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# A Risk Assessment Based Model for Assessing the Environmental Sustainability of Tourism and Recreation Areas

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# ABSTRACT

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Assessing the environmental quality of tourism and recreation areas is considered fundamental to the sustainable management of these resources. However, existing methodologies for such assessments rely on sets of environmental data that are often poorly linked and difficult to interpret and integrate in a holistic manner.

Risk assessment is a concept that has developed to the point where it has the potential to address current limitations in environmental assessment methodologies. This thesis presents a new model for the application of risk assessment to the management and assessment of environmental sustainability in the tourism and recreation sector. This model was applied and tested at two contrasting tourism and recreation areas in Ireland and a detailed methodology was developed.

The results of this research identify key problem areas with respect to environmental sustainability at the two study areas. These results also demonstrate the strengths of the risk assessment approach and indicate that this methodology represents a valuable alternative to existing methodologies.

# DECLARATION

**I certify that this thesis which I now submit for examination for the award of PhD, is entirely my own work and has not been taken from the work of others, save and to the extent that such work has been cited and acknowledged within the text of my work.**

**This thesis was prepared according to the regulations for postgraduate study by research of the Dublin Institute of Technology and has not been submitted in whole or in part for another award in any institute.**

**The work reported on in this thesis conforms to the principles and requirements of the Institute's guidelines for ethics in research.**

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**Candidate**

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# Chapter One

# INTRODUCTION and LITERATURE REVIEW

## 1.1 Research Summary and Rationale

It is widely accepted that the quality of the natural environment can play a key role in the sustainability of tourism and recreation areas. This is particularly the case for areas where elements of the natural environment form an inherent part of their attraction (Newsome, Moore & Dowling, 2002). Butler (1993) is one of a number of authors who have sought to highlight the link between the continued viability of tourism and recreation areas and their environmental quality.

The quality of the natural environment at tourism and recreational areas can be affected by a wide variety of factors. Not least amongst these are those associated with the tourism and recreation industry itself (Newsome et al., 2002). Such impacts can be associated with the development and construction phase of a tourism and recreation area or with its ongoing operation once established. With regard to the former, it is well documented that the construction of tourism infrastructure and accommodation can lead to a range environmental impacts such as large-scale habitat destruction and loss of visual amenity (Newsome et al., 2002). With regard to the latter, the day-to-day activities and requirements of tourism and recreation may likewise be associated with adverse effects on the environment including water and noise pollution, traffic congestion and over exploitation of local resources (Hunter & Green, 1995; Liddle, 1997; Newsome et al., 2002; Mason, 2003). Even relatively benign forms of tourism activity such as camping or hiking can have adverse effects on environmental quality such as the erosion of soils, disturbance to wildlife and littering (Cole, 1992; Marion, 2002). Activities external to the tourism and recreation industry which may affect the environmental quality of these areas are equally varied and include, for example, various forms of industrial pollution, the disposal or escape of agricultural wastes and the disposal of domestic wastewater or sewage (EPA, 2000).

In response to these pressures, a variety of methods have been developed, or adapted, to assess and manage environmental factors affecting the sustainability of tourism and recreation areas. The use of sustainability indicators is perhaps the most widely used of these methods and is endorsed by the World Tourism Organisation (Collins, 1998; Schianetz, Kavanagh & Lockington, 2007; Twinning-Ward & Butler, 2002; WTO, 2004). Environmental Impact Assessment is also relevant in this context but applies predominantly to the planning stages of tourism infrastructure development (Ding & Pigram, 1995). More recent concepts, which are also relevant, include Environmental Audit and Ecological Footprint (Ding & Pigram, 1995; Hunter & Shaw, 2005; Schianetz et al., 2007). Survey based methods such as the Delphi Technique have also been applied to this field with some success (Green, Hunter and Moore, 1990). A number of tourism planning frameworks that include an element of environmental assessment have also been developed. These include the concepts of Carrying Capacity, Limits of Acceptable Change, Visitor Impact Management and Tourism Optimisation Management (McCool & Lime, 2001; Moore et al., 2003; Newsome et al., 2002). Finally, Multi-Criteria Analysis is a decision support tool which has had some recent application regarding the environmental effects of tourism (Schianetz et al., 2007).

All of the aforementioned methodologies have their areas of strength and potential fields of application. However, various limitations are associated with their use. These limitations apply in particular to the availability, use and quality of environmental data upon which these methodologies ultimately rely. In particular, the ability of researchers to objectively link, combine and interpret such data in order to provide meaningful evaluation of environmental effects has been questioned (Hughes, 2002; Williams, 1994). Various authors have also questioned the non-integrated nature of existing methodologies and have advocated the need for a more integrated, structured and applied approach to the problem. (Farrell & McLellan, 1987; Inskeep, 1987; Lee, 2001). In addition, McCool & Lime (2001) highlighted the need for more systematic decision making processes which acknowledge the impracticalities of relying exclusively on objective scientific data and allow for the use of value judgement in a transparent manner.

Risk assessment is a concept which has evolved concurrently within Science, Engineering and Social Science disciplines (Frosdick, 1997). User/practitioner risk assessment is an adaptation of established risk assessment techniques with an emphasis on the social science model (Cox & Tait, 1997). This particular form of risk assessment is used extensively in disciplines such as safety management (McDonald & Hrymak, 2002) and is designed to overcome the difficulties of evaluating impact or risk arising within complex or abstract systems where the relationship between cause and effect are multifaceted and difficult to quantify (Waring & Glendon, 1998). Such complexities are synonymous with tourism, recreation and the natural environment and therefore the use of a user/practitioner risk assessment methodology presents itself as a more practical alternative for the assessment of environmental quality and sustainability with respect to tourism and recreation areas.

This thesis presents a novel risk assessment based model for evaluating the environmental sustainability of established tourism and recreation areas. The risk assessment approach was adopted in order to address some of the key limitations of established methods, as discussed above. In particular, the intention was to address uncertainties regarding the interpretation of environmental data and to provide a more structured, integrated and inclusive framework for providing information required for the sustainable management of tourism and recreation areas.

As part of the research, the model was applied and tested over the course of two years at two discreet tourism and recreation areas in Ireland. Broadly speaking, these areas are the North Tipperary side of Lough Derg on the River Shannon and the southern end of Dublin Bay, including Dun Laoghaire Harbour, on the east coast of Ireland (see Section 1.4 below). Arising from this research a detailed methodology for applying the model was developed. This methodology and the associated research results and findings are also presented in detail in this thesis.

The risk assessment model is based on three distinct stages (see Chapter 2). The first stage is referred to as Risk Assessment. This stage involved the undertaking of a structured hazard identification exercise followed by a lengthy monitoring programme. The purpose of the hazard identification exercise was to identify and select a set of variables which were identified as being representative of environmental conditions necessary for sustainability yet vulnerable to adverse affect in the context of recreational activities. Such variables could be either quantitative or qualitative and covered such domains as the noise environment, water quality and area upkeep. The monitoring programme involved repeated recording or measurement of the selected variables and was carried out on a weekly or fortnightly basis over the course of a year. A comprehensive inventory of data recorded in respect of all variables was generated.

The second stage of the methodology is referred to as Risk Evaluation. This stage applies predominantly to the data recorded in respect of the quantitative variables. The key feature of this stage is the determination of a qualitative or descriptive measure of the risk to sustainability associated with the recorded values of quantitative variables. This measure or characterisation of risk was based on three categories (low, medium or high) and was applied on the basis of prescribed criteria (see Sections 1.9.2 and 1.5.5 for explanations and definitions of the risk concept). These criteria were generated by way of reference to established and relevant standards of environmental quality where they exist. Such standards included, for example, requirements set under the Blue Flag Beach Standard (ENCAM , 2008) or under relevant Irish environmental legislation such as the 1992 Bathing Water Regulations (S.I. 155 of 1992). Where quality standards relevant to a particular variable were found not to exist then discretionary criteria were devised, where possible, with reference to any consensus or opinion found in the associated literature. An additional feature of the second stage of the Methodology is the undertaking of trend analysis in respect of both the recorded quantitative and qualitative data. This analysis was intended to identify features of significance in the various data sets regarding for example, season, location and observed levels of various aspects of recreation.

The third and final stage of the methodology is known as Risk Management. This stage involved the generation of 'sustainability risk ratings' with respect to individual variables, season and particular locations. The main function of these ratings are to provide a means of communicating key findings from the monitoring programme in a manner that will aid and promote decision making by appropriate authorities. A final, though not undertaken, feature of the Risk Management Stage of the methodology is the actual implementation of measures required to achieve or promote sustainability by such authorities.

## 1.2 Aims and Objectives

The general research aim was to devise and test a risk assessment based model for assessing the environmental sustainability of tourism and recreation resources. In pursuit of this aim six specific research objectives were established. These are as follows:

1. To develop the aforementioned model in line with current practice in the field of risk assessment.
2. To develop a detailed methodology, based on the risk assessment model, and implement it at two contrasting study areas.
3. To carry out trend analyses in order to identify features or patterns of significance in recorded data.
4. To describe key findings arising from the research undertaken.
5. To assess the strengths and weaknesses of the methodology in the context of the research findings and in the context of relevant alternative methodologies.
6. To identify conclusions and make recommendations concerning this area of research.

## 1.3 Thesis Structure

This thesis is organised into five chapters. These comprise an introduction and literature review chapter, a chapter which describes the risk assessment model, a methodology chapter, a results chapter and a discussion and conclusions chapter. The remainder of this first (introduction) chapter includes a detailed review of subject literature. This review covers a variety of relevant topics including tourism, sustainability, environmental impacts, existing methods of assessment and risk assessment. The literature review is intended to put the research into context and provide a rationale for the research undertaken. The second chapter describes in detail the origins, structure and theory behind the risk assessment based model.

The methodology chapter provides details of all aspects of the applied research including descriptions of the study sites, background information on chosen variables and methods and materials used for recording all variables and for undertaking subsequent data analysis. The results chapter presents the key findings of the research. In addition, the data recorded in respect of key variables is presented graphically by means of charts. A brief interpretation of data charts is given as well as a discussion of any significance trends observed in the data.

The discussion and conclusions chapter reviews all findings with respect to the methodology design and application of the model at the chosen study areas. The wider implications of the research findings are discussed in the context of relevant existing methodologies and the potential application of this methodology. The conclusions and recommendations are based on this discussion.

## 1.4 Background to Selected Study Areas

As noted earlier, the model was applied and tested at two separated locations in the Republic of Ireland. These two locations can be broadly described as the north-eastern shore of Lough Derg on the River Shannon and the southern end of Dublin Bay on the east coast of Ireland. For convenience, these areas are referred to generally as the Lough Derg and Dublin Bay study areas. Within both study areas a number of specific study sites were selected for specific application and testing of the methodology. A brief description of the general study areas follows. A detailed description of the study sites selected within the larger study areas is given in the Methodology Chapter.

### 1.4.1 The Lough Derg Study Area

The north-eastern shore of Lough Derg lies in the county of North Tipperary which is found in the mid-west region of Ireland. The area is an established tourism and recreation area which is known for its lake based recreational opportunities. These include angling, picnicking, swimming, bird watching and boating of all kinds. Although the area is well established as a tourism and recreation destination, the area is rural in nature and quite isolated. For this reason the tourism and recreation activity undertaken here tends to be relatively low key.

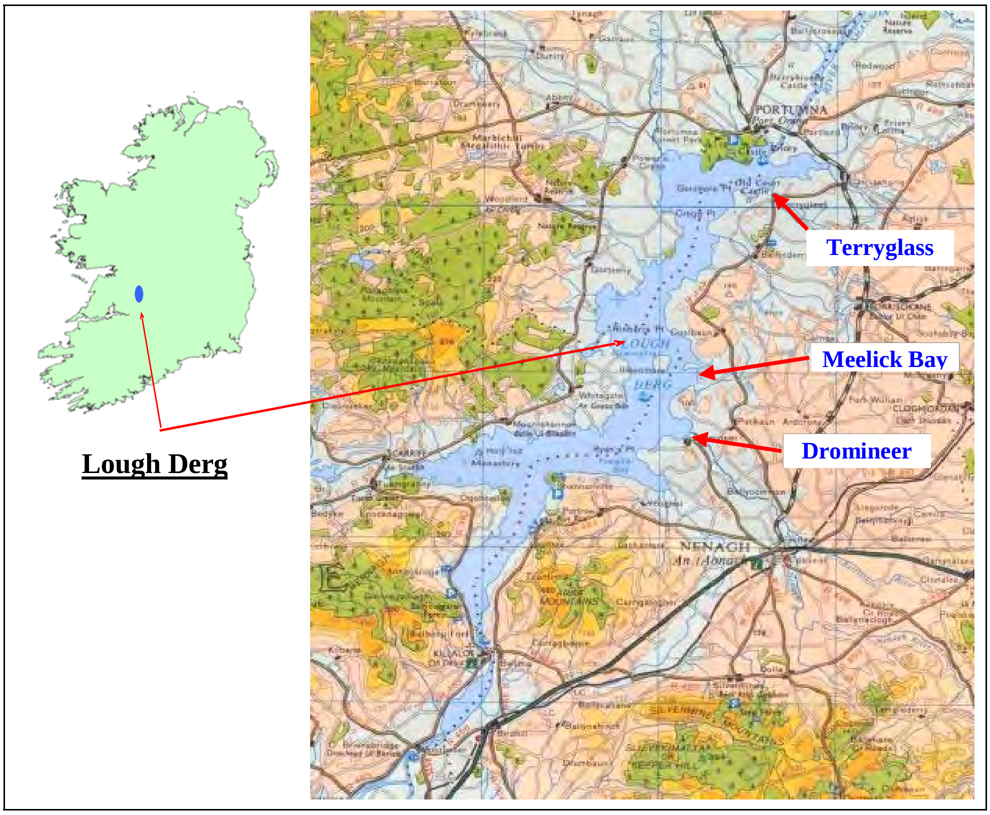



**Figure 1.1 - Location of the Lough Derg Study Area and Selected Study Sites**

Lough Derg is the largest lake on the River Shannon system and is known for its wide variety of high quality lakeshore natural habitat and its populations of wintering bird life (NPWS, 2004; Crowe, 2005). Lough Derg is designated a Special Area of Conservation (SAC) under the European Union Habitats Directive (92/43/EEC) (Europa, 1992). The northeast shore of the lake is also designated as a Special Protection Area (SPA) under the European Union Birds Directive (79/409/EEC) (Europa, 1979). The physical character of the northeast shore of the lake is typified by varying types (and quality) of lakeshore habitat backed by agricultural pasture land. Specific habitats occurring along the north east shore of Lough Derg include rich fen, alluvial semi-natural woodland, limestone pavement, Yew woodland, Juniper scrub, heath, calcareous grassland and marsh (NPWS, 2004).

Three specific study sites were selected in this area. These three sites are referred to in this thesis as Terryglass Harbour, Dromineer Harbour and Meelick Bay. All of these sites have been purpose built as tourism and recreation amenity areas (North Tipperary County Council, 2004) and they possess varying levels of facilities which are maintained by local authorities. Much of the physical character of the three sites is dictated by their location on Lough Derg. Terryglass and Dromineer, in particular are associated with a variety of types of boating activity. Detailed descriptions of each site are given in the Methodology Chapter (see Section 3.2)

### 1.4.2 The Dublin Bay Study Area

In contrast to Lough Derg, the southern end of Dublin Bay is a coastal region which is backed by the urban conurbation of south Dublin City. However, in spite of its proximity to urban development, this region of Dublin bay is recognised for its wildlife habitat particularly with respect to marine bird life (Brunton, Convery & Johnson, 1987). It is designated a Special Protection Area under the EU Birds Directive (79/409/EEC) (Europa, 1979). This area of Dublin bay offers a variety of recreational opportunities ranging from sailing to kayaking to swimming. Dun Laoghaire Harbour at the southern end of the area, in particular, is renowned for boating of all kinds and is considered an important tourism destination (Dun Laoghaire Rathdown County Council, 2004).

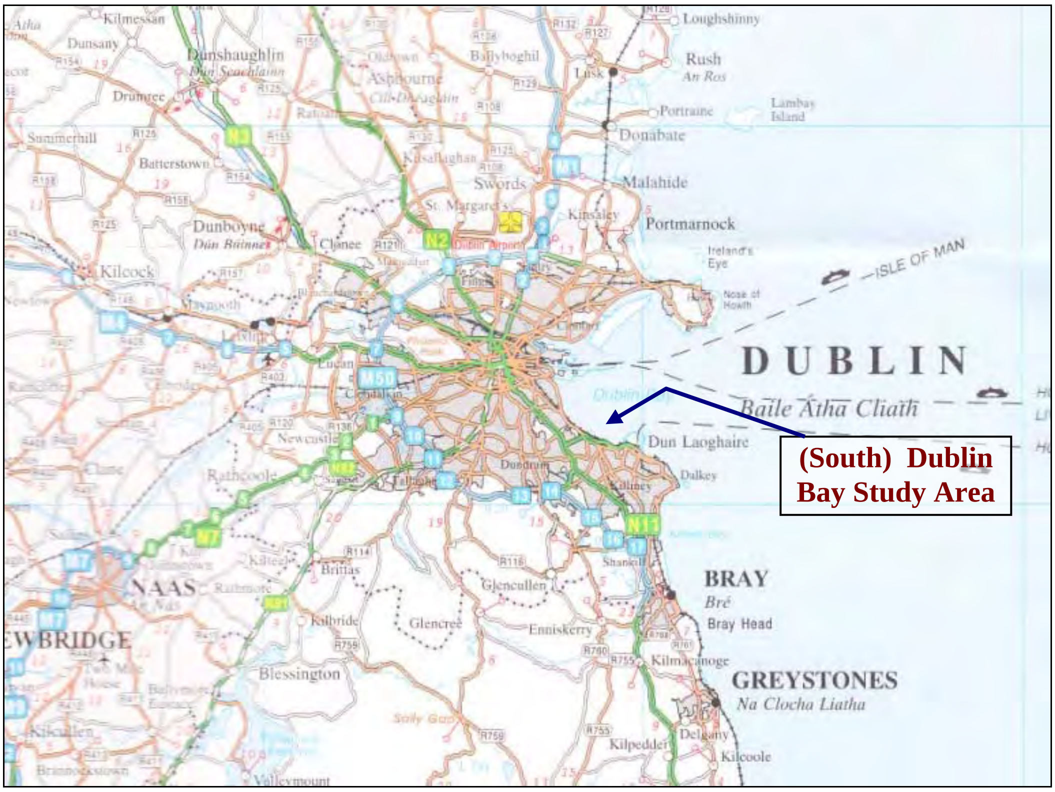



**Figure 1.2 - Location of the Dublin Bay Study Area**

Three specific study sites were also chosen in this area. These are the bathing and amenity area at Seapoint, the amenity area at Monkstown and the West Pier and northern western corner of Dun Laoghaire Harbour. For convenience, these three areas are referred to in this thesis as Seapoint, Monkstown and Dun Laoghaire Harbour. Where a distinction needs to be made between the West Pier at Dun Laoghaire and the actual harbour area then this is made accordingly. Further details of the three individual study sites are given in the Methodology chapter.


**Figure 1.3 - Location of the Three Study Sites in the Dublin Bay Study Area**

### 1.4.3 Rationale for Selection of Study Areas

A precursor to this particular research was a research project, sponsored by the Environmental Protection Agency, which was set up to investigate ways of promoting the sustainable development of tourism in Ireland (Flanagan et al., 2007). The principal study area for this research project was the region known as 'The Tipperary Lakeside Area' in the county of North Tipperary in Ireland. This area comprises both the northeast shore and hinterland of Lough Derg on the River Shannon. It was chosen for the aforementioned research project as it was considered an identifiable tourism area which was as yet largely unaffected by but nevertheless still vulnerable to the typical problems associated with larger more developed tourism destinations.

The same Lough Derg area was also chosen for this research as it was possible to identify a number of distinct tourism and recreation areas which were subject to a variety of environmental pressures from both within the tourism and recreation field and from external sources. In addition, it was felt that the findings of the preceding research project and experience gained of the research area could be utilised advantageously in this project.

The Dublin Bay area was chosen in response to a need, identified as part of the research process, to apply and further test the methodology at a second location. In order to identify a suitable study area for this second application of the methodology, a selection process was initiated. The first phase of this selection process was to identify a shortlist of possible options. Four possible areas were selected. These were a repeat of the Lough Derg study area, Lough Ree in County West Meath, Brittas Bay in County Wicklow and the southern end of Dublin Bay. The selection of these sites was based on the premise that they represented a set of options which would best allow the essential workings of the methodology to be tested. A brief description of each of these sites follows together with a brief rational for their selection in the shortlist.

Lough Ree is another lake on the River Shannon which lies to the north of Lough Derg. In terms of natural features and recreational amenity areas, this lake is very similar in character to Lough Derg. It was therefore considered that testing the methodology at this second site would provide a research framework in which direct comparisons could then be made between the sites.

Dublin Bay offered a contrast to Lough Derg in that this area is both coastal and is also backed by a large urban conglomeration. However, similarly to the Lough Derg study area, the recreational opportunities at Dublin bay are largely associated with its proximity to water. Dublin Bay also features a number of distinct tourism and recreation areas though, unlike Lough Derg, these tend to be quite different in character and therefore provide fewer opportunities for direct comparison.

Brittas Bay is a coastal area in County Wicklow to the south of Dublin City. The bay is known for its long stretch of sandy beach which is backed by a narrow dune system. This area is largely rural in nature and is a popular recreation destination during the summer months. The principal form of accommodation in the area is in the form of numerous mobile home holiday villages which adjoin the coast. Recreational activities are somewhat limited in this area with swimming, kayaking and beach going being the principal attractions. This area offered a contrast to Lough Derg in that it is a coastal location. However, similarly to Lough Derg, Brittas bay is largely rural in character and location.

The re-selection of the Lough Derg study area for the second year of field research would have offered the opportunity to repeat the methodology at the same location. In many respects, this would have allowed a direct comparison of the results of the two separate years of research. In addition to providing a contrast between consecutive years such a repetition of the methodology at the same location would, potentially, have provided a measure of the reproducibility of the methodology.

The final selection of the second study area was done on the basis of a matrix which compared the advantages and disadvantages of each of the four candidate areas. The Dublin Bay area was ultimately selected as it was felt to provide the best balance of advantages and disadvantages in terms of the following points:

- The Dublin Bay area provided a contrast to the Lough Derg area in terms of location but with similarities in terms of the types of recreation activity occurring there. This provided a useful comparative analysis in terms of the testing of the methodology.
- A number of distinct recreation areas were identifiable in the area which could serve as individual study sites. These study sites were subject to a variety of pressures and potential sustainability hazards, both internal and external to the tourism and recreation industry, which meant that the number of variables selected could be maximised. This in turn would maximise the benefits or strengths of the data and findings generated with respect to this area.
- The area was in close proximity to the host institute for this research (the DIT) and therefore the number of sampling occasions could be maximised with minimum use of resources in terms of travel costs and time.

## 1.5 Explanation and Definition of Key Terms

### 1.5.1 Tourism and Recreation Areas

Defining tourism in a general sense is fraught with a number of problems and is discussed in more detail in Section 1.6.1. However, a key issue that arises in the context of this research is whether it is necessary to distinguish between the different types of visitors to an area which may include, for example, foreign or domestic visitors or indeed local residents. Given the practical difficulties associated with making such a distinction, it is interesting to note Mason's (2003) contention that many studies that address tourism and sustainability are now placing less of an emphasis on this distinction. Moreover, as discussed in Section 1.6 below, a growing number of studies in this field are now referring to sustainability in the context of both tourism and recreation. Although there are limitations with this approach, it does circumvent the impracticalities of trying to distinguish between tourists and other visitors to a particular area.

Although the issue of tourism sustainability has been a prominent factor in the origins of this research, a decision was made to avoid the complications regarding the distinction between different visitor types by focusing instead on what are referred to in this thesis as ‘tourism and recreation areas’. In this context, the term ‘tourism and recreation areas’ is therefore used to describe a recognised and defined area or location that is frequented by a variety of visitor types in the pursuit of recreation. Such visitors may include international or domestic tourists, day-trippers and people local to the area. In making this definition, however, it is important that the potentially greater value of tourists to a local economy and the implication of this regarding sustainability is not overlooked.

### 1.5.2 Environmental Sustainability

This research is primarily focused on the difficulties associated with the assessment of environmental conditions and the meaningful interpretation and communication of associated findings. However, the research is undertaken in the context of tourism and recreation and is therefore also concerned with the possible implications of poor environmental condition for the sustainability of tourism and recreation resources or areas. In this respect, it is acknowledged that there is currently a lack of consensus regarding the precise meaning of the term ‘sustainability’ or indeed ‘environmental sustainability' in a tourism context (see discussion below in Section 1.6.2) (Sharpley, 2000; Tao & Wall, 2008; Wall, 1995).

Notwithstanding this lack of consensus, a literal meaning of 'sustainability' is adopted for this research. Thus the term 'environmental sustainability' is used in this thesis to describe the extent to which the viability or popularity of a tourism and recreation area can be maintained based on the quality of the natural and physical environment of the area. A broad interpretation of this definition, therefore, is that where an area is described as not being environmentally sustainable then it would be expected that the popularity or level of use of such an area would decline over time due to poor environmental quality. On the other hand, an area described as being environmentally sustainable would be expected to at least maintain its popularity.

With regard to this definition, note also that the wider, global aspects of sustainability are not considered as such.

### 1.5.3 Amenity Value

When considering environmental quality in the context of tourism and recreation, it is useful to consider also the closely linked concept of 'amenity value'. The term amenity value is used in this thesis to describe the extent and quality of opportunities which exist for enjoyment and recreation at a given tourism or recreation area. The amenity value of an area may be enhanced by both man-made features, such as a lakeside picnic area, or natural features such as a beach or woodland. The condition of such features also contributes to the amenity value of an area. Where the term natural amenity value is used this is intended to distinguish the natural elements of amenity value and highlight their key role in amenity value in a general sense.

### 1.5.4 Environmental Quality

In this thesis the defined meaning of the term ‘environmental quality’ is quite similar to that defined above for amenity value. However, the term environmental quality is used to distinguish elements of the physical and natural environment which may have value beyond that which enhances the amenity value of an area as perceived by visitors. Thus, for example, reference to ‘environmental quality’ would include the quality of less obvious, but equally important, features of the environment such as microbial and chemical water quality and habitat quality.

### 1.5.5 Risk and Risk Assessment

As discussed in Section 1.8, a variety of alternative but accepted definitions exist for the term ‘risk’. Such definitions depend largely on the disciplines within which the concept is applied including, for example, Engineering, Science or Social Science disciplines. A generic definition of risk proposed by the Royal Society (1992) is ‘the probability that a particular adverse event occurs during a stated period of time or results from a particular challenge’. Although this definition provides a useful guide to the general meaning of risk it should be noted that it does not necessarily meet the more quantitative requirements of the engineering profession or the more qualitative requirements of social science disciplines, for instance. In this regard, there is a general acceptance that definitions of risk are largely case specific (Royal Society, 1992).

Given the complex interplay between environmental quality and tourism and recreation sustainability a semi qualitative social science approach is adopted for defining risk with regard to this research. In the context of assessing the environmental sustainability of tourism and recreation, risk is therefore defined as 'the likelihood and extent to which the environmental sustainability (as defined above) of a defined tourism and recreation area will be adversely affected'. It can therefore be taken that the greater the risk to environmental sustainability then the greater the extent and likelihood that the use and popularity of an area will decline. In this sense, therefore, the risk arises as a result of the environmental and physical condition of an amenity area and applies to users' (including locals and tourists) perceptions of the area and their willingness to continue using the area. Ultimately, it is considered that this risk will have economic implications for the area in question.

As with the term 'risk' the meaning of the term 'risk assessment' also largely depends on the context and discipline within which it is applied. Nevertheless two generic definitions are considered relevant in this context. The Royal Society (1992) gives one very broad definition of risk assessment as 'the integrated analysis of the risks inherent in a system and their significance in an appropriate context'. Likewise the Department of Environment, UK (1995) defines risk assessment as simply 'the structured gathering of information about risks and the formation of judgments about them'. In the context of this research the term 'risk assessment' is not defined as such but its meaning follows the two general definitions above and ultimately should be taken from the methodology as described.

## 1.6 Tourism and Recreation, Sustainability and Environmental Quality

### 1.6.1 Tourists and Tourism

The term ‘tourism’ is naturally complex and refers to both the people who partake in tourism and also the businesses and employees who cater for their needs (Butler, 1993). Tourism can therefore be thought of as comprising a range of individuals, businesses, organisations and places which combine to deliver a travel experience of one sort or another (Cooper et al., 1993). In this regard, early work by Leiper (1979, 1990) maintained that tourism should be viewed as an open system with a number of elements which are intrinsically connected. These elements include tourists, generating regions, transit regions, transit routes, destination regions and a tourist industry (Leiper, 1979). The elements interact with and operate within physical, cultural, social, economic, political and technological environments. Such is the connectivity between the elements of the tourism system, Leiper (2000) has more recently argued that the field of tourism study and research can reasonably be viewed as an independent academic discipline.

Notwithstanding the work of Leiper (1979, 1990 and 2000), it is nevertheless broadly recognised in tourism literature that there is still no generally accepted definition of tourism (Cooper et al., 1993; Fennell, 2003; Mason, 2003). This is largely attributed to the complex and varied nature of tourism. Nevertheless, a number of definitions have been suggested and generally a distinction is made between the demand aspect of tourism (the tourists) and the supply aspect of tourism (the services). Thus, the World Tourism Organisation (WTO, 1994) defines tourism, from a demand perspective, as ‘the activities of persons travelling to and staying in places outside of their usual environment for not more than one consecutive year for leisure, business and other purposes'. In terms of supply, tourism can be defined as 'the firms, organisations and facilities which are intended to serve the specific needs and wants of tourists' (Cooper et al., 1993). However, there are obvious problems with such a definition since many businesses involved in tourism also cater for the needs of locals and residents. A general definition encompassing both the supply and demand aspects of tourism is proposed by Matthieson and Wall (1982). This definition states that tourism comprises 'The temporary movement of people to destinations outside their normal places of work and residence, the activities undertaken during the stay in those destinations, and the facilities created to cater for their needs'.

When addressing the issue of sustainability at tourism and recreation areas the question arises as to whether it is necessary to distinguish between the influence of tourists and tourism and the influence of the leisure activities of resident populations. Where such a distinction is considered necessary then this provokes a need to provide a technical definition of tourism which allows a distinction to be made between tourists and residents. To account for this, early definitions of the term 'tourist' made reference to the need for a tourist to spend at least one night at a destination to which he or she has travelled. Other requisites concerned the maximum length of stay (normally one year) and the purpose of visit (Cooper et al., 1993). Such definitions deliberately exclude day visitors or 'excursionist'. These comprise a group which is gaining greater recognition as having an important role to play in the sustainability of tourism areas or destination (Cooper et al., 1993; Mason, 2003). Thus, when considering the sustainability of tourism, Mason (2003) points out that it is often of no consequence whether those influencing this sustainability are staying overnight in the region or simply visiting for the day. As a result of this Mason (1993) contends that the distinction between day and overnight visitors when defining tourists has become less apparent in more recent tourism research and literature. In this respect, it is evident that many studies which address the environmental aspect of sustainable tourism do away with this distinction and refer simply to impacts due to recreation (Broadhurst, 2001; Liddle, 1997). Thus, a growing number of studies now refer to the effects of ‘recreation’ or ‘tourism and recreation’.

### 1.6.2 Tourism, Recreation and Environmental Sustainability

In a literal context, the term ‘sustainability’ simply means, in one sense, the ability to maintain or prolong something (Collins Dictionary, 2003). However, the term has undoubtedly received greatest recognition (and greater meaning) as a result of the recent popularisation of the concept of sustainable development. This concept has been brought to the fore of public, media and political attention through initiatives such as the publication of the Brundtland Report in 1987 by the UN World Commission on the Environment and Development (WCED, 1987) and the holding of the 1992 United Nations Conference on the Environment and Development (known as the Rio Earth Summit). The commonly cited definition of sustainable development given in the Brundtland report is ‘development that meets the needs of present generations without compromising the ability of future generations to meet their own needs’ (WCED, 1987). Although this definition is considered by some to be very vague (Ceron & Dubois, 2003; Saarinen, 2006) it is clear that its focus is global in context (Baker, 2006). In addition, a central tenet of the Brundtland report is that sustainable development can only be achieved by finding common ground between ecological, socio-cultural and economic needs (Saarinen, 2006). This conviction was reinforced by the Rio Earth Summit which sought to reconcile the need for environmental protection and resource conservation with global economic development aspirations (Baker, 2006).

In spite of the official recognition of the concept of sustainable development, the actual interpretation of this concept is still the subject of considerable debate (Sharpley, 2000). Many authors highlight the problems presented by this ambiguity and, at least in part, put the problem down to the general and ambiguous nature of the definitions provided by world authorities such as the WCED (Sharpley, 2000; Ceron & Dubois, 2003; Saarinen, 2006).

Given the resource dependent nature of the tourism and recreation sector, it is not surprising that the notion of sustainable development has been embraced, in principle at least, by both the industrial and academic representatives of this sector. Symbolically, the World Tourism Organisation (WTO) have given their official backing to the concept and have stated that the application of the principles of sustainable development to the tourism industry is of strategic importance to the sector (WTO, 2004). Nevertheless, in spite of this official recognition, it is very evident in the subject literature that the ambiguity regarding the meaning of sustainable development has crossed over into the domain of the tourism and recreation sector (Sharpley, 2000). Although, some authors see the lack of a concise and agreed interpretation of the concept of sustainable tourism as problematic (Ceron & Dubois, 2003; Liu, 2003; Sharpley, 2000) others see this as a strength. For example, Hunter & Green (1995) see sustainable tourism as an adaptive concept that will necessarily change depending on the circumstance of its application. Nevertheless, established definitions of sustainable tourism do exist. These include the very general definition provided by the WTO who define sustainable tourism development as ‘tourism which meets the needs of present tourists and host regions, while protecting and enhancing opportunities for the future’. Arguably of more value in this context is Butler's (1993) definition which views sustainable tourism as 'tourism, which is developed and maintained in an area in such a manner, and at such a scale, that it remains viable over an indefinite period and does not degrade or alter the environment (human and physical) in which it exists to such a degree that it prohibits the successful development and well-being of other activities and processes'.

Notwithstanding the issues regarding the meaning of the term sustainable tourism development, it is useful to note Sharpley's (2000) and Ceron & Dubois's (2003) assertion that the interpretation of the concept of sustainable tourism often falls into either of two categories or points of view. These are, on the one hand, the view which considers sustainability in the context of tourism only and, on the other hand, that which also considers the wider global implications of the sector. Ceron & Dubois (2003) argue that it is important to be aware of this distinction between these points of view but contend that in literature and policy this distinction is often not clear. In addition, although the concept of sustainable development involves the reconciliation of environmental, social and economic requirements (Butler, 1993; Saarinen, 2006) it is also reasonable to assume that an emphasis can be placed on one particular area when researching ways for promoting sustainable tourism development. In this regard, Hardy, Beeton & Pearson (2002) contend that the field of sustainable tourism research has traditionally given more focus to environmental conservation and economic development than the social aspects of sustainability.

With regard to the above and given the public and media attention concerning environmental issues, it is not surprising therefore that a large sector of sustainable tourism research has focused on the assessment of the environmental effects of tourism and recreation. Moreover, it can be argued that the motivations underpinning the theoretical development of methods for assessing the environmental effects of tourism and recreation may well have been generated in the context of the wider global principles of sustainable tourism development. However, it is evident from the subject literature that, in practice, many existing tools for the such assessment are actually focused more on the assessment of environmental condition and how this may affect the viability of a particular area rather than the preservation of global resources.

The above assertion leads to the term 'environmental sustainability' and how this is defined in tourism and recreation literature. Firstly, with regard to the use of the term 'sustainability', it is evident in the tourism literature that little distinction is make between the use of the this term and the term 'sustainable' (given in the context of sustainable tourism development). From a purely grammatical point of view, the use of the term sustainability invokes a question as to whether tourism is sustainable or not. However, it can also imply an element of scale or magnitude to the concept of sustainable tourism, as in the term 'sustainability indicators'. Nevertheless, it is evident in the subject literature that these terms, sustainability and sustainable, tend to be used interchangeably. This would suggest that the use of either term depends mainly on grammatical context and that the implied meaning of 'sustainability' is generally based on the meaning adopted for the term 'sustainable'. Likewise, where reference is made to 'environmental sustainability', little clarification tends to be given regarding its implied meaning. However, it would seem logical that this term is simply used to isolate the environmental or natural resource requirement when considering the sustainability of tourism in general or of a particular tourism area. Thus, in the absence of any agreed definition of environmental sustainability and taking Butler's (1993) definition of sustainable tourism into account, a plausible generic meaning for 'environmental sustainability', in the context of tourism, could simply be; 'the extent to which a tourism or recreation area meets the environmental requirements of sustainable tourism'. That is, the environmental quality should be of a standard that does not compromise the viability of the area as a tourism and recreation location.

Aside from the matter of defining the term 'environmental sustainability' in a tourism context, it is useful to note that there remains a strong political consensus that tourism should not only be developed in a manner that complies with the principles of sustainability generally, but particularly with a view to conserving natural resources and the physical environment. By way of example, the recently appointed (European Commission) Tourism Sustainability Group (TSG), stress in a recent report (TSG, 2007) that tourism development within the European Union should seek to preserve and add value to the physical integrity and biological diversity of tourism and recreation areas. In an Irish context, the Environmental Action Plan 2007-2009 (Failte Ireland, 2007) published by Failte Ireland stresses that 'the future of Irish tourism is inextricably linked to the quality of the environment' and that 'the economic viability and competitiveness of the Irish Tourism Industry can only be sustained if the quality of (environmental) resources is maintained'. Also notable in an Irish context is the fact that the latest 'State of the Environment' report by the Environmental Protection Agency (EPA, 2008) contains a section dedicated to 'tourism and travel'. This section highlights the connection between tourism and environmental conservation and calls for impacts of tourism on the environment to be closely monitored.

