study sites (data adapted in part from COSTELLO *et al.*, 1990).

In Irish waters, as indeed in other countries, the fauna and flora of maërl beds has received relatively little attention. This is surprising, given the conservation value of these habitats and their potential for economic extraction. There is clearly an urgent need to address this imbalance.

3.2. Fauna of Maërl Beds

Very few studies have addressed ecological aspects of the faunal communities associated with Irish maërl beds. Other information may be found in several unpublished PhD theses, carried out in the Galway Bay region by University College Galway. BOSENCE (1979) in Mannin Bay and KEEGAN (1974) in Galway Bay studied the larger faunal elements and included a comparison of the different types of sedimentary facies. Both studies only looked at the larger faunal elements, mainly molluscs and crabs, excluding the more abundant smaller infaunal elements, such as amphipods. The latter group was shown by DE GRAVE (1999) to be the most abundant macrofaunal element in most of the Irish maërl beds. Over 75% of all macrobenthic species (0.5mm sieve size) are Crustacea, the majority of which are Amphipoda (Figure 15).

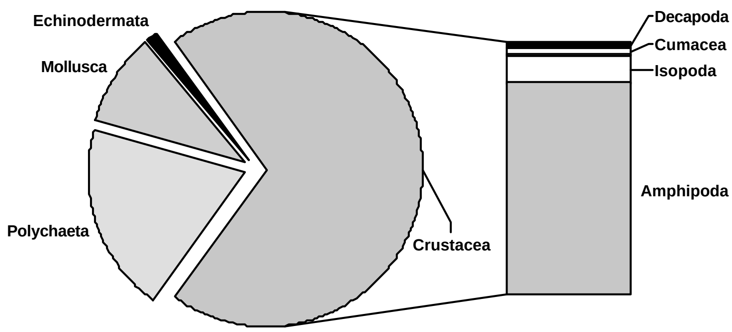


Figure 15. Taxonomic composition of five 1 litre diver-removed substratum samples. Only mean values are shown, expressed as a percentage.

In a comparison of benthic habitats in Galway Bay, O'CONNOR e*t al.* (1993) provided some cursory information on the fauna of maërl beds in the Galway Bay region, most of which was extracted from unpublished PhD work by the authors. DE GRAVE (1999) provided a detailed analysis of the smaller crustacean fauna of the different sedimentary facies in Mannin Bay, whilst ANON (1998) contrasted the crustacean fauna of two different architectural types of maërl: *Lithothamnion corallioides* and *Lithophyllum dentatum* (see IRVINE & CHAMBERLAIN, 1994 for figures). ANON (1998) studied the epibenthic and hyperbenthic fauna at two locations, in different sedimentary facies and of two types of architectural complexity.

Most studies agree that the fauna associated with maërl beds is very similar to gravel and other coarse substratum communities, undoubtedly linked to the similarity in terms of hydrodynamic conditions and the three dimensional structure of the sediment matrix itself. Similarities with hard substratum faunas, especially epiphytic grazers in both algal communities and kelp forest are also evident.

Based on a comparison of macro-, epi- and hyperbenthos, the maërl associated community can be more or less differentiated from other sedimentary habitats (O'CONNOR e*t al.*, 1993; ANON, 1998) due to the abundance and or presence of certain species. It remains to be seen, however, if this holds for broader based geographical comparisons, as the majority of species, if not all species, are also known from other habitats. In addition, biogeographical, and hydrodynamic factors may also play a role in the delineation of communities on a local scale. Furthermore, the study of different taxonomic and ecological groups may result in different conclusions being reached. For instance, ANON. (1998) contrasted two architectural types of maërl and discovered a core set of macrofaunal species, with differences between both architectural types only encountered at the level of rarer species. In contrast, ANON. (1998) found clear differences in the hyperbenthic community structure of the two architectural types.

Most studies also indicate that the sedimentary make-up of the maërl bed, in terms of the proportions of live maërl and maërl debris and the inclusion of varying proportions of other sedimentary fractions exerts an influence on the associated community (see CABIOCH, 1968). In terms of crustaceans, DE GRAVE (1999) demonstrated that these consist of shifts in numerical abundance of a set of co-dominant species along a hydrodynamic gradient, rather than in species displacements which would result in a clear definition of distinct communities.