### 1.6.3 The Environmental Impacts of Tourism and Recreation.

Tourism has obvious benefits for the local economies of tourist destinations and recreation areas but inevitably it also brings various pressures to these areas. These pressures can have negative implications for the social, cultural and also environmental aspects of a destination (Fennell, 2003). Concern over the ecological effects of tourism has greatly increased since the 1970s due to the realisation that tourism has the capability to radically transform destination regions in adverse ways (Fennell, 2003).

A key problem regarding tourism and the environment is the overexploitation and subsequent deterioration of the natural environmental resource and amenity value at a destination (Butler 1993). The natural environment and associated amenity value is often the major attraction of a tourism destination. Thus, as Butler (1993) established, any deterioration in the natural environment of a destination area has serious implications for the continuing success of that area. In addition to commercial implications, the problems associated with tourism and the environment have merit in their own right, particularly in the context of the need for conservation of habitat and biodiversity throughout the world.

Factors which may affect the environmental quality of tourism and recreation areas are wide ranging and often complex. Not least amongst these are those associated with the tourism and recreation industry itself. Concern over the environmental effects of tourism and recreation has greatly increased in recent decades due, in part at least, to the realisation that tourism has the capability to radically transform destination regions in adverse ways (Fennell, 2003). The complex nature of tourism and recreation impacts are largely due to the complexity of natural ecosystems and also to the extensive variety of recreation activities which may take place in a wide variety of natural environments. Nevertheless, there are many examples of tourism impacts that are well publicised in the literature on the subject.

For example, a frequently cited effect of tourism and recreation concerns the use of water and energy resources. An example of this is cited by Jackson (1986) regarding problems of elevated water and power consumption by tourists on small tropical islands in the Caribbean and the subsequent occurrence shortages for resident populations. By contrast, Mader (1998) draws attention to the plight of the natural environment of the European Alps in where unchecked development of the region for skiing has exposed the area to problems of forest clearance, soil erosion, disturbance to wildlife and air pollution. In the Algarve in Portugal, Barret (1989) highlights areas where natural character and beauty is being destroyed due to large scale changes to the visual landscape resulting from poorly planned tourism development.

A huge variety of more specific environmental effects associated with tourism and recreation have also been studied. These include, for example, adverse affects on the breeding success of the loggerhead turtle on the Greek Island of Zakynthos due to disturbance of nesting sites (Ryan, 2003). Even relatively benign forms of tourism activity such as camping are not without their potential impacts. Cole (1992) and Marion (2002) have carried out extensive research on the effects of camping in wilderness areas. Impacts that are cited include the compaction of vegetation, erosion of soils, disturbance to wildlife, littering and the health risks associated with human waste.

In Ireland the Environmental Protection Agency (EPA, 2000 & 2004) cites damage occurring to sand dune systems, as a result of walking, camping or golfing, as a typical impact of concern with regard to tourism in Ireland. The EPA (2004) also draws attention to the problems of additional pressures been put on wastewater treatment, water and energy supply, waste generation and traffic congestion as a result of poorly planned tourism in rural areas. The problem of litter is also considered by the EPA and acknowledgement is made of the adverse effect that litter can have on tourism (EPA, 2000). The Department of the Environment in Ireland has published reports which cite the problems of litter identified by surveys that have been carried out at various locations around the country including recreation areas and beaches (Dept. of Environment, 1995 and 1997). These surveys have shown that litter remains a significant problem in Ireland though no reference is made to the sources of litter at these locations and whether or not tourism adds to this problem.

Although the impacts of tourism are often specific to a particular destination, many impacts can be associated with tourism in general, regardless of location, and are frequently identified in the literature on this subject. Table 1.1 overleaf presents a list of some of the more general environmental impacts which may occur due to the various activities and requirements associated with tourism and recreation

**Table 1.1 - List of General Impacts of Tourism and Recreation on the Natural Environment**

| Area of Effect | Example Impacts | Example causes |
| --- | --- | --- |
| **Biodiversity and Natural Habitat** | Disruption of breeding and feeding patterns.<br>Restriction of wildlife movements.<br>Loss and fragmentation of habitat .<br>Reduction in species numbers and diversity of plants and wildlife.<br>Change in species composition.<br>Destruction of vegetation. | Construction of tourism infrastructure, roads, accommodation, facilities, golf courses and amenity areas.<br>Land clearing amenity areas and tourist facilities.<br>Disturbance to wildlife due to tourist activities such as hiking, boating, wildlife watching and participation in adventure sports.<br>Hunting. |
| **Integrity of physical landscape** | Erosion leading to soil loss, reduced vegetation and possible water pollution.<br>Physical damage to site. | Land clearance, removal of woodland, trampling by walkers or campers.<br>Land clearing for construction or infrastructure development. |
| **Infrastructure** | Water shortages.<br>Traffic and parking congestion.<br>Power shortages. | Overloading of water or electricity supply network.<br>Diversion of water supply to meet tourist requirements (e.g. swimming pools, golf courses).<br>Car usage exceeding road capacity. |
| **Natural Resources** | Depletion of surface and groundwater.<br>Depletion of local building material sources. | Excessive demand on existing water resources.<br>Use of local materials for construction of tourist accommodation. |
| **Physical and Visual Landscape** | Loss of traditional land use.<br>Detrimental change to visual landscape. Loss of visual amenity. | Land transfer to tourism development.<br>Inappropriate tourism development and design. |
| **Aquatic Environment** | Water pollution resulting in reduced water quality and amenity value. | Sewage disposal from tourist accommodation, pleasure boats.<br>Fuel Spillages from pleasure boats. Littering. |
| **Air and Noise Environment** | Noise pollution resulting in disturbance to wildlife and reduced amenity value.<br>Deterioration of ambient air quality. | Use of vehicles, generators, quad bikes, power boats, jet-skis, etc.<br>Noise from parties and bars.<br>Vehicle and generator emissions. |
| **Waste Management** | Litter.<br>Odours.<br>Increase in pest species. | Rubbish Dumping.<br>Littering. |

(adapted from Hunter & Green, 1995: Newsome et al., 2002 and Mason & Dowling, 2002)

#### *1.6.3.1 Lake Destinations and Tourism and Recreation Impacts:*

Lakes in many parts of the world form important tourism and recreation areas. This is largely due to the potential of lakes for recreation activity and also the attractive scenery with which lakes are often associated (Hall & Harkonen, 2006). Lakes also provide human beings with a variety of functional requirements such as drinking water, irrigation and transportation. Recent conferences such as the International Lake Tourism

Conference held in Savonlinna, Finland in 2003 (Lake Tourism Project, 2003) and the Lake Shore Conference held at Lake Constance, Germany also in 2003 (Shmieder, 2004) have served to highlight a variety of significant issues concerning lake development, conservation and tourism.

From an ecological point of view, lakes are often associated with extensive natural habitat and ecosystems which provide shelter and breeding areas for a wide range of wildlife and flora. Lakes in this respect are considered to be of great importance to biodiversity (Hall & Harkonen, 2006). Many of the individual environmental impacts listed in Table 1.1 above are also relevant to tourism at lakeside destinations. However, many additional examples of environmental impact specific to lakeside destinations have been investigated and are cited in the literature on the subject. Liddle (1997) and Hall & Harkonen (2006), among others, provide a comprehensive review of this subject area.

Lake shores form transition zones between land and water and provide extensive habitat for both terrestrial and aquatic organism. Lake shores also provide a focus for economic, cultural and recreational use and human settlement. This human interest in lake shores has resulted in extensive deterioration of lake shores through out Europe such that many European lakes now comprise of shorelines which are largely artificial and devoid of natural habitat or value (Schmieder, 2004). Much of the deterioration of lake shores in Europe has occurred as a result of direct modification of the shoreline. Modifications of the shoreline can have a variety of detrimental effects including the erosion of natural shore defences, the loss of submersed and littoral vegetation, the reduction of habitat and general disruption to the complex feeding webs of the littoral fauna (Schmieder, 2004). Modifications to the lake shoreline can be undertaken for a variety of reasons. These include the construction of buildings, bridges, breakwaters, marinas and amenity facilities. The construction of these structures is often driven by tourism development and hence many of the detrimental effects associated with lake shore modifications can be attributed to the tourism and recreation industry.

In addition to the impacts on lakes which may result from the construction of tourism infrastructure and facilities, many impacts also arise as a result of everyday activities associated with tourism and recreation such as boating, camping or picnicking. In this respect, boating activity on lakes is associated with a number of potential threats to the lake environment. These include boating wash, turbulence, propeller action, direct contact and disturbance due to presence and noise of boats (Liddle, 1997). All of these have the potential to negatively impact lake ecosystems to differing extents depending on factors such as the size and speed of passing boats, the sensitivity of wildlife and plant life and the size and depth of the affected water body (Liddle, 1997). A study carried out by Van der Zande & Vos (1984) provided evidence that the density of birds observed in groves and hedges on lake shores in the Netherlands was adversely affected by recreational use of the area. Rodgers & Schwikert (2002) showed that flush distances (the approach distance which causes birds to take flight) for self propelled craft were less than half that for boats powered by outboard engines. Keller (1989) showed that although Great Crested Grebes showed adaptive behaviour to the presence of humans on lakes in Switzerland, nesting success for this species was more successful on undisturbed lakes. Hammerl and Gattenloehner (2006) have also drawn attention to the fact that the shallow bay areas of Lake Constance, which are the preferred habitats for endangered animals and plants, are the favourite places for anchoring boats.

Boat wash is implicated in the erosion of plant roots along river and lake shorelines (Haslam, 1978). Shoreline vegetation provides important shelter, protection and breeding sites for lake wildlife and so any erosion of this vegetation can have detrimental effects on wildlife communities. Boating activity has also been implicated in increases in the level of turbidity in lake waters, though Liddle (1997) argues that there exists little quantitative evidence to support this. A study by (Moss, 1977) found that levels of turbidity occurring in the Norfolk broads was not strongly correlated with levels of boating activity.

Sewage entering lake waters from pleasure boats or on-shore tourist accommodation is another potential cause of negative impacts to lakes that is addressed in the literature. Liddle & Scorgie (1980) comment that the impact of such sources of sewage discharge ultimately depends on the quality and volume of both the sewage effluent and the receiving freshwater body. Nevertheless, the nature of sewage is such that where direct discharges of untreated sewage waste occur, levels of key nutrients such as phosphates and nitrates and levels of coliform bacteria would be expected to rise in the receiving waters. This reasoning is supported by (Barbaro et al., 1969) who found marinas were the prime areas of nutrient and bacterial pollution in their study of Ross Barnett reservoir in the United States. Ultimately, any release of sewage into recreational waters is likely to have implications for nutrient enrichment and human health.

Noise pollution issues in rural lakeside areas are attracting increasing media attention though there is little information in the literature on the subject to substantiate this issue. Nevertheless, the European Commission has adopted a Directive relating to the assessment and Management of Environmental Noise (2002/49/EC, Europa, 2002) which recognises the need to monitor and preserve environmental noise quality in both urban and rural contexts. In addition, Waugh et al., (2006) draws attention to the changes in human activity which is adversely affecting the noise environment of ‘quiet areas’ in Ireland and stresses the need for monitoring and control of this problem.

The situation regarding the impacts of tourism at Irish lake destinations is less clear. Since the early 1970s, the focus of investigations into lake quality in Ireland has been almost exclusively on water quality issues associated with agricultural activity and the discharge of untreated sewage from towns and villages into lake tributaries. The EPA and their predecessors the Environmental Research Unit and An Foras Forbatha have been involved in the majority of these investigations and a variety of studies and reports have been published (Bowman, 1996; Bowman & Toner, 2001; Irvine et al, 2001; Toner et al., 2005). However, no mention of the potential effects of tourism on lake water quality is made in any of these reports.

#### *1.6.3.2 Coastal Areas and Tourism and Recreation Impacts*

Many of the environmental impacts of tourism and recreation previously discussed, including those associated with lake areas, are also relevant in the context of coastal and marine areas. However, the unique and varied nature of coastal fringes and coastal recreation mean that such areas are vulnerable to a wide range of potential impacts many of which are particular to coastal environments (Liddle, 1997). A number of these impacts are well documented and include the following. From a physical perspective the construction of breakwaters and sea walls may be associated with the development of tourism infrastructure on coastal fringes. Such constructions can cause the interruption of natural shoreline processes resulting in the erosion or alteration of seashore habitat (Liddle, 1997). Dune systems may also be adversely affected by such constructions as well as by excess trampling due to uncontrolled access to these areas (Newsome et al, 2002).

Specific recreation impacts at coastal zones are also varied. The use of power boats, for example, can be associated with disturbance to bird and animal species (Liddle, 1997). Noise pollution can also be an issue in this regard. Engine powered craft in general are associated with the potential for the accidental release of oil or petrol causing pollution (Newsome et al, 2002). In addition, Liddle (1997) cites several studies that indicate an association between increased levels of pathogenic organisms and water-based recreation such as the use of pleasure boats. The general popularity of the seashore for walking, picnicking and swimming means that littering and dog fouling can be problematic issues at coastal recreation areas (Liddle, 1997). Furthermore, the problems of littering can be exacerbated by the effect of tides which can concentrate litter into unsightly accumulations at the top of beach areas and rocky shorelines .

Other specific problems associated with recreation and tourism in coastal areas include, for example, problems of noise and erosion caused by the use of motorcycles and beach buggies in sensitive dune environments. Disturbance of the breeding sites of turtles and some seabirds, due to light pollution and human activity, is also becoming a more recognised problem (Newsome et al., 2002). Damage to coral reefs due to the poor management and behaviour of scuba divers and snorkellers in tropical locations is now also a much cited problem associated with recreation in marine areas (Cater & Cater, 2001).

## 1.7 Existing Methods for Assessing the Environmental Sustainability of Tourism and Recreation Resources

A variety of methods exist for assessing the various environmental issues associated with tourism and recreation areas and their sustainability. These methods have certain features in common but they tend to differ in their specific aims and scope of application. In addition, some of these methods have been developed specifically with the tourism and recreation industry in mind whereas others have been originally established in other disciplines but have now found application in a tourism and recreation context. Given the relatively narrow definition of environmental sustainability adopted for this research, many of these methods described in this section are not directly relevant. However, they are included here as they are well cited in the context of more general definitions of environmental sustainability of tourism and recreation. A general description of these existing methodologies (with some critique) is given in this section. A more detailed critique of the more relevant methodologies follows in Section 1.8.

### 1.7.1 Sustainable Tourism Indicators

The idea of sustainable tourism indicators (also referred to as ‘sustainability indicators’) has arisen largely from the need to provide tourism managers and policy makers with the information necessary to ensure the continued popularity and viability of established tourism destination areas (WTO, 2004). In this context, indicators can be viewed simply as sets of recorded data which respond to identified risks or hazards in a manner which can be used to provide warning or a record of adverse affects at a particular tourism area

(Manning, 1999). Notwithstanding this view, the WTO (2004) provide a more explicit definition of indicators; that is 'measures of the existence or severity of current issues, signals of upcoming situations or problems, measures of risk and potential need for action, and means to identify the results of our actions'. Given this definition, it is evident that chosen indicators must meet a number of criteria in order for them to be viable and effective. An example of such criteria is provided by the MEANS programme, which reflects the findings of research by the European Commission (1999) into the general area of sustainable development. The MEANS programme identifies various criteria within eight headings which include relevance, availability, meaning, sensitivity, reliability and comparability.

Although the sustainability of tourism is influenced by a wide range of economic and social factors, the relationship between sustainability and the natural environment has become a focus for the application of indicators by the industry (Hughes, 2006, Swarbrooke, 1998*).* In this context, the use of the term 'environmental indicator' has become prevalent and is often used in order to distinguish between indicators of the environmental aspects of tourism sustainability on the one hand and indicators of the social and economic aspects of tourism sustainability on the other (Hughes, 2006) (Note that, in this thesis, the term 'environmental indicators' is also used, where appropriate, in order to highlight this distinction).

A feature of the early development of sustainability indicators was the absence of any organised framework for either their selection or application. However, in the early 1990s, the World Tourism Organisation sought to formalise and promote the use of sustainability indicators as a 'central instrument for improved planning and management in tourism' (WTO, 2004). To this end, the WTO has identified a variety of environmental indicators which can be used at various destination types and has also developed criteria for the selection of additional indicators by tourism managers as and when required (WTO, 2004). Guides regarding the selection of sustainable tourism indicators (including environmental indicators) have also been produced by bodies such as the United Nations Environment Programme (UNEP, 2005) and the Department for Culture, Media and Sport (DCMS, 2001) in the United Kingdom.

Although, the aforementioned indicator lists and guidelines provide some structure to the process of indicator selection, they cannot strictly be considered frameworks for indicator selection. To this end, the Tourism Management Institute (TMI, 2003) have produced the VICE model for sustainable tourism which provides a framework for the selection of indicators and application of management practices to promote sustainable tourism. More recently, the Faculty of Tourism and Food in the Dublin Institute of Technology have produced a detailed model, known as the ACHIEVE model, for the selection of tourism sustainability indicators in an Irish tourism context (Flanagan et al., 2007).

Despite the official promotion and recognition of sustainability indicators, and the existence of framework models such as the VICE and ACHIEVE models, a considerable degree of controversy still surrounds the use of 'environmental indicators' in this context. This is largely due to difficulties associated with the actual use, communication and interpretation of the environmental data produced by such indicators (Hughes, 2006). In this regard, Hughes (2006) contends that the use of environmental indicators has become an established though not necessarily proven means of evaluating the environmental quality and sustainability of tourism and recreation areas.

### 1.7.2 Carrying Capacity

Carrying capacity is a concept which has stemmed from a desire to introduce a more quantitative element to the evaluation of tourism sustainability (Newsome et al., 2002). This is particularly the case with regard to the use and application of sustainability indicators, which often lack an empirical element (Hughes, 2002). In essence, the carrying capacity approach is intended to provide a means by which the relationship between intensity of use, resource degradation and continued viability of a destination can be determined (Farrell and Runyan, 1991). In this regard, the application of the carrying capacity concept should provide a quantitative measure of the level of visitor activity that is sustainable in a particular area or destination. Such a measure would then provide a basis for developing effective management strategies necessary for achieving the crucial balance between levels of visitor use and conservation of tourism and recreation resources (Newsome et al., 2002).

In spite of the initial expectation regarding the concept of carrying capacity when it was first introduced it is evident from the literature that this concept has failed to deliver in practice. Specifically, the generation of quantified visitor use limits in the field has proven largely impractical (Newsome et al, 2002). As Krumpe & Stokes (1994) point out, this is largely because numerous studies have shown that there is no clear or predictable relationship between use and impact in a tourism and recreation context. Furthermore, Krumpe & Stokes (1994) and Roggenbuck & Watson (1993) also contend that it is often more the behaviour of visitors to an area which determines the nature and scale of impact rather than simple numbers of users as defined by the carrying capacity concept. By way of example, Garrigos Simon, Narangajavana & Palacios Marques (2004) found that one of the biggest obstacles to measuring carrying capacity at Hengistbury Head recreation area (near Bournemouth, UK) was a simple lack of knowledge regarding the nature of impact of visitors on biological systems and the natural cycles of erosion.

In spite of the cited shortcomings of the carrying capacity concept, Glasson et al. (1995) contend that it is the focus on determining absolute limits that has hindered the practical application of this concept in the filed. In this regard, Glasson et al. (1995) argue that the concept of carrying capacity still has merit, though largely as a notional or abstract concept which can be used to highlight resource use issues in the context of sustainable tourism and recreation.

### 1.7.3 Visitor Planning Frameworks

Visitor Planning Frameworks were initially developed for planning and managing the recreational use of wilderness and backcountry areas in North America. More recently they have also seen application in other regions such as Australia and New Zealand (Moore et al., 2003). These frameworks were intended to enhance the protection of natural resources while optimising the visitor experience and, notably, they were generally developed as alternatives to the carrying capacity approach for managing visitor impacts in recreational areas (Newsome et al., 2002). This was largely due to a realization that carrying capacities for wilderness areas could not be simply expressed as a number of users beyond which resources would deteriorate (Krumpe & Stokes, 1994).

Over the past three decades, a number of distinct visitor planning frameworks have been developed by various research teams. However, they all share common features with a focus on resource conditions, the visitor experience and management using an objective approach (Moore et al., 2003). A further feature in common is the selection of resource indicators which are used to monitor progress against set standards. Two such frameworks are particularly relevant in the context of this research. These frameworks are known as Limits of Acceptable Change (LAC) (Stankey, Cole, Lucas, Petersen & Frissell, S. (1985) and Visitor Impact Management (VIM) (Graefe, Kuss & Vaske (1990). These are described in further detail below.

#### *1.7.3.1 Limits of Acceptable Change*

The Limits of Acceptable Change (LAC) concept was first developed by members of the US Department of Agriculture Forestry Service as a new management framework for the Bob Marshall Wilderness Complex in Montana, North America (Stankey, McCool and Stokes, 1984). A central premise of the Limits of Acceptable Change (LAC) framework is the recognition that any level of recreational use of an area will affect social and resource conditions and that the key to successful management of such areas is identifying what level of impact or change is considered acceptable (Stankey et al., 1985). A further distinguishing feature of LAC is the recognition that the level of acceptance of particular visitor impacts will depend on the general nature of recreation associated with a given area. This characterisation of recreation type is referred to as ‘opportunity classes’ (Stankey et al., 1985). Thus a key aspect of LAC is identifying the nature of opportunity classes at a recreation area and setting standards that reflect these classes and the desired objectives for resource conditions (Newsome et al., 2002). In short, LAC provides a process for deciding what environmental and social conditions are acceptable, given the nature of recreation occurring, and what management actions area required for achieving these conditions (Newsome et al., 2002).

In practice, the LAC process involves nine sequential steps (Stankey et al., 1985). The initial part of the process involves identifying issues of concern and establishing opportunity classes associated with a given area. Indicators are then selected in order to allow the characterisation of existing resource and social conditions. Standards are then set with regard to the resource and social conditions which are considered desirable and unacceptable conditions are identified. Finally, management actions are prescribed for achieving desired conditions and an ongoing monitoring programme is initiated in order to ensure continued compliance with desired conditions (Stankey et al., 1985, 1984).

Glasson et al. (1995) contend that a general strength of the LAC framework is that it avoids establishing outright limits regarding the levels of use or types of development permitted at a recreation area. Instead, the focus is on understanding and establishing the nature and extent of impact or change that is considered acceptable at a given tourism or recreation area, particularly in the context of the type and nature of recreation associated with the area. In addition an underlying understanding of the framework is that the acceptable impact level is ultimately a matter for managerial judgment. In this respect, a key feature of the framework is that quality standards must be set regarding resource and social conditions which reflect the accepted level of change or impact, as determined. However, Glasson et al. (1995) point out that this process can be problematic as it relies on environmental data and where such data proves unreliable or difficult to interpret then a danger exists that quality standards will be adopted arbitrarily. In this regard, Cole & Stankey (1997) hold the view that the identification of standards remains the most pivotal and problematic aspect of the LAC process. Furthermore, Newsome et al. (2002) contend that in some cases there is a general reluctance by management to set standards due to concern regarding their accuracy or effects. To further complicate the matter, in a study of wilderness areas in the United States, Roggenbuck & Watson (1993) found that visitor perceptions concerning acceptable conditions and standards for these areas tended to vary widely within and between sites. Nonetheless, Newsome et al. (2002) contend that concern over setting standards is unnecessary due to the iterative nature of LAC which means that quality standards (and associated indicators) can be revised as improved information becomes available.

With regard to the application of the LAC framework, it is evident that much if not all of the early application of this framework was undertaken by the US Forest Service, the initial developers of the framework (USDA Forest Service, 1987). Thus, McCool (1996) highlighted the fact that, at the time, LAC formed the basis for nearly all the protected area management planning by the US Forest Service. In 1994, Krumpe & Stokes (1994) reported that 75% of the 57 national forests in six western US states were applying the LAC framework as the basis for the recreational management of these areas. In addition to the United States, LAC has also been applied in National Park areas of Australia and New Zealand (Moore et al., 2003). By way of example, McKay (2006) has undertaken research into the general application of LAC in New Zealand based on the specific application of LAC in the Authors Pass National Park. In addition, McCool (1996) has previously sought to highlight the potential for implementing the LAC framework in National Marine Parks in Malaysia (though no subsequent literature appears to exist to indicate that such recommendations were undertaken). In a more general context, Cole & Stankey (1997) have also sought to highlight the potential for applying a more generic form of LAC beyond recreation management in wilderness areas to other recreation area types and tourism destinations.

#### *1.7.3.2 Visitor Impact Management*

The Visitor Impact Management (VIM) planning framework was developed for national parks by researchers working for the US National Parks and Conservation Association (Graefe et al., 1990). In contrast to LAC, this framework is focused on identifying and assessing the level of impact associated with visitor use of recreational areas regardless of the type of recreation occurring. A key feature of VIM is the establishment of general objectives for a recreational area, the identification of visitor impact indicators and setting of standards with respect to these indicators. Where standards are exceeded, such impacts are deemed to be unacceptable and management intervention is required (Newsome et al., 2002). An assumption of the requirement for management intervention is that the probable cause of unacceptable impacts should be identified. In addition, the means of intervention are not specified but Graefe et al. (1990) recommend the use of matrices for evaluating alternative intervention options. Notwithstanding this, an underlying objective of VIM is that management intervention should involve the development of strategies to keep visitor impacts within acceptable levels (Newsome et al., 2002).

In practice, VIM is a sequential process involving eight steps whereby general management objectives for a given recreation area are first reviewed and determined in the context of previous research and existing legislation and policies (Newsome et al., 2002). Objectives to be established can relate to both the desired visitor experience as well as the management of resources. Both social and ecological indicators are then selected in order to provide an indication of the level of visitor impact in the context of specific objectives (Newsome et al., 2002). The nature of such indicators can be diverse and ranges from quantitative measurements to qualitative ratings of visual condition (Moore et al., 2003). Cited examples include campsite area, damage to trees, quantity of litter and water quality. Standards, which correspond to the management objectives, are set for each indicator and a monitoring programme is initiated. Where standards are exceeded then the probable cause of this should then be ascertained and appropriate management strategies identified and implemented (Newsome et al., 2002).

Newsome et al. (2002) contend that a principle strength of VIM is the incorporation of scientific assessment with subjective judgment in order to guide visitor management strategies. Furthermore, Glasson et al. (1995) point out that the process of VIM recognises the need to understand factors behind the occurrence of impacts before management strategies can be implemented affectively. However, this can also be seen as a weakness due to the general difficulties in establishing the causative nature of environmental impacts. In addition, to achieve such objectives it may ultimately be necessary to determine the relationship between key impact indicators and visitor use patterns. Such an exercise is widely considered to be impractical (Glasson et al., 1995). In this regard, a further difficulty with VIM is that, as with the LAC framework, managers can be reluctant to set standards relating to resource condition due to the lack of reliable data on impacts and the potential consequences of poorly informed management decisions (Moore, Smith and Newsome, 2003)

With regard to the application of the Visitor Impact Management framework, a general absence of literature on this subject suggests that this framework has had little (reported) application beyond the original work by Graefe et al., (1990). This is despite (or perhaps because of) the similarities between this framework and Limits of Acceptable Change and the fact that the greater simplicity of VIM renders it more applicable to smaller recreation areas (Newsome et al., 2002).

### 1.7.4 Environmental Impact Assessment (EIA)

Environmental Impact Assessment (EIA) has been developed primarily as a tool for the assessment of proposed developments in the context of land use planning and construction (Schianetz et al., 2007; Scannell, 2006). In the European Union (EU) the concept of EIA has been formalised as a result of the EU Directive on Environmental Impact Assessment (Scannell, 2006). This directive requires that member states implement legislation to ensure that an Environmental Impact Assessment is undertaken for certain developments prior to planning approval. In the EU EIA is therefore applicable to the tourism industry where the nature and scale of tourism infrastructure development meets the criteria for EIA prior to planning approval and construction. A feature of EIA is it predictive nature. That is, EIA is normally used in anticipation of development with the assessment of impacts being largely based on the assessment of pre-development conditions and subsequent prediction of potential impact by expert opinion and analysis (EPA 2003; Scannell, 2006).

### 1.7.5 Environmental Audit (and Environmental Management Systems)

Environmental Audit (EA) is an established feature of the environmental management process. For example, EA plays a key role in the implementation of environmental management systems (EMS) as required by the International Standards Organisation (ISO) for their environmental performance standard, ISO 14001 (ISO, 1996). In this context, EA is used as an external audit of the environmental performance of an industrial facility measured against external standards and also environmental targets set internally by the facility. The use of EA is also promoted by the European Union as an integral component of environmental management systems as required for industrial facilities which fall under the requirements of EU Directive on Integrated Pollution and Prevention Control (Scannell, 2006). With regard to the tourism industry, Ding & Pigram (1995) highlight the fact that, in essence, EA is simply a monitoring tool which provides feedback about overall environmental performance of any given organisation and identifies opportunities for corrective action. In this context, Ding & Pigram (1995) stress the potential role that EA could play in monitoring the ongoing environmental performance of a tourist destination.

### 1.7.6 Ecological Footprint

Ecological footprint (EF) is largely an abstract concept which relates the resource use and waste production of a particular activity or population to an equivalent, but hypothetical, land area requirement or ‘footprint’ (Hunter & Shaw, 2005). The size of this footprint will vary according to the resource requirements of a particular activity and therefore EF allows comparison of the environmental performance of activities which may otherwise be distinctly different in nature (Schianetz et al., 2007). Hunter &

Shaw (2005) point out that EF has obvious, though under utilised, potential application with regard to the environmental sustainability of the tourism industry. Crucially, Hunter & Shaw (2005) argue that EF is unique in that it can provide a global perspective of the environmental affect of a particular form of tourism or recreation by taking into account wider resource implications such as travel to and from a destination.

### 1.7.7 Multi-Criteria Analysis

Multi-Criteria Analysis (MCA) is a desk based comparative tool which can be used to aid decision making in the context of alternative environmental planning and resource use options (Schianetz et al., 2007). The principal function of MCA is data analysis and the methodology is based on the selection of criteria for ranking alternative project or design options. A feature of Multi-Criteria Analysis is that it allows the evaluation of differing sets of both quantitative and qualitative data through the use of data standardisation, ranking and weighting protocols. However, Multi-Criteria Analysis is a theoretical tool which ultimately relies on the judgement of experts in setting desk based criteria and estimating the relative performance of alternative planning or project options (Schianetz et al., 2007).

### 1.7.8 Other Miscellaneous Methods of Assessment

Williams (1994) outlines five miscellaneous techniques of environmental impact analysis which have been used for tourism related studies. These are referred to as ad hoc procedures, overlay techniques, checklists, matrices and networks. Ad hoc procedures involve the assembling of specialists to identify impacts in their areas of expertise. Overlay techniques involve the use of land-use maps to identify sensitive areas and potential impact. Checklists techniques simply involve the use of master lists of different types of environmental impacts typically associated with various kinds of physical developments. Matrix techniques are essentially a more thorough version of the checklist technique where possible actions are cross-referenced against aspects of the environment that may be vulnerable to impact. Network techniques go a step further in so far as they try to determine the secondary and tertiary effects of tourism developments (Williams, 1994).

Ap & Crompton (1998) tested a method for the assessment of tourism impacts based on the development of a Tourism Impact Scale. This scale was based exclusively on the responses and opinions of residents and tourists and did not involve the collection of other forms of data. The scale was applied to the three primary domains of sustainable tourism (economic, social/cultural and physical/environmental) and the authors claim that it offers a useful measurement tool to tourism marketers and planners.

MacKay & Campbell (2004) tested a mixed method approach for assessing the environmental impacts of tourism in natural, outdoor recreational settings. This approach involved monitoring biotic, abiotic and cultural parameters as they related to hiking and camping activity in a backcountry area of a National Park in Canada. The biotic and abiotic parameters recorded concerned mainly vegetation patterns and soil condition. The cultural dimension of the study focused on use patterns by campers and their opinions on environmental impacts. Although, none of the individual assessment methods used were novel, the authors reasoned that combining the data recorded using the three methods provided a more comprehensive picture of backcountry camping impacts. In particular, MacKay & Campbell (2004) claimed that they were able to establish that visitors to the region greatly underestimated the environmental impact of their activities and were an unreliable source of opinion.

The Delphi Technique is an established forecasting method which has occasionally been applied within the tourism industry. This technique is again based solely on opinion (albeit of experts) and involves reducing uncertainty and achieving consensus through the use of successive questionnaire rounds (Moeller & Shafer, 1994)

## 1.8 The Need for an Alternative Method for Assessing the Environmental Sustainability of Tourism and Recreation Areas

This section explores the need for an alternative approach to existing methods used for assessing the environmental sustainability of tourism and recreation areas in the context of relevant literature. In considering this need, it is important to keep in mind the relatively narrow definition of environmental sustainability adopted for this research and to first make some important distinctions regarding these methods as described in the previous section. As will be evident from reading the following discussion, these distinctions affect the degree of relevance of these methodologies in the context of this particular research.

Firstly, such methods can be broadly divided into two opposing categories. That is, those which are primarily focused on the prediction of the consequences associated with proposed infrastructure development and those which are intended to monitor progress regarding the ongoing environmental record or performance of a particular tourism or recreation area (Schianetz et al., 2007). Schianetz et al. (2007) refer to these two categories of assessment as ‘prospective’ and ‘retrospective’ methods respectively. A second distinction can be made between methods involving some form of physical measurement in the field and those based solely on either expert or visitor opinion. Finally, a distinction can be made between methods which are intended to provide a site specific assessment and those providing assessment in a regional or even global context (Schianetz et al., 2007).

Given the definition of environmental sustainability adopted for this research, it follows that the focus of this thesis is on the evaluation and management of the ongoing, or 'retrospective', environmental quality occurring within the confines of established tourism and recreation areas. Existing assessment tools which are predictive in nature are therefore not considered directly relevant in this context. Examples of predictive tools include Environmental Impact Assessment and also some of the miscellaneous methods, discussed above, such as the Delphi Technique and overlay methods (Williams, 1994; Schianetz et al., 2007). In addition, ecological footprint is an example of a method which is intended to assess the environmental impact of a given activity beyond the physical confines of a particular geographical area (Hunter & Shaw, 2005). As discussed, the proposed methodology is intended to be site, or area, specific and hence the concept of ecological footprint also falls largely outside the scope of this discussion.

A number of the establish methods in question are based on opinion and surveys as opposed to physical measurement. These include the Delphi Technique, Multi-Criteria Analysis, overlay methods as well as the other miscellaneous methods described above such as those based on the use of impact scales, checklists or matrices. While Green, Hunter & Moore (1990) contend that such methods can be an effective and convenient means of identifying potential or perceived impact, Williams (1994) maintains that they are not intended to provide confirmation or an evaluation of actual impacts occurring in the field. Nevertheless, Schianetz et al., (2007) maintains that the technique of Multi-Criteria Analysis does offer potential as a mechanism for dealing with unrelated sets of data in environmental analysis. However, the technique appears complex and requires the cooperation of a panel of experts in order to form a consensus of opinion regarding criteria for data analysis and comparison of options. Notwithstanding this, it is important to note that these methodologies contrast, in a general sense, with the proposed methodology where the focus is on the physical or observed measurement of actual impact.

With regard to the existing methods which are based primarily on physical measurement and are specifically used to evaluate ongoing impact on a site specific basis, it is evident from the literature that five principal methods fall into this category. These are the concept of carrying capacity, environmental audit, the use of sustainability indicators and the two visitor planning frameworks; Limits of Acceptable Change and Visitor Impact Management

Tourism Carrying Capacity is a concept which initially held much promise as a method which could be used to assess the significance and implications of the environmental effects of tourism (Newsome et al., 2002). In theory at least, the calculation of carrying capacity should provide a convenient and quantifiable measure of the level of tourism which, if exceeded, would reduce the environmental sustainability of a given destination. In real terms, however carrying capacity is now recognised as a highly complex measure which must take account of an array of variables, often unrelated to each other, and complex cause and effect relationships (Collins, 1998; Hughes, 2002). In this respect, many authors have come to the conclusion that carrying capacity is an elusive and questionable concept which is difficult to apply in practice (Williams, 1994; Romeril, 1989; Farrell & Runyan, 1991).

Environmental Audit has had little application regarding the environmental impact of tourism to date (Ding & Pigram, 1995). However, it is has been identified by a number of authors as a useful tool which could be adapted and applied to the tourism and recreation sector (Ding & Pigram, 1995; Manning & Dougherty, 2000). Nevertheless, it is important to note that the effectiveness of Environmental Audit is ultimately determined by the ability of the audit team and crucially the standard and nature of data upon which the audit is based (Schianetz et al., 2007). Some of the limitations associated with the (environmental) indicator approach described in the following paragraphs are therefore also relevant to Environmental Audit. In terms of the actual application of Environmental Audit, Ding & Pigram (1995) also stress that there is currently a lack of any formal mechanisms for the implementation of an environmental auditing process in the tourism sector.