Faunistic studies in Irish waters have included the work on Amphipoda by MYERS & MCGRATH (1980, 1982, 1983) from Kilkieran Bay, DE GRAVE & MYERS (1999) on Crustacea from several locations and NUNN (1983) on Mollusca from Mulroy Bay. WILKINS (1998) documented the presence of the rare fish species, *Lebetus scorpioides* in Irish waters. None of the species listed in these faunistic contributions appear to be unique to maërl habitats, with the exception of *Listriella mollis* (Crustacea, Amphipoda) which is presently only known from the type locality (Kilkieran Bay, see MYERS & MCGRATH, 1983). Again, the similarity of maërl communities to gravel communities is evident from these faunistic contributions.

3.3. Flora of maërl beds

The epiphyte flora of maërl beds is extraordinarily species-rich and contributes greatly to the high algal biodiversity of the west of Ireland. Amongst other things, the number and variety of algae found within a maërl community varies with depth, clarity of the water, wave and current exposure, and season.

In winter, the epiphyte flora of the maërl may be confined to crustose, perennial algae and the creeping basal parts of perennating algae. In spring, beds may have extensive populations of *Halarachnion ligulatum* gametophytes formed from the spores of crustose tetrasporophytes (*Cruoria*-phase) that persist from year to year on the maërl. Later in the year the gametophytes of *Atractophora hypnoides* P.L.Crouan & H.M.Crouan, a particularly uncommon species, may be found regularly on maërl, where it also alternates with another crustose phase known previously as *Rhododiscus pulcherrimus* P.L.Crouan & H.M.Crouan. In summer, most Irish maërl beds in shallow water are dominated by a dense covering of *Dictyota dichotoma* (Hudson) J.V.Lamouroux, which decreases in percentage cover in deeper water (MAGGS, 1983), and which probably form year after year from perennating basal frangments. Some clear-water maërl may, particularly in late summer, have populations of *Halymenia latifolia* P.L.Crouan & H.M.Crouan ex Kützing, a very rare and beautiful foliose algae that in Ireland is confined almost exclusively to maërl (MAGGS & GUIRY, 1982), and which may be present as fully-grown plants only in certain years. MAGGS (1983) in a comprehensive study described a number of rare and poorly-known species found commonly or exclusively on maërl. These include *Gelidiella calcicola* Maggs & Guiry (MAGGS & GUIRY, 1988) and *Peyssonnelia armorica* (P.L.Crouan).

H.M.Crouan) Weber Bosse (IRVINE & MAGGS, 1983). *Gelidium maggsiae* Rico & Guiry (RICO & GUIRY, 1997) was later added as a characteristic maërl species that is easily confused with *Gelidium spinosum* (S.G.Gmelin) P.C.Silva [formerly *G. latifolium* (Greville) Bornet]. Irish maërl is very species-rich, as is the maërl in Brittany (CABIOCH, 1969), and it is clear that the maërl flora of both areas is very similar in its composition and seasonality.

In the present study it was established that species richness is significantly higher at sheltered locations within beds rather than between beds sampled. At such locations, competition for space is high. Sheet-like forms and K-selected dominants are common. Competition is clearly not the principal selection pressure operating on exposed maërl beds: epiphytic cover was less than 10% at these locations. Comparatively high proportions of creeping competitive ruderals and opportunistic filamentous species also suggest that community structure is dictated by disturbance rather than by competition. Such forms benefit from the refuges from abrasion afforded by the maërl host in winter and often grow quickly in summer. They offer little resistance to water movement; their thin, sheet-like forms, which are easily abraded and which catch water currents with ease, are less common in areas subject to strenuous movements. Large, foliose plants may play an important part in colonisation by maërl of new areas when such plants are moved by water movement. Epiphytic species found within the various maërl beds varied from exposed sites to sheltered sites. *Ulva lactuca* was found at the most sheltered sites rather than the more disturbed locations as one might first expect. Similarly, the exposed sites, where one would expect to find r-selected plants there was a high proportion of K-selected plants that include *Gelidium maggsiae* and *Gelidiella calcicola* both of which have a creeping habit.

In terms of the species diversity of the maërl itself, more species appear to assume maërl-like morphologies in sheltered sites than in exposed sites. It is important to note that most maërl species cannot be recognised on the basis of external morphology. Similar forms of the two main maërl species in Ireland *Phymatolithon calcareum* and *Lithothamnion corallioides* are found in similar habitats and individual are frequently misidentified. Anatomical examination is necessary for all samples and it is this requirement that has made it difficult to be certain of the identity of most of the samples taken during the present study. There is still a crisis of identity affecting even the rare species such as *Lithophyllum dentatum* (Kützing) Foslie and *Lithothamnion hibernicum* Foslie which may be little more than forms of *Lithophyllum incrustans*, a common crustose species in the mid- and lower intertidal of wave-exposed coasts and frequently used by *Paracentrotus lividus* as a parasol, or some other common species. A comprehensive anatomical and nomenclatural study of these forms was beyond the scope of the present work.