As previously discussed, both of the visitor planning frameworks (LAC and VIM) were developed as more practical alternatives to the carrying capacity concept (Krumpe & Stokes, 1994). Nevertheless, key aspects of these approaches and the sustainability indicator approach involve the acquisition and interpretation of environmental indicator data. In this regard, it is notable that the use of environmental indicators remains the predominant tool promoted and used within the tourism industry to assess environmental sustainability (Manning, 1999; Twinning-Ward & Butler, 2002). Furthermore, Hughes (2002) has reported that there appears to be a general optimism within the industry concerning the ability to devise ‘environmental indicators’ which will provide tourism managers with the necessary information to manage tourism in an environmentally responsible and sustainable manner. Hughes (2002) contends that this view is based largely on the assumption that the application of science to the challenges of environmental sustainability will provide unambiguous data that identifies the links between tourism, sustainability and environmental conservation. In practice, however, there is a growing recognition that the use of environmental indicators to provide empirical estimates of environmental effect and sustainability in tourism and recreation is associated with fundamental problems (Ceron & Dubois, 2003; Flanagan et al., 2007; Hughes, 2002; Twinning-Ward & Butler, 2002). It is evident that the majority of these problems are associated with limitations in the use and interpretation of environmental data used for indicator development. These limitations are complex but can be summarised as follows.

Firstly, the interactions between human activity and environmental systems are complex and hence the production and interpretation of environmental data will always be subject to varying degrees of uncertainty (Ceron & Dubois, 2003; Hughes, 2002). This is particularly the case where the selection of indicators relies on historical data which is available from sources external to the tourism industry (Flanagan et al., 2007). Hughes, (2002) argues that while such data may be useful in some respects it often lacks temporal and spatial consistency with trends in tourism thus further exaggerating any uncertainties within. Even where data is specifically recorded for a particular indicator the true relationship between data generated and the activity under scrutiny may still be unknown or difficult to establish (Ceron & Dubois, 2003).

A second limitation is that many aspects of environmental quality vital to tourism and recreation sustainability can be difficult or impossible to quantify numerically (Ceron & Dubois, 2003; Liddle, 1997). This applies particularly to the more abstract features of environmental quality such as visual condition of amenities or, for example, levels of overcrowding. Ultimately, it is argued that this presents the problem of establishing meaningful criteria for qualitative description of such effects. It is evident that this difficulty has led to a situation where some of the more qualitative aspects of the tourism environment relationship have been overlooked or avoided when identifying environmental indicators (Newsome et al., 2002).

Lastly, it is logical to assume that the environmental sustainability of a tourism and recreation area ultimately depends on the accumulated effects on environmental quality. These effects are naturally diverse and can only be recorded using a variety of quantitative and qualitative parameters which will naturally be measured in differing units and scales. Such data can be difficult to compare and also presents the problem of establishing a means by which the combined impact of these effects can be evaluated (Green et al., 1990). Ultimately, as Williams (1994) contends, the interpretation of combined indicator data tends to be ambiguous at best and invariably prone to subjectivity.

With regard to the sustainability indicators approach in particular, both Williams (1994) and Hughes (2002) argue that new and evolving methods need to be developed in order to address the limitations associated with this approach. In particular, Williams (1994) calls for the involvement of new disciplines such that a better appreciation of the influence of tourism on the natural and physical environments can be more clearly understood. In this context, Ceron & Dubois (2003) also stress the need to develop mechanisms which will collect new indicator data and which will assess the quality of the data on which more established indicators are built. This position is supported by Farrell and McLellan's (1987) early contention that a multidisciplinary approach is required in order to address the complex relationship between tourism and the natural environment.

With regard to the above, Environmental Audit and Multi-Criteria Analysis are methods which are considered by Ding & Pigram (1995) and Schianetz et al. (2007), respectively, to have useful potential. However, as yet there is no formal framework for the application of these methods to the tourism industry. In addition, the visitor planning frameworks, Limits of Acceptable Change and Visitor Impact Management do go some way to address the above issues. In particular, they provide a more structured and management focused approach than the sole use of sustainability indicators. However, with these methodologies there is still no formal or explicit technique for addressing the issues which arise when using environmental data as the basis for setting quality standards and making management decisions. As Glasson et al. (1995) point out, this presents the likelihood that quality standards will be set and upheld without due regard for the potential limitations in the environmental data used.

## 1.9 Risk Assessment as an Alternative Approach

### 1.9.1 Introduction

As described in the following sections risk assessment methodologies have been specifically developed in order to address relationships and data with inherent uncertainties and to allow a more structured approach to subsequent decision making. In more recent years social science approaches to risk assessment have also been developed which allow the combined interpretation of unrelated sets of either qualitative and/or quantitative data. Specifically these approaches are designed to overcome the difficulties of evaluating impact or risk arising within complex or abstract systems where the relationship between cause and effect are multifaceted and difficult to quantify (Waring & Glendon, 1998). Such complexities are synonymous with tourism and the natural environment (Hughes, 2002; Ceron & Dubois, 2003) and thus the proposal to use a risk assessment based approach to assess the environmental risk or impact from tourism presents itself as a logical extension of the risk based methodologies currently being developed by scientists, engineers and social scientists.

### 1.9.2 The Risk Assessment Concept

#### *1.9.2.1 Risk and Risk Assessment*

In a landmark publication, the Royal Society (1992) defined risk as: ‘the probability that a particular adverse event occurs during a stated period of time, or results from a particular challenge’. To meet the needs of engineers and scientists who specialise in risk studies, the Royal Society report also included definitions from British Standard No. 4778 (1991) which defined risk as ‘as a combination of the probability, or frequency of occurrence of a defined hazard and the magnitude of the consequences of the occurrence' (Royal Society, 1992). The UK Dept. of Environment (1995) defines risk assessment as simply the structured gathering of information about risks and the formation of judgments about them.

In a general sense, therefore, risk assessments are intended to inform decision makers about effective actions for managing risks, that is, avoiding, removing, reducing, improving and generally controlling risks (Waring & Glendon, 1998). Risk Assessment is a central component of risk management. The Royal Society Study Group considers that risk management involves 'the making of decisions concerning risk and their subsequent implementation and flows from risk estimation and risk evaluation' (Royal Society, 1992).

Notwithstanding the variety of existing definitions of risk assessment, a number of traditional schools of thought concerning the theory and practice of risk assessment are recognised (Amendola, 2002; Barlow & Illing, 1998). The Royal Society (1992) has conveniently categorised these schools of thought into science based, engineering based and social science based views of risk assessment. More recently, Cox & Tait (1997) have identified an emerging approach to risk assessment which they refer to as 'user practitioner risk assessment'. This approach combines the more practical elements of both science and social science approaches to risk assessment. In addition, risk assessment methodologies have now also been adapted in order to address specifically the threat of chemical and/or industrial risk to ecological systems. These approaches are known as Environmental Risk Assessment (ERA) or Ecological Risk Assessment (EcRA) and they are largely based on the science school of thought regarding risk assessment (EEA, 1998; US EPA, 1992). A description of all the aforementioned approaches to risk assessment follows:

#### *1.9.2.2 Science Based Risk Assessment*

Science based risk assessment is normally used within the disciplines of toxicology and epidemiology and is broken up into four components (Royal Society, 1992). The first component is known as hazard identification. This involves identifying biological, chemical or physical agents that may have adverse effects on recipient populations or ecological systems. In the second component, establishing a dose response curve or assessment (also known as hazard characterisation) is carried out and consists of determining, in quantitative terms, the nature and severity of the adverse effects associated with the causal agents or activity. This can be done from laboratory controlled studies on biological agents on animals or humans or by epidemiological studies. The third component is exposure assessment. This consists of quantitatively evaluating the probability of exposure to the agent under study. Apart from information on the agents themselves (source, distribution, concentrations, characteristics, etc.) there is a need for data on the probability of contamination or exposure of the population or environment to the hazard. Lastly, the risk characterisation component corresponds to the qualitative estimation, taking account of inherent uncertainties, of the combined probability of the frequency and severity of the known or potential adverse environmental or health effects liable to occur (Royal Society, 1992).

#### *1.9.2.3 Engineering Risk Assessment*

According to Hurst (1998) engineering risk assessment is usually considered to involve an estimation of the risk and then an evaluation of the significance of the risk. The techniques of risk estimation often involve the discipline referred to as Quantified Risk Assessment (QRA) (Frosdick, 1997). QRA is defined as 'the identification of causes of possible accidents followed by a technical analysis to determine the likelihood of occurrence and potential consequences of those accidents leading to a numerical estimate of an appropriate measure of risk (Wells, 1996).

In essence, engineering risk assessment is largely based on measured probabilities of structural or mechanical failure and the consequences of that failure. However, in practice, engineers also acknowledge that public perception of risk depends very much on beliefs, feelings and judgements (Frosdick, 1997). Hence, it can be argued that there will always be an element of subjectivity and qualitative analysis when making decisions based on measured risk. However, engineers maintain that in order to create a target for their risk assessment technique it is necessary for them to quantify numerically what is considered an acceptable risk (Frosdick, 1997). That said, if fully quantitative methods are not practical, engineering approaches to risk assessment do allow the use of semi-quantitative approaches which allow for expert subjective judgments to be made regarding the measurement of risk (Frosdick, 1997).

#### *1.9.2.4 Social Science Risk Assessment*

Social science risk assessment is a general term used to describe 'the process of gauging the most likely outcomes of a set of events, situations or options and the significant consequences of those outcomes' (Waring & Glendon, 1998). Although, it is generally qualitative and relies on individuals' collective judgement, the social science approach to risk assessment may also include some form of quantification (Waring & Glendon, 1998).

In practice, a social science risk assessment may include observational and predictive studies and psychometric analysis and may take account of human reliability data and human error. Social science risk assessment usually involve the use of a questionnaire, structured interview, semi-structured interview and/or focus groups (Royal Society, 2005).

One of the arguments in favour of social science based risk assessment is that the general public's view of risk assessment can be influenced by attitude, climate or culture, behaviour and knowledge (Cox & Tait, 1997). Thus when taking steps to address or alleviate risk, strictly quantitative measures of risk are not always considered appropriate.

#### *1.9.2.5 User/Practitioner Risk Assessment*

Basic human motivations of predicting and controlling our surroundings, mediated by managerial and organisational imperatives for effectiveness and survival, have combined to produce formal risk assessment methodologies (Waring & Glendon, 1998). All approaches to risk assessment share the common purpose of estimating or assessing a particular risk or set of risks on the basis of the best available information which, by its nature, is often imperfect (Waring & Glendon, 1998). With the exception of social science approaches, the techniques of risk estimation mentioned above are largely quantitative (Frosdick, 1997). In this regard, Waring & Glendon (1998) note that the detailed but narrow base of technical knowledge on which many quantified risk assessments are made creates a false, reduced picture of real-world settings in which risk behaviour can be very complex. Because the concept of risk is multi-dimensional, Waring & Glendon (1998) argue that different approaches to risk assessment are required to cover the variety of risks and their contexts.

User/practitioner risk assessment is such an approach and is essentially an adaptation of established risk assessment techniques with an emphasis on the social science model (Cox & Tait, 1997). This approach acknowledges and utilises the strengths of established risk assessment techniques by allowing for the application of both quantitative and qualitative elements of these methodologies as and when appropriate to a particular situation. It is used extensively in disciplines such as safety management (McDonald & Hrymak, 2002) and is designed to overcome the difficulties of evaluating impact or risk arising within complex or abstract systems where the relationship between cause and effect are multifaceted and often difficult to quantify (Waring & Glendon, 1998).

#### *1.9.2.6 Environmental and Ecological Risk Assessment*

Established science based risk assessment methodologies are primarily associated with the toxicity of chemicals and human health and safety. However, with the increasing concern for the environment in recent decades the scope of risk assessment has been broadened to include effects on natural ecosystems. This has led to the development of the disciplines of Environmental Risk Assessment (ERA) and Ecological Risk Assessment. A number of international organisations have been involved in the development of ERA. These include the UK Dept. of Environment (1995), the European Environment Agency (1998) and the Organisation of Economic Co-operation and Development (OECD). ERA largely follows the approach of the more established scientific based risk assessment. As with science based risk assessment methodologies the discipline of Environmental Risk Assessment is also normally associated with the toxic hazards presented by chemical or industrial waste production for example (EEA, 1998).

Ecological Risk Assessment is a process that has been developed by the United States Environmental Protection Agency (US EPA, 1992). As with ERA, it employs a scientific perspective, which evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors. Notably, it is a process which is used to systematically evaluate and organise data, generated from situations where there may be inherent uncertainties and ambiguities, in order to produce a dose response curve (US EPA, 1992). This process can therefore help understand and predict the often ambiguous relationships between stressors and ecological effects. As with Environmental Risk Assessment, the discipline of Ecological Risk Assessment has primarily been applied to the chemical industry (US EPA, 1992).

# Chapter Two

# THE RISK ASSESSMENT MODEL

## 2.1 Aims of the Model

The risk assessment model, as developed, is intended to provide a structured and integrated methodology for the assessment of environmental sustainability at tourism and recreation areas. Inherent in this intention is a need to provide a realistic and practical evaluation of the environmental quality of such areas and an assessment of factors adversely affecting this quality. In addition, it is imperative that the model provides a means of communicating the findings of such assessment in order that this information can be used to aid the successful management of the tourism and recreation areas under investigation.

As discussed earlier a number of fundamental difficulties exist when attempting to assess factors affecting the environmental quality of a given area. In this respect, a key issue concerns the need to be able to obtain and combine environmental data in a manner that can provide meaningful evaluation of environmental effects. At the core of this difficulty are three key factors which the proposed model is intended to address:

(i) Although recognised scientific measurement of environmental parameters (be they physical, chemical or biological) has proven levels of accuracy and reliability, the interpretation of any environmental data is prone to issues of uncertainty. This is due to the complex behaviour of environmental parameters generally and is particularly the case when trying to establish possible causes and effects regarding such parameters within the natural environment.

(ii) Many aspects of environmental quality are perceptive in nature or relate to biological systems and therefore can be difficult to quantify.

(iii) Data generated in respect of different elements of environmental quality are recorded in differing units and are therefore difficult to combine or interpret collectively.

Given the above problems associated with environmental data, a number of underlying objectives of the proposed model are identified. These are summarised below:

- The model should allow for the identification of key parameters which are intrinsically linked to environmental sustainability.
- It should account for uncertainties in environmental data as and where possible.
- It should allow for more meaningful interpretation of recorded environmental data through the identification and analysis of data trends and patterns
- It should provide a means by which the significance of complex environmental data can be usefully communicated in a manner that is understandable and encourages effective management intervention.

The proposed model addresses the above factors and objectives within a single risk assessment based framework (or methodology). This framework is intended to be flexible and allow for the incorporation of elements of established methods for environmental assessment. Thus, the proposed model draws mainly from the evolving fields of user/practitioner risk assessment and environmental risk assessment and also incorporates elements of other disciplines including Environmental Management Systems (EMS), Environmental Audit and Environmental Impact Assessment. Crucially, the proposed methodology is management focused and is intended to provide and present data in a manner which will both aid and promote decision making with respect to the environmental sustainability of tourism and recreation areas.

## 2.2 Development of The Model

The concept model for the proposed risk assessment approach to evaluating the environmental effects of tourism and recreation is shown in Figure 2.3. The basic three stage framework of the model (incorporating Risk Assessment, Risk Evaluation and Risk Management) has been adapted from frameworks developed by the Royal Society for generic uses of risk assessment (Waring & Glendon, 1998) (see Figure 2.1) and also by the European Environment Agency (EEA, 1998) (see Figure 2.2) and the US Environmental Protection Agency (1992) for Environmental and Ecological Risk Assessment (ERA). Whereas the principal focus of ERA is on the assessment of chemical hazards their environmental effects, the focus of this methodology is on the hazards to sustainability presented by activities internal or external to the tourism and recreation industry. The adaptation made to the ERA framework is therefore designed to address the perhaps more complex and less quantifiable nature of risk due to tourism and recreation. This is achieved by placing an emphasis on and expanding the risk evaluation and risk management stages of ERA. These stages represent key steps in the proposed concept model. Details of each stage are given in the following section.

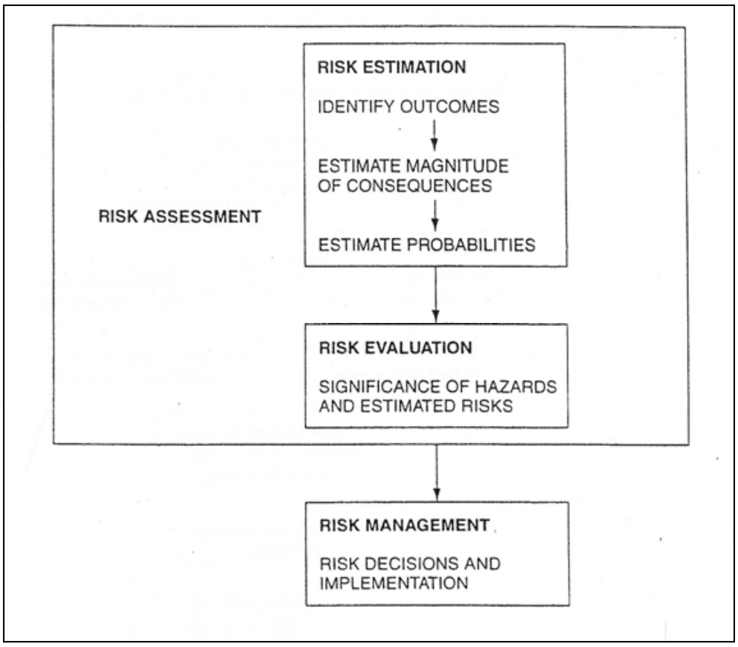



**Figure 2.1 – Generic Model for the Risk Assessment Process Developed by the Royal Society (Waring & Glendon, 1998)**

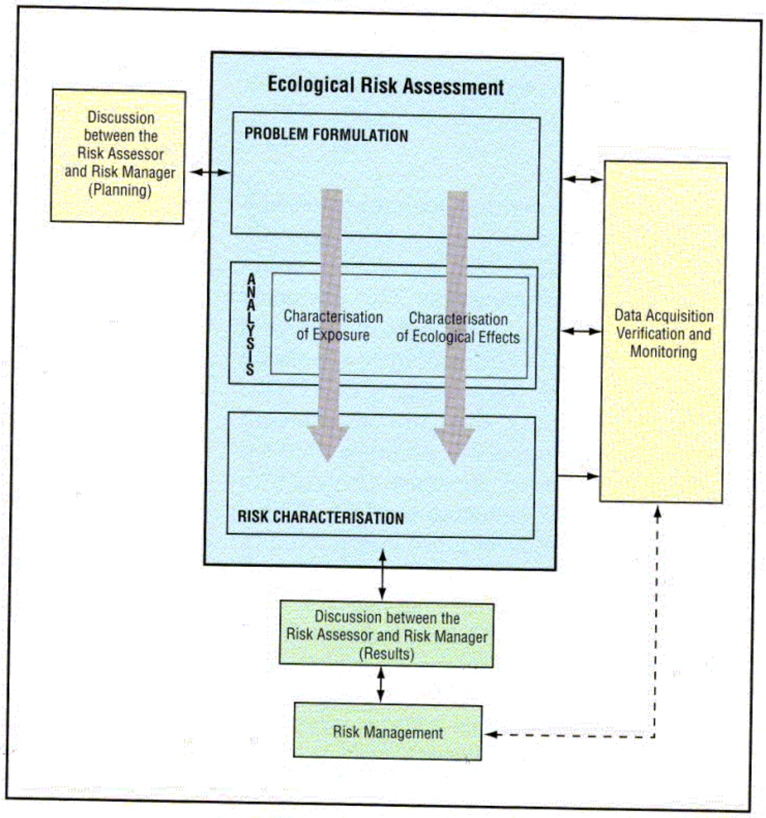



**Figure 2.2 – European Environment Agency (1998), Model For Ecological Risk Assessment**

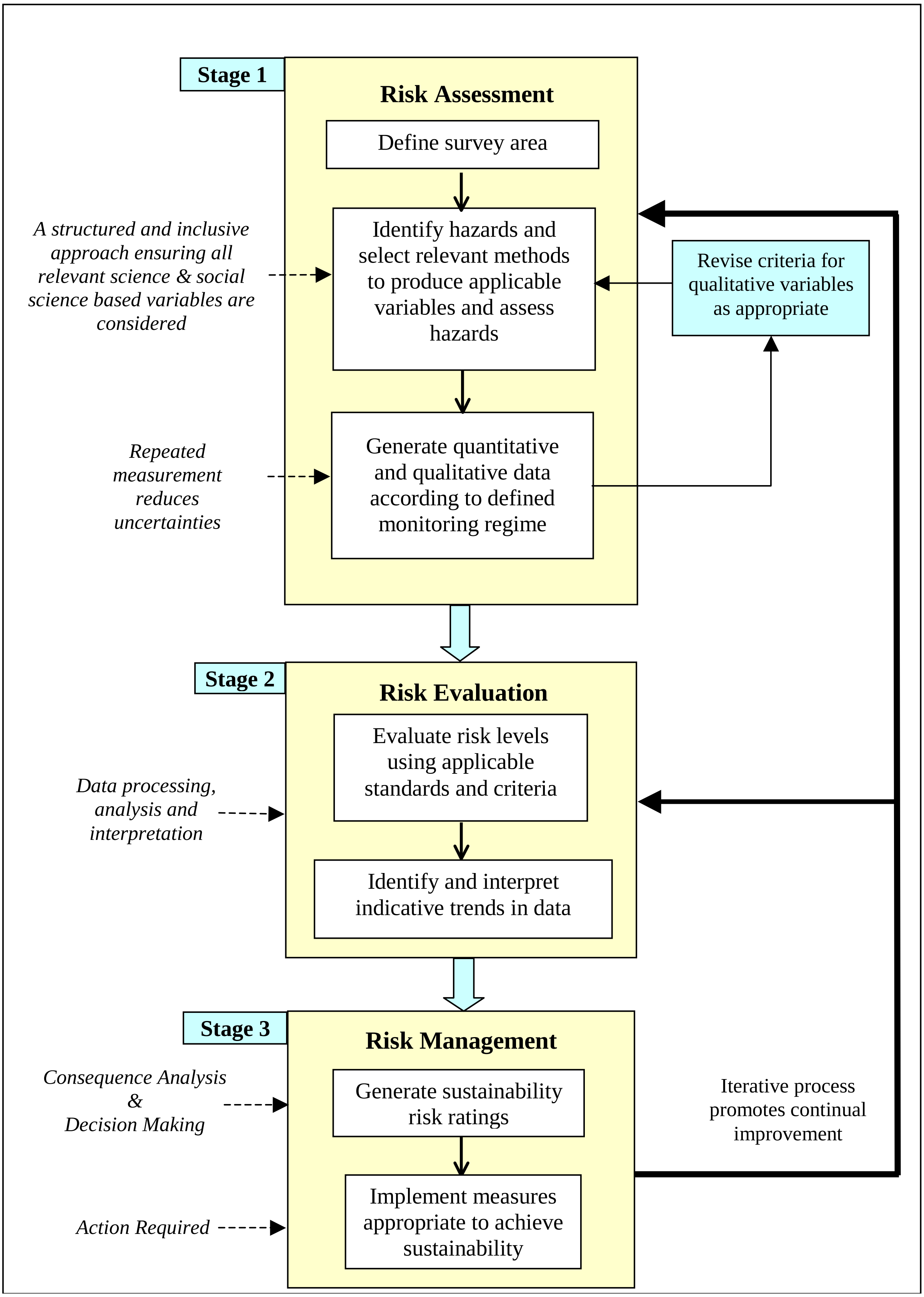



**Figure 2.3 - The Risk Assessment Model**

## 2.3 Structure of the Model

### 2.3.1 Stage 1 – Risk Assessment

#### *2.3.1.1 Definition of Survey Area*

Tourism and recreation areas normally consist of multiple systems and zones with natural elements overlapping man-made structures and modified landscapes (Newsome et al., 2002). This means that many potential hazards to environmental quality may be unapparent and easily overlooked. In order to address this, the initial step of the first stage of the model involves dividing the area under investigation into a number of constituent subsystems or elements (natural and man-made) which are considered likely to be of significance regarding the environmental sustainability of the area. The choice of elements is not prescribed, as this will differ depending on the type of destination under investigation. The intention is that a defined area is divided into a number of smaller units thereby facilitating a more effective hazard identification process. This approach was developed originally in the discipline of architecture where the delineation of a site to identify applicable variables is an established surveying technique (Wells, 1997). In this instance, by way of example, a destination might be divided into some or all of the elements listed below:

- Natural habitat (specific examples might include areas of woodland, meadow, foreshore, river and lake shoreline).
- Wildlife (including wild birds, mammals and invertebrates for example).
- Visual amenity (including views and the condition of man-made structures such as buildings or monuments).
- Natural resources (including water quality, air quality and the noise environment).

- Physical amenities (including lawns, landscaped areas, picnic areas and walkways for example).
- Infrastructure (including access roads, parking areas, toilets and recreational facilities such as marinas or slipways).

#### *2.3.1.2 Hazard Identification and Selection of Variables and Monitoring Methodologies.*

The next step prescribed by the model is the identification of potential hazards to environmental sustainability. This should be undertaken using a technique known as structured observation. This technique consists of a systematic and pre-ordered observation of all conditions and behaviours in the survey area. Again this approach is extensively used in the architectural profession (Wells, 1996) and has also been adapted for social science risk assessment methodologies. For example, the technique is now used routinely in the field of safety management in order to decrease the possibility of overlooking potential hazards existing within multifaceted systems or structures (McDonald & Hrymak, 2002).

Once potential hazards are identified the next prescribed step is the selection of appropriate variables and monitoring methods which can be used to assess these hazards and ultimately verify the level of risk presented. Traditionally, the monitoring of environmental variables has relied on quantitative methods of analysis derived from the field of science (Wells, 1996). Such analysis can provide accurate and reliable data particularly with respect to parameters such as air and water quality or, for example, the noise environment. The expertise and cost of equipment required for these methods of analysis tends to vary greatly. However, recent advances in analytical technology means that many scientific methods of analysis are now affordable, accessible to semi-skilled personnel and may be carried out in the field using handheld instruments.

Despite the recognition afforded to scientific methods of analysis, it is also recognised that the scope of their application can still be limited (Royal Society, 1992). In practice, many environmental parameters cannot be measured quantitatively or in a strictly analytical manner. This is particularly the case with impacts related to perception such as those affecting the visual amenity and condition of an area. Impacts relating to natural habitats and ecological systems are also notoriously difficult to quantify (Liddle, 1997). Although it may not be possible to measure these types of impact in a quantitative manner their importance in the context of environmental sustainability is nevertheless recognised and therefore addressed in the model.

In this regard, the model specifies the use of qualitative descriptors as a means of assessing impacts that are more perceptive or subjective in nature and which are difficult to measure quantitatively. Qualitative (or Likert type) descriptors are drawn from established social science risk assessment methodologies and are used in this discipline to describe an observed effect or condition within the defined area of investigation (Waring & Glendon, 1998). In risk assessment, descriptor scales can range from three to five or even seven points and are often used to define risk categories based on specified criteria (Manuele, 2008). Such category scales therefore form the basis of a qualitative, or descriptive, risk ranking systems (Manuele, 2008). Specifically the model prescribes that qualitative variables should be recorded on a three point risk category scale using the descriptors; low, medium and high. The recording of such variables is undertaken, in the field, on the basis of direct observation and by way of reference to specific criteria or guidelines prescribed for each descriptor (or risk category) and variable. In turn, the criteria for each risk category and associated variable should be based on relevant and established standards of environmental quality where they exist (see Section 2.3.2 for further explanation of this approach). This approach is a well practiced and evidenced technique in social science based risk assessments. For example McDonald & Hrymak (2002) have successfully used this approach when assessing safety management performance on construction sites. Examples of other disciplines where this approach has been used include the definition of Ecological Status Classes with respect to the Water Framework Directive (EPA, 2005), the qualitative measurement and risk assessment of the environmental effects of shellfish farming in Tasmania (Crawford, 2003) and the risk management of pedestrian surfaces in Melbourne, Australia (Hunt-Sturman & Jackson, 2009).

A further consideration of the methodology is that many impacts which may affect environmental sustainability can be measured easily by using simple observational counts. Such impacts might include, for example, the occurrence of litter, traffic or wildlife. These impacts can be of real significance in the context of environmental sustainability and therefore observational counts are a key feature of the proposed methodology.

In summary, a requirement of the model is that all potential hazards identified at a survey area should be monitored where possible. Although it is recognised that ideally the data generated should be as objective, accurate and reliable as possible, it is also recognised that the selection of hazard identification methods will ultimately be governed by costs, practicalities and available resources. As a guide therefore, the following criteria should be used when selecting methods of analysis to generate a range of variables for subsequent monitoring:

a) Where they exist, scientific (quantitative) methods of analysis should be used if they are practical and provide meaningful data regarding the parameter in question.

b) Where a number of alternative quantitative methods exist due regard should be given to the associated practicalities, benefits and costs of each technique and of the significance of the parameter in question.

c) Where appropriate quantitative methods of analysis are not available or are not applicable then qualitative descriptors should be used to describe observable effects.

d) Structured observational counts should be used as and where applicable.

Although the model prioritises the use of quantitative methods of analysis where possible, it is also an intention of the model that an emphasis is placed on maximising the range of variables monitored rather than strictly on the accuracy and reliability of data generated from individual variables. Thus, when allocating resources to the selection of variables and generation of data, a trade off must be established between the need for highly accurate quantitative data and the need for as broad a range of variables as possible.

Completion of this step of the model should produce a comprehensive list of environmental variables identified for the tourism and recreation area under study. These variables represent the possible conditions, behaviours and hazards which may affect the environmental quality of the area under study and ultimately its sustainability. In addition, the methodologies to be used to monitor these variables should be identified and clearly defined. By way of example, the list of environmental variables identified with respect to this research is given in the Methodology chapter in Section 3.3.

#### *2.3.1.3 Generating Quantitative and Qualitative Data – The Role and Nature of Monitoring.*

The complex nature of natural systems and the interactions of human activities has been discussed earlier in this thesis. In this respect, it is recognised that it can be difficult to make accurate interpretations regarding such systems and interactions based on individual measurements of environmental parameters. To address this, a key stipulation of the risk assessment model is that regular and structured monitoring of a wide range of environmental variables is undertaken. This approach is deemed necessary in order to establish, where possible, the natural behaviour over time of recorded environmental variables. Consequently this approach should also allow the identification of any significant variations associated with other relevant factors such as the changing levels of tourism and recreational activity associated with low and high seasons. In general, this requirement for repeated measurement of multiple variables will serve to reduce the uncertainty regarding the significance of measured variables in the context of sustainability. Notwithstanding this, it is recognised that this approach will not necessarily isolate the actual links between cause and effect. However, it will allow the creation of an overall picture of natural fluctuations occurring in the environment and possible influences of recreation activity occurring. Such a picture can be used to help inform judgements which must be made regarding the significance of observed environmental effects as outlined in the following section.

Although the frequency of monitoring undertaken may ultimately be dictated by available resources, this is still an issue which must be given some consideration. Newsome et al. (2002) point out that the required frequency of sampling can really only be determined once some idea of potential data variability has been determined. In practice, this may take some time to establish and therefore it is envisaged that where possible site visits should initially be carried out on a weekly basis until deemed otherwise. A further consideration here is that because a variety of variables are sampled, the variable which requires most frequent sampling will ultimately determine the frequency of site visits. With regard to the duration of monitoring it is recommended that monitoring should initially cover the course of an entire year, covering both the low and high tourist seasons.

### 2.3.2 Stage 2 – Risk Evaluation

#### *2.3.2.1 Evaluating Sustainability Risk using Applicable Standards.*

Implementing a monitoring regime, as described above, will generate a range of values recorded for each variable over the course of the monitoring period. A key challenge of this methodology is to interpret meaning from these recorded values and communicate their significance in the context of sustainability. In addition, it is recognised that it is equally important to communicate the combined significance of recorded variables in this regard. The model addresses this difficulty by converting all quantitative data to the same three point risk category scale used to record the qualitative variables. Assigning the quantitative values to these risk categories (low, medium and high) is also undertaken using predefined criteria which are based on established external standards of environmental quality where they exist. In line with contemporary approaches to risk assessment (Amendola, 2001; EEA, 1998; USEPA, 1998), these risk levels are intended to represent or characterise the likely level of risk to sustainability associated with recorded variables, as expressed in terms of the level of non-compliance with recognised environmental quality standards. Given the management focus of the risk assessment model, this characterisation of risk is in intended to greatly simplify both the interpretation and communication of multiple and complex data sets. In addition, this approach also means that both qualitative and quantitative data are ultimately express in the same terms. This ultimately enables the assessment of the combined significance of such data (see Section 2.3.3 regarding the risk management stage of the model).

This representation of quantitative data in terms of qualitative descriptors, in order to aid its interpretation and communication, is again a feature of social science approaches to risk assessment (Amendola, 2002; McDonald and Hrymak, 2002; Manuele, 2008). In addition, this technique is also used in environmental management. For example, the Irish Environmental Protection Agency have developed a biological water quality ranking system, known as the Q-Rating System, which is based on the relative proportion of different recorded species of invertebrates (Toner et al., 2005; Clenaghan, 2003). The Organisation for Economic Cooperation and Development (OECD) have developed a similar ranking system, based on recorded physical and chemical parameters, for defining the trophic (nutrient) status of lake waters (OECD, 1982). Cairncross, John & Zunckel (2007) have also used this approach in order to develop an air pollution index based on mortality risk associated with short-term exposure to common pollutants.

With regard to the use of external standards for producing risk category criteria, it is noted that such standards exist for a variety of environmental parameters such as, for example, air and water quality. These standards may take the form of limit values set by government legislation or they may exist as guidelines set by semi-state or non-government organisations. Examples of the former include air quality standards or legal limits set for industrial noise emissions. Examples of the latter include bathing water guidelines such as those set for the Blue Flag Beach Standard in Europe (FEE, 2008). Although many such standards may not have been set with the tourism and recreation industry in mind, they still represent an authoritative means by which the significance of observed values of different variables can be interpreted and understood in the context of environmental sustainability.

A common feature of standards applicable to environmental variables is that a range of values is often specified or different standards specify different values. This discrepancy usually reflects the range of opinion as to what level is considered appropriate for a given variable. However, in the case of this model any identified range in standards can be used to set the levels of cut off points for the low, medium or high risk categories.

Where specific and formal standards do not exist for a given variable (prevalence of litter for example) then the subject literature should be explored in order to ascertain if any tolerance levels or guidelines exist with respect to the variable in question. Failing this then discretionary standards or criteria may be set for any remaining variables. Although this will obviously involve a subjective and value laden exercise, an important consideration here is that the purpose of any assigned criteria is to set a benchmark against which environmental quality can be compared. Ultimately, the intention of any such criteria, either set arbitrarily or using external standards, is intended to drive improvements in environmental quality and therefore promote environmental sustainability. Again this use of applicable standards is an established social science based practice when assessing risk (McDonald & Hrymak, 2002; Waring & Glendon, 1998).

#### *2.3.2.2 Identifying and Interpreting Indicative Trends in the Data.*

This step is undertaken in order to provide greater understanding of the factors influencing the recorded values of selected variables. As discussed earlier, frequent monitoring of environmental variables over a protracted period can be used to generate an overall picture of how variables behave over time. A variety of possible factors can influence this behaviour including those associated with natural phenomenon and those associated with human activity (including tourism and recreation activity). The analysis of fluctuations and trends in the recorded data can provide some insight into which factors are at play with respect to a given variable. In particular, this analysis can provide an indication as to possible causes poor environmental quality as and when they occur.

In this respect, an underlying assertion behind this methodology is that the seasonal nature of tourism provides an opportunity to examine the behaviour of environmental variables with respect to the varying levels of tourism activity which occur through the course of a given year. This provides a means of identifying the potential role of tourism and recreation in the behaviour of these variables. In the same manner, the analysis of differences in values for given variables undertaken at different locations can also provide useful information.

With regard to the above, where the values recorded in respect of a particular variable during the high tourist/recreation season are noticeably different from those recorded during the low season it is useful to determine whether this difference is statistically significant. This can be achieved using simply statistical tests of significance and can determine whether the difference is actually significant and not due to other factors (such as random error or natural variation) causing the observed variations in the data. In addition to such statistical significance tests it is also useful to take into account the following possible attributes of the data:

- The level of variance or standard deviation in the recorded data values.
- Any significant trends identified in the data that provides insight into the behaviour of a variable with respect to season and location.

It is also important to note that where significant difference are determined in the values of variables recorded during the high and low seasons this does not assume an association with tourism and recreation activity. Instead, such analysis is intended to simply highlight significant features regarding the behaviour of the variables under investigation throughout the course of a year. In this respect, it is acknowledged that seasonal variations in the behaviour of certain variables may be due not just to the effects of tourism and recreation but to any number of either natural or other anthropogenic influences. Notwithstanding this, the trend analysis is nevertheless intended to provide a basis upon which possible cause and effect relationships, with respect to tourism and the environment, can be inferred from the generated data. Any significant features that are identified will be of importance regarding the Risk Management stage of the methodology.

### 2.3.3 Stage 3 - Risk Management

#### *2.3.3.1 Generation of Sustainability Risk Ratings.*

The data generated by the first two stages of the model will be expressed in terms risk categories recorded in respect of each variable. This data can be presented in terms of the relative proportion, or frequency distribution, of the risk categories recorded over the assigned monitoring period. Although, this form of data will provide valuable information regarding each individual variable, it is recognised that interpreting the significance of risk category frequency distributions for multiple variables would be impractical, particularly in a management context. The principal aim of the risk management stage of the model is therefore to provide a framework for condensing this data and allowing the presentation of key findings in a concise manner which is easy to interpret and encourages effective decision making. To achieve this the concept of 'sustainability risk ratings' are introduced into the model.