The depths at which maërl beds occur shows considerable variation with location. In the Mediterranean, where waters are optically much clearer than in Ireland, some maërl beds are found at depths of greater than 100 m. In waters less clear, such as the Atlantic coasts of France few maërl beds are deeper than 20 m (JACQUOTTE, 1962). The deepest maërl beds in Ireland are at about 30 m and then only in the unusually clear water off the Aran Islands.

4. Conservation Issues

The species, *Lithothamnion corallioides* and *Phymatolithon calcareum* are listed in Annex V of the EU Habitats Directive (Council Directive 92/43/EEC) which states that exploitation should be compatible with the maintenance of a favourable conservation status. The other maërl bed forming species in Irish waters are not afforded species-level conservation status, which is rather ironic as these are much rarer species, both on an Irish (GUIRY, 1978; IRVINE & CHAMBERLAIN, 1994) and a European scale (IRVINE & CHAMBERLAIN, 1994). As yet no legislation is in place to deal with the conservation status of marine species listed in the Annex, perhaps caused by the lack of knowledge regarding their locations and status, the general lack of scientific study in Irish subtidal ecosystems and the lack of economic or social pressure. Nevertheless in other countries, pressure from exploitation and coastal eutrophication (GRALL & GLÉMAREC, 1997) and increased siltation due to changing current patterns (HILY *et al.*, 1992) has resulted in an increased scientific knowledge of maërl beds.

Within Irish waters, an existing impact, specifically relating to maërl beds, is dredging of the resource (Lonehort Point, Bantry Bay) and the resultant increase in suspended solid loading in the surrounding area. Other existing or potential impacts, in common with other subtidal ecosystems, include damage due to trawling for demersal fish and shellfish, aquaculture activities, coastal euthropication, increased siltation and boat moorings. Some, but not all, of these impacts occur in Irish waters (Table 7).

Location	Impact	Comments
Lonehort Point	Dredging	Impact studied by DE GRAVE & WHITAKER (1999b)
Kinvarra Bay	Scallop trawling	Impact not known
Kilkieran Bay	Scallop trawling	Impact not known
Long Island Bay	Mussel aquaculture	Extensive long lines in maërl bed area, impact not known

Table 7. Location of impacts to maërl beds in Irish waters.

Compared to France, where in 1990-1998 as much as 500,000 tonnes was extracted per annum, present levels of extraction in Ireland are very low and are carried out at only one location. Celtic SeaMinerals holds a license to extract 5,000 tonnes per annum from a dead maërl bed at Lonehort Point, Bantry Bay. The extraction site consists of a mud-dead maërl matrix, adjacent to a live maërl bed. The environmental impact of dredging for maërl has been addressed by GRALL & GLÉMAREC (1997) at the Glénan Bank (Brittany), where live maërl has been extracted for as much as 40 years, and by DE GRAVE & WHITAKER (1999b) at the Lonehort Point extraction site where only dead maërl is extracted. Both studies concluded that changes in macrobenthic community structure, in terms of trophic and taxonomic composition had occurred, along the lines suggested by other types of dredging activity. Most noticeable was a shift in the dominance from omnivorous crustaceans and polychaetes to suspension-feeding bivalves. This is linked to the relative instability of the sediment at the dredged site, mobilisation of food resources and the increased suspended solid loadings, similar to many other studies on the impact of dredging.

Demersal trawling for scallops has taken or is still taking place in Kinvarra Bay and Kilkieran Bay. Damage by trawling has been scientifically well documented (JONES, 1992). Damage may be of a direct or indirect nature, with the former category being the most severe. Scraping and ploughing of the substratum, sediment re-suspension and destruction of benthos all have been documented (BERGMAN & HUP, 1992).

In the inner parts of Long Island Bay (the inner part of Roaringwater Bay), extensive mussel long-line culture takes place. It has been documented that increased siltation takes place underneath long lines, partly caused by faecal material (MATTSSON & LINDÉN, 1983), although the mussel long lines themselves presumably may also alter the current patterns in the area. Other documented changes include large numbers of epibenthic predators, such as starfish (MATTSON & LINDEN, 1983) and changes in the fish fauna (IGLESIAS, 1981).