Sustainability risk ratings are used simply as a means of representing the relative proportion of high, medium and low risk levels recorded for each variable (quantitative and qualitative) as a single score or rating. The rating is based on a percentage scale (that is, from 1 to 100) and is calculated on the basis of a weighting applied to each risk category (see Section 3.4 in the Methodology Chapter for further explanation). Thus where a greater proportion of high risk levels are recorded for a particular variable then the sustainability risk rating will be closer to 100. Where a greater proportion of medium or low risk levels are recorded then the rating will be closer to 0. In effect, this rating system allows the portrayal of complex data regarding the level of non-compliance of variables with environmental quality standards (expressed in terms of risk levels) as a single figure or score. A key consideration here is that a higher sustainability risk rating implies a less satisfactory situation in the context of environmental sustainability.

In this manner, the rating provides a useful indication of the potential threat to environmental sustainability associated with each recorded variable, with a high rating representing a greater threat. In addition, it is intended that ratings generated with respect to individual variables can then be amalgamated (or averaged) in order to generate combined ratings for groups of variables or a particular study area. Thus comparisons can be made between different areas and between different groups of related variables.

Scoring or rating systems are a feature of modern approaches to risk assessment but vary in their mode of application and level of complexity (Manuele, 2008). Specifically, for example, similar scoring systems have been used in the risk management of pedestrian surfaces (Hunt-Sturman & Jackson, 2009) and the risk assessment of the environmental affects of shellfish farming (Crawford, 2003) and air pollution (Cairncross et al., 2007). In addition, Moore et al. (2003) cites a number of examples where scoring systems have been applied in the case of tourism planning frameworks such as Visitor Impact Management.

#### *2.3.3.2 Implementation of Measures Appropriate to Achieve Sustainability.*

This final step is ultimately considered a management issue which involves implementing measures deemed appropriate to achieve sustainability based on the findings of the implemented risk model. The nature of these measures is not specifically addressed by the model which focuses, instead, on generating the information necessary to identify where and when measures are required. Nevertheless, environmental management standards which allow environmental performance to be assessed using internationally recognised practices may be useful in this process. ISO 14001, for example, would be a relevant standard with which the measures implemented to promote the environmental sustainability of tourism destinations could be assessed.

Finally, an underlying aspect of the risk management stage of the model is the concept of risk tolerance or risk acceptance as it is now more commonly referred to. This concept originates from established risk assessment methods and stems from the assumption that it is often unrealistic to attempt to eliminate all risk arising from a particular activity (Royal Society, 1992; Waring & Glendon, 1998). Risk practitioners strive instead to achieve a level of risk which is considered acceptable in the context of the hazard in question. It can be argued that a similar situation presents itself with regard to the tourism and recreation industry and environmental sustainability. Thus, it is envisaged that it is up to relevant authorities to decide on the level of risk to sustainability, as indicated by the findings of this methodology, that is considered acceptable. In this manner, it would be expected that most authorities would not pursue a zero sustainability risk rating for a given tourism and recreation area but rather a decision would be made on a level that would require action. Such a decision would be based on a general review of findings for the area in question as well as findings of trend analysis. In addition, repetition of the methodology prescribed by the model would provide additional insight into the nature of sustainability issues at the area and any expected action of recourse.

# Chapter Three

# METHODOLOGY

## 3.1 Introduction

The following research methodology is based on the application of the risk assessment concept model at the two chosen study areas, Lough Derg and Dublin Bay. This model provided the overall framework from which this detailed methodology was developed. This Methodology Chapter therefore describes in detail the finalised methodology as applied and tested at the six study sites within the Lough Derg and Dublin Bay study areas. Key elements of the methodology include the selection of study sites, the identification of environmental variables and the means by which collected data was analysed and processed. In addition, the final section of this Chapter provides a detailed description of all selected variables together with an outline of the materials and methods required for their sampling and analysis.

### 3.1.1 Aims and Objectives

The general research aim was to devise and test a risk assessment based model for assessing the environmental sustainability of tourism and recreation resources. In pursuit of this aim six specific research objectives were established. These are as follows:

1. To develop the aforementioned model in line with current practice in the field of risk assessment.
2. To develop a detailed methodology, based on the risk assessment model, and implement it at two contrasting study areas.

3. To carry out trend analyses in order to identify features or patterns of significance in recorded data.
4. To describe key findings arising from the research undertaken.
5. To assess the strengths and weaknesses of the methodology in the context of the research findings and in the context of relevant alternative methodologies.
6. To identify conclusions and make recommendations concerning this area of research.

### 3.1.2 Summary of Applied Methodology

The methodology was first applied to the three study sites within the Lough Derg study area (Terryglass, Dromineer and Meelick Bay). The associated field research was carried out over a period of 13 months between November 2006 and December 2007. The methodology was subsequently applied to the three study sites within the Dublin Bay study area. This research covered a period of 10 months between February and November 2008.

The key elements of the applied methodology were the same for all six study sites and followed the framework set out in the devised risk assessment model illustrated in Figure 2.3 in Chapter 2. A structured survey of each study site was first undertaken. This survey provided a general appraisal of the site in question. Specifically, the survey was undertaken in order to identify survey boundaries and to divide the site into identifiable zones or areas where possible. Such zones included for example, distinct areas of natural habitat, access roads and parking, lawn and picnic areas, berthing facilities for boats and the transition areas between shore and land based amenities. The structured survey was also used to identify the nature of recreational activity occurring at each site and general areas or situations where potential conflict between recreational activity and environmental quality could arise.

The next step of the methodology involved the identification of hazards with respect to environmental sustainability. During this stage all aspects of the physical environment and recreational activity occurring were examined in detail in order to identify all issues which could potentially affect the environmental sustainability of the area as defined. This exercise was applied in a systematic manner using the zones and other information identified in the initial survey and using prescribed survey techniques derived originally from the field of architecture (Wells, 1996)

Following the hazard identification exercise, the next step was to identify appropriate methods, either quantitative or qualitative, to generate variables and assess the identified hazards using a structured monitoring programme. With respect to the qualitative variables, literature was reviewed in order to identify relevant standards, where available, and generate suitable criteria for recording the variables.

A total of 32 quantitative and qualitative variables were identified for the three study sites at Lough Derg while 36 variables were selected for the Dublin Bay sites. The methods of measurement and recording of variables ranged from visual observations and counts to on-site analysis using portable instruments (noise meter, for example) to sampling followed by laboratory analysis (in the case of some water quality variables, for example). The generated variables (listed in Tables 3.1 – 3.4) were then recorded on a weekly basis (approximately) over the course of 13 months in the case of the Lough

Derg study sites and 10 months in the case of the Dublin Bay sites. In total, 40 sampling visits were made to the Lough Derg study area and 25 to the Dublin Bay study area.

All data recorded from the field monitoring programme was filed using Microsoft Excel spreadsheets. This included both the quantitative and qualitative variables, with the latter being recorded directly using the likert scale risk categories, low, medium and high. All data was next transferred to the SPSS statistical software package which was then used to convert the quantitative data to the same three point risk category scale (low, medium and high) and to carryout frequency analysis of both the converted quantitative data and the qualitative data. Literature was again reviewed in order to identify relevant standards for generating the criteria used to convert the quantitative data to risk categories. Typical standards which were identified in this respect included, for example, the Blue Flag Beach Standard (FEE, 2008) and the Irish Bathing Water Quality Regulations of 1992 (S.I. No. 155 of 1992).

The frequency analysis data was next transferred back to Microsoft Excel spreadsheets which were then used to produce charts depicting the frequency of each risk category recorded for all applicable variables (quantitative and qualitative). Microsoft Excel was also used to generate line charts illustrating the raw data values recorded in respect of the various sampling locations chosen for recording the quantitative variables. Trend analysis of quantitative data was supported, where appropriate, using the statistical T-test tool available with Microsoft Excel in order to confirm significance differences identified in key sets of related data. Finally, a simple macro program was developed using Microsoft Excel in order to convert the relative proportion of risk categories recorded for each applicable variable into a sustainability risk rating score. This rating or score was generated first with respect to individual variables and then combined where relevant in order to produce aggregated sustainability risk ratings for the study sites and ultimately for the two study areas, Lough Derg and Dublin Bay. All sustainability risk ratings were illustrated using bar charts generated with the Microsoft Excel software.

## 3.2 Selection and Description of Study Sites

### 3.2.1 Introduction

Two general locations were ultimately chosen for the development and testing of the risk assessment based methodology for assessing the environmental sustainability of tourism and recreation areas. These two locations are referred to generally as the Lough Derg and Dublin Bay study areas. Detailed background information regarding these study areas is given in the Introduction Chapter. Within both study areas a number of specific study sites were selected for specific application and testing of the methodology. The study sites in the Lough Derg study area are referred to as Terryglass Harbour, Dromineer Harbour and Meelick Bay. The study sites in the Dublin Bay study area are referred to as Seapoint, Monkstown and Dun Laoghaire Harbour. A detailed description of all six individual study sites is given in the following sections.

### 3.2.2 Lough Derg Study Sites

The location on Lough Derg of each of the three study sites selected for this study area are shown in the figures overleaf. More detailed maps of each study site are provided in the following sections.

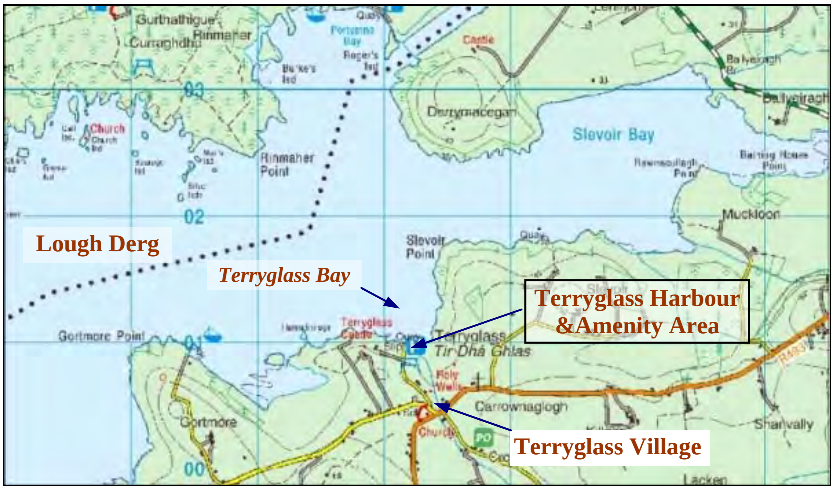



**Figure 3.1 – Location of Terryglass Harbour and Amenity Area on Lough Derg**

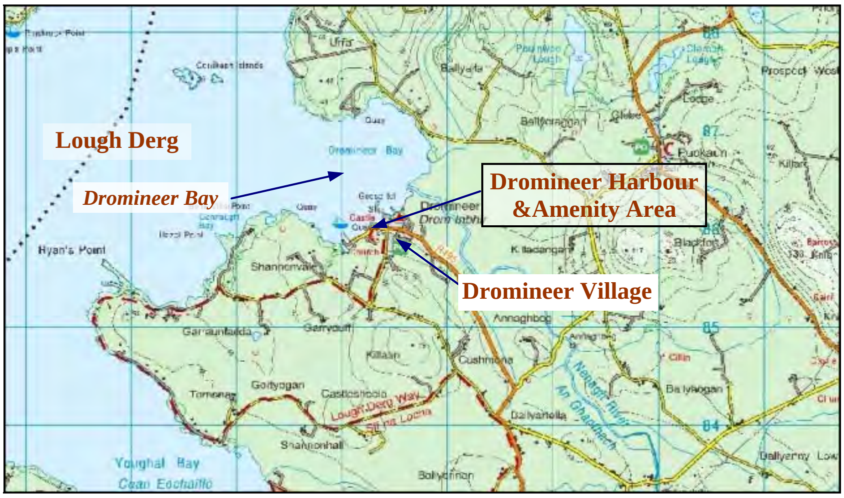



**Figure 3.2 - Location of Dromineer Harbour and Amenity Area on Lough Derg**

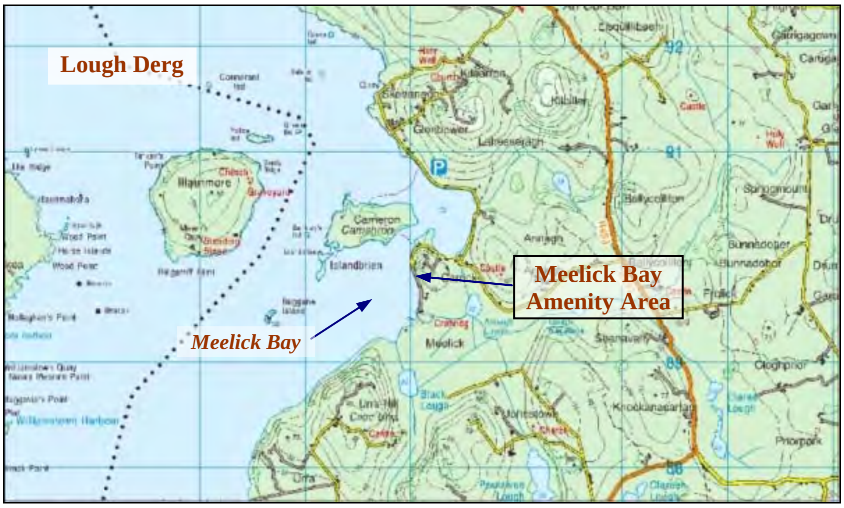



**Figure 3.3 - Location of Meelick Bay Amenity Area on Lough Derg**

#### 3.2.2.1 Terryglass Harbour Amenity Area

Terryglass Harbour amenity area is located towards the northern end of the Lough Derg study area (see Figure 3.1). This amenity area consists of two jetties which form a sheltered harbour area between the jetties and the adjacent shoreline (see map in Figure 3.4). Adjoining the harbour are areas of open lawn space, a small woodland and a car parking area. The western end of the amenity area comprises an area of semi-natural lakeshore backed by open lawn space. Facilities provided at Terryglass Harbour amenity area include a toilet block, picnic tables and a slipway. More recent additions to the facilities provided include a small playground area and barbeque facilities. Public lighting is also provided around the area.

An additional notable feature of Terryglass Harbour is its proximity to Terryglass village (See Figure 3.4). This village is a small but recognised tourism destination which is known for its restaurant and public house (North Tipperary County Council, 2004). A number of small holiday cottage complexes are located in the area between Terryglass village and Terryglass Harbour. The Terryglass River is a small river which flows northwards through the village before entering Terryglass Harbour.

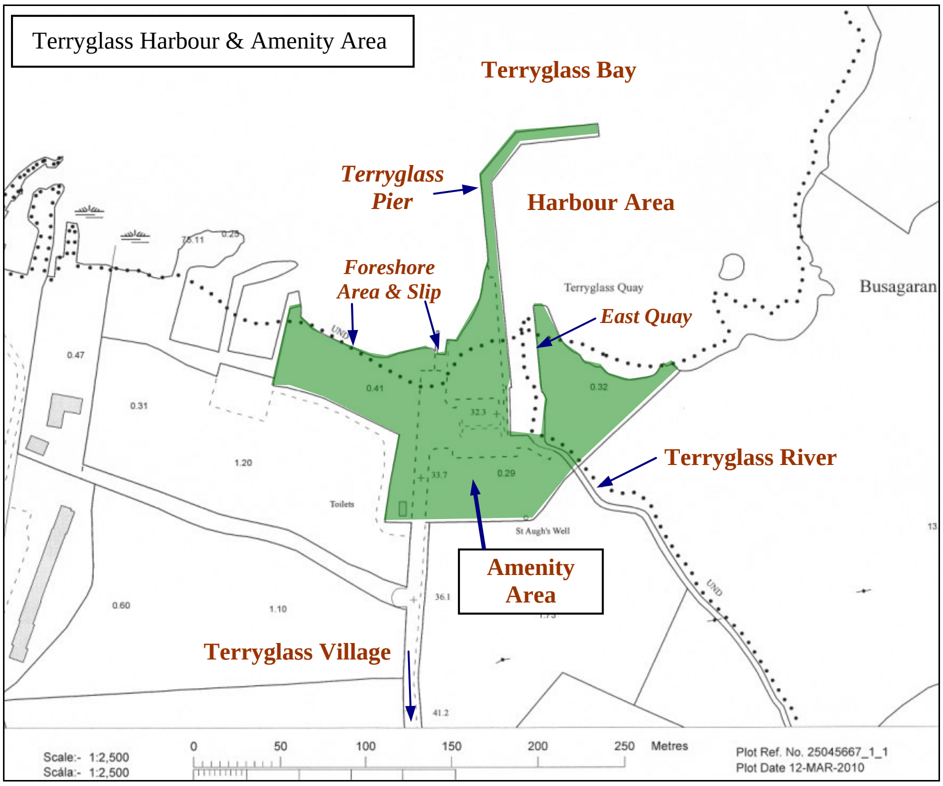



**Figure 3.4 – Outline of the Terryglass Harbour & Amenity Area with Key Features Labelled**

**Figure 3.5 - View of Terryglass Harbour (from the pier)**

**Figure 3.6 - View of Terryglass Harbour (from the south)**

**Figure 3.7 - View of Natural Shore Habitat adjoining Terryglass Harbour**

**Figure 3.8 – Floating Oil Films Observed at Terryglass**

#### *3.2.2.2 Dromineer Harbour Amenity Area*

Dromineer Harbour amenity area is located near the southern end of the Lough Derg study area (see Figure 3.2). This area adjoins the village of Dromineer which comprises a number of residences, a small hotel, hostel, shop and a public house. A number of holiday cottage complexes adjoin the village area. This site is similar in character to the Terryglass site, consisting of a harbour area adjoined by areas of open lawn space and car parks (see map in Figure 3.9). However, at Dromineer the harbour area is more developed with more extensive birthing facilities for cruising boats. To the south of the harbour area an area of modified lake shoreline serves as an informal beach area. Facilities provided at Dromineer Harbour include three separate car parking areas, a playground, picnic tables, bench seats and a slipway. A number of private jetties and a clubhouse owned by a local sailing club are located to the north of Dromineer Harbour. Interspersed between the areas of developed shoreline are areas of relatively natural lake shoreline habitat.

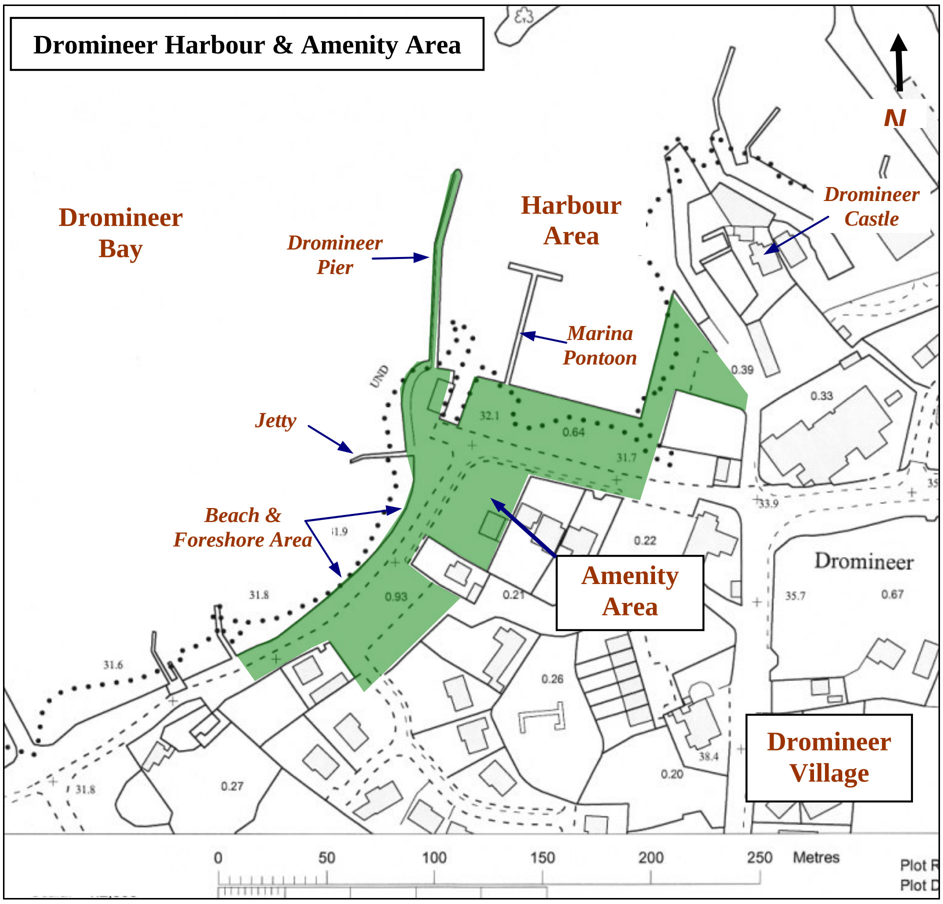



**Figure 3.9 - Map of Dromineer Harbour & Amenity Area with Key Features Labelled**

**Figure 3.10 - View of Dromineer Harbour (from the south)**

**Figure 3.11- View of Dromineer Harbour (eastwards from the pier)**

**Figure 3.12 - View of Dromineer Beach and Foreshore (from the south)**


**Figure 3.13 – Floating Litter and Surface Algae at Dromineer Harbour**

**Figure 3.14 – Algal Bloom at Dromineer Beach and Foreshore**

### *3.2.2.3 Meelick Bay Amenity Area*

Meelick Bay amenity area is located near the centre of the Lough Derg study area (see Figure 3.3). This area is relatively isolated with no villages or other centres of population within approximately five kilometres. However, a number of individual dwellings are located in proximity to the area. In contrast to Terryglass and Dromineer, Meelick Bay consists simply of an area of open lake shoreline adjoined by an open grassy area (see map in Figure 3.15). A small private jetty and boathouse is located at the northern end of the area. The amenity area is separated from an area of woodland by a narrow road with provides access to the amenity area and also to a private dwelling located further south. Facilities at Meelick Bay are basic with only very limited parking spaces provided and some waste receptacles. Observations made during the course of field research reveal that, in general, Meelick Bay is very quiet with few people frequenting the area. However, during the Mayfly season, a number of anglers were seen to use the area to launch their small angling boats.  Meelick Bay is adjoined to the north and south by areas of high quality natural lake shore habitat including extensive areas of rushes backed by stands of yew and juniper woodland.

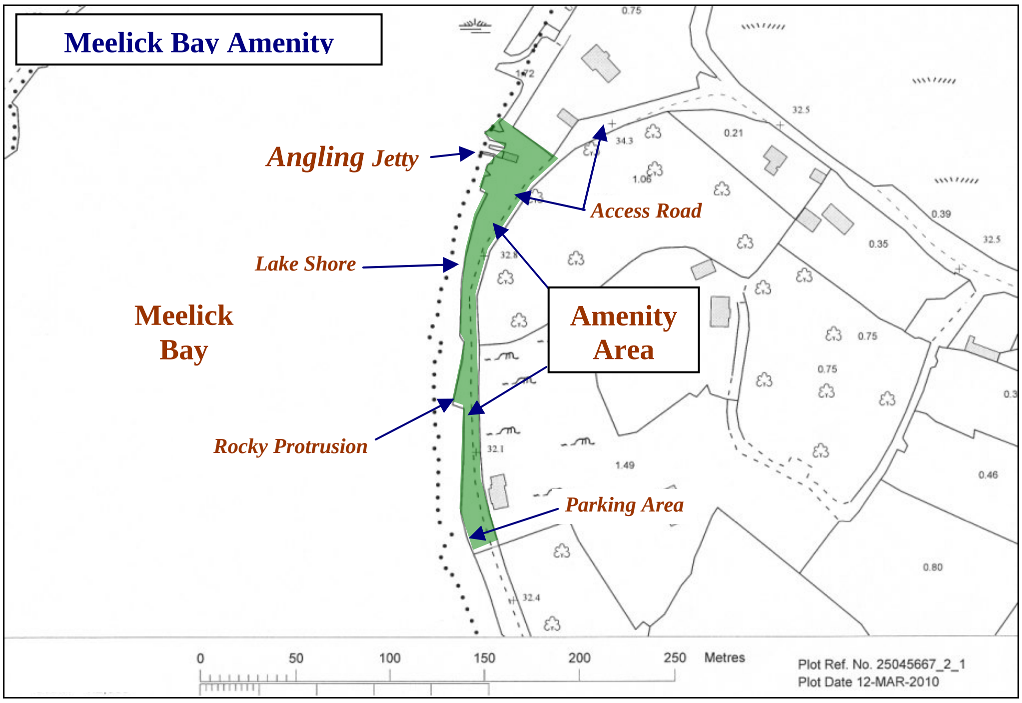



**Figure 3.15 - Map of Meelick Bay Amenity Area with Key Features Labelled**

**Figure 3.16 - View of Meelick Bay and Amenity Area (from the North)**

**Figure 3.17 – View Westwards from Meelick Bay Amenity Area showing Areas of High Quality Natural Lakeshore Habitat**

### 3.2.3 Dublin Bay Study Sites

The relative location of the three study sites at Dublin Bay are shown in Figure 3.18 below. As can be seen these sites are in relatively close proximity but contrast in nature. More detailed maps of each study sites are provided in the following sections.

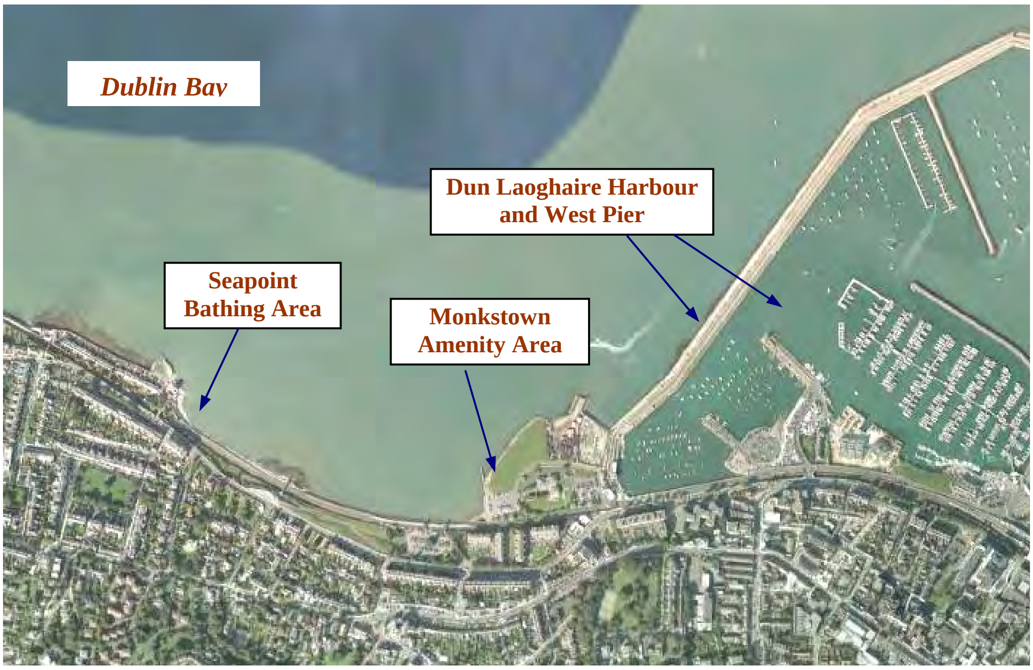



**Figure 3.18 – Aerial View Showing Relative Locations of Dublin Bay Study Sites (courtesy Google Maps)**

#### *3.2.3.1 Seapoint Bathing Area*

Seapoint is a long establish bathing area at the southern end of Dublin Bay (see map overleaf). The area comprises a section of heavily modified shoreline lying just seaward of the Dublin Wexford railway line. A concrete promenade structure is provided to the south of the area which provides level seaside space and backs a sandy beach area which exists at mid to low tide. At high tide the sea meets the promenade and covers the beach. The centre section of Seapoint is marked by an old watch tower around which the shoreline is built up and reinforced to form a concreted area with various ledges for changing and sitting. Slipways and steps are provided in this area to allow bathers safe access to the sea. Just north of the tower is an open grassy area which lies above the shoreline. A larger slipway is also provided here. To the north of the amenity area the access road lies adjacent to the shore and is protected by a sea wall. The seashore at this location is more natural with areas of rocky outcrop providing some habitat for bird life.

Facilities provided at Seapoint include limited parking along the access road to the north of the tower (this parking is also used by local residents with permits). Seating areas, life buoys and a number of waste receptacles are also provided. During the summer months, lifeguards employed by the local authority are on duty at this bathing area.

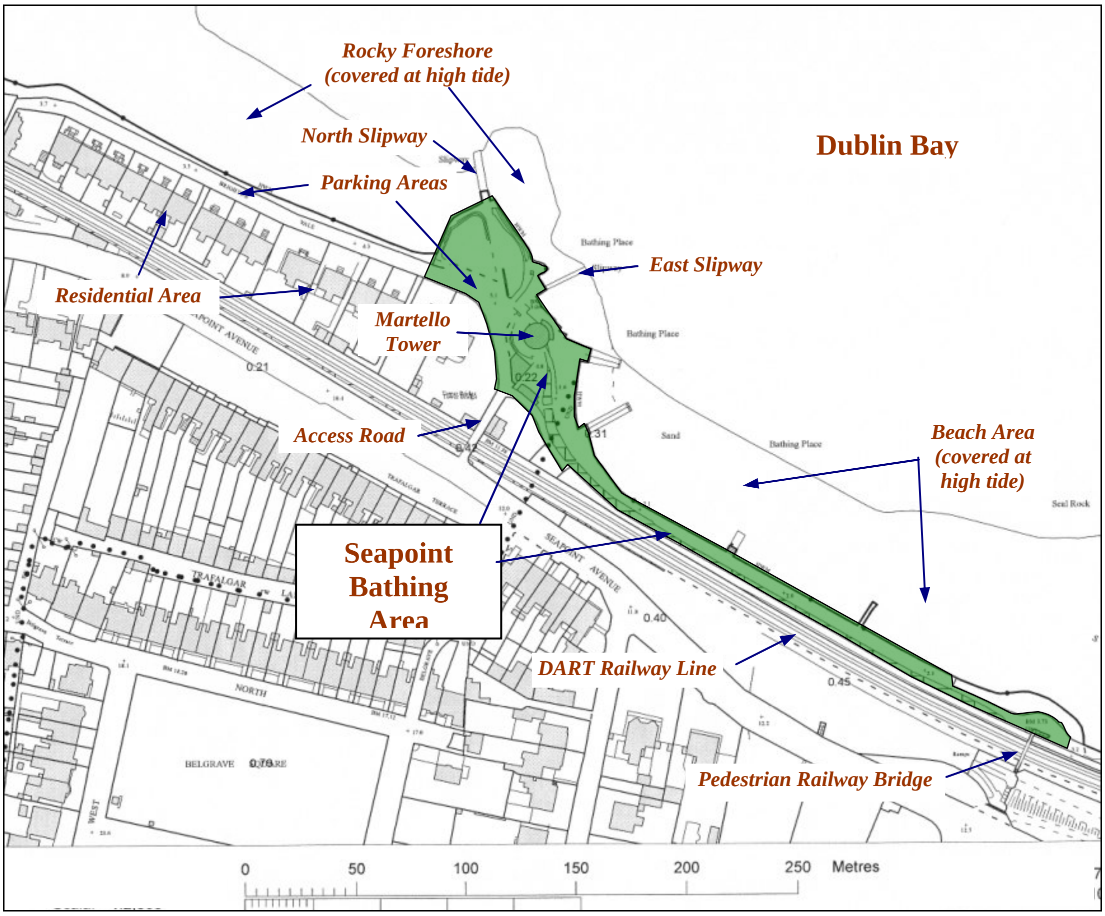



**Figure 3.19 – Map of Seapoint Bathing Area with Key Features Labelled**

**Figure 3.20 - View of Seapoint Bathing Area (from the South)**

**Figure 3.21 – View of Main Bathing Area At Seapoint**

**Figure 3.22 – View of Rocky Foreshore and Lawn Area to the North of the Main Bathing Area at Seapoint**

### *3.2.3.2 Monkstown Amenity Area*

Monkstown is an open amenity space located to the south of Seapoint, just north of Dun Laoghaire harbour (see Figure 3.18). The area provides open views northwards across Dublin Bay and comprises of a large parking area adjoining an open green both of which faced onto the shore of Dublin bay (see map in Figure 3.23 overleaf). The shoreline here is largely modified with sea walls providing protection from the sea. At high tide a small section of foreshore remains exposed just to the left of the parking area. At low tide the foreshore dries to expose an extensive area of sandy foreshore which extends northwest as far as the Seapoint amenity area. Although the foreshore at Monkstown is accessible it is generally not used for public bathing. Instead, the primary use of the shore here is by users of a local dingy sailing venture and by occasional windsurfers or kayakers, for example. The area is also popular with members of the public who use the area for walking, picnics, walking their dogs or for simply taking advantage of its scenic location. Facilities provided by the local authority at Monkstown include the aforementioned parking space and also a number of picnic tables and benches. Waste receptacles are also provided.

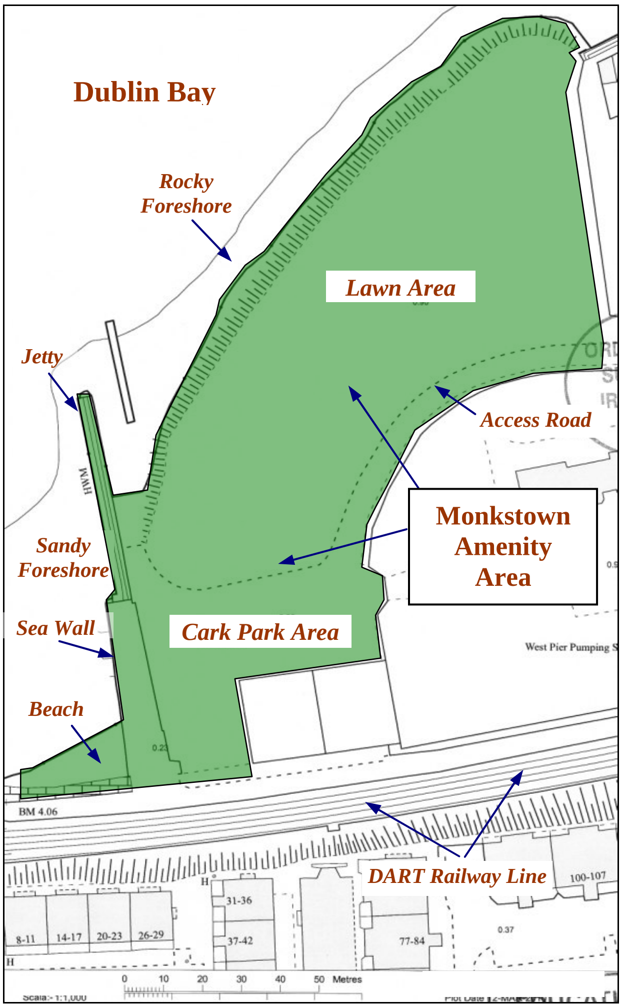



**Figure 3.23 - Map of Monkstown Amenity Area with Key Features Labelled**

**Figure 3.24 – View North-westwards from Monkstown Amenity Area**

**Figure 3.25 – Algal Bloom Accumulations on Monkstown Foreshore**

#### *3.2.3.3 Dun Laoghaire Harbour (and West Pier)*

Dun Laoghaire harbour comprises two large breakwater pier structures (each up to 1.5 km in length) which enclose an extensive area of man made harbour (see Figures 1.3 and 3.18). Originally constructed as a commercial port and safe haven, the harbour is now used primarily for recreational sailing purposes and is home to two yacht clubs as well as a number of smaller dingy sailing clubs. The harbour continues to serve two commercial interests with the Stena Line high-speed ferry terminal and a commercial fishing pier located within the harbour area.

As Dun Laoghaire harbour covers an extensive area, a smaller subsection of the harbour was chosen as the study site for this research. This subsection essentially comprises the north western corner of the harbour which is enclosed by the new internal west pier breakwater (see map in Figure 3.26). Within this subsection can be found the Dun Laoghaire Marina, the Traders Wharf (the commercial fishing pier) and a number of designated mooring areas for various private sailing and motorised craft. Also included in this study site is the West Pier itself.

Dun Laoghaire harbour comes under the jurisdiction of the Dun Laoghaire Harbour Company. This authority provides and maintains a number of facilities over and above the marina and mooring. Such facilities include extensive parking and the provision of benches and waste receptacles along both piers. The West Pier of Dun Laoghaire harbour is used extensively by both walkers and sea anglers.

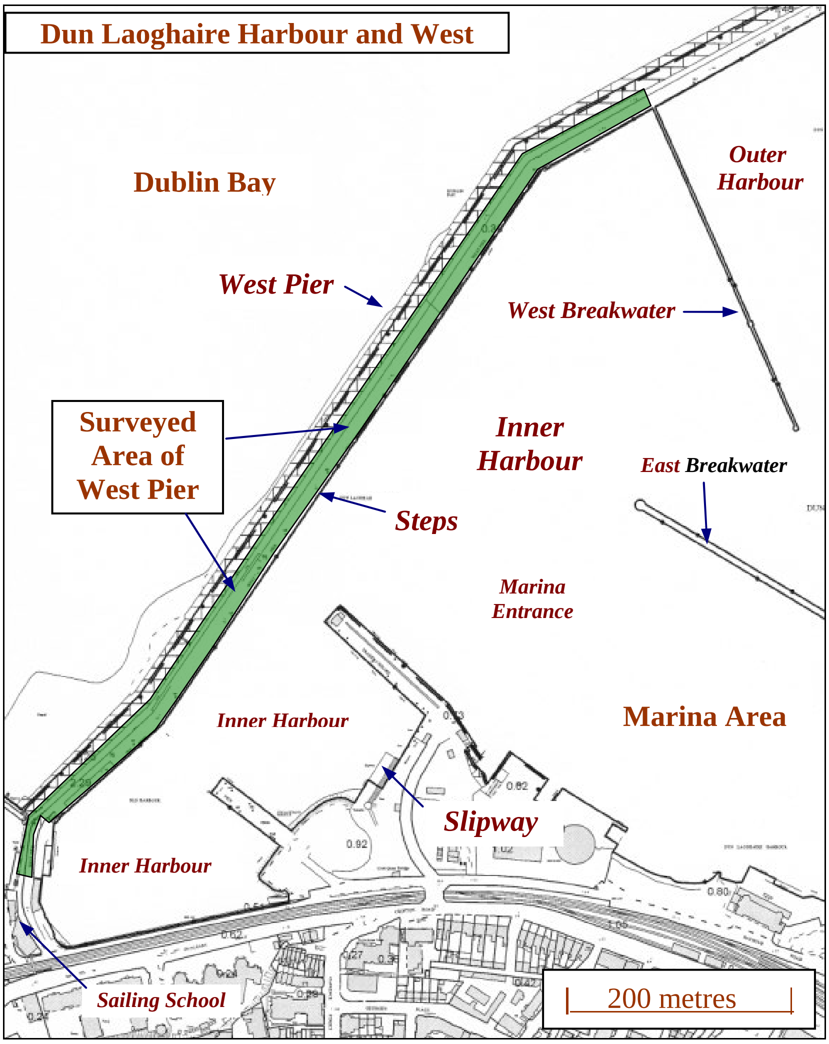



**Figure 3.26 - Map of Dun Laoghaire Harbour & West Pier with Key Features labelled.**

**Figure 3.27 - View of Inner Harbour Area from the West Pier Looking South**

**Figure 3.28 - Noise Monitoring: Overlooking Inner Harbour Area, Opposite the Marina Entrance at Dun Laoghaire**

## 3.3 Selection of Variables

### 3.3.1 Introduction

The selection of variables is considered a fundamental element of the prescribed methodology. This is because it is the selected variables which ultimately provide the data upon which the assessment of environmental sustainability is made. In line with emerging risk assessment approaches, a general contention is that the greater the number of variables that can be identified and measured, the more comprehensive and robust the subsequent assessment of sustainability (Wells, 1996; McDonald and Hrymak, 2002). Hence, a general aim was to identify as broad a range of relevant variables as possible. However, a number of factors existed which tended to limit the number of variables which were ultimately selected for continued monitoring. These factors primarily involved practical issues such as the availability of equipment for measuring quantitative variables, the ability to set useful criteria for qualitative variables and the relevance of the data produced by variables in a general sense.

### 3.3.2 Method

The initial stage of the methodology involved the selection of environmental variables at each study site. In a risk assessment context, the variables selected are those which are considered to best reflect or monitor the principal hazards to the sustainability of tourism and recreation at each site. In line with the risk assessment approach adopted, the identification of such variables was therefore achieved using a hazard identification approach. This approach involved a number of steps which are described below.

The first step involved observing and surveying the chosen study sites at length in order to determine their physical character and layout and the general nature of activities pursued therein. Elements of interest regarding the physical character of the sites included the juxtaposition and/or interaction of the natural and human built environment. Activities of interest included any which were considered related to tourism and recreation or posing a risk to this field.

The next step involved the undertaking of a structured delineation of each study site (after Wells (1996)) and the identification of hazards to sustainability. This step was carried out in order to establish appropriate boundaries within which relevant variables should be identified and to identify all hazards to the environmental quality and amenity value of the area. Within this perimeter, all relevant natural and human built amenities are contained including, for example, car parks, lawn areas, boat moorings, natural habitat, noise sources and access routes. The delineation exercise was also used to determine zones where different types of hazard may be realised. Such zones included areas identified as being vulnerable with respect to noise nuisance, habitat interference, poor water quality, congestion, aesthetic appearance and housekeeping issues such as litter and dog fouling. More specific hazards were then identified using a structured approach which involved assessing each zone with respect to activities observed and to the list of general hazards types formulated for each site. In addition, information from literature on factors affecting the environmental quality and amenity value of amenity sites was used to back up the physical assessment of the sites.

As part of the next step the identification of appropriate environmental variables was undertaken with respect to the identified zones and potential hazards. A key criterion for the selection of variables was that they would provide a reliable yet practical and realistic means of assessing and monitoring the identified hazards and the general environmental quality of the areas in question. In general, an emphasis was placed on quantitative assessment, however, where quantitative assessment could not provide a realistic measure of a hazard then qualitative parameters (or variables) were considered and selected instead. The finalised list of both qualitative and quantitative variables selected at each study area are given in Tables 3.1 to 3.4 in Section 3.3.3 below. As can be seen from these tables 32 and 36 variables were monitored at the Lough Derg and Dublin Bay study sites, respectively. Based on the ensuing quality and relevance of the data generated, 25 of the Lough Derg variables and 23 of the Dublin Bay variables were selected for more detailed analysis. Finally, of these variables, 17 were used to generate sustainability risk ratings for the three Lough Derg study sites and 15 for the Dublin Bay sites. The variables omitted from this process were those which proved difficult to relate to risk level in the context of sustainability. These included variables such as the number of pets, cars, boats or weather conditions.

Although, the number of variables used to generated the risk ratings was substantially less than the number identified for assessment initially, it was nevertheless considered that these variables provided a good cross sectional representation of the key issues influencing the environmental sustainability of the areas in question. Furthermore, the data from variables which were which were not ultimately used to generate sustainability risk ratings was still considered important as this provided useful background information which helped put some of the other data into better context. Thus for example, the data from variables related to boat and car usage were used to define the high and low recreation seasons and to provide insight into trends relating to variables such as littering, overcrowding and noise.

The final step of this stage of the methodology involved the precise identification of sampling sites and recording locations for each of the selected variables at each study site. Zones for undertaking surveys for variables such as litter, motor boat activity or bird life were also established as part of this step.

### 3.3.3 List of Selected Variables

The final set of variables selected as part of the structured hazard identification process (described above) are listed in Tables 3.1 – 3.4 below. Variables listed in the table are grouped according to particular environmental themes referred to as sustainability categories. The tables also provide additional summary information regarding each variable in adjoining columns. This includes whether the variable is qualitative or quantitative in nature, the method of measurement and the means (or units) by which the data is recorded. Information regarding the significance of each variable in the context of sustainability is also given. Not all variables were ultimately considered appropriate for the generation of sustainability rating scores or for performing trend analysis. Thus the final two columns of each table indicate whether or not a particular variable was subjected to a rating or trend analysis.

### *3.3.3.1 Lough Derg Study Area Variables*

**Table 3.1 – List of Variables Selected for the Lough Derg Study Sites**

| | Selected Variable | Sustainability Hazard &/or Significance | Data Type - Measurement (& Units) | Risk Rating Applied? | Trend Analysis Applied? |
|---|---|---|---|---|---|
| **Time & Weather** | **Time & Day of Week** | Visitor behaviour, context | N/A | No | Partial |
| | **Date & Season** | Visitor behaviour, context | N/A | No | Yes |
| | **Weather Condition** | Visitor behaviour & experience | Qualitative Data- Visual Observations | No | Yes |
| | **Wind Strength & Direction** | Visitor experience, litter distribution | Quantitative - Anemometer, (Beaufort Scale, etc) | No | No |
| | **Temperature** | Visitor behaviour & experience | Quantitative – Thermometer (Degrees Celsius) | No | No |
| **Water Quality** | **Dissolved Oxygen** | Key water quality Indicator, ecology | Quantitative – Portable DO meter (mg/l $O_2$) | Yes | Yes |
| | **% Saturation Dissolved Oxygen** | Key water quality Indicator, ecology | Quantitative – Portable DO meter (% Saturation DO) | Yes | Yes |
| | **Water Temperature** | Background information | Quantitative – Thermometer (ºC) | No | Partial |
| | **Ortho-Phosphates** | Indicator of nutrient enrichment – Ecology, algal blooms | Quantitative – Photometer (mg/l $PO_4$) | Yes | Yes |
| | **Ammonia** | Indicator of nutrient & faecal contamination - Health & ecology | Quantitative – Photometer (mg/l $NH_3$) | No | No |
| | **Faecal Coliforms** | Indicator of faecal contamination - Health & ecology | Quantitative – Laboratory Analysis (Coliforms/100mls) | Yes | Yes |
| | **Total Coliforms** | Indicator of faecal contamination - Health & ecology | Quantitative – Laboratory Analysis (Coliforms/100mls) | Yes | Yes |
| | **Floating Oil Films** | Visual appeal of water, visitor perceptions | Qualitative – Visual Observation (3 Point Scale: L,M,H) | Yes | Partial |
| | **Algal blooms** | Perception of water quality - Health | Qualitative – Visual Observations (3 Point Scale: L,M,H) | Yes | Partial |
| | **Water Transparency** | Water quality Indicator -Visual appeal | Quantitative - Secchi Disk (Centimetres) | Yes | Yes |

**Table 3.2 - Continued List of Variables Selected for the Lough Derg Study Sites**

| | Selected Variable | Sustainability Hazard & Significance | Data Type - Measurement (& Units) | Risk Rating Applied? | Trend Analysis Applied? |
|---|---|---|---|---|---|
| **Habitat Value** | **No. of Birds Present** | Perception of habitat quality | Quantitative – Visual Counts (Nr. birds present) | No | Partial |
| | **Bird Species Richness** | Indicator of habitat quality, ecology | Quantitative – Visual Counts (Nr. species. present) | Yes | Partial |
| | **Dog Count** | Wildlife disturbance, dog fouling | Quantitative – Visual Counts | No | Yes |
| **Area Upkeep/ House Keeping** | **Litter – General** | Visual appeal, visitor perceptions | Quantitative - Visual Counts (items/100m$^2$) | Yes | Partial |
| | **Floating Litter** | Visual appeal, visitor perceptions. | Quantitative - Visual Counts (items/50m) | Yes | Partial |
| | **Dog Fouling** | Visual appeal, hygiene | Quantitative - Visual Counts (No. per 100m$^2$) | Yes | Yes |
| | **Graffiti** | Visual appeal, visitor perceptions | Quantitative - Visual Counts | Yes | Partial |
| | **Odours** | General appeal, visitor perceptions | Qualitative - Observation (3 Point Scale: L,M,H) | No | Partial |
| | **Overcrowding** | Visual appeal, visitor satisfaction | Qualitative – Visual Observations (3 Point Scale: L,M,H) | Yes | Partial |
| **Traffic, Boating, & Noise** | **Car counts (in car parks)** | Level of recreation activity, visitors | Quantitative – Visual Counts | No | Partial |
| | **Incidences of Illegal parking** | Access restriction, visitor satisfaction | Quantitative – Visual Counts | Yes | No |
| | **No. of Boats in Harbour** | Level of boating activity, visitors | Quantitative – Visual Counts | No | Partial |
| | **Harbour Congestion** | Visitor perceptions & convenience | Quantitative – Visual Counts | Yes | Partial |
| | **No. Motor Boats Operating** | Level of boating activity, noise | Quantitative – Visual Counts | No | Partial |
| | **Number sailing boats in use** | Sailing activity, visitor perceptions | Quantitative – Visual Counts | No | Partial |
| | **Power boats operating** | Noise environment, visitor perceptions | Quantitative – Visual Counts | No | Partial |
| | **Ambient Noise Levels** | Habitat quality and nuisance | Quantitative – Noise Meter (Decibels: $L_{Aeq,}$ $L_{90}$) | Yes | Yes |

### *3.3.3.2 Dublin Bay Study Area Variables*

**Table 3.3 - List of Variables Selected For the Dublin Bay Study Sites**

| | Selected Variable | Sustainability Hazard &/or Significance | Data Type - Measurement (& Units) | Sites Applied to? | Risk Rating Applied? | Trend Analysis Applied? |
|---|---|---|---|---|---|---|
| **Time & Weather** | **Time & Day of Week** | Visitor behaviour, context | N/A | All | No | Partial |
| | **Date & Season** | Visitor behaviour, context | N/A | All | No | Yes |
| | **Weather Condition** | Visitor behaviour & experience | Qualitative - Visual observations | All | No | Partial |
| | **Wind Strength & Direction** | Visitor experience, litter distribution | Quantitative - Anemometer (Beaufort Scale, etc) | All | No | No |
| | **Temperature** | Visitor behaviour & experience | Quantitative – Thermometer (ºC) | All | No | No |
| **Water Quality** | **Dissolved Oxygen** | Key water quality indicator, ecology | Quantitative – Portable DO meter (mg/l $O_2$) | None | No | Partial |
| | **Dissolved Oxygen, % Saturation** | Key water quality indicator, ecology | Quantitative – Portable DO meter (% Saturation DO) | DLH | Yes | Yes |
| | **Water Temperature** | Background Information | Quantitative – Thermometer (ºC) | SP, DLH | No | No |
| | **Ammonia** | Indicator of nutrient & faecal contamination. Health & ecology | Quantitative – Photometer (mg/l $NH_3$) | SP DLH | Yes | Yes |
| | **Nitrates** | Indicator of nutrient enrichment. Ecology & algal blooms | Quantitative – Photometer (mg/l N) | SP DLH | No | No |
| | **Enterococci** | Indicator of faecal contamination. Health & ecology | Quantitative – Laboratory Analysis (cfu's/100mls) | All | Yes | Yes |
| | **Floating Oil Films** | Visual appeal of water, visitor perceptions | Qualitative – Visual Observations (3 Point Scale: L,M,H) | All | Yes | Partial |
| | **Algal blooms** | Perception of water quality. Health | Qualitative – Visual Observations (3 Point Scale: L,M,H) | All | Yes | Partial |
| | **Water Transparency** | Water quality Indicator. Visual appeal | Quantitative - Secchi Disk (Centimetres) | DLM | No | Yes |
| | **Water Turbidity** | Perception of water quality, visual appeal | Qualitative – Visual Observation (3 Point Scale: L,M,H) | All | Yes | Partial |
| **Habitat Value** | **No. of Birds Present** | Perception of habitat quality | Quantitative – Visual Counts (No. of birds present) | All | No | No |
| | **Bird Species Richness** | Indicator of habitat quality, ecology | Quantitative – Visual Counts (No. of species. present) | All | No | No |
| | **Disturbance to Bird Life** | Habitat quality | Quantitative - Visual Count (No. of Incidences) | All | No | No |

**Table 3.4 - Continued List of Variables Selected for the Dublin Bay Study Sites**

| | Selected Variable | Sustainability Hazard & Significance | Data Type - Measurement (& Units) | Sites Applied to? | Risk Rating Applied? | Trend Analysis Applied? |
|---|---|---|---|---|---|---|
| **Area Upkeep/ House Keeping** | **Litter – General** | Visual appeal, visitor perceptions | Quantitative - Visual Counts (items/100m$^2$) | All | Yes | Yes |
| | **Floating Litter** | Visual appeal, visitor perceptions. | Quantitative - Visual Count (items/50m) | DLH | Yes | Yes |
| | **Foreshore Litter** | Visual appeal, visitor perceptions. | Quantitative - Visual Count (items/50m) | SP MK | Yes | Partial |
| | **Incidences of Dumping** | Visual appeal, perceptions. | Quantitative - Visual Count (No. of Incidences) | All | No | No |
| | **Full Waste Receptacles** | Litter & perceptions | Quantitative - Visual Count (No. of Incidences) | All | Yes | Partial |
| | **Dog Fouling** | Visual appeal, hygiene | Quantitative - Visual Counts (No. per 100m$^2$) | All | Yes | Yes |
| | **Dog Count** | Dog fouling | Quantitative – Visual Counts (Max. Nr. observed) | All | No | No |
| | **Graffiti** | Visual appeal, visitor perceptions | Quantitative - Visual Counts (no. observed) | All | Yes | Partial |
| | **Odours** | General appeal, visitor perceptions | Qualitative - Observation (3 Point Scale: L,M,H) | All | Yes | Partial |
| | **Overcrowding** | Visual appeal, visitor satisfaction | Qualitative – Visual Observations (3 Point Scale: L,M,H) | All | Yes | Partial |
| **Traffic, Boating, & Noise** | **Car counts (in car parks)** | Level of recreation activity. Visitor numbers | Quantitative – Visual Counts | SP MK | No | Partial |
| | **Car counts (reg. area)** | Origin of visitors | Quantitative – Visual Counts | SP MK | No | Partial |
| | **Improper parking** | Restriction of access | Quantitative – Visual Counts | All | Yes | Partial |
| | **Number of Boats Moored** | Recreation season information | Quantitative – Visual Counts | DLH | No | Partial |
| | **Motor Boats Operating** | Season information. Noise Environment | Quantitative – Visual Counts | All | No | Partial |
| | **Sailing Boats** | Season Information. | Quantitative – Visual Counts | All | No | Partial |
| | **Power Boats Operating** | Noise environment. Visitor Perceptions | Quantitative – Visual Counts | All | No | Partial |
| | **Ambient Noise Levels** | Habitat quality and Nuisance | Quantitative - Noise Meter (Decibels: $L_{Aeq,}$ $L_{90}$) | All | Yes | Yes |

### 3.3.4 Sampling Locations for Selected Variables

The process of selecting sampling sites or survey areas for the different variables was relatively complex. However, this complexity very much depended on the variables in question and was compounded by an underlying imperative of this research to explore beyond the simple assessment of environmental condition and attempt to identify factors contributing to recorded data values. Thus a comprehensive and strategic approach was taken regarding the selection of sampling sites with, in some instances, a number of sites chosen for each variable at a particular study site. By way of example, for water quality variables a complicating factor in the selection of sampling sites was the need to try and establish whether water quality issues were arising from local recreation based factors, such as the use of cruising boats, or from other external factors. This was addressed by selecting sampling sites within, for example, the harbour areas of the study sites and at locations at the proximity of these areas and at other strategic sites such as the entrance points of nearby rivers which were identified as potential sources of water contamination. In this way, it was intended that comparisons could be made between the data for zones subject to recreational use and pressures and the data for zones peripheral to these areas (including inflowing rivers).

The selection of survey areas for variables such as litter, floating litter, dog fouling or graffiti was considered more straightforward. A guiding factor in these cases being the need to optimise the relevance and consistency of the data generated and minimize the time required to carry out the survey. For variables such as boat and car counts it was simply a matter of defining appropriate areas within which the count should apply. Selection of suitable sampling sites for the variable ‘ambient noise’ was complicated by specified criteria for the positioning of the noise meter, such as maintaining distance from vertical structures (Brüel and Kjær, 2000). However, in practice this did not present any particular problems.

A general guide with regard to the selection of sampling sites was that, where possible, they should represent the most appropriate and representative points for recording the associated variable. Tables 3.5 to 3.10 below list and describe the location of all sampling points or survey areas designated for the selected variables. In this regard, note that a table of sampling points is given for each of the three study sites in the Lough Derg and Dublin Bay study areas. To identify and locate the site features referred to in the following tables, the reader is referred to the detailed maps of each study site given in Section 3.2.

#### *3.3.4.1 Lough Derg Study Sites*

**Table 3.5 - Name and Description of Sampling points and Survey Areas at Terryglass**

| Variables | Description of Designated Sampling Points or Survey Areas | Designated Name of Sampling Point or Survey Area |
|---|---|---|
| **Dissolved Oxygen, % Sat. of DO, Phosphates, Faecal and Total Coliforms, Water Transparency** | From the mid point of the main quay and pier. On the harbour side. | Terryglass Harbour |
| | From the west (or lake) side of the main pier (west quay). At the elbow section of the pier. | Terryglass Pier |
| | From the riverside approx. 5 metres above its confluence with Terryglass Harbour | Terryglass River |
| **Floating Oil Films, Floating Litter, Algal Blooms** | The harbour area enclosed by the complete length of the main pier/quay and east quay. | Terryglass Harbour |
| | The lake area immediately adjoining the length of foreshore to the west of the main pier. | Terryglass Foreshore |
| | The lake waters immediately adjoining the west (or lake) side of the main pier. | Terryglass Pier (excluding floating litter) |
| **Litter, Dog Fouling** | The lawn and paved areas adjoining the harbour and foreshore. | Terryglass Amenity Area |
| **Dog Count** | The complete amenity and harbour area including car parks, green areas and quaysides. | Terryglass |
| **Graffiti** | All vertical surfaces and facades within the general amenity area | Terryglass Amenity Area |
| **Overcrowding** | Applies to all facilities within the general amenity area. | Terryglass |
| **Bird Counts (Species richness)** | The lake and harbour area within a radial and visible distance of approx. 500 metres from the end section of Terryglass Pier. | Terryglass |
| **Ambient Noise** | Meter placed at the west end of the Terryglass foreshore area. | Terryglass |
| **Parked Cars** | All roads and designated parking areas with the amenity area. | Terryglass |
| **Moored Boats, Harbour Congestion** | The harbour area enclosed by the east quay and main pier. | Terryglass Harbour |
| **Boat Count (Motoring)** | The Terryglass harbour and bay area. | Terryglass |

**Table 3.6 - Title and Description of Sampling Points and Survey Areas at Dromineer**

| Variables | Description of Designated Sampling Points or Survey Areas | Designated Name of Sampling Point or Survey Area |
|---|---|---|
| **Dissolved Oxygen, % Sat. of Dissolved $O_2$, Phosphates, Faecal and Total Coliforms, Water Transparency** | From the mid point of the main pier. On the harbour side. | Dromineer Harbour |
| | From the lake side of the main pier At the elbow section of the pier. | Dromineer Pier |
| | From the end of the small jetty which marks the northern end of the beach area | Dromineer Beach (applies to faecal & total coliforms only) |
| | From the river bank approximately 1km upstream of the river entrance to Lough Derg | Nenagh River (Applies to phosphates only) |
| **Floating Oil Films, Floating Litter, Algal Blooms** | The harbour area enclosed by the south and east quays and the main pier. | Dromineer Harbour |
| | The lake waters immediately adjoining the west (or lake) side of the length of the main (west) pier. | Dromineer Pier (excluding floating litter) |
| | The lake waters adjoining the length of the constructed beach front area. | Dromineer Beach (or foreshore) |
| **Litter, Dog Fouling** | The lawn and paved areas adjoining the harbour and foreshore areas | Dromineer Amenity Area |
| **Dog Count** | The complete amenity and harbour area including car parks, green areas and quaysides. | Dromineer |
| **Graffiti** | All vertical surfaces and facades within the general amenity area | Dromineer Amenity Area |
| **Overcrowding** | Applies to all facilities within the general amenity area. | Dromineer |
| **Bird Counts (Species richness)** | The lake and harbour area within a radial and visible distance of approx. 500 metres from the end of the Dromineer Pier. | Dromineer |
| **Ambient Noise** | Meter positioned at the base of the main pier facing towards the open lake. | Dromineer |
| **Parked Cars** | All roads and designated parking areas within the amenity area. | Dromineer |
| **Boat Count (Moored), Harbour Congestion** | The harbour area enclosed by the south and east quays and the main pier. | Dromineer Harbour |
| **Boat Count (Motoring)** | The Dromineer harbour and Bay area. | Dromineer |

**Table 3.7 - Title and Description of Sampling Points and Survey Areas at Meelick Bay**

| Variables | Description of Designated Sampling Points or Survey Areas | Designated Name of Sampling Point or Survey Area |
|---|---|---|
| **Dissolved Oxygen, % Sat. of DO Phosphates, Faecal and Total Coliforms,** | From a rocky protrusion mid way along the Meelick Bay amenity area lake shoreline. | Meelick Bay |
| **Floating Oil Films, Floating Litter, Algal Blooms** | The lake waters immediately adjoining the length of the Meelick Bay amenity area lakeshore. | Meelick Bay (Foreshore) |
| **Litter, Dog Fouling** | The lawn areas adjoining the lake foreshore. | Meelick Bay Amenity Area |
| **Dog Count** | The complete amenity area including access road, parking area and green space. | Meelick Bay |
| **Graffiti** | All vertical surfaces and facades within the general amenity area | Meelick Bay Amenity Area |
| **Overcrowding** | Applies to all facilities within the general amenity area. | Meelick Bay |
| **Bird Counts (Species richness)** | The lake area within a radial distance of approx. 500 metres from the rock promontory at the mid section of the amenity area | Meelick Bay |
| **Ambient Noise** | Meter positioned on the lawn area close to the small angling jetty facing towards the open lake. | Meelick Bay |
| **Parked Cars** | The side road and small parking area at the end of the amenity area. | Meelick Bay |

### *3.3.4.2 Dublin Bay Study Area*

**Table 3.8 - Title and Description of Sampling Points and Survey areas at Seapoint**

| Variables | Description of Designated Sampling Points or Survey Areas | Designated Name of Sampling Point or Survey Area |
|---|---|---|
| **Ammonia, Enterococci** | From the 'east slipway' just north of the tower. | Seapoint |
| **Water Turbidity, Floating Oil Films, Algal Blooms.** | The sea waters adjoining the Seapoint shoreline from the pedestrian rail bridge in the south to the north slipway. | Seapoint |
| **Litter (land based), Dog Fouling** | The all paved and lawn areas accessible to the public between the pedestrian rail bridge and the north slipway. | Seapoint |
| **Foreshore Litter** | The waters or exposed shoreline (to a distance of 10 metres) adjoining the Seapoint bathing area between the north slipway and the pedestrian rail bridge. | Seapoint |
| **Full Waste Receptacles** | All receptacles within the defined bathing area | Seapoint |
| **Graffiti,** | All vertical surfaces and facades within the defined bathing area. | Seapoint |
| **Overcrowding** | Applies to all public facilities within the defined bathing area. | Seapoint |
| **Odours,** | Observations made at both ends and centre point of the bathing area | Seapoint |
| **Incidences of Dumping** | Applies to all areas of the bathing area including the adjoining foreshore | Seapoint |
| **Bird Counts** | The foreshore and sea (to a distance of approx. 100m from the shore) adjoining the bathing area and the residential area to the northwest of the bathing area | Seapoint |
| **Parked Cars, improper parking** | Access road and designated public parking area between residential houses and seafront to the northwest of the bathing area. | Seapoint |
| **Boat Counts (Sailing or Powered)** | The sea area adjoining the bathing area (and residential area to northwest) to a distance of approx. 200m from the shore | Seapoint |

**Table 3.9 - Title and Description of Sampling Points and Survey Areas at Monkstown**

| Variables | Description of Designated Sampling Points or Survey Areas | Designated Name of Sampling Point or Survey Area |
|---|---|---|
| **Turbidity, Floating Oil Films, Algal Blooms** | The sea waters adjoining the shoreline below the car park area retaining seawall. | Monkstown |
| **Litter, Dog Fouling** | The open lawn area adjoining the parking area. | Monkstown |
| **Foreshore Litter** | The waters or exposed foreshore adjoining the jetty, seawall and beach area (to a distance of 10 metres) and the beach area itself. | Monkstown |
| **Full Waste Receptacles** | All receptacles within the defined amenity area. | Monkstown |
| **Graffiti,** | All vertical surfaces and facades within the defined amenity area and the seawall immediately north of the amenity area. | Monkstown |
| **Overcrowding** | Applies to all public facilities within the defined bathing area. | Monkstown |
| **Odours,** | Observations made at both extremes and centre point of the amenity area. | Monkstown |
| **Incidences of Dumping** | Applies to all areas of the amenity area including the adjoining foreshore. | Monkstown |
| **Bird Counts** | The foreshore and sea (to a perpendicular distance of approx. 100m from the shore) adjoining the amenity area. | Monkstown |
| **Parked Cars, improper parking** | Access road and designated public car park. | Monkstown |
| **Boat Counts (Sailing or Powered)** | The sea area adjoining the defined amenity area to a distance of approx. 200m from the shore | Monkstown |
| **Ambient Noise** | Noise meter located at the sea edge of the lawn area approximately 50 meters from the car park. | Monkstown |

**Table 3.10 - Title and Description of Sampling Points and Survey Areas At Dun Laoghaire**

| Variables | Description of Designated Sampling Points or Survey Areas | Designated Name of Sampling Point or Survey Area |
|---|---|---|
| **Dissolved Oxygen, % Sat. of Dissolved $O_2$, Ammonia, Enterococci,** | From the steps opposite the marina entrance | Dun Laoghaire Pier |
| | From approximately mid way down the slipway, from the side. Area refers to the water adjoining the slip. | Dun Laoghaire Slipway |
| | From the side of the central pontoon, mid way down its length. | Dun Laoghaire Marina |
| **Water Turbidity, Floating Oil Films, Algal Blooms,** | The harbour waters enclosed by the west breakwater, the west pier and the east breakwater. Observations made from the west pier. | Dun Laoghaire Inner Harbour |
| | The sea waters adjoining the east side of the west pier beyond the west breakwater. Observations made from the west pier. | Dun Laoghaire Outer Harbour |
| | Waters within the general marina area. Observations made from the side of the central pontoon, mid way down its length. | Dun Laoghaire Marina |
| | Waters adjoining the slipway | Dun Laoghaire Harbour Slip Area |
| **Water Transparency** | From the central pontoon, mid way down its length. | Dun Laoghaire Marina |
| **Litter, Dog Fouling,** | The length of the west pier from the sailing school to the west breakwater | Dun Laoghaire Pier |
| **Full Waste Receptacles** | All receptacles along the surveyed length of the west pier (i.e. from the sailing school to the west breakwater). | Dun Laoghaire Pier |
| **Floating litter** | Harbour waters adjacent to the west pier. | Dun Laoghaire Pier |
| **Incidences of Dumping** | Applies to the surveyed length of the west pier (from the sailing school to the west breakwater) and adjoining waters. | Dun Laoghaire Pier |
| **Graffiti,** | All vertical surfaces and facades along the surveyed length of the west pier. | Dun Laoghaire Pier |
| **Overcrowding** | Applies to all public facilities along the surveyed length of the pier. | Dun Laoghaire Pier |
| **Odours,** | Observations made at both ends and centre point of the surveyed length of the west pier | Dun Laoghaire Pier |
| **Bird Counts** | The general harbour area enclosed by a line drawn from the end of the west pier to the marina entrance | Dun Laoghaire Harbour |
| **Boat Counts (Sailing and Powered)** | Applies to the entire harbour area enclosed by the west and east piers. | Dun Laoghaire Harbour |
| **Moored Boats** | The entire harbour area enclosed by the west and east piers, excluding the marina. | Dun Laoghaire Harbour |
| **Ambient Noise** | Noise meter located at the (west) pier edge opposite and facing the marina entrance | Dun Laoghaire Inner Harbour |
| | Noise meter located at the join of the west pier and west breakwater facing towards the harbour entrance. | Dun Laoghaire Outer Harbour |

## 3.4 Recording and Presenting Data - Calculation of Sustainability Risk Ratings

The prescribed monitoring exercise generated a large resource of both quantitative and qualitative data which was recorded in respect of a range of environmental variables selected for each study site (see Tables 3.1–3.4 above). In accordance with the prescribed risk assessment model, all qualitative data was recorded directly on the basis of a three-point risk category scale (low, medium or high). In contrast, data values recorded in respect of quantitative variables were assigned to the same risk category scale on the basis of prescribed criteria generated from appropriate external standards where available and applicable. A percentage risk rating was then generated for all recorded variables. These individual ratings were subsequently used to generate combined risk ratings for both groups of variables and aggregated areas. Details of this process are given in this section under the headings below.

### 3.4.1 Recording and Presenting Data

The data recorded in respect of the selected variables at each study site was either quantitative or qualitative in nature (see Tables 3.1 – 3.4). Qualitative variables were assessed at specified locations by visual observation (further details for each variable are given in Section 3.6). The actual value of a variable was recorded by way of a three-point risk category scale (low, medium or high) in accordance with specified criteria. The criteria for each qualitative variable are outlined under each variable heading in Section 3.6. An example of criteria used for recording the qualitative variable ‘visible oil films' is given in Figure 3.29 below. The data sets generated for qualitative variables were first recorded in Microsoft Excel spreadsheets. These data sets comprise of a series of low, medium or high categories, recorded at the various locations, with corresponding recording dates. An example of such a data set is given in Figure 3.30 below. The actual presentation of the qualitative data sets in this thesis is achieved by means of category frequency charts. These charts show the total number of times over the course of the monitoring period (the frequency) that each risk category was recorded in respect of a particular variable at a particular location. An example chart is given in Figure 3.31. Details of the process of generating the risk category frequency charts is given in the next section (Section 3.4.3).

| **Risk Category Criteria for Recording Visible Oil Films** | | |
|---|---|---|
| **Category** | **Criteria (Qualitative)** | **Source** |
| **Low** | No visible presence and no detectible odour | Quality of Bathing Water Regulations 1992 (S.I. No. 155 of 1992); The Bathing Water Directive (76/160/EEC) and the Blue Flag Beach Scheme |
| **Medium** | Oil films present but not to an extent considered offensive, obvious or widespread (i.e. no more than one separate oil film should be present and this should not exceed 4 square metres in size) | The Bathing Water Regulations (S.I. 155 of 1992) |
| **High** | Oil films present to an extent considered offensive, obvious or widespread | The Bathing Water Regulations (S.I. 155 of 1992) |

**Figure 3.29 – Example of Criteria Specified for Recording the Qualitative Variable 'Visible Oil Films' into Appropriate Risk Categories.**

| Sampling Date | Sampling Month | TG Harbour | DR Harbour | Meelick |
|---|---|---|---|---|
| 20-Nov-06 | Nov. | Low | Low | Low |
| 30-Nov-06 | Nov. | Low | Low | Low |
| 2-Dec-06 | Dec. | Low | Low | Low |
| 4-Dec-06 | Dec. | Low | Low | Low |
| 18-Dec-06 | Dec. | Low | High | Low |
| 19-Dec-06 | Dec. | Low | Medium | Low |
| 1-Feb-07 | Feb. | Low | High | Low |
| 5-Feb-07 | Feb. | Low | High | Low |
| 6-Feb-07 | Feb. | Low | High | Low |
| 13-Feb-07 | Feb. | High | High | Low |
| 14-Feb-07 | Feb. | Low | Low | Low |
| 20-Feb-07 | Feb. | High | Low | Low |
| 21-Feb-07 | Feb. | Low | High | Low |
| 5-Mar-07 | March | Low | Low | Low |
| 24-Apr-07 | April | Low | Low | Low |
| 25-Apr-07 | April | Low | Low | Low |
| 8-May-07 | May | Low | Low | Low |
| 5-Jun-07 | June | High | High | Low |
| 6-Jun-07 | June | Low | High | Low |
| 18-Jun-07 | June | Low | Low | Low |
| 29-Jun-07 | June | Medium | Low | Low |
| 2-Jul-07 | July | High | High | Low |
| 9-Jul-07 | July | High | High | Low |
| 14-Jul-07 | July | Low | High | Low |
| 15-Jul-07 | July | High | Medium | Low |
| 23-Jul-07 | July | High | Low | Low |
| 24-Jul-07 | July | High | High | Low |
| 31-Jul-07 | July | High | Low | Low |
| 7-Aug-07 | Aug. | Low | Medium | Low |
| 8-Aug-07 | Aug. | Low | High | Low |
| 17-Aug-07 | Aug. | High | Low | Low |
| 19-Aug-07 | Aug. | High | High | Low |
| 3-Sep-07 | Sept. | Low | Low | Low |
| 4-Sep-07 | Sept. | High | Low | Low |
| 12-Sep-07 | Sept. | High | Low | Low |
| 21-Sep-07 | Sept. | High | Low | Low |
| 24-Sep-07 | Sept. | Medium | Low | Low |
| 27-Sep-07 | Sept. | Medium | Low | Low |
| 17-0ct-07 | Oct. | Medium | Low | Low |
| 31-0ct-07 | Oct. | High | Low | Low |
| 19-Dec-07 | Dec. | Medium | Low | Low |

**Figure 3.30 – Example of Data Set Recorded for the Qualitative Variable ‘ Visible Oil Films’**

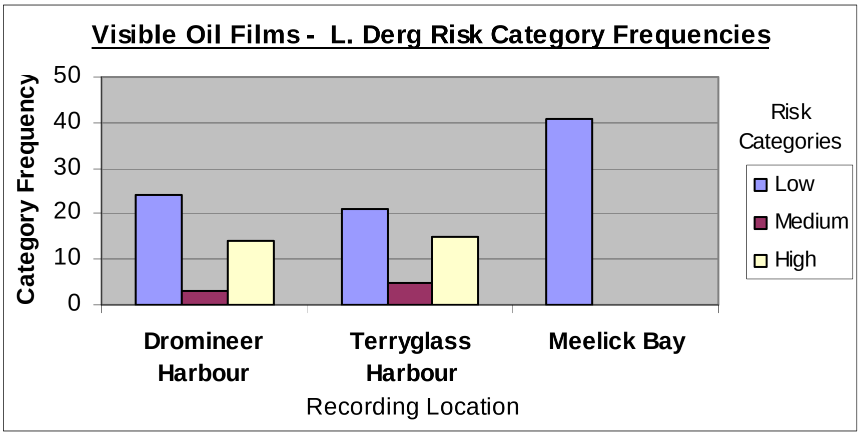



**Figure 3.31 - Example of Category Frequency Chart Recorded for the Qualitative Variable ‘Visible Oil Films’**

Quantitative variables were recorded initially in terms of the units appropriate to each variable (see Tables 3.1-3.4). The physical method of sampling and measurement for all the quantitative variables is described in Section 3.6. The raw data sets generated in respect of quantitative variables were also recorded using Microsoft Excel spreadsheets (see Figure 3.32 for an example data set in respect of the variable ‘water transparency’). Data values in these spreadsheets were recorded against the various sampling dates within the monitoring period. The presentation of quantitative data in this thesis is achieved using standard line charts generated using the Microsoft Excel chart function. These charts show the recorded values on the y-axis (in relevant units) with the sampling occasions on the x-axis. Due to the large number of sampling occasions for each variable, the months within which samples were undertaken are shown on the x-axis rather that the individual sampling dates. The latter option being deemed to be confusing. Depending on the variable and the nature of information to be portrayed, the line charts have been designed to depict one or more sets of data corresponding to different locations and study sites as appropriate. Figure 3.33 gives an example of a line chart for the quantitative variable ‘water transparency’.