Coastal eutrophication and increased siltation has not yet impacted on Irish maërl beds, as most beds are situated in relatively well flushed embayments. Nevertheless, the beds in the inner portion of Galway Bay may indeed at some point in the future become under threat from coastal eutrophication in view of their proximity to urban areas and the potential of agricultural run-off in the area.

5. A Case Study: Celtic Sea Minerals Ltd.

Introduction:
Seaweeds used as fertilisers and soil-conditioning agents are mainly species of brown algae. Several crustose, calcareous red algae of the family Corallinaceae known collectively as maërl, are used, primarily on acid soil (BLUNDEN *et al.* 1975). Maërl has been collected from the Cornish coast of England for use in agriculture from at least the 18th century, but it would appear that it was not utilised in this way in France until the beginning of the 19th century. Commercial supplies of maërl are obtained by dredging from around the coasts of Brittany in France and off Falmouth Harbour in England. Chemical analysis of maërl shows that it is composed almost entirely of calcium and magnesium carbonates, with the calcium content, calculated as Ca^{2+}, varying from 25.5 to 33.3% of the dry weight, and the magnesium content, calculated as Mg^{2+}, varying from 1.7 to 3.3%.

Harvesting of calcified seaweed or sand as it is known in West Cork has a long tradition in the Beara Peninsula. Lime was needed to improve the acid soil of the area and the sand boats were used to collect the sand in the local waters. The boats used for the work were in the region of 40 ft in length and had sails with masts of 30 ft high. The earlier boats used sails or oars and usually had four men on board.

A boat could load 14 tonne in 1.5 hours and the unloading ports were at Bank, Bunaw, Adrigole and Castletownbere. In fact, the pier at the bank was built specifically for unloading sand boats. A load at the time cost £7.50 and this included a £4 subsidy. Harvesting using this method had ceased by 1954.

Times have changed in this industry; Celtic Sea Minerals now harvest using the most modern techniques and the vessel the *Marigot Bay* has a 500 hp engine and sounding equipment to locate the beds containing the calcified seaweed. The crew consists of 3 people and the average load contains 120 tonnes which is normally harvested in 3 hours.

Location:
Celtic Sea Minerals harvest maerl, under license from the Department of the Marine and Natural resources, off the north eastern point of Bere Island in the south west of Ireland. The area is contained within the following limits, described by latitude and longitude:

51°38’85”N	9°48’00”W
51°38’97”N	9°47’15”W
51°38’89”N	9°47’15”W
51°38’66”N	9°47’90”W

Activity Description:
The activity carried out by Celtic Sea Minerals includes the harvesting of maërl from the described site at a rate of 5,000 tonnes per annum and on-shore processing at Dinish Island. The Lonehort Point maërl bed has been harvested for many decades and since the early 90’s has been commercially utilised. Figure 16 shows the different main steps of the activity. Basically, the maërl is transferred from the seafloor by pump dredger. This vessel transports the material to Dinish Island where the processing plant is located. The plant includes two buildings, a 1 x 3000 sq ft processing building and a 1 x 4,800 sq ft building for processing and storage. The material is transferred from the ship to the plant where it is stored for later processing.

The processing activity includes the following phases: drying, sieving, grinding, blending and packaging