| Sampling Date | Sampling Month | TG Harbour | DR Harbour | Meelick |
|---|---|---|---|---|
| 20-Nov-06 | Nov. | Not Recorded | Not Recorded | Not Recorded |
| 30-Nov-06 | Nov. | Not Recorded | Not Recorded | Not Recorded |
| 2-Dec-06 | Dec. | Not Recorded | Not Recorded | Not Recorded |
| 4-Dec-06 | Dec. | 110 | 90 | 60 |
| 18-Dec-06 | Dec. | 100 | 150 | 150 |
| 19-Dec-06 | Dec. | 100 | 150 | 150 |
| 1-Feb-07 | Feb. | 200 | 210 | 200 |
| 5-Feb-07 | Feb. | 200 | 210 | 200 |
| 6-Feb-07 | Feb. | 200 | 210 | 200 |
| 13-Feb-07 | Feb. | 170 | 160 | 160 |
| 14-Feb-07 | Feb. | 150 | 180 | 180 |
| 20-Feb-07 | Feb. | 120 | 150 | 155 |
| 21-Feb-07 | Feb. | 120 | 150 | 150 |
| 5-Mar-07 | March | 150 | 140 | 135 |
| 24-Apr-07 | April | 200 | 210 | 200 |
| 25-Apr-07 | April | 180 | 210 | 200 |
| 8-May-07 | May | 160 | 150 | 150 |
| 5-Jun-07 | June | 270 | 210 | 270 |
| 6-Jun-07 | June | 280 | 210 | 270 |
| 18-Jun-07 | June | 230 | 130 | 260 |
| 29-Jun-07 | June | 160 | 190 | 240 |
| 2-Jul-07 | July | 210 | 210 | 240 |
| 9-Jul-07 | July | 170 | 180 | 260 |
| 14-Jul-07 | July | 180 | 210 | 250 |
| 15-Jul-07 | July | 190 | 180 | 250 |
| 23-Jul-07 | July | 180 | 180 | 230 |
| 24-Jul-07 | July | 210 | 210 | 180 |
| 31-Jul-07 | July | 230 | 210 | 250 |
| 7-Aug-07 | Aug. | 180 | 180 | 200 |
| 8-Aug-07 | Aug. | 170 | 190 | 180 |
| 17-Aug-07 | Aug. | Not Recorded | 210 | 230 |
| 19-Aug-07 | Aug. | 130 | 140 | 190 |
| 3-Sep-07 | Sept. | Not Recorded | Not Recorded | Not Recorded |
| 4-Sep-07 | Sept. | 190 | 200 | 230 |
| 12-Sep-07 | Sept. | 190 | 210 | 190 |
| 21-Sep-07 | Sept. | 210 | 210 | 220 |
| 24-Sep-07 | Sept. | 250 | 100 | 100 |
| 27-Sep-07 | Sept. | 210 | 210 | 250 |
| 17-0ct-07 | Oct. | 260 | 210 | 280 |
| 31-0ct-07 | Oct. | 230 | 210 | 280 |
| 19-Dec-07 | Dec. | 150 | 160 | 170 |

**Figure 3.32 - Example of a Data Set Recorded for the Quantitative Variable ' Water Transparency'**

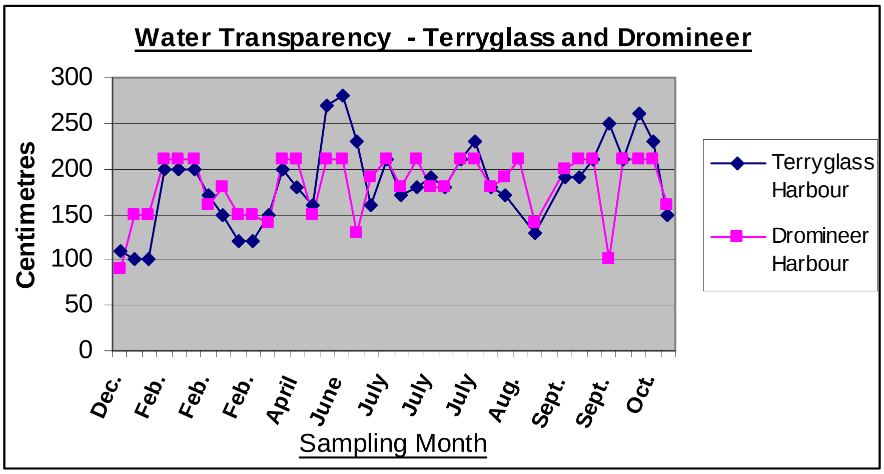



**Figure 3.33 - Example of a Line Chart Generated in Respect of the Quantitative Variable ' Water Transparency'.**

### 3.4.2 Assigning Quantitative Data to Sustainability Risk Categories

In line with the research aims, all data values recorded in respect of the quantitative variables were assigned to a three-point risk category scale similar to that used for the qualitative variables. This exercise was undertaken on the basis of prescribed criteria for each variable which were generated from appropriate external standards where available. Details of these criteria are given in Section 3.6 under the relevant variable headings. By way of example, the criteria for converting water transparency values to corresponding risk categories is given in Figure 3.34 below. The process of converting quantitative data values to risk categories, according to the prescribed criteria, was undertaken using the SPSS visual binning tool. The quantitative data sets (recorded initially in Excel spreadsheets) were transferred to SPSS data editor files. The risk category conversion criteria for each variable were inputted into the SPSS visual binning tool which then sorted the data values into low, medium or high risk categories. This process generated a series of tabulated data sets recording the risk levels generated for the various quantitative variables at specified sampling locations for the various sampling dates. These data sets were similar to those produced for the qualitative variables (see Figure 3.30).

| **Risk Category Conversion Criteria for Water Transparency Data** | | |
|---|---|---|
| **Category** | **Criteria (units Metres)** | **Source** |
| Low | > 2 | 1976 EU Bathing Water Directive |
| Medium | 1 - 2 | |
| High | < 1 | Irish Bathing Water Regulations, 1992 |

**Figure 3.34 - Example of Criteria Specified for Converting Quantitative Data Values to Corresponding Risk Categories**

### 3.4.3 Generating Category Frequency Charts

The generation of category frequency charts was again carried out using a combination of the SPSS (15.0) statistical software package and Microsoft Excel software. For both qualitative and quantitative variables, the risk category data sets (see example, Figure 3.30) were transferred to an SPSS file. The SPSS frequency analysis tool was then used to generate tables showing the frequency of each recorded risk category for each variable and location (see Figures 3.35 and 3.36). This data was then transferred back to an Excel spreadsheet where the Excel chart function was used to create charts depicting the frequency of each category (low, medium or high) as determined by the SPSS software. As an example, a risk category frequency chart generated in respect of the quantitative variable 'water transparency' is given in Figure 3.37.

**Oil Films, Terryglass Harbour (LMH)[a]**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Low | 15 | 65.2 | 65.2 | 65.2 |
| | Medium | 4 | 17.4 | 17.4 | 82.6 |
| | High | 4 | 17.4 | 17.4 | 100.0 |
| | Total | 23 | 100.0 | 100.0 | |

a. Tourism Season = Low

**Figure 3.35 - Example of Category Frequency Table Generated by SPSS Software for the Qualitative Variable 'Visible Oil Films'**

**Water Transparency, Terryglass Harbour (cms) (Binned)**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Low | 2 | 4.9 | 5.6 | 5.6 |
| | Medium | 23 | 56.1 | 63.9 | 69.4 |
| | High | 11 | 26.8 | 30.6 | 100.0 |
| | Total | 36 | 87.8 | 100.0 | |
| Missing | 9999 | 5 | 12.2 | | |
| Total | | 41 | 100.0 | | |

**Figure 3.36 - Example of Category Frequency Table Generated by SPSS Software for the Qualitative Variable ' Water Transparency'**

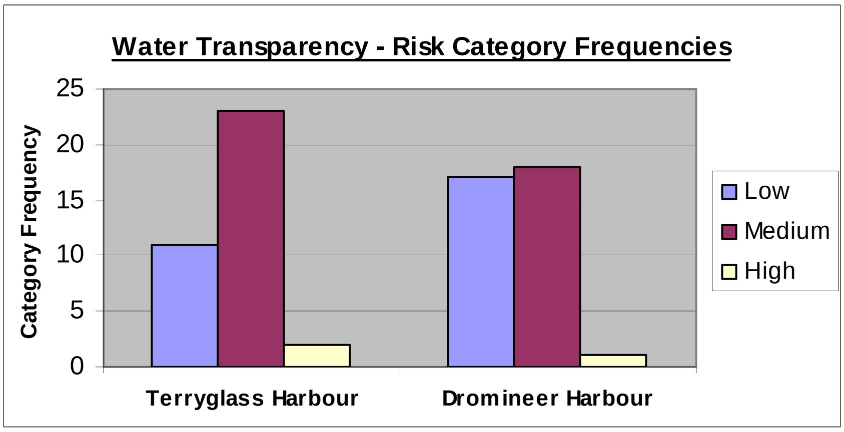



**Figure 3.37 - Example of a Risk Category Frequency Chart Generated in Respect of the Quantitative Variable 'Water Transparency'.**

### 3.4.4 Calculating Sustainability Risk Ratings

The generation of 'sustainability risk ratings' addresses the difficulty associated with interpreting the relative proportion, or frequency distribution, of the low, medium and high risk categories recorded for each variable. The sustainability risk rating therefore represents this proportion or distribution in the form of a single score. This system is intended to greatly aid the communication of this important relationship for each variable. In addition, the use of the risk rating system provides a means of combining the results for individual variables in order to generate an aggregated or average rating for groups of variables or a particular location.

Sustainability risk ratings were generated in the same manner for both quantitative and qualitative variables. As stated the risk rating for each variable represents the relative proportion of low, medium and high categories recorded for that variable and was calculated on basis of a simple weighting system which was applied to each risk category (see below for actual method of calculation). To enhance the communicative value of the rating system it was decided that the rating would be percentage based with, therefore, maximum and minimum values of 100 and 0 respectively. This approach requires that the proportion of recorded low, medium and high risk categories (see example Figure 3.37 above) was first expressed as a percentage proportion (this approach also takes account of the inevitable variations in the number of sampling occasions for each variable which would other wise introduce systematic error into the rating calculations).

The weighting system was then chosen such that if the proportion of high risk categories recorded was 100% then a rating of 100 would be returned. By contrast, if the proportion of low risk categories was 100% then a rating of 0 would be returned. For the medium risk categories, it was decided that a 100% proportion should correspond to a risk rating of 50. In line with this stipulation, weightings of 1.0, 0.5 and 0.0 were applied, respectively, to the risk categories, high, medium and low.

The actual method of calculating the sustainability risk ratings was as follows. Percentage based proportions of low, medium and high risk categories recorded for each variable were first calculated according to Equation 1 below:

*Equation 1:*

$$\frac{\text{Frequency of Specified Risk Category}}{\text{Total Number of Measurements}} \times 100 = \%\ \text{Frequency of Recorded Category}$$

Calculation of the risk rating was then based on assigning the weightings or multipliers to the percentage proportion (or frequency) of each risk category and summing the result. The multipliers (weightings) assigned to the percentage proportion of each risk category are as follows:

Percentage proportion of 'Low' categories; Multiplier = 0

Percentage proportion of 'Medium' categories; Multiplier = 0.5

Percentage proportion of 'High' categories; Multiplier = 1.0

The risk rating for each particular data set was then calculated according to Equation 2 below:

*Equation 2:*

$$\left( \begin{array}{ll} \text{Percentage of 'low' categories recorded} & \times 0 \\ + & \\ \text{Percentage of 'medium' categories recorded} & \times 0.5 \\ + & \\ \text{Percentage of 'high' risk categories recorded} & \times 1.0 \end{array} \right) = \text{Sustainability Risk Rating}$$

The use of these particular multipliers to calculate the risk rating means that in the event, for example, that only low risk categories are recorded for a given variable at a particular sampling site then the corresponding risk rating will be zero (indicating no risk to sustainability). On the other hand if only high or only medium categories are recorded then the corresponding ratings would be 100% and 50%, respectively.

A worked example for data corresponding to the variable 'water transparency' is provided below using the risk category frequency data given in Figure 3.38 overleaf.

| Risk Category Frequency Data for Water Transparency at Terryglass Harbour | |
|---|---|
| Risk Category | Frequency |
| **Low** | **11** |
| **Medium** | **23** |
| **High** | **2** |
| Total No. of Measurements | **35** |

**Figure 3.38 - Risk Category Frequency Data for 'Water Transparency' at Terryglass Harbour**

Calculation of percentage proportion of low categories recorded. Apply equation 1.

Percentage of 'Low' categories recorded = $\frac{11}{35} \times 100 = 31.4\%$

Percentage of 'Medium' categories recorded = $\frac{23}{35} \times 100 = 65.7\%$

Percentage of 'High' categories recorded = $\frac{2}{35} \times 100 = 5.7\%$

Calculation of percentage sustainability risk rating. Apply Equation 2 using values generated from Equation 1.

$$\left( \begin{array}{c} 31.4 \times 0 \\ + \\ 65.7 \times 0.5 \\ + \\ 5.7 \times 1.0 \end{array} \right) = \underline{38.5}$$

(The Sustainability Risk Rating for 'water transparency' at Terryglass Harbour)

### 3.4.5 Combining Sustainability Risk Ratings

Initial risk ratings were generated in respect of complete data sets recorded for individual variables at a particular sampling site (as per the worked example given above). This process produced a number of risk ratings for the various variables recorded at each sampling site as presented in the example chart in Figure 3.39 below.

Individual ratings were then combined in order to produce risk ratings for specified areas (Terryglass Harbour or Lough Derg, for example, see Figure 3.40 below) or for groups of variables (known as ‘sustainability risk groups’). This process was achieved by simply calculating the mean value of the individual risk ratings constituent to an aggregated area or larger variable group.

In addition, the process of risk rating calculation was also applied to subgroups of the data sets in order to generate ratings for individual variables but in respect of low and high season data, for example. The process of combining ratings was then the same as that applied to the all year data sets as detailed above.

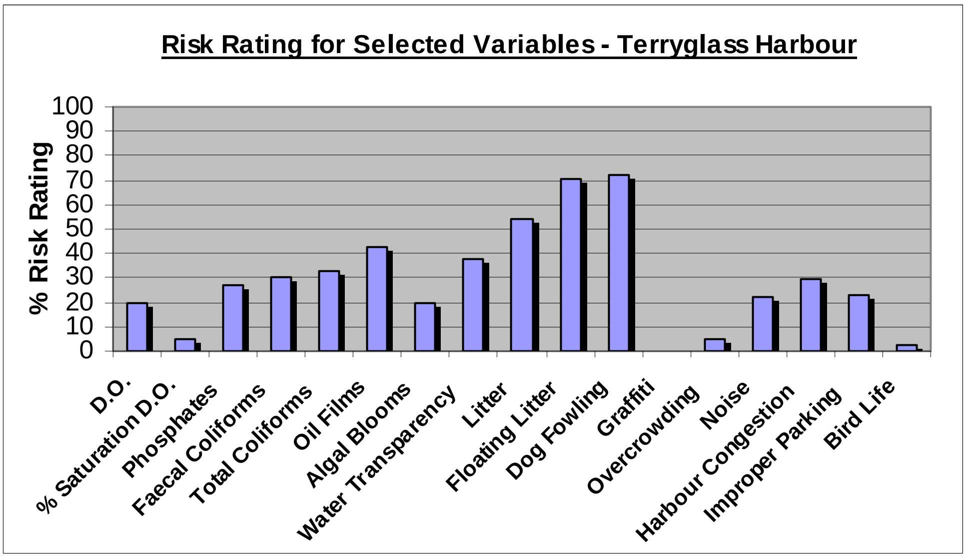



**Figure 3.39 - Example of Risk Ratings Generated for Variables Recorded at Terryglass Harbour**

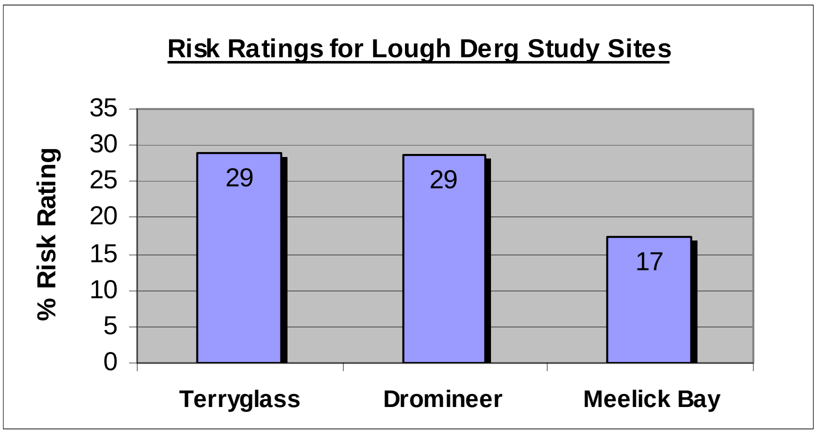



**Figure 3.40 - Example of Combined Risk Ratings Generated for the Lough Derg Study Sites**

## 3.5 Analysis of Raw Data – Identification of Significant Trends

The trend analysis undertaken for each variable was intended to examine a number of potential issues. These issues included the possible influence of recreation activity on the variable, the identification of possible external factors influencing the variable and also the general behaviour of the variable with respect to factors such as the time of year or weather conditions. In practice the relevance of these issues very much depended on the variable under investigation but they nevertheless dictated the general approach to the trend analysis process. By way of addressing these issues, the trend analysis for each variable involved one or more of the following approaches:

- A general review of the data for any evident patterns associated with the duration of monitoring period, such as time of year.
- A comparison of data between different study sites within each study area.
- A comparison of data between different sampling sites within a particular study site.

- A comparison between data values recorded during the low and high recreation seasons, as defined. This was used to provide an indication as to the potential influence of levels of recreational activity on the variables in question.

With respect to quantitative variables, generally, the initial analysis involved simply plotting all values against the date on which they were recorded. This provided a useful picture of the behaviour of the variable on a week by week basis over the course of a sampling year. By identifying the peak tourist season at a study site (by reference to the number of cars and boats present, for instance) the trend in data values for a particular variable could also be analysed against the changing tourist and recreation seasons. Where deemed appropriate, the data for a given variable recorded at separate sampling sites, within a given study site or a larger study area, could be displayed on the same line graph in order to aid the identification of possible associations between sampling sites or locations. This approach was used, for example, in the case of water quality variables which were indicative of organic pollution, in order to test whether the concentration of cruise boats in the Lough Derg harbour areas was contributing to observed levels of such pollution or whether the problem was more associated with the lake in general.

Where relationships of interest, such as differences or similarities in potentially related sets of data (from two different sampling points or high and low seasons, for example) statistical tests were used to confirm whether the observed differences or similarities were actually statistically significant and not due to, for example, random error in the sampling method. The tests used were predominantly two tailed T-Tests which were available as a software tool with Microsoft Excel. The generated ‘P Values’ were used to verify the significance at a confidence level of 95%.

Trend analysis with respect to qualitative variables was largely confined to the analysis of the relative proportion of risk categories recorded for each variable. This analysis provided useful insight into the performance and behaviour of qualitative variables over the course of the monitoring period. Useful comparisons could also be made between qualitative data recorded at different locations. In addition, by presenting qualitative data with respect to high and low recreation season it was possible to gain insight into the relative performance of particular variables with respect to the different seasons.

## 3.6 All Selected Variables – Background Information, Sampling Strategy, Method of Analysis and Risk Category Criteria

### 3.6.1 Dissolved Oxygen

#### *3.6.1.1 Background Information and Significance*

The meaningful interpretation of dissolved oxygen values in fresh water can be complex but there are two main issues of significance in the context of this study. Firstly, dissolved oxygen is essential for the metabolism of various aquatic animals and hence a certain level of dissolve oxygen is crucial for the survival of fish and for the general health of an aquatic ecosystem (EPA, 2001). Secondly, naturally occurring dissolved oxygen levels will normally be adversely affected by organic or nutrient pollutants entering a water body and hence dissolved oxygen levels can indicate the presence of pollution (EPA, 2001). Organic pollutants (animal wastes for example) entering freshwater will be broken down by aerobic bacteria which consume oxygen in the process. Even small quantities of such pollution can cause dramatic drops in dissolved oxygen levels which can result in fish kills and damage to other members of the aquatic ecosystem (EPA, 2001).

A key consideration when interpreting dissolved oxygen levels is that the solubility of oxygen in water has an inverse relationship with the temperature of the water. This means that water has the ability to absorb (or contain) higher levels of dissolved oxygen at lower temperatures. For example, in fresh waters the maximum dissolved oxygen concentration possible at 20ºC is 9.2 mg/l whereas at 10ºC it is 11.3 mg/l (EPA, 2001).

This means that the ambient water temperature is an influential factor in the recorded level of dissolved oxygen (EPA, 2001). To overcome the potential complexities regarding the interpretation of dissolved oxygen levels which are presented by this solubility/water temperature relationship, the related parameter of 'percentage saturation' of dissolved oxygen can be used in addition to dissolved oxygen concentration values on their own (see Section 3.6.2 below).

#### *3.6.1.2 Method of Analysis and Sampling Procedure*

*Materials*

Dissolved oxygen levels were recorded directly using a Thermo Electron Corporation portable dissolved oxygen meter and probe (Model, Orion 3 Star).

*Sampling Procedure (Method)*

The meter display was set for dissolved oxygen read out as per the manufacturers instructions. For each reading the probe was lowered into the water to a depth of approximately 50cms. The dissolved oxygen value, in mg/l, was then read from the meter display and recorded.

*Equipment Calibration*

Calibration of the DO Meter was carried out on the day of each sampling occasion. This was done according to the manufacturers instructions and involved setting up a calibration sleeve into which the DO probe was place for 15 minutes before actuating the automated calibration function on the meter.

#### *3.6.1.3 Criteria for Assigning Risk Categories.*

The most relevant criteria for the dissolved oxygen (DO) data are taken from the Freshwater Fish Directive (78/659/EEC). This directive specifies that, for salmonid waters (i.e. freshwaters providing habitat for salmon and trout species) 50% of water samples must return DO values of greater than 9 mg/l $O_2$ (mandatory level) and 100% of returned values must be greater than 7 mg/l $O_2$ (guide level). DO levels above 9mg/l are considered High; Levels between 7 and 9 mg/l are considered Medium and levels below 7mg/l are considered Low.

The criteria for Low, Medium & High categories for Dissolved Oxygen (mg/l) are summarised in Table 3.11 below; Note that these criteria apply to freshwater DO values only and therefore are only applicable to the Lough Derg sites. In the absence of relevant DO criteria applicable to marine waters, no risk categories were assigned to the Dublin Bay data.

**Table 3.11 - Risk Category Conversion Criteria for Dissolved Oxygen Data**

| Risk Category | Criteria (units mg/l $O_2$) | Source |
|---|---|---|
| Low | < 7 | EU Freshwater Fish Directive |
| Medium | 7 - 9 | |
| High | > 9 | EU Freshwater Fish Directive |

### 3.6.2 Percentage Saturation of Dissolved Oxygen

#### *3.6.2.1 Background Information and Significance*

Measuring dissolved oxygen in terms of its percentage (of maximum possible) saturation, essentially circumvents the influence that water temperature has on dissolved oxygen levels. Hence, unpolluted waters (both freshwater and marine) should normally have dissolved oxygen levels close to the maximum (or 100%) saturation level regardless of the water temperature and any deviations from this can give cause for concern regarding the general health of a fresh water body and regarding the possibility of pollution occurring. As a general rule of thumb, the percentage saturation level of dissolved oxygen should fall ideally fall within the range of 70 – 120% (EPA, 2001).

#### *3.6.2.2 Method of Analysis and Sampling Procedure*

*Materials*

Percentage saturation of dissolved oxygen levels were recorded using a Thermo Electron Corporation portable dissolved oxygen meter and probe (Model – 3 Orion Star)

*Sampling Procedure (Method)*

The meter display was set for percentage saturation of dissolved oxygen and read out as per the manufacturers instructions. For each reading the probe was lowered into the water to a depth of approximately 50cms. The percentage saturation of dissolved oxygen value was then read from the meter display and recorded.

*Equipment Calibration*

Calibration of the DO Meter was carried out on the day of each sampling occasion. This was done according to the manufacturers instructions and involved setting up a calibration sleeve into which the DO probe was place for 15 minutes before actuating the automated calibration function on the meter.

### 3.6.2.3 Criteria for Assigning Risk Categories

For percentage saturation data, the most applicable criteria has been generated from criteria designated in a combination of the EU Bathing Water Directive 1976 and the Irish Quality of Bathing Water Regulations 1992 (S.I. No. 155 of 1992). The Quality of Bathing Water Regulations 1992 stipulates a range for percentage saturation of DO of between 70 and 120 % for good quality bathing waters. The equivalent range specified by the Bathing Water Directive is 80 – 120%. In this context, for both the Lough Derg and Dublin Bay data, % Saturation DO values below 70% and/or above 120% are categorised as low. Values falling between 70 and 80 % are categorised as Medium. Values between 80 and 120 % are categorized as High (see summary table below).

The criteria for Low, Medium & High categories for the percentage saturation of dissolved oxygen values are summarised in Table 3.12 below:

**Table 3.12 - Risk Category Conversion Criteria for % Saturation Dissolved Oxygen Data**

| Risk Category | Criteria (units mg/l $O_2$) | Source |
|---|---|---|
| Low | > 80% < 120% | Irish Bathing Water Regs. & EU Bathing Water Directive |
| Medium | > 70% < 80% | EU Bathing Water Directive 1976 |
| High | < 70% or >120% | Irish Bathing Water Regulations 1992 |

### 3.6.3 Phosphates

#### *3.6.3.1 Background Information and Significance*

The variable 'phosphates' was only applied to the Lough Derg study area. This was due to difficulties with identifying a practical method for analysing phosphates in marine waters and also due to the fact that phosphates are known to play a more central role in the water chemistry and ecology of freshwaters as apposed to marine waters. The following details apply therefore to the significance of phosphates in freshwaters only.

As with many lakes in Ireland, elevated phosphorus levels are an ongoing problem (Bowman & Toner, 2001) and are primarily associated with run-off water from adjoining agricultural lands and domestic waste-water (Toner et al., 2005). The main significance to the tourism industry, therefore, is the association of high phosphorus levels in lakes with the proliferation of algal blooms (see discussion under 'Algal Bloom' variable in Section 3.6.8 below) which can be very unsightly and can cause odour problems.

The element phosphorus occurs naturally in plants, micro-organisms and in animal waste. As such, residual levels of phosphorus occur naturally in lake waters either in true solution, in colloidal suspension or adsorbed onto particular matter (EPA, 2001). The analytical procedure for determining ortho-phosphate levels does not distinguish between these form of phosphorus but is considered a useful technique as it does not require pre-treatment of samples and still provides a good approximation of phosphorus levels in water (EPA, 2001).

Phosphorus is widely used as an agricultural fertilizer and is also a major constituent of domestic and commercial detergents. Thus surface run-off and sewage can be important contributors of phosphorus to surface waters and can be responsible for elevating levels over and above those occurring naturally (Toner et al., 2005). Although, not a health hazard in its own right, the principal significance of phosphorus is its use in highlighting the potential presence of sewage and/or agricultural run-off contamination in surface waters (EPA, 2001). As an important growth nutrient, phosphorus is a key contributor to eutrophication in lakes especially where elevated levels occur (Bowman and Toner, 2001). In an amenity context eutrophication can manifest itself in terms of excessive shore algal growth and algal blooms. Such occurrences can lead to odour problems, loss of visual appeal and, in extreme cases, the closure of lakeside beaches due to potentially toxic algal blooms.

#### *3.6.3.2 Method of Analysis and Sampling Procedure*

*Materials and Reagents:*

Ortho-Phosphate analysis was undertaken in the laboratory using a Hannah C200 multi-parameter bench photometer (Series HI 83000).

Other required materials were as follows:

A 500ml glass sampling jar attached to the end of a sampling pole

100ml glass transport jars.

A set of 10ml glass phials (supplied with the photometer).

Required Reagents are supplied by Hannah Instruments and were as follows:

Molybdate Reagent (Code 93717A-0)

Reagent B (Code 93717B-0)

*Sampling Procedure:*

At the assigned sampling points the sampling jar was first rinsed a number of times with the water to be sampled. The 500ml sampling jar was then lowered (using the sampling pole) to a depth of approximately 50 cms and filled completely. The contents were transferred to a 100ml glass transport jar which was filled completely, labelled and transferred to an insulated storage container.

*Method of Analysis:*

Measurement of phosphate levels in each sample was undertaken according to the manufacturers instruction manual for 'Phosphate High Range'. The method used is based on an adaptation of the Standard Methods for the Examination of Water and Wastewater, 18th Edition, Amino Acid method. The reaction between phosphate and the reagents causes a blue tint in the sample which is analysed by the photometer using the principals of light absorption at specific wavelengths.

In summary, the process of analysis involved first calibrating the photometer. This was done by filling a 10ml glass phial with a 'blank' sample of distilled water which was then inserted into the photometer for the calibration stage. The second stage involved preparing a second 10ml glass phial with the sample and reagents. This phial was then allowed to stand for a specified time and transferred to the photometer for reading the phosphate level. The level was read from the photometer display.

#### *3.6.3.3 Criteria for Assigning Risk Categories.*

The existing standards for phosphorus levels in Irish freshwaters are complex. A range of standards exists which relate to different categories of lakes or river. In addition, standards are expressed in terms of both ortho-phosphates and total phosphorus levels. The standards for lakes are given largely in terms of 'Total Phosphorus'. However, this parameter is more difficult to analyse and therefore for practical reasons it was decided to record phosphorus levels in terms of ortho-phosphate levels. The standards for this expression of phosphorus are less definitive. However general guide levels do exist, particularly with respect to river waters. Depending on the pollution status of a river, the EPA have set out phosphate target levels (expressed as annual median values) which range from between 0.015 to 0.070 mg/l P. In addition the Environmental Protection Agency states that from their experience once phosphate levels in lakes exceed 0.02mg/l then algae and plant growth can reach 'nuisance' proportions (EPA, 1997). The following criteria for the Low, Medium and High risk categories (see Table 3.13) have been generated using a combination of the guide values described above (note that the upper limit of 0.05 mg/l P is based on the target level for moderately polluted rivers).

The criteria are summarised in Table 3.13 below:

**Table 3.13 - Risk Category Conversion Criteria for Ortho-Phosphate Data**

| Risk Category | Criteria (units mg/l P) | Source |
|---|---|---|
| Low | <0.02 | EPA Guidance Notes |
| Medium | 0.02 – 0.05 | |
| High | > 0.05 | EPA Environmental Quality Standards |

### 3.6.4 Ammonia

Note that reagents were not available in time for applying this variable to the Lough Derg Study Area. Thus this variable was applied to the Dublin Bay sites only

#### *3.6.4.1 Background Information and Significance*

Ammonia occurs naturally in waters as a result of the microbial decomposition of vegetative material. However, concentrations are normally very low (EPA, 2001). The significance of Ammonia as a indicator of water quality arises as a result of the high levels of ammonia which occur in domestic wastewater (sewage). Thus where elevated levels of ammonia are found in marine or fresh waters this can be considered an indicator of possible sewage contamination (EPA, 2001)

Measurement and the setting of guideline levels of ammonia is complicated by the complex chemistry of ammonia in water. Depending on the pH and temperature of the water, ammonia (in the form of $NH_3$) will readily convert to ammonium (in the form of $NH_4^+$). Thus to circumvent these complexities, guide limits for ammonia are normally specified in terms of the parameter 'total ammonia' (as mg/l of Nitrogen) which effectively includes the concentration of both ammonia and ammonium (EPA, 2001). As a rule of thumb, total ammonia levels above 0.1mg/l N are considered to be elevated and may indicate the presence of sewage contamination of the water (EPA, 2001). Other guide limits with respect to this parameter are discussed in Section 3.6.4.3 below.

#### *3.6.4.2 Method of Analysis and Sampling Procedure*

*Materials and Reagents:*

Ammonia analysis was undertaken in the laboratory using a Hannah C200 multi-parameter bench photometer (Series HI 83000).

Other required materials were as follows:

A 500ml glass sampling jar attached to the end of a sampling pole

100ml glass transport jars.

A set of 10ml glass phials (supplied with the photometer).

Required Reagents are supplied by Hannah Instruments and were as follows:

First Reagent (Code 93715A-0)

Second Reagent (Code 93715B-0)

*Sampling Procedure:*

At the assigned sampling points the sampling jar was first rinsed a number of times with the water to be sampled. The 500ml sampling jar was then lowered (using the sampling pole) to a depth of approximately 50 cm and filled completely. The contents were transferred to a 100ml glass transport jar which was filled completely, labelled and transferred to an insulated storage container.

<u>*Method of Analysis:*</u>

Measurement of ammonia levels in each sample was undertaken according to the manufacturers instruction manual for ‘Ammonia Medium Range’. The method used is based on an adaptation of the ASTM Manual of Water and Environmental Technology, D1426-92, Nessler method. The reaction between ammonia and the reagents causes a yellow tint in the sample which is analysed by the photometer using the principals of light absorption at specific wavelengths.

In summary, the process of analysis involved first calibrating the photometer. This was done by filling a 10ml glass phial with a ‘blank’ sample of distilled water which was then inserted into the photometer for the calibration stage. The second stage involved preparing a second 10ml glass phial with the sample and reagents. This phial was then allowed to stand for a specified time and transferred to the photometer for reading the ammonia level. The level was read from the photometer display.

#### *3.6.4.3 Criteria for Assigning Risk Categories*

Neither the Bathing Water Regulations (S.I. No. 155 of 1992) or the Blue Flag Standard stipulate guide or limit values for the parameter ammonia. However, ammonia is considered under the EPA Environmental Quality Objectives and Standards proposal and the Water Quality Management Plan for Dublin Bay. Both of these standards propose that ‘total ammonia’ levels should not exceed 0.3 mg/l in the case of estuary waters and 0.8 mg/l in the case of coastal or marine waters. As the Dublin Bay study sites can be considered to lie within the transition zone between the River Liffey estuary and deeper coastal waters both of the above specified levels have been adopted as risk category criteria for this research. Thus, ammonia values below 0.3mg/l are assigned to the low risk category, values between 0.3 and 0.8 mg/l are assigned to the medium risk category and values above 0.8 mg/l are considered high risk. These criteria are summarised in Table 3.14 below:

**Table 3.14 - Risk Category Conversion Criteria for Total Ammonia Data**

| Risk Category | Criteria (mg/l N) | Source |
|---|---|---|
| **Low** | < 0.3 | Dublin Bay Water Quality Management Plan and EPA EQS limit value for coastal waters |
| **Medium** | 0.3 – 0.8 | Between high and low categories |
| **High** | > 0.8 | Dublin Bay Water Quality Management Plan and EPA EQS limit value for estuary waters |

### 3.6.5 Faecal and Total Coliforms

Note that limitations with the chosen method of analysis meant that this parameter could only be measured in freshwaters. Thus, this variable was applied to Lough Derg study area sites only.

#### *3.6.5.1 Background Information and Significance*

Coliforms are a very common group of bacterial micro-organisms which grow in large numbers in soils or the intestines of warm blooded animals. In particular, Faecal coliforms grow exclusively in the human or animal intestine and are past in large numbers in faecal waste (EPA, 2001). Due to their relative ease of detection and quantification, faecal coliforms are used as an indicator of faecal contamination of water (due primarily to either domestic sewage or animal farm waste) while total coliforms are used as an indicator of the general level of microbial contamination of a water body (EPA, 2001). Most coliform bacteria are not a health hazard in their own right. However, as an indicator of faecal contamination they highlight and quantify the potential presence of other pathogenic (disease causing) bacteria which are associated with animal or human waste (EPA, 2001).

Faecal and Total Coliforms are recorded quantitatively and results can be expressed as the ‘Most Probable Number’ of colony forming units (CFUs) per 100 millilitres. A ‘colony forming unit’ is essentially a living and viable bacterial cell and ‘Most Probable Number’ is a statistical representation (required for the analytical technique) of the actual number of bacteria in a sample at a 95% confidence level.

### *3.6.5.2 Method of Analysis and Sampling Procedure*

*Materials and Reagents:*

Analysis for both total and faecal coliforms was undertaken in the laboratory using an Idexx Colilert-18 Test Kit in conjunction with a 51 cell Idexx Quanti-Tray Enumeration System. This kit includes the following items.

(51 cell) Idexx Quanti-Tray Enumeration trays.

An Idexx Quanti-Tray Sealer.

A standard laboratory incubator set at 35ºC (±0.5ºC).

A UV viewing box supplied with a 6 watt, 365nm UV light.

Idexx Colilert-18 media snap packs.

Sterile 100ml sealable plastic containers.

10 ml sterile plastic pipettes

*Sampling Procedure*

At the assigned sampling points the 100ml plastic sampling jars were first rinsed a number of times with the water to be sampled. The jars were then lowered to a depth of approximately 50 cm and filled completely and sealed with the lids supplied. Aseptic technique was used throughout the process. The plastic jars were then labelled and transferred to an insulated storage container.