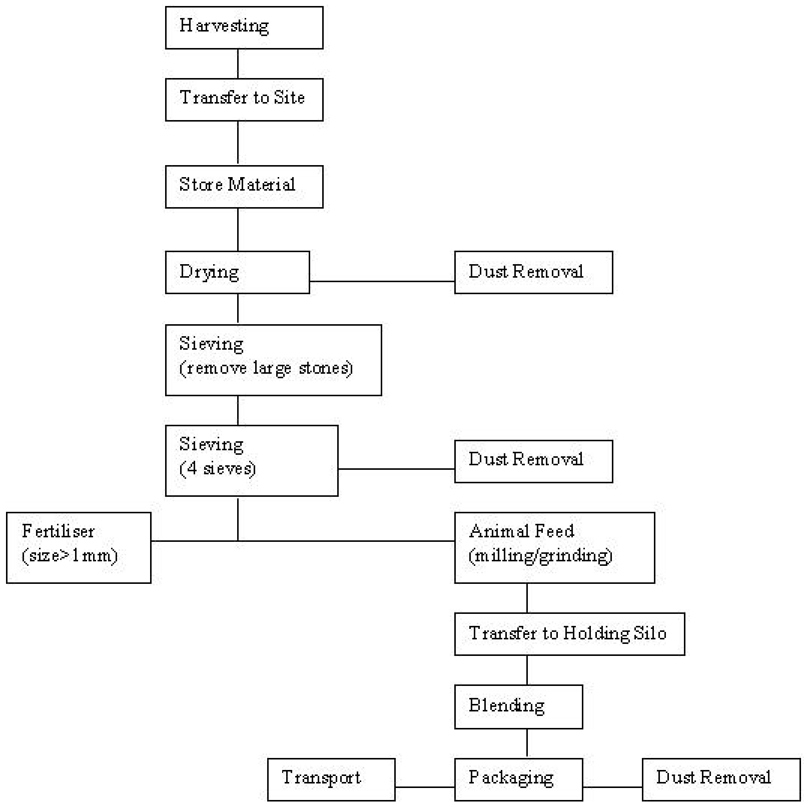


Figure 16. Main processing steps.

Harvesting:
A dredger is used to harvest the maërl from the seafloor. The material is lifted hydraulically by suction through a drag arm and pumped into the hopper bin. The size of the vessel is 200 tonnes and it has a capacity of 120 tonnes. The harvesting activity is carried out with a frequency of 3-4 times per week, and takes place all year round. The berth space is located in Castletownbere Harbour, on the west side of Dinish Island. The pier is approximately 100 m from the processing plant. Except for some large stones and shells, all the material is processed. The transfer of material from the vessel to the shore is done using a crane with a large grab, while a truck is used to transport the material to the open storage area which is located beside the treatment plant. A washing area for lorries is provided beside the storage area. The road is washed down after the transport of the material from the vessel to the site by Celtic Sea Minerals.

Drying:
A rotary direct flame injection drier which reaches a temperature of 1500 °C is used to dry the maërl. During this process large stones are removed and collected for later use as land fill. To optimise the efficiency in burning the diesel, it is ionised to remove the static force which allows it to expand and therefore efficiencies of ca.99.9% are achieved.

Sieving:
There are four rotary sieves installed in the plant. Depending on the later use of the maërl, different particle sizes are required. The particle sizes range from >1mm which is used as fertiliser to dust used in animal food.

Milling/Grinding:
To reduce the particle size, a pendulum grinder is used. In this section there is a bag filter which works with a compressed air system. All the dust collected by this system is gathered in 2 silos and reused.

Dust Removal:
During the drying, sieving, milling/grinding processes and other down stream activities, dust is generated. In order to control this, dust removal systems have been installed.

Blending & Packaging:
To mix the milled material a 2 x 2 tonne capacity blender is used. All products are packaged in 25 kg, 500 kg or 1000 kg sacks. In the bagging area, a electrical dust removal device has been installed, and all the dust collected is reused and packed.

Markets:
Celtic Sea Minerals has developed a number of products based on Calcified Seaweed for the Irish market. These products include Shamrock Sea Cal for use on Grassland. Shamrock Sea Cal is rich in calcium and magnesium which helps with grass tetany in animals and together with a range of trace elements which are essential for healthy grass growth. The fertility of products sourced from the sea is well known to farmers everywhere. Shamrock Sea Cal brings that fertility to grassland in the form of a mineral rich seaweed.

6. **Extraction and Exploitation of the Resource**

6.1. Renewability and Extraction of the Resource

The estimated size of the exploitable maërl resource (3 x 10^6 m^3) in Irish waters provides an opportunity for the development of the resource, although perhaps not at the level of French extraction. Certainly, the Irish deposits are much thinner, in many cases being less than a few meters thick, and also a considerable portion of the total resource is situated in either deeper water, hindering economically viable extraction or are situated in proposed Natural Heritage Areas (pNHA) (e.g. Kilkieran Bay, Mannin Bay), in which extraction licenses may not be granted.

When extraction is considered it is important to bear in mind that the maërl resource cannot be considered, in the strictest sense, to be renewable in nature. Growth rates are slow, with a maximum summer growth rate of 1.9 µm per day in the Ria de Vigo (Portugal) (ADDEY & MCKIBBEN, 1970). Under Irish conditions, growth rates are thought to be similar (see Section 2.4). Using a different technique, Potin *et al.* (1990) estimated that annual calcium carbonate deposition was 876 grams per m^2 per year in an area holding approximately 2 kg per m^2, illustrating the slow growth rate.

It must also be borne in mind that under certain hydrodynamic conditions, dredging can result in an increase of suspended solids in the water column and the settling out of such particles on the maërl plants themselves. Both of these processes may result in either a slower growth rate or indeed a complete stop to growth due to smothering of thalli. Although the generation of dredging induced plumes may not be a feature of deposits solely consisting of maërl thalli, in many locations varying proportions of finer sediment are mixed with maërl thalli or the maërl deposit is quite thin and overlies a muddy sandy sub-surface deposit.

Given the slow growth rate of maërl, it can be assumed that once extraction commences on any given maërl bed this will inevitably result in the partial or complete obliteration of the bed and its associated fauna and flora. In addition, sedimentation, where it occurs, will impede recolonization and regrowth. Indeed, GRALL & GLÉMAREC (1997) noted below bed level craters, devoid of all animal life, to the full depth of the previously present maërl bed, known to be of 10m thickness.

Other factors play a role in the economic viability of extracting any given maërl bed, most notable the percentage maërl present in the sediment matrix, a percentage which will decline moving deeper into the matrix. Furthermore, dredged craters and tracks may be slowly filled by sediment from both the surrounding area and re-settlement of suspended fines, further lowering the actual percentage of maërl debris present. Once a maërl bed is extracted to a level at which it is no longer economically viable given the low percentages of maërl, the operation will have to move to a new location. Although possibly some remnants of the maërl bed may persist, it is highly unlikely that these will be able to re-colonise and re-establish the former maërl bed, at least on a human time scale.

6.2. Framework for Extraction

When considering the extraction of maërl it is important to realise that maërl can be present in a number of different sedimentary facies. Broadly speaking these can be divided into three main categories:

1. maërl can occur as extensive live deposits, often forming banks;

2. maërl debris facies can be encountered in which dead, broken maërl thalli are mixed in varying proportions with other sedimentary fractions;
3. maërl can form a minor to co-dominant fraction in a sedimentary matrix, mainly consisting of other fractions, usually mud.

Each of these presents a different, but not necessarily unique level of biodiversity. Both live maërl beds and dead maërl debris hold a similar faunal community, with potentially higher levels of species richness in live maërl beds. In contrast, the fauna of the mud-maërl matrix is almost entirely composed of species characteristic of muddy environments.

From a conservation point of view, it would be most desirable to extract the mud-maërl matrices, as these do not hold the characteristic fauna of maërl beds or maërl debris. From an economic point of view, it may be difficult to locate these deposits, as many surveying tools will not distinguish between mud and the muddy deposits in which maërl is present. For instance, Roxann will only recognise this sedimentary facies as distinct from mud, if large maërl pieces are lying on the surface. This however, is usually not the case, as mud is indicative of depository environments, in which fines are continuously deposited and re-distributed. However, based on historical knowledge, these deposits are known to exist in a number of places, such as at several locations within Bantry Bay.

Should a proposal be put to the regulatory authorities to extract a live maërl bed or a maërl debris facies, the application should be carefully scrutinised, both for economic feasibility and from a biodiversity point of view. Certainly, extensive site investigations should be carried out to calculate the potential longevity of the extraction period, especially as it is assumed that most maërl beds in Irish waters are only in the order of 1-2 m in thickness. These site investigations should take the form of extensive sub-surface profiling combined with vibro-core or other type of drilling studies. Secondly, an extensive study into the local biodiversity and community structure should be carried out. In order to include as much of the full spectrum of biodiversity as possible, prior agreement should be sought with the authorities as to what needs to be included in such a study. As an absolute minimum the following taxonomic groups should be included: flora (incl. seagrasses), macrobenthic infauna, hyperbenthos. Studies should take account of the fact that, at least for the algae, pronounced seasonal fluctuations in abundance levels and even in the presence of certain species, occur on maërl beds. Furthermore, the three-dimensional aspect of the maërl matrix should be taken into account, as more species are known to live deeper in the matrix than in the surficial layers.

In view of the inclusion of both the main maërl bed forming species in the EU Habitats Directive, any application to extract live or dead maërl should be required to submit an Environmental Impact Statement. Although no specific guidelines in relation to information to be contained in such a document are in existence for maërl beds, generic guidelines on both a national and international level are in existence as are international guidelines dealing with the extraction of marine gravel deposits. The latter have a direct bearing on the information to be supplied, in view of the similarities between both habitats. Although special cognisance should be taken of the perhaps unique features of the maërl habitat vs. gravel habitats, these would primarily relate to the living nature of the resource itself.

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