<u>*Method of Analysis:*</u>

Measurement of total and faecal coliform levels in each sample was undertaken according to the test kit manufacturers instruction leaflet. The method used is based on the manufacturers patented Defined Substrate Technology. When total coliforms metabolise Collilert-18's nutrient-indicator (ONPG) the sample turns yellow. When *E. coli* metabolises Colilert-18's nutrient-indicator (MUG) the sample fluoresces. Colilert-18 can simultaneously detect these bacteria at 1 colony forming unit (cfu)/100 ml within 18 hours.

In summary, the method of analysis involved a number of stages and aseptic technique was observed throughout. For each sample a Colilert-18 snap pack was first opened and the media added to sample. The lid was replaced (on the sample jar) and the sample was shaken and the media allowed to dissolve. Next the sample/media solution was transferred to an Idexx 51 cell Quanti-Tray enumerator. The Quanti-Tray was then heat sealed using the Idexx Quanti-Tray sealer. The tray was then labelled and transferred to the incubator set at 35°C. Prepared Quanti-Trays were then incubated for a minimum of 18 hours.

Reading of results were as follows; For total coliforms the number of positive cells (turned a distinct yellow colour) on the Quanti-Tray was recorded. For faecal coliforms the Quanti-Tray was viewed under fluorescent light and the number of positive (fluorescing) cells was recorded. In both cases the most probably number of colony forming units (cfu's) per 100mls was then calculated using the MPN table supplied by Idexx.

For a standard undiluted sample the 51 cell Quanti-Tray enumerator allowed the measurement of most probable number of cfu/100ml values in the range <1 to >200.5. Where pilot study results indicated that this range was likely to be exceeded at a particular sampling point then a dilution of x10 or x100 was performed on the sample prior to analysis. This procedure allowed MPN values in the range of <10 to >2005 and <100 to >20050 cfu/100mls to be calculated in each case. Dilutions were achieved by first transferring by means of sterile pipettes either 10mls (for the x10 dilution) or 1mls (for the x100 dilution) of the sample to a sterilised 100ml glass jar and then making the solution up to 100mls using sterilised distilled water. This diluted sample was then processed in the same manner as described above for the undiluted sample. Values were then simply multiplied by a factor of 10 or 100, as appropriate, to get the actual result for the original undiluted sample. Sterilisation of the 100ml glass jars and distilled water was achieved using an autoclave at 115°C for 15 minutes.

#### *3.6.5.3 Criteria for Assigning Risk Categories*

Three standards are considered relevant with regard to setting criteria for categorising the quantitative data for both Faecal and Total Coliforms. These are the Bathing Water Regulations 1992 (S.I. No. 155 of 1992) and the Blue Flag Beach Standard. For Faecal Coliforms the Bathing Water Regulations specify a level of <1000 colony forming units (this is equivalent to MPN cfu's) per 100 mls to be conformed by at least 80% of samples. A second level is also specified which is < 2000 colony forming units to be conformed by at least 95% of samples. The equivalent levels set by the Bathing water Regulations for Total Coliforms is <5000 and <10,000 colony forming units, respectively. The Blue Flag scheme sets out two limit levels for both Faecal and Total Coliforms. These are 100 and 2000 colony forming units per 100mls (to be achieved by

80% and 95% of samples, respectively) in the case of Faecal Coliforms and 500 and 10,000 colony forming units (again, to be achieved by 80% and 95 % of samples, respectively) in the case of Total Coliforms.

These standards have been used to set the following criteria (in Tables 2.15 and 2.16) for converting the quantitative coliform data into Low, Medium and High categories.

**Table 3.15 - Risk Category Conversion Criteria for Faecal Coliform Data**

| Risk Category | Criteria (MPN CFUs/100ml) | Source |
|---|---|---|
| **Low** | < 100 | Blue Flag 80% Limit Value |
| **Medium** | 100 – 1,000 | |
| **High** | > 1,000 | Bathing Water Regs. ('92) 80% Limit Value |

**Table 3.16 – Risk Category Conversion Criteria for Total Coliform Data**

| Risk Category | Criteria (MPN CFUs/100ml) | Source |
|---|---|---|
| **Low** | < 500 | Blue Flag 80% Limit Value |
| **Medium** | 500 – 5,000 | |
| **High** | > 5,000 | Bathing Water Regs. ('92) 80% Limit Value |

### 3.6.6 Enterococci

The variable enterococci applies exclusively to the Dublin Bay sites. As outlined below, this is largely because this parameter provides a more practical indicator of microbial contamination in marine waters than coliforms as described above.

#### *3.6.6.1 Back ground Information and Significance.*

Enterococci are a group of micro organisms which, like faecal coliforms, originate in the faeces of both humans and animals. Unlike faecal coliforms, enterococci do have some pathogenic properties but nevertheless their main use is also as indicators of faecal pollution of water bodies. As an indicator, the determination of enterococci levels is considered to be very reliable and their estimation can be used to clarify the microbial position of waters in certain circumstance (EPA, 2001). Moreover, in the context of this research, the determination of enterococci in marine waters can be undertaken using a similar (very practical) method to that available for the determination of coliforms in freshwaters (this method can not be used for coliforms in marine waters). As with coliforms, the numbers of enterococci are recorded in a quantitative manner using the statistical representation referred to as the 'most probable number' (MPN) of colony forming units per 100 millilitres.

#### *3.6.6.2 Method of Analysis and Sampling Procedure*

*Materials and Reagents:*

Analysis for enterococci was undertaken in the laboratory using an Idexx Enterolert Test Kit in conjunction with a 51 cell Idexx Quanti-Tray Enumeration System. This kit includes the following items.

(51 cell) Idexx Quanti-Tray Enumeration trays.

An Idexx Quanti-Tray Sealer.

A standard laboratory incubator set at 35ºC (±0.5ºC).

A UV viewing box supplied with a 6 watt, 365nm UV light.

Idexx Enterolert media snap packs.

Sterile 100ml sealable plastic containers.

10 ml sterile plastic pipettes

*Sampling Procedure*

At the assigned sampling points the 100ml plastic sampling jars were first rinsed a number of times with the water to be sampled. The jars were then lowered to a depth of approximately 50 cm and filled completely and sealed with the lids supplied. Aseptic technique was used throughout the process. The plastic jars were then labelled and transferred to an insulated storage container.

*Method of Analysis:*

Measurement of enterococci levels in each sample was undertaken according to the test kit manufacturers instruction leaflet. The method used is based on the manufacturers patented Defined Substrate Technology. When enterococci utilise their ß-glucosidase enzyme to metabolise Enterolert's nutrient-indicator, 4-methyl-umbelliferyl ß-Dglucoside, the sample fluoresces. Enterolert detects enterococci at 1 colony forming unit (cfu)/100 ml sample within 24 hours.

In summary, the method of analysis involved a number of stages and aseptic technique was observed throughout. For each sample an Enterolert snap pack was first opened and the media added to the sample. The lid was replaced (on the sample jar) and the sample was shaken and the media allowed to dissolve. Next the sample/media solution was transferred to an Idexx 51 cell Quanti-Tray enumerator. The Quanti-Tray was then heat sealed using the Idexx Quanti-Tray sealer. The tray was then labelled and transferred to an incubator set at 35°C. Prepared Quanti-Trays were then incubated for a minimum of 24 hours.

Reading of results was achieved by placing the Quanti-Tray into the UV lamp viewer and counting the number of positive (fluorescing) cells on the Quanti-Tray. The most probably number of colony forming units (cfu's) per 100mls was then calculated using the MPN table supplied by Idexx.

For a standard undiluted sample the 51 cell Quanti-Tray enumerator allowed the measurement of most probable number of cfu/100ml values in the range <1 to >200.5. Where pilot study results indicated that this range was likely to be exceeded at a particular sampling point then a dilution of x10 or x100 was performed on the sample prior to analysis. This procedure allowed MPN values in the range of <10 to >2005 and <100 to >20050 cfu/100mls to be calculated in each case. Dilutions were achieved by first transferring by means of sterile pipettes either 10mls (for the x10 dilution) or 1mls (for the x100 dilution) of the sample to a sterilised 100ml glass jar and then making the solution up to 100mls using sterilised distilled water. This diluted sample was then processed in the same manner as described above for the undiluted sample. Values were then simply multiplied by a factor of 10 or 100, as appropriate, to get the actual result for the original undiluted sample. Sterilisation of the 100ml glass jars and distilled water was achieved using an autoclave at 115°C for 15 minutes.

#### *3.6.6.3 Criteria for Assigning Risk Categories.*

Two standards are considered relevant with regard to setting criteria for categorising the quantitative enterococci data into equivalent risk categories. These are the Bathing Water Regulations 1992 (S.I. No. 155 of 1992) and the Blue Flag Beach Standard. For the European Blue Flag Standard 90% of samples must return enterococci results of 100 colony forming units per 100mls or less. This standard is taken as the cut off point for the low risk category. The Irish Bathing Water Regulations state that waters should not exceed levels of 300 CFUs per 100mls (to be conformed with by 95% of samples and not to be exceeded by two consecutive samples). This standard is adopted as the cut off point for the high risk category. The medium risk category therefore includes values between 100 and 300 CFUs per 100 mls. These criteria are summarised in Table 3.17 below:

**Table 3.17 - Risk Category Conversion Criteria for Enterococci Data**

| Risk Category | Criteria (MPN CFUs/100ml) | Source |
|---|---|---|
| **Low** | < 100 | European Blue Flag Standard |
| **Medium** | 100 – 300 | |
| **High** | > 300 | Irish Bathing Water Regulations |

### 3.6.7 Floating Oil Films

#### *3.6.7.1 Background Information and Significance:*

Floating oil films can originate from the contamination of water by hydrocarbon based substances such as petroleum products, oils, grease and other related materials. As well as being a health hazard (many of these compounds are carcinogenic) and visibly objectionable, the presence of these substances on a water body can interfere with important aquatic processes such as the transfer of oxygen from the air to the water column (EPA, 2001). Oil films can also directly interfere with and damage aquatic plants and animal life (EPA, 2001).

An obvious source of oil films is the escape of fuels, oils and greases from the engine and fuel systems of motorised leisure craft. Most motorised craft (using either inboard or outboard engines) circulate external water as part of the engine cooling systems. Leaks occurring in such systems can create a direct conduit for oils to escape into the aquatic environment. Poor storage equipment for fuels or direct spillages, either on shore or directly from craft, can also be a major source of oil films, those occurring on land being subsequently washed into adjoining waters during times of rainfall.

Hydrocarbon substances can be measured using quantitative scientific techniques such as gas chromatography. However, analytical trials carried out as part of this research project showed that such techniques were unable to reliably detect or the presence of oil contamination even where oil films were clearly visible. This was the basis of the decision to record this parameter in a qualitative (visual) manner for both the Lough Derg and Dublin Bay study sites.

#### *3.6.7.2 Method of Analysis and Recording*

The variable floating oil films was recorded primarily in a qualitative manner. Thus the level of occurrence of floating oil films at a given sampling site was recorded by direct observation and according to the criteria developed for assigning risk categories to this variable. The origins and values of these criteria are described in the following section.

#### *3.6.7.3 Criteria for Assigning Risk Categories:*

As a qualitative variable, the level of occurrence of floating oil films at a given site was recorded directly as either low, medium or high according to prescribed risk category criteria. Three standards were particularly relevant with regard to setting criteria for the qualitative recording of visual oil films into specified categories. These are the Quality of Bathing Water Regulations 1992 (S.I. No. 155 of 1992), the parent Bathing Water Directive (76/160/EEC) and the Blue Flag Beach Scheme (FEE, 2008). All three of these standards specify that ‘no (oil) film should be visible on the surface of bathing water and no odour (should be present)’. In addition, the Bathing Water Regulations (S.I. 155 of 1992) also specify that, in the case of ‘tarry residues’, ‘no offensive presence’ should be permitted in bathing waters. Although this standard does not technically apply to visible oil films, it is considered relevant in the context of this research, particularly as it provides a means of setting criteria for medium and high category risk ratings for visible oil films.

Thus the criteria for low, medium and high categories are given in the Table 3.18 overleaf:

**Table 3.18 – Risk Category Criteria for Recording Floating Oil Films**

| Category | Criteria (Qualitative) | Source |
|---|---|---|
| **Low** | No visible presence and no detectible odour | Quality of Bathing Water Regulations 1992 (S.I. No. 155 of 1992); The Bathing Water Directive (76/160/EEC) and the Blue Flag Beach Scheme |
| **Medium** | Oil films present but not to an extent considered offensive, obvious or widespread (a quantitative guide used as an aid for this category was that no more than one separate oil film should be present and this should not exceed 4 square metres in size) | The Bathing Water Regulations (S.I. 155 of 1992) |
| **High** | Oil films present to an extent considered offensive, obvious or widespread | The Bathing Water Regulations (S.I. 155 of 1992) |

### 3.6.8 Algal Blooms

#### *3.6.8.1 Background Information and Significance.*

The term ‘algal bloom’ refers to the sudden and extensive growth of tiny free floating algal organisms in lake or marine waters. This can lead to dense and unsightly accumulations of the organisms in the water column or on downwind shorelines. Such blooms can occur naturally but are more often associated with the excess input of nutrients into a water body as a result of human activity such as disposing of domestic wastewater or the application and subsequent runoff of fertilisers or animal slurries to adjacent agricultural lands (National Rivers Authority, 1990). Algal blooms tend to occur almost exclusively during the spring or summer months when warm sunny weather, along with dissolved nutrients accumulated during the winter months, allows algae to metabolise rapidly in the water column (Neill, 2005).

Although, the main problem associated with algal blooms is their negative effect on the visual and olfactory quality of an affected water body or shoreline, algal blooms are also associated with issues of toxicity in both marine and lake waters. In lakes a particular group of algal species known as cyanobacteria is known to produce chemicals that can be toxic to mammals, including humans (National Rivers Authority, 1990). Waters subject to algal blooms with a high proportion of cyanobacteria are considered potentially dangerous to certain animals and humans if ingested in significant quantities (National Rivers Authority, 1990). In Lough Derg there have been a number of reported incidents of dogs falling ill (often fatally) apparently after ingesting water from shorelines affected by algal blooms (Neill, 2005). Such incidents have prompted the local authority to post warning signs along the shores of Lough Derg alerting the public to the possible dangers associated with algal blooms and advising people not to swim or walk their dogs in the lake water during the summer months. In marine waters the toxicity issue regarding algal blooms is manifested mainly through the eating of shellfish harvested from affected waters. In this case, certain species of marine algae contain produce toxins which bio accumulate in the flesh of shellfish and can in certain circumstances present a hazard to humans who eat affected shellfish (National Rivers Authority, 1990).

#### *3.6.8.2 Method of Analysis and Recording*

The variable algal blooms was recorded in a qualitative manner. Thus the level of occurrence of algal blooms at a given sampling site was recorded by direct observation and according to the criteria developed for assigning risk categories to this variable. The origins of these criteria are described in the following section.

#### *3.6.8.3 Criteria for Assigning Risk Categories.*

The variable ‘algal blooms’ was recorded exclusively in a qualitative manner with the observed level of algal bloom occurring recorded directly on the basis of low, medium and high categories according to prescribed criteria. No directly relevant standards exist with respect to the acceptability or otherwise of differing densities of algal growth in the water column or levels of accumulation on the water surface or on shorelines. Furthermore, there is no direct and/or feasible method of quantifying the level of algal bloom occurring in the water column or on affected shorelines (Assessment of Chlorophyll and water transparency are used to some extent as an indirect estimate of algae levels in fresh and marine waters (EPA, 2000). However, the measurement of chlorophyll is relatively complex and the relationship between water transparency and algae density is not consistent).

The recording of algal bloom levels into low, medium and high categories was therefore undertaken entirely on the basis of perception and visual observation of the water column and shorelines. In order to introduce some level of consistency to this qualitative assessment, the specified criteria for designation of low, medium or high categories were very broad. That is to say, to qualify as a low category reading, no presence of algae should be readily noticeable on close inspection of the water column and no fresh algal material should be observable on relevant shorelines (note that in the case of marine shores this criteria does not include the larger sea algae vegetation commonly known as seaweed). For the medium category, free-floating algae were noticeable on close inspection of the water column or shoreline but otherwise not obvious on casual observation. Levels recorded as high corresponded to situations where profuse growth of free-floating algae or accumulations was plainly obvious either in the water column, on the water surface or on shorelines.

In spite of the absence of any directly relevant external standards with respect to algal blooms, the above criteria were also designed to follow the principle of the various standards which apply to the variable ‘floating oil films’ described above. Thus, the low category is where no algae are present to any significant degree and the high category is where the level of algal bloom is observable to such an extent where it is likely to be considered offensive (or at least, as a marked detraction from the perceived level of water quality by the majority of observers). These qualitative criteria are summarised in Table 3.19 below along with the standards that are consider of indirect relevance:

**Table 3.19 – Risk Category Criteria for Recording the Level of Algal Blooms**

| Risk Category | Criteria (Qualitative) | Related Source |
|---|---|---|
| **Low** | No visible presence on close inspection of the water column or surface.<br>No visible presence of fresh (not decayed) algae matter on shorelines. | Quality of Bathing Water Regulations 1992 (S.I. No. 155 of 1992); The Bathing Water Directive (76/160/EEC) and the Blue Flag Beach Scheme |
| **Medium** | Algae visible in the water column or on the surface on close inspection only.<br>Algal matter visible on shorelines on close inspection only. | The Bathing Water Regulations (S.I. 155 of 1992) |
| **High** | Algal growth in the water column, on the water surface or on shorelines obvious even at some distance (>5metres). | The Bathing Water Regulations (S.I. 155 of 1992) |

## 3.6.9 Water Transparency

### *3.6.9.1 Background Information and Significance.*

The level of transparency (measured in cm) provides an indication of the presence or absence of suspended matter, both living or inert, in the water column and can be considered to be a reflection of the overall water quality (EPA, 2001). However, it must be noted that the parameter will not show the presence of contaminants which are dissolved in the water and high levels of suspended solids (giving low transparency) can be a natural feature of shallow coastal waters where wave action can bring bottom sediments into suspension. Water transparency is widely used in lake studies to assess the abundance of suspended algae (EPA, 2001). It is also used, in the context of bathing waters, to assess the aesthetic suitability of such waters for bathing.

### *3.6.9.2 Method of Analysis and Recording.*

Water transparency levels were recorded using a Secchi Disk. This comprises a steel circular disk, with a distinct black and white pattern on the top surface, to which is attached a graduated measuring line. The disk was lowered into the water column from the shore side at the assigned sampling points. The disk is lowered in the water column to the point where the black and white pattern on the Secchi Disk is just discernable in the water below. The transparency value is then read in centimetres from the measuring line at the point which coincides with the water surface.

### *3.6.9.3 Criteria for Assigning Risk Categories.*

The criteria for the Low, Medium and High categories for water transparency has been generated from requirements set out in both the EU Bathing Water Directive 1976 and the Irish Quality of Bathing Water Regulations 1992 (S.I. No. 155 of 1992). The Quality of Bathing Water Regulations 1992 stipulates a National Limit Value for water transparency in bathing waters of > 1 metre. The 1976 Bathing Water Directive also stipulates a guide value for transparency of bathing water of > 2 metres. Using these standards, the criteria for the low, medium and high risk categories for the variable 'water transparency' were generated. Note that, unlike previous variables, higher values for the variable 'water transparency' are associated with lower risk to sustainability and vice versa. Thus, in order to maintain the stated meaning and significance of the low, medium and high risk categories for this variable, the risk categories have in effect been inverted such that the lower criteria for water transparency fall into the high risk category and vice versa. The criteria are given in Table 3.20 below:

**Table 3.20 – Risk Category Conversion Criteria for Water Transparency Data**

| Category | Criteria (units Metres) | Source |
|---|---|---|
| Low | > 2 | 1976 EU Bathing Water Directive |
| Medium | 1 - 2 | |
| High | < 1 | Irish Bathing Water Regulations, 1992 |

## 3.6.10 Water Turbidity

### *3.6.10.1 Background Information and Significance*

Water ‘turbidity’ was identified as a variable in order to account for the difficulties associated with the quantitative measurement of water transparency (using a Secchi disk) at certain locations. This variable was only assessed at the Dublin Bay study area and the locations in question included the beach areas at Seapoint and Monkstown and the harbour waters adjoining the West pier of Dun Laoghaire harbour. At Seapoint and Monkstown there was no reliable access to deep waters where a Secchi disk could be used (the tidal nature of these locations meant that the waters would recede well below any promenades or other means of accessing deep water). The problem at Dun Laoghaire West Pier was due to the slope of the pier which again meant that a Secchi disk could not be usefully deployed.

Due to the nature of recreational activity taking place at Seapoint, Monkstown and Dun Laoghaire West Pier it was identified that the aesthetic appearance of the water column at these locations was of considerable importance and any problems with this appearance would represent a hazard and risk to sustainability. Thus, in the absence of a reliable quantitative method of measurement of water transparency, it was decided to record a qualitative record of the perceived transparency or level of turbidity. The term ‘turbidity’ was chosen in order to distinguish this qualitative measure from the quantitative measure of transparency using a Secchi disk.

Note also that this variable is different to the quantitative measure of 'turbidity' which is referred to in the 1998 EU Drinking Water Directive (98/83/EC) and which is measured using a process known as nephelometry.

#### *3.6.10.2 Method of Recording*

Recording the level of 'turbidity' was undertaken by direct observation of the water column from the waterside. The turbidity level was recorded directly into low, medium or high (risk) categories according to the criteria specified in the following section.

#### *3.6.10.3 Criteria for Recording Risk Categories*

No standards exist which are directly applicable to this particular variable. However, a number of related standards have been identified which form the basis of the criteria established for this variable. The standards used are contained in the Blue Flag Standard, the Irish Bathing Waters Regulations 1992 and the EU Bathing Water Directive of 1976. For instance, the Blue Flag standard and the 1976 EU Bathing Water Directive stipulates that substances such as mineral oils should be 'absent' from the water column. Likewise the Irish Bathing Water Regulations (1992) stipulate that 'no offensive presence' of articles such as tarry residues or other floating materials should be present in bathing water. The references to 'absent' and 'no offensive presence' in these stipulations form the basis of the criteria for the low and high risk categories for the variable 'turbidity' as outlined in the table below:  Note also that the standards and criteria used with respect to the related variable of 'Transparency' were also used as guides in the development of these particular criteria. The criteria are summarised in Table 3.21 below:

**Table 3.21 - Risk Category Criteria for Recording The Level of Turbidity**

| Risk Category | Criteria (Qualitative) | Related Source |
|---|---|---|
| **Low** | No obvious presence of suspended solids on close inspection of the water column or surface. The water appears clear (potentially > 2 metre visibility) | Quality of Bathing Water Regulations 1992 (S.I. No. 155 of 1992); The Bathing Water Directive (76/160/EEC) and the Blue Flag Beach Scheme |
| **Medium** | Suspended solids clearly visible in the water column but not to any significant or offensive degree. | The Bathing Water Regulations (S.I. 155 of 1992) |
| **High** | Suspended solids visible to a degree that renders the water column unappealing. The water appears murky (<1metre visibility) | The Bathing Water Regulations (S.I. 155 of 1992) |

### 3.6.11 Litter

#### *3.6.11.1 Background Information and Significance.*

Littering is a common factor affecting the quality and value of amenity areas and recreation based tourism destinations in general (Mason, 2003). A significant issue concerning the prevalence of litter is its unsightly nature. In this respect, the presence or absence of litter can have an immediate affect on people's perceptions of an area (Mason, 2003: Tudor & Williams, 2008). Litter can also attract vermin and is considered a general sign of poor management of a recreation area (Liddle, 1997).

The quantitative measurement of litter is complicated by the variety of litter types and sizes which can occur. A useful precedence in this respect is a beach classification scheme known as the 'Assessment Protocol for Classifying Coastal and Bathing Beaches' which is produced by a collaboration between the UK Environment Agency and the UK National Aquatic Litter Group (EA/NALG, 2000). Under this protocol litter is grouped into a number of different categories, including 'general litter', 'gross litter', 'harmful litter' and 'sewage related debris'. During the pilot study phase of this research, it was noted that the vast majority of litter occurring in the study areas fell into the 'general litter' category prescribed under the EA/NALG protocol. This category includes such items as drink cans, food packaging, cigarette packaging and other items with a maximum diameter or length of less than 50 cm and minimum diameter of greater than 1 cm. For the purposes of practicality it was decided to restrict litter counts to items falling within this 'general litter' category. Litter counts were recorded over the entire area of each study site and the counts were divided by area (in square metres) in order to produce an average number of litter items occurring per $100m^2$.

The choice of unit area size ($100m^2$) for reporting litter counts follows that used for a 'Beach Littering Measuring System' advocated under the Blue Flag Scheme (FEE, 2008). This system was created by a collaboration between the Keep Holland Tidy Foundation and the Royal Dutch Touring Club (ANWB and Nederland Schoon, 2006).

#### *3.6.11.2 Method of Recording*

Litter counts were conducted my means of a structured walk over the area under survey. This involved walking a series of parallels across the area. Parallels were located approximately 4 metres from each other. Thus during the walk of each parallel the counting of litter was restricted to the area lying within two metres of each side of the surveyor. As described in the preceding section, the litter count was restricted to items falling within the 'general litter' category as classified by UK National Aquatic Litter Group (EA/NALG, 2000). All counts were recorded manually on site.

#### *3.6.11.3 Criteria for Assigning Risk Categories.*

Although litter is a very visible and ongoing problem which receives much attention generally in the tourism literature, there a few actual agreed standards regarding observed quantities of litter in amenity areas and levels of associated environmental quality. In addition, the standards that do exist tend to be overly complex and are difficult to relate directly to the assignment of simple risk categories for this variable. Nevertheless, two standards do exist which, though technically applying to beach areas, are considered relevant. Theses are the Blue Flag Beach Standard (FEE, 2008) and the EA/NALG beach classification protocol described above (EA/NALG 2000).

A general expectation of the Blue Flag Scheme is that beach areas and adjoining amenity land should be visibly free of litter (ENCAM, 2008). More specifically, the

Blue Flag Scheme advocates the use of the Keep Holland Tidy Foundation/Royal Dutch Touring Club beach litter measuring system described above (ANWB and Nederland Schoon, 2006). This system sets out various qualitative and quantitative litter criteria which are assigned to different beach cleanliness levels. The highest cleanliness level requires zero litter units per $100m^2$ while the next level is 1-3 units per $100m^2$. The equivalent EA/NALG Protocol criteria are 0 and 0-49 units per 100-metre stretch of beach up to a maximum of 50 metres wide. This essentially equates to a maximum area of $5000m^2$. Thus converting this standard to the number of litter items per $100m^2$ (units used for this study) gives an equivalent standard of between 0 and 1.0 units of litter per/$100m^2$. This latter standard is adopted the medium risk category for the number of 'general' litter items observed per $100m^2$. With regard to the Blue Flag expectation that a beach area should be free of litter, the low risk category standard is therefore effectively set at zero items per $100m^2$. In this respect, note that in order to allow for the near non-existence of cases where no litter was recorded, the low risk category is actually set slightly above zero (i.e. 0.1 items/$100m^2$). It is felt that this allows recognition and distinction of amenity areas where very few items of litter are visible. The above criteria for converting the litter count data to low, medium and high risk categories is summarised in Table 3.22 below;

**Table 3.22 - Risk Category Conversion Criteria for Litter Data**

| Category | Criteria (no. of items/$100m^2$) | Source |
|---|---|---|
| **Low** | < 0.1 | Reflects General Blue Flag Standard<br>EC Bathing Water Directive |
| **Medium** | 0.1 – 1.0 | EA/NALG Assessment Criteria for Classifying Beaches. |
| **High** | > 1.0 | EA/NALG Assessment Criteria for Classifying Beaches.<br>FEE Blue Flag Beach Criteria |

### 3.6.12 Floating Litter

#### *3.6.12.1 Background Information and Significance.*

The variable 'floating litter' includes any items floating at the surface of the water that are not considered of natural origin. In general, floating litter primarily includes items of regular litter that have either been deposited directly into the water or first disposed of on land and then blown into the water. The distribution of floating litter is largely determined by wind direction with items tending to gather along leeward shorelines or other harbour structures. Evaluation of floating litter involved a simple count of observable items along a defined length of shoreline, harbour wall or pier.

The main significance of floating litter in the context of this research is its tendency to detract from the visual aesthetics of an amenity area. The presence of floating litter at an amenity area can also give an impression of poor management of the area. The units used for presentation of floating litter count data is the number of items observed per 50 metres of shore or quayside surveyed. This 50 metre reporting unit was chosen as it is compatible with the Irish National Litter Monitoring System survey guidelines (DOE&LG, 2000) and it was considered appropriate for this application.

#### *3.6.12.2 Method of Recording*

Floating litter was recorded by direct observation from the shore or quayside. At each study site a specified length of quay or shore was walked. All items of floating litter within five metres of the shore or quayside were counted. The maximum dimension of items included in this category were restricted to between 50 cm and 1 cm. This follows the dimensions specified for the 'general litter' category under the EA/NALG protocol described in under the section addressing the 'litter' variable above. All counts were recorded manually on site.

#### *3.6.12.3 Criteria for Assigning Risk Categories.*

Three external standards have been used to generate the criteria for converting the quantitative data into Low, Medium and High (risk) categories. These are the Bathing Water Regulations 1992 (SI No.155 of 1992), the EC Bathing Water Directive 1976 (76/160/EEC) and the Blue Flag Beach Standard. Both the Bathing Water Directive and the Blue Flag Standard stipulate that floating matter should be absent in good quality bathing waters. On the other hand the Bathing Water Regulations stipulate that 'no offensive presence' of floating matter should be observable at bathing locations. This latter stipulation is very much a qualitative requirement and is obviously open to interpretation regarding the actual numbers of floating litter items observed at an amenity area. Thus for the purposes of this study, the Bathing Water Directive and Blue Flag Beach Standard have been used to set the criteria for the Low risk category, that is, no floating litter present. The criteria for the High risk category is essentially an interpretation of the 'no offensive presence' requirement of the Bathing Regulations, which is set at greater than two items of floating litter observed per 50 meters of sampled shore length. Values between zero and two items per 50 metres are correspondingly assigned a medium risk level. The criteria for converting the 'floating litter' count data are summarised in Table 3.23 below:

**Table 3.23 - Risk Category Conversion Criteria for Floating Litter Data**

| Category | Criteria (no. of items/50m) | Source |
|---|---|---|
| **Low** | 0 | Blue Flag Standard<br>EC Bathing Water Directive |
| **Medium** | 0 - 2 | |
| **High** | > 2 | Bathing Water Regulations 1992 – Stipulates 'no offensive presence', interpreted as ≤ 2 items/50m |

### 3.6.13 Foreshore Litter

#### *3.6.13.1 Background Information and Significance:*

This variable was identified as a means of resolving the problems associated with the assessment of litter on marine beach and foreshore areas where the high water mark is above the highest point of the beach (thus at high tide the beach will be under water). Both Seapoint and Monkstown are of this nature and the problem originates from the fact that the state of tide tends to alter the proportion of litter floating along the shoreline and that left on the foreshore or beach. Thus where litter is prevalent at a beach area, at high tide much or all of this litter will be floating while at low tide most will be left on the beach by the receding tide. This means that counts of floating or foreshore litter will tend to vary depending on the state of the tide. The solution to this was to simply include both litter categories under the one heading and count.

Items of litter monitored under this variable will tend to be pushed into a line by the rising tide. Accumulations of this litter at the top of a beach area will also tend to be in a line. For this reason the units chosen for this variable are items per 50 metres of beach or foreshore length (as apposed to units based on items per unit area).

#### *3.6.13.2 Method of Recording*

Foreshore litter counts were conducted by means of a shore walk along the length of the upper tide line within the area specified. All items of litter visible above or below this tide line (whether in or out of the water) were recorded. The maximum dimension of items included in this category were restricted to between 50 cm and 1 cm. This follows the dimensions specified for the 'general litter' category under the EA/NALG protocol described in under the section addressing the 'litter' variable above (EA/NALG, 2000). All counts were recorded manually on site.

#### *3.6.13.3 Criteria for Assigning Risk Categories.*

In the absence of any standards pertaining to 'Foreshore and Floating Litter', the criteria and associated standards used for assigning risk categories to this variable are the same as those used for the variable 'floating litter' described in Section 3.6.12 above. The criteria are summarised in Table 3.24 below:

**Table 3.24 - Risk Category Conversion Criteria for Foreshore Litter Data**

| Category | Criteria (no. of items/50m) | Source |
|---|---|---|
| **Low** | 0 | Blue Flag Standard<br>EC Bathing Water Directive |
| **Medium** | 0.1 - 2 | |
| **High** | > 2 | Bathing Water Regulations 1992 – Stipulates 'no offensive presence', interpreted as ≤ 2 items/50m |

### 3.6.14 Full Waste Receptacles

#### *3.6.14.1 Background Information and Significance*

The principal significance of this variable concerns the assumption that waste receptacles which are full are both a sign of poor litter management of an area and are also liable to lead to increased levels of littering due to the decreased availability of a means of discarding litter in a proper manner.

#### *3.6.14.2 Method of Recording*

This variable was recorded by observation of all waste receptacles in an area. Where it was ascertained that it would be difficult to securely dispose of further litter in a waste receptacle (i.e. without danger of it falling out) then this receptacle was recorded as full.

#### *3.6.14.3 Criteria for Assigning Risk Categories*

No specific standards were identified which gave specific criteria regarding numbers of full waste receptacles deemed acceptable or otherwise . However, the blue flag standard (ENCAM, 2008) specifies that waste disposal receptacles provided at beach areas should be available in adequate numbers and emptied regularly. Based on this guideline, the criteria for the low risk category was set at zero. Given the often limited number of waste receptacles provided at amenity areas the criteria for the medium and high risk categories was set at 1 and >2, respectively. The criteria are outlined in Table 3.25.

**Table 3.25 - Risk Category Conversion Criteria for variable 'Full Waste Receptacles'.**

| Category | Criteria (No. of adjoined boats) | Source |
|---|---|---|
| **Low** | 0 | Blue Flag Standard |
| **Medium** | 1 | Blue Flag Standard |
| **High** | 2 + | Discretionary |

### 3.6.15 Dog Fouling

#### *3.6.15.1 Background Information and Significance.*

Public amenity areas can present a potential conflict between the attraction of such areas for dog walking and the aesthetic and health risk considerations posed by the inevitable and associated occurrence of dog fouling. Aside from potential negative, and subjective, perceptions generated by the presence of dog fouling, dog faeces does present a recognised health risk to users of amenity areas. This risk, though not entirely substantiated, affects children in particular as they are more likely to come into direct contact with dog faeces. The risk arises primarily due to the potential presence of various pathogenic micro organisms in dog faeces (Thompson, Palmer & Handley, 2008; Houf et al., 2008). In particular, the link between dog fouling and the infection known as toxicariasis is well established (Wells, 2007) and is a significant cause for concern regarding the occurrence of dog fouling at public amenity areas.

#### *3.6.15.2 Method of Recording*

Dog fouling counts were conducted my means of a structured walk over the area under survey. This involved walking a series of parallels across the area. Parallels were located approximately 4 metres from each other. Thus during the walk of each parallel the counting of dog fouling was restricted to the area lying within two metres of each side of the surveyor. All counts were recorded manually on site. In line with the criteria for the variable ‘litter’, the dog fouling data is presented in terms of total number of dog faeces recorded and also the number recorded per 100 $m^2$ of survey area. This latter unit was used for converting the quantitative data to risk categories as described below.

#### *3.6.15.3 Criteria for Assigning Low, Medium and High Risk Categories.*

As is the case with litter, there a few agreed standards in the literature regarding observed quantities of dog faeces in amenity areas and levels of associated environmental quality. Two standards do exist which, though technically applying to beach areas, are considered relevant. Theses are the Blue Flag Beach Standard (FEE, 2008) and the EA/NALG beach classification protocol described above under the variable 'Litter' (EA/NALG 2000).

A general expectation of the Blue Flag Scheme is that beach areas and adjoining amenity land should kept free of dog faeces (ENCAM, 2008). In addition, the EA/NALG Protocol sets out various criteria with respect to dog faeces and environmental quality categories (note that criteria in the EA/NALG Protocol are set for a maximum area of $5000m^2$. These criteria have therefore been divided by a factor of 50 in order to match the $100m^2$ units which were the basis of dog faeces counts for this research). The three relevant standards for dog faeces under the EA/NALG Protocol are zero, <0.1 and > 0.1 items of dog faeces observed per $100m^2$. These standards have been assigned as the criteria for converting the dog faeces data to low, medium and high categories, respectively. The criteria for converting the dog faeces count data is summarised in Table 3.26 below:

**Table 3.26 - Risk Category Conversion Criteria for Dog Faeces Data**

| Category | Criteria (no. of items/$100m^2$) | Source |
|---|---|---|
| **Low** | 0 | General Blue Flag Standard<br>EA/NALG Assessment Criteria for Classifying Beaches (Category A). |
| **Medium** | 0 – 0.1 | EA/NALG Assessment Criteria for Classifying Beaches (Category B). |
| **High** | > 0.1 | EA/NALG Assessment Criteria for Classifying Beaches (Category C). |

### 3.6.16 Graffiti

#### *3.6.16.1 Background Information and Significance.*

Graffiti is a variable which has obvious significance in the context of tourism and environmental sustainability. However, the variable is difficult to record either quantitatively or qualitatively. This is because of the nature of observed incidences of graffiti which can vary greatly in both size and form. In addition, it can at times be difficult to discern where one set or item of graffiti finishes and another begins. Because the size and form of graffiti will obviously affect an onlooker's impression of an area to differing degrees, both quantitative and qualitative measurement of the variable would be ideal in the circumstances. However, qualitative assessment of graffiti was considered to be impractical for this methodology as criteria for such assessment would have to be complex and thereby difficult to follow or reproduce with any consistency. A semi-quantitative method was therefore chosen whereby the level of graffiti occurring at a particular location was measured by a simple count of identifiable individual incidences of graffiti irrespective of size or form.

#### *3.6.16.2 Method of Recording*

Graffiti counts were recorded by means of a general visual survey of all vertical built structures within the specified survey area. Individual items of graffiti were defined as markings (letters or drawings) which were distinguishable from others. Hence, for example, a set of letters forming a recognisable word or name was considered one item of graffiti and counted as such. Individual drawings or markings whether drawn by the same hand or otherwise were considered separate items of graffiti. The count was not restricted to any particular range of size of graffiti.

#### *3.6.16.3 Criteria for Assigning Risk Categories.*

With the exception of the Blue Flag requirement that all buildings and equipment of a beach should be clean and properly maintained, there are no standards in the literature regarding the acceptability of differing levels of graffiti at beaches or amenity areas. In the absence of such standards, discretionary criteria were set for the low, medium and high risk categories for this variable. The setting of these criteria was largely based on review of the collected count data for all surveyed sites in both Lough Derg and Dublin Bay with consideration given to perceived and observed nature of the surveyed sites. The criteria for assigning the risk categories is given in the table below:

**Table 3.27 - Risk Category Conversion Criteria for Graffiti Data**

| **Category** | **Criteria (no. of observed incidences)** | **Source** |
|---|---|---|
| **Low** | 0 | Discretionary |
| **Medium** | 1 - 5 | Discretionary |
| **High** | > 5 | Discretionary |

### 3.6.17 Odours

#### *3.6.17.1 Background Information and Significance*

The potential implications or impact of unappealing odours at tourism and recreation sites receives little or no attention in the literature on the subject. However, this variable was identified as a potential hazard for the Dublin Bay study sites during the hazard identification exercise prescribed by the methodology. In particular, odours from the decomposition of excessive algal material (that associated with algal blooms) at Seapoint and Monkstown and odours from potential oil pollution occurring in Dun Laoghaire Harbour were identified as potential hazards.

#### *3.6.17.2 Method of Recording*

In the absence of any reliable and practical quantitative measure of odours this variable was assessed in a qualitative manner according to the prescribed criteria outlined in the following section.

#### *3.6.17.3 Criteria for Assigning Risk Categories*

No standard was found with general criteria relating to odours in the context of amenity value and recreation. However, three standards were found which did specify criteria relating to amenity value and potential odours from (mineral) oils. These standards were the Blue Flag Standard (FEE, 1998), the Irish Bathing Water Regulations (1992) and the EU Bathing Water Directive (1976). All three of these standards stipulate that no odour associated with mineral oils should be detectable at bathing locations. This standard has been adopted here for more general use with the variable defined here as ‘odours’. Thus the criteria specified for the low risk category is that no identifiable odours should be detectable (that is, odours associated with a particular origin). For the high risk category the Irish Bathing Water Regulations were used. In particular, the wording in these regulations relating to ‘no offensive presence’ (of tarry residues) was adopted as the criteria for assigning odour observations to the high risk category. That is, levels of odours which were detected and deemed to constitute an offensive presence were to be recorded as high risk. In turn, odours identifiable to a particular source but not to a level considered offensive were recorded as medium risk.  These criteria are summarised in the table below.

**Table 3.28 - Risk Category Criteria for Recording Odours**

| Category | Criteria (Qualitative) | Related Source |
|---|---|---|
| **Low** | No odours (identifiable to a particular source) detectable | Quality of Bathing Water Regulations 1992 (S.I. No. 155 of 1992); The Bathing Water Directive (76/160/EEC) and the Blue Flag Beach Scheme |
| **Medium** | Odours (identifiable to a particular source) detectable but not to an extent considered offensive | |
| **High** | Odours (identifiable to a particular source) present and to an extent considered offensive. | The Bathing Water Regulations (S.I. 155 of 1992) |

### 3.6.18 Bird Life

#### *3.6.18.1 Background Information and Significance.*

Bird counts can be a useful potential indicator of the habitat value of a given area for number of reasons (Padoa-Schioppa et al., 2006). Firstly, birds form an intrinsic part of the natural food web. In theory, therefore the condition of a given ecosystem would normally be reflected in the make up and size of the bird life population in that ecosystem. From a practical point of view, many species of birds, unlike other animal groups, tend to be relatively visible and therefore lend themselves to quantitative counts. This is the particularly the case for certain species of lake and marine birds who spend much of their time on open water. In addition, many lake and marine bird species are quite distinctive in appearance. Therefore, with the aid of a good reference guide, an observer can easily tell species apart thereby adding extra information to a quantitative bird count.

On the other hand, interpretation of the data generated by bird counts is complicated by a number of factors. Firstly, the relationship between the nature of observed bird populations and ecosystem value can be very complex and will often be unique to a given area (Padoa-Schippa et al., 2006). Secondly, the breeding and migratory behaviour of different bird species can have a profound effect on bird count data from season to season. In the context of lake and marine recreation areas, the interaction of humans (such as feeding birds) with bird populations can also have a significant and distorting influence on the size and make up of observed bird populations.

However, in a general sense there is agreement that, notwithstanding the presence of human influenced species (such as mallard ducks, for example) the observation of larger bird populations with greater number of bird species occurring (species richness) can be taken as an indicator of a healthy ecosystem.

For this research bird populations were chosen as an indicator due to the potential relationship between levels of recreational activity and the make up and size of bird populations. The assumption here being that habitat destruction due to over development of an area and interference by human recreation activity would be expected to cause a reduction in the numbers of birds and bird species occurring at a given recreation area. In the case of the Lough Derg sites, it was decided to record both total number of birds occurring and also a restricted subset known as 'resident lake species'. This subset excludes birds which were observed to be attracted to an area due to the presence of humans feeding birds (examples include all gulls and mallard species of duck). The subset also excluded birds which are known to migrate to and from the area according to the different natural seasons (a prominent example here was the tufted duck). This measure therefore is intended to exclude the distorting influence on bird population data due to human interaction and migratory behaviour. A third data set involved the quantification of the number of different species recorded during each bird count. This variable is known as 'species richness' and higher values are normally taken as an indicator of better ecosystem quality.

#### *3.6.18.2 Method of Recording*

Bird counts were conducted from specified locations at each of the relevant study sites. The count was conducted over a period of 15 minutes and included all individuals observed within the specified survey area (see Tables 3.7 and 3.9 in Section 3.3.4). The maximum number of individuals that were observable at any one time during the 15 minute period was recorded for each identifiable species. Thus where, for example, a flock of 14 lapwings were sited at the beginning of the count and a flock of 20 lapwings were sited near the end of the count the final count of lapwings would have been 20 (and not 34). This approach was designed to remove the possibility of repeated counts of the same individuals. In addition it also provided ample opportunity for bird individuals in the count area but initially hidden from sight (behind vegetation or under water, for example) to come into view and be counted.

A pair of standard field binoculars was used to aid the identification of bird species together with an identification guide.

#### *3.6.18.3 Criteria for Assigning Risk Categories*

Although much study is undertaken into bird population trends in Ireland by organisations such as Birdwatch Ireland, no standards exist for the expected size or nature of bird populations occurring at specified habitat types or locations. This is presumably due to the complex behavioural patterns associated with bird species in general. Criteria for assigning risk categories in the context of this research were therefore generated on the basis of observations made in the context of this research. In this respect, the bird count data recorded at Meelick Bay was used as a benchmark for assigning criteria for the Lough Derg data. No suitable control benchmark was identified for the Dublin Bay Study Area and hence the bird life data recorded at this area was not assigned to risk categories.

Meelick Bay is a relatively pristine lakeshore location with little or no human activity and extensive and differing areas of lakeshore habitat. Thus, an assumption was made that the nature and size of bird populations occurring at this location should be representative of a low risk situation and the data values recorded here can be used to generate the risk category criteria for the Lough Derg data. In addition, further analysis of the raw bird count data for all three Lough Derg study sites showed that the sub variable designated as 'bird species richness' was the most consistent over the course of the year at Meelick Bay. It was therefore decided that the risk category criteria would be generated from and apply to this sub variable. Review of the data for Meelick Bay (see Results Chapter) shows that the recorded species richness values ranged from 0 to 9 species. However, the vast majority of values were 3 or greater with only one incidents of 0 species being recorded. Working on the assumption (as outlined above) that Meelick Bay represents a low risk location with respect to bird life, then the criteria outlined in the following table were deemed most appropriate and applicable in this particular research context.

**Table 3.29 - Risk Category Conversion Criteria for 'Bird Species Richness' Data**

| Category | Criteria (no. of species observed) | Source |
|---|---|---|
| **Low** | 3 + | Discretionary - reference to Meelick Bay data |
| **Medium** | 1- 2 | Discretionary - reference to Meelick Bay data |
| **High** | 0 | Discretionary - reference to Meelick Bay data |

(NB. Criteria only applies to Lough Derg Data)

### 3.6.19 Ambient Noise

#### *3.6.19.1 Background Information and Significance*

Noise (or sound) may be defined as any air pressure variation that the human ear can detect. Such pressure variations originate from a sound source and propagate in a wave motion from the source in all directions. Technically, sound or noise is measured in the standard units of pressure known as Pascals (Pa). In these units the sound pressure variations which are audible range from approximately 20 μPa ($20x10^{-6}$ Pa) to 100,000,000 μPa (100 Pa) (Brüel and Kjær, 2001).

As can by seen from the above, the range of audible sound pressures comprises large and unwieldy numbers. In addition, the perception of noise level generated by the human ear is more aptly expressed using a logarithmic scale of sound pressure variation. Therefore, for reasons of practicality (regarding both scale and perception), sound levels are expressed on a logarithmic scale known as the decibel scale or dB (Brüel and Kjær, 2001). On this scale the audible range of sound pressure variations ranges from approximately 0 to 130 dB (and over) and a doubling of sound pressure is represented by an increase of 6 dB.

The measurement of the ambient noise level at a particular location invariable involves assessing a fluctuating, combined noise level which originates from a variety of sources. Because of the fluctuating nature of ambient environmental noise it is unrealistic to record the instantaneous sound pressure level in decibels. To address this issue, a number of noise parameters exist which express various aspects of environmental noise. The 'equivalent continuous sound level' (the $L_{eq}$) is generally accepted as the parameter which best represents the average sound pressure level (or ambient noise) over a given time period. Technically, the $L_{eq}$ parameter can be defined as the level of sound that, had it been a steady level during the measurement period, would represent the amount of energy present in the measured, fluctuating sound pressure level (Brüel and Kjær, 2001). The $L_{eq}$ is measured and computed directly by an integrating sound level meter such as the Brüel and Kjær 2238 Mediator used for this research (see Section 3.6.19.2 below).

A further complication regarding the assessment of ambient noise is that human hearing is less sensitive at very low and very high sound frequencies (Brüel and Kjær, 2001). The sound frequency corresponds to the number of pressure variations from a source that occur per second (and not the magnitude of pressure variation). Sound frequency is measured in hertz (Hz) and affects the tonal quality (or pitch) of a perceived sound but not its' loudness (Brüel and Kjær, 2001). In order to account for the varying sensitivity of the human ear at different frequencies a weighting filter can be applied when measuring sound. The most common frequency weighting in current use is known as 'A-weighting'. This weighting provides a measure of sound (or noise) which conforms closest to the response of the human air. Noise measurements using such a weighting are denoted as dB(A) and associated noise parameters such as $L_{eq}$ are denoted $L_{Aeq}$ (Brüel and Kjær, 2001).

$L_{Aeq}$ is recognised as the most common parameter or standard which is used to measure environmental noise (Brüel and Kjær, 2001). In addition, this parameter is frequently used to monitor noise levels from industrial and transport noise at sensitive locations and is used by the Environmental Protection Agency and other authorities to set standards in this respect (EPA, 2006). A second noise parameter known as $L_{A90}$, is a statistical computation which essentially provides an average noise level in the same manner as the $L_{eq}$ parameter but excludes, in the calculation, the top 10% of noise recorded. This measure is considered by some to provide a more representative measure of environmental noise as it eliminates noise attributed to random and infrequent noise events such as, for example, a distant gunshot (Waugh et al., 2003).

The main significance of noise as a variable is associated with people's perceptions of the tranquillity of an area. The operation of any machinery, whether for industrial or recreational purposes, has the potential to greatly increase the natural level of background noise in a given area as well as altering its quality. Where this happens, the noise may be considered a nuisance and can affect people's level of enjoyment. This is considered to be at odds with the sustainability of a recreation area, particularly in the case of more rural and isolated tourism destinations. Although, the noise parameter $L_{Aeq}$ does not provide a direct measure of the potential annoyance associated with a given sound environment, extensive research has shown that this parameter does correlate well with annoyance (Brüel and Kjær, 2001).

#### *3.6.19.2 Method of Analysis and Sampling*

*<u>Equipment and Software:</u>*

Noise recording was undertaken using a Brüel and Kjær Type 2238 Mediator modular sound level meter installed with enhanced SLM BZ7125 Version 1.1.0 software. The meter was supplied with a microphone and microphone preamplifier. The microphone was a type 4188 Prepolarised Free-field 1/2" Condenser Microphone with a frequency range of 8Hz-16kHz (±2dB). The microphone preamplifier was a type ZC0030.

Calibration of the meter was undertaken using a Sound Level Calibrator Type 4231 together with the semi-automatic function installed in the mediator.

A 90mm wind screen was attached to the microphone. For all recording the mediator was set up on a standard height adjustable tripod. Data was transferred from the mediator to a desktop computer using a 9 pin connector and the Brüel and Kjær 'Environmental Software' interface. Files were stored as txt.files.

*Recording Procedure:*

Recording of ambient noise levels at each specified location was undertaken according to the Brüel and Kjær Field Guide for Simple Measurements Using the 2238 Mediator (Brüel and Kjær, 2000).

The operational parameters of the meter were set up as follows:

Range: 20.0 – 100.0 dB

Peaks Over: 140dB

Detector 1 (RMS):

Bandwidth = Broadband

Frequency Weighting = A

Sound Incidence: Frontal

Windscreen Correction: On

In summary, the procedure followed for making noise recordings was as follows: The noise meter was attached to the tripod and set at a height of approximately 1.3 metres. The wind screen was next attached to the mediator microphone. The mediator was then switched on and checked that the chosen operational settings were set as specified above. The start button was then pressed and the recording commenced. Recording intervals were generally set for 15mins.

The following criteria were followed when choosing a suitable location for recording ambient noise:

- The meter was placed away from obstacles and facades
- The meter was operated only in dry conditions with a wind speed of less than 5 metres per second.
- The microphone was positioned between 1.2 – 1.5 m above ground level.

Calibration was undertaken at approximately monthly intervals. The calibration procedure involved placing the mediator microphone in the Sound Level Calibrator and activating the semi-automatic calibration function on the 2238 Mediator. The sensitivity of the calibration was then checked to ensure it complied with the required standard.

On the 2238 Mediator all noise measurements are stored automatically in electronic files. The names of such files and corresponding measurement locations, times and dates were noted manually as and when they were generated. The electronic files were uploaded to a desktop PC at various intervals. The data from these files was then transferred as appropriate to Microsoft Excel spread sheets for further analysis and processing in accordance with the prescribed risk assessment methodology.

#### *3.6.19.3 Criteria for Low, Medium and High Categories.*

No universal statutory noise standards apply in Ireland (South Tipperary County Council, 2008). However, a number of guidelines do exist with varying degrees of relevance to this research. The EPA have published a 'Guidance Note for Noise in Relation to Scheduled Activities (under the IPC licensing system) (EPA, 2006). This guidance note stipulates that 'the noise attributable to on-site activities (of licensed facilities) should not generally exceed a $L_{AR,T}$ (equivalent to $L_{Aeq}$) value of 55 dB by daytime (08:00-22:00), at any noise sensitive location.

However, it is considered reasonable to presume that this guidance note is primarily intended for use with respect to more urban areas where industrial development is more likely to occur (the document itself acknowledges that lower noise limits may be more appropriate in areas where the background noise levels are particularly low). Thus a second standard has been identified which is considered to be more relevant in the context of rural areas. This standard is contained in the planning guidelines for wind energy developments which is published by the Department of Environment, Heritage and Local Government (DEHLG, 2008). These guidelines are as such intended for the wind energy sector but nevertheless, in the context of this research, they are considered relevant since they set out one of the few noise standards specifically applicable to rural areas with naturally low background noise levels. The noise standard suggested in these guidelines is that a lower fixed limit of 45dB or a maximum increase of 5 dB above background levels should not be exceeded during daytime hours. Note that in the absence of similarly relevant criteria for the Dun Laoghaire and Monkstown sites (these sites are more urban in nature) these guidelines and criteria were also adopted for these sites.

Thus the above two standards have been used to set the criteria for the low, medium and high risk categories with respect to the LAeq parameter for noise. The EPA limit of 55 dB marks the transition to a high risk level, while the level of 45dB outlined in the DEHLG guidelines marks the level for the low risk category. Levels between 45 and 55 dB fall into the medium risk category.

A further noise standard exists which is applicable to the $L_{A90}$ noise parameter (see earlier section for further explanation of this parameter). This is an EPA report on 'Environmental Quality Objectives for Noise in Quite Areas' (Waugh et al., 2003). Although this report is largely aimed at identifying 'Quiet Areas' in lieu of the Noise Directive 2002/49/EC (Europa, 2002), it does recommend that recorded noise levels in such areas should not exceed an $L_{A90}$ level of 30 dB by day. This standard therefore has been used to set the upper limit of the low risk category with respect to the noise parameter $L_{A90}$. In the absence of any other standards applicable to this particular parameter, the DEHLG guidelines described above regarding the noise levels not exceeding 5 dB above background levels have been used to set the threshold for the high risk category. In this respect, the background levels are deemed to be the average of mean values recorded for a location during the low season.

The criteria for converting both the $L_{Aeq}$ and the $L_{A90}$ noise data in to equivalent environmental risk categories are summarised in the tables 3.30 and 3.31overleaf:

**Table 3.30 - Risk Category Conversion Criteria for Ambient Noise ($L_{Aeq}$) Data, Applies to Lough Derg and Dublin Bay Sites**

| Category | Criteria (Dbs) | Source |
|---|---|---|
| **Low** | < 45 | DEHLG Guidelines regarding wind energy developments |
| **Medium** | 45 - 55 | |
| **High** | > 55 | EPA IPC Guidance Note for Noise in Relation to Scheduled Activities |

**Table 3.31 - LMH Risk Category Conversion Criteria for Ambient Noise ($L_{A90}$) Data, Applies to Lough Derg Sites only**

| Category | Criteria (Dbs) | Source |
|---|---|---|
| **Low** | > 30 | EPA ‘Noise in Quiet Areas’ Synthesis Report |
| **Medium** | 30 - 55 | |
| **High** | > 5 above low season background | DEHLG Guidelines regarding wind energy developments |

### 3.6.20 Harbour Congestion

#### *3.6.20.1 Background Information and Significance*

This variable was identified only for the Lough Derg Study Area. At both Terryglass and Dromineer harbours, there exists only limited space for tying up the various pleasure boats which use these harbours. In time of high demand, this means that the occupants of cruising boats can arrive at these harbours to find them effectively full. The observed solution to this problem is for cruisers to moor along side each other, sometimes up to several boats thick. An obvious implication of such harbour congestion is that visitors using cruising boats are faced with uncertainty regarding the availability of mooring space at these locations and, where harbours are full, they face difficulties finding a place to moor their boat. Such visitors may also experience difficulties departing from the harbour area the following day if other boats are moored alongside them. Harbour congestion is therefore considered to detract from the attraction of these areas, as any difficulties experienced with mooring are presumed to be undesirable and ultimately stressful, particularly for arriving visitors arriving on cruise boats late in the day.

#### *3.6.20.2 Method of Recording*

Harbour congestion was recorded by means of a simple inspection of the mooring or berthing areas of the harbours. Such inspections were usually undertaken as early or as late in the day as possible when congestion was most likely to occur. Harbour congestion was measured in terms of the number of boats which had been forced to birth alongside other vessels instead of directly adjacent to available piers, quays or pontoons.

#### *3.6.20.3 Criteria for Recording Risk Categories*

No standards were identified which specified acceptable levels of congestion within public harbour or marina areas. The criteria set for converting 'harbour congesting' data to risk categories were therefore established on a discretionary basis using information gathered from observing the movement of boats within the harbour areas of Terryglass and Dromineer. The criteria for this variable are outlined in the table below.

**Table 3.32 - Risk Category Conversion Criteria for the variable 'Harbour Congestion'**

| Category | Criteria (No. of adjoined boats) | Source |
|---|---|---|
| **Low** | 0-1 | Discretionary |
| **Medium** | 2 - 4 | Discretionary |
| **High** | 5 + | Discretionary |

### 3.6.21 Improper (or Illegal) Parking

#### *3.6.21.1 Background Information and Significance*

Improper or illegal parking is defined for the purpose of this research as any parking outside of designated areas. Parking within designated areas without appropriate payment (where such requirement exists) is not considered in this definition. The principal significance of improper or illegal parking is that it can cause obstruction, inconvenience to the public and may represent a hazard with regard to the safe passage of pedestrians and the available access to emergency vehicles.

#### *3.6.21.2 Method of Recording*

This variable was recorded by means of a simple inspection of all access and parking areas within each study site. Any cars parked, for any length of time, outside of the designated parking areas were counted.

#### *3.6.21.3 Criteria for Assigning Risk Categories*

No standards were identified which specified acceptable levels of illegal parking within public amenity areas. The criteria set for converting the 'improper parking' data to risk categories were therefore established on a discretionary basis using information gathered from observing the implications of improper parking within the relevant study areas. The criteria outlined in the table below were adopted for this variable.

**Table 3.33 - Assigned Risk Category Criteria for variable 'Improper Parking'**

| Category | Criteria (No. of improperly parked cars) | Source |
|---|---|---|
| **Low** | 0 | Discretionary |
| **Medium** | 1-2 | Discretionary |
| **High** | 3 + | Discretionary |

### 3.6.22 Availability of Facilities (Overcrowding)

#### *3.6.22.1 Background Information and Significance*

The variable ‘overcrowding’ relates to the availability of the various facilities provided for the general public at a given amenity or bathing area. Amenity facilities may include the following, parking areas, picnic tables, seats/benches, walkways, playground equipment and changing areas, for example. An assumption is made that where the level of use of a recreation area reaches a point where access to facilities become restricted then this is deemed to diminish the perceived quality or attraction of such an area. Thus ‘overcrowding’ is considered to be at odds with environmental sustainability in this context.

#### *3.6.22.2 Method of Recording*

This variable was recorded by means of observation of all facilities provided within each study site. This observation was undertaken over a 5 minute period chosen at random. The assigned risk category applied to that particular observation period and was recorded on the basis of the prescribed criteria given in Table 3.34 below.

#### *3.6.22.3 Criteria for Recording Risk Categories*

No standards were identified which specified acceptable levels of this interpretation of the variable ‘overcrowding’. The criteria set for assigning risk categories to the observed levels of overcrowding were therefore established on a discretionary basis using information gathered from observing the implications of overcrowding within the relevant study areas. The criteria outlined in Table 3.34 below were adopted for this variable.

**Table 3.34 - Risk Category Criteria for Recording Qualitative Variable 'Overcrowding'**

| Category | Criteria (Qualitative) | Source |
|---|---|---|
| **Low** | Unrestricted availability of amenity facilities (i.e. a number of options exist for each facility provided) | Discretionary |
| **Medium** | Restricted availability of one or more amenity facilities (i.e. only one option exists for one or more facilities). | Discretionary |
| **High** | One or more facilities unavailable due to use. Restricted availability of remaining facilities | Discretionary |

## 3.7 Limitations of the Methodology

A number of potential limitations are identified with regard to the risk assessment model and methodology as described in this chapter. These limitations are outlined under the relevant headings that follow. Justification of these limitations in the context of the research findings and alternative methods of assessment is discussed in detail in the Discussion and Conclusions chapter (Chapter 5) of this thesis.

*The Use of Qualitative Variables:*

The recording of qualitative variables involves an element of subjective judgement regarding both the development of suitable criteria and their application in the field. In this regard, it is recognised that the use of broad and often purely descriptive criteria for recording such variables can be questionable in terms of the repeatability of the methodology and therefore the consistency and reliability of the generated data. In more traditional academic disciplines this approach is likely to be considered lacking in scientific accuracy and rigour (Waring & Glendon, 1998).

*The Conversion of Quantitative Data to Risk Categories:*

It is recognised that the conversion of data values to a three point risk category scale (low, medium and high) can be viewed as an oversimplification of otherwise significant scientific data. This process is essentially converting objective data using subjective criteria. In addition, the somewhat discretionary selection of environmental standards (which may or may not be directly related to the variable in question) and the subsequent generation of the conversion criteria may be open to question due to the necessary elements of subjectivity involved.

*Availability of External Standards:*

The methodology relies on the availability of external standards of environmental quality in order to generate the criteria for recording qualitative variables or converting quantitative data to the risk categories. It is necessary that such standards should be relevant and applicable to the selected variables. However, it is recognised that in the case of certain variables it may not be possible to identify standards that are suitably relevant. In such cases it will be necessary to generate criteria by referring to other less relevant standards or subject literature. In this regard, the authority and objectivity of such criteria would be reduced.

*Trend Analysis:*

It is recognised that any analysis of trends in the data may be complicated by the existence of multiple factors affecting the data under analysis. This is common feature of environmental data generally (Hughes, 2002) and this means that even where repeated measurement of multiple variables in undertaken elements of uncertainty will still exist regarding the interpretation of such data. Furthermore, the ability to correlate potentially related variables in order to verify associations or cause and effect is likely to be impractical in many instances.

The second potential limitation regarding the trend analysis concerns the need to account and control, where possible, for the influence of external factors on the environmental quality of the selected study sites. Such factors are considered likely to compound any potential conclusions which could be drawn regarding possible relationships between identified environmental effects and recreational activity, for instance. A typical example in this regard concerns the influence of external sources of pollution on the finding for water quality variables recorded at the various study sites.

*Generation of Sustainability Risk Ratings:*

Two potential limitations are recognised with regard to the generation of sustainability risk ratings. The calculation of confidence intervals with respect to sustainability risk ratings is not a feature of the methodology. This is due to complex and stage orientated nature of the methodology whereby data from multiple variables is converted to (or recorded using) risk categories based on subjective criteria. This means that any possible measure of statistical confidence in individual quantitative data values cannot be reliably transferred to the calculated sustainability risk ratings. As a result of this, the sustainability risk ratings should not be considered as a mathematical measure but rather a representation or characterisation of sustainability risk level (Amendola, 2001).

A second potential limitation identified with respect to the sustainability risk ratings concerns the fact that when aggregating risk ratings for individual variables in order to produce a rating for a particular area, the same weightings are applied to all the individual risk ratings. Given that certain variables may be perceived as being of greater significance in the context of sustainability, an argument exists for applying different weightings to different variables when aggregating risk ratings. However, it is recognised that any such application of different weightings would involve further additions of subjectivity to the process. In addition, the combining of ratings based on ordinal data (when aggregating risk ratings), is not considered technically mathematically correct in some disciplines (Moore et al., 2003). Thus an assumption is made that the ratings are additive.

# Chapter Four

# RESULTS

## 4.1 Introduction

A key general finding or assertion in the context of this research is that the results, as presented, demonstrate that the devised risk assessment based model provides a realistic and effective means of assessing the environmental sustainability of tourism and recreation destinations. Furthermore, the manner in which this assessment is presented means that useful interpretation and comparison of generated data can easily be made with respect to either location, sustainability category or individual variables.

This chapter presents the principal findings and data (including analysis) arising from the application of the risk assessment model and methodology as described in Chapters 1, 2 and 3. To accommodate the large set of results and data generated by the methodology, this Results Chapter is structured as follows: Principal findings concerning the application of the methodology and the two selected study areas, Lough Derg and Dublin Bay, are presented first. This is followed by presentation of more detailed results and findings with regard to the three study sites selected within each of the larger study areas. The study sites at Lough Derg are referred to as Terryglass Harbour, Dromineer Harbour and Meelick Bay. The study sites at Dublin Bay are Seapoint, Monkstown and Dun Laoghaire Harbour. The final section presents the basic data and analysis that was generated in respect of all variables selected for each study area. In this regard, where more in-depth material relating to a general finding is required, the reader is directed to the latter sections of this chapter.

## 4.2 Principal Findings and Results

### 4.2.1 Sustainability Risk Ratings for Lough Derg and Dublin Bay Study Areas.

Application of the methodology allowed a single percentage based 'sustainability risk rating' to be generated for selected variables at each study site, from extensive sets of field data. In accordance with the methodology, these ratings were also combined in order to give an overall sustainability risk rating for each of the two study areas, Lough Derg and Dublin Bay. These ratings are presented in Figure 4.1 below.

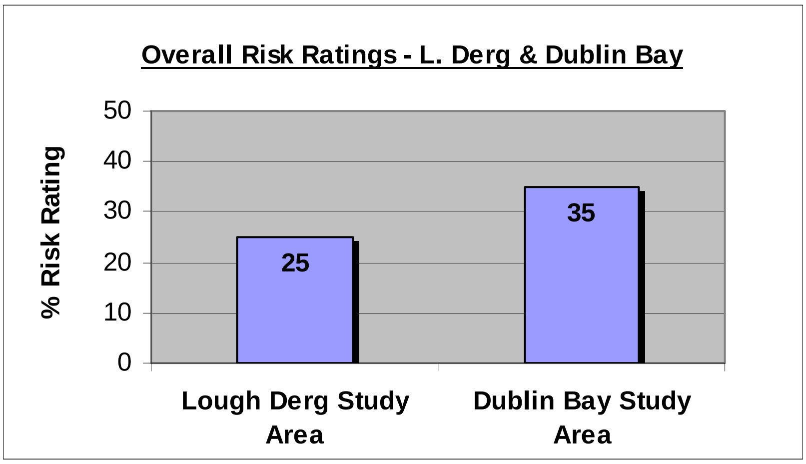



**Figure 4.1 – Sustainability Risk Ratings for the Lough Derg and Dublin Bay Study Areas**

As described in the Methodology Chapter, the ratings presented in Figure 4.1 above are simply an average of the sustainability risk ratings calculated for the individual variables recorded at all three study sites within each study area. In one respect these aggregated risk ratings can be interpreted as representative of the overall level of non-compliance with established standards of environmental quality at each study area. However, in accordance with the definition of sustainability adopted for this research (see Section 1.5), the ratings can also be viewed as a characterisation or representation of the risk to the continued environmental sustainability of these areas (Amendola, 2001). Thus, in the case of the Lough Derg and Dublin Bay study areas, the ratings represent a 25% and 35% level (respectively) of non-compliance with established standards across a broad spectrum of environmental parameters. In the context of sustainability, the main significance or interpretation of these ratings is that for both areas there is deemed a substantial level of risk (25 to 35 on a scale of 0 to 100) that these areas are not sustainable with regard to environmental quality. Ideally, this level (or sustainability risk rating) should be close to or at zero.

With regard to the Lough Derg and Dublin Bay study areas, the significance of the methodology and generated ratings is that they serve to highlight the fact that problems exist with regard to environmental sustainability at both of these areas. This is particularly significant with regard to the Lough Derg area which is normally perceived and marketed as having a pristine and high quality environment (North Tipperary County Council, 2004). The result for Dublin Bay on the other hand is not entirely unexpected given its suburban location and proximity to a large population centre. Nevertheless, the rating generated for the Dublin Bay area provides a useful reminder of issues regarding sustainability and provides a benchmark against which authorities can strive to improve the environmental quality (and sustainability) of this area.

### 4.2.2 Sustainability Risk Ratings for 'Sustainability Risk Categories'.

In addition to providing the basis of a general area rating (as described in the previous section), sustainability risk ratings for individual variables were also aggregated in order to generate ratings with respect to groups of variables. These groups are referred to as 'sustainability risk categories'. Their main significance is that they serve as an aid to the interpretation of the overall risk ratings for a given location and they allow quick identification of key factors contributing to a general risk rating. The significance of this feature of the methodology is highlighted by reference to the following charts (Figures 4.2 and 4.3) which present sustainability risk ratings generated for different categories of variables recorded at Lough Derg and Dublin Bay.

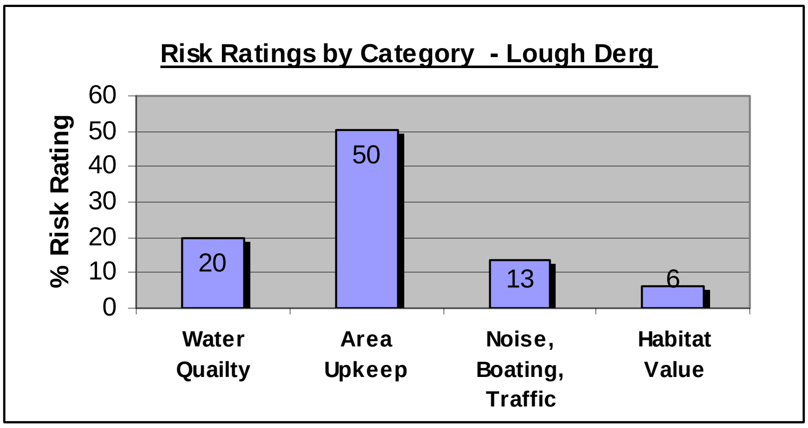



**Figure 4.2 – Risk Ratings for Selected Sustainability Categories – Lough Derg Study Area**

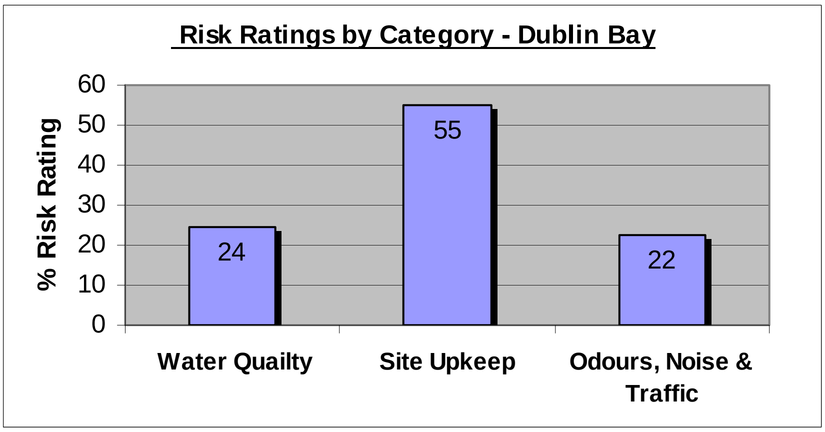



**Figure 4.3 - Risk Ratings for Selected Sustainability Categories – Dublin Bay Study Area**

The above charts provide useful insight into the nature of the sustainability (or environmental quality) issues at both areas. It can be seen that in the case of both Lough Derg and Dublin Bay it is variables associated with ‘site upkeep’ (or housekeeping) which factored most prominently in the overall risk ratings. Variables grouped in this category include litter, dog fouling and graffiti (see Methodology Chapter, Section 3.3). In many regards these particular ratings indicate that the threats to environmental sustainability at both locations is largely as a result of poor housekeeping by the relevant authorities. On a positive note, this also implies that the sustainability risk at both sites could be greatly reduced by simply improving the upkeep of these areas.

Water quality issues are identified as the second biggest contributor to sustainability risk, again at both the Lough Derg and Dublin Bay study areas. However, the implications of the ratings for water quality are more complex. In-depth analysis of the water quality data (see Section 4.4) has shown that the underlying causes of the poor water quality risk ratings vary from site to site and tend to be a result of complex factors such as the quality of urban waste water treatment and modern day agricultural practices. In effect, this means that the recorded water quality problems were predominantly due to factors external to the tourism and recreation industry and solving these problems is likely to be a complex matter involving various authorities.

The risk rating for the category ‘noise, boating and traffic’ for the Lough Derg sites is relatively lower (at 13%) but is still considered unsatisfactory. Detailed analysis of recorded data indicates that the principal factors behind this rating were noise and congestion associated with motor boat activity at Terryglass and Dromineer, primarily during the summer months. This is therefore an example of a sustainability issue driven largely by recreational activity. At the Dublin Bay study area, the risk rating of 22% for the third category ‘odours, noise and traffic’ was close to that of the water quality rating and again a cause for concern. Principal factors identified behind this rating were urban noise at Monkstown and constricted parking at Seapoint. ‘Habitat value’ was a forth category generated for the Lough Derg data only. The risk rating generated in respect of this category is considered largely satisfactory. From a wildlife conservation perspective this is considered a positive feature of the Lough Derg data.

### 4.2.3 Sustainability Risk Ratings for Individual Variables

As detailed in the Methodology chapter, sustainability risk ratings were generated initially in respect of individual variables. These ratings are based on the relative proportion of the number of low, medium and high categories recorded for each particular variable. The ratings for individual variables recorded at the specific study sites were then averaged in order to generate an aggregated rating for each particular variable with respect to the larger study areas, Lough Derg and Dublin Bay. In this manner, Figures 4.4 and 4.5 present the average risk ratings for individual variables recorded at the three study sites at both Lough Derg and Dublin Bay. The significance of this process and of the following charts is that they provide further insight into the nature of the problems facing the Lough Derg and Dublin Bay study areas.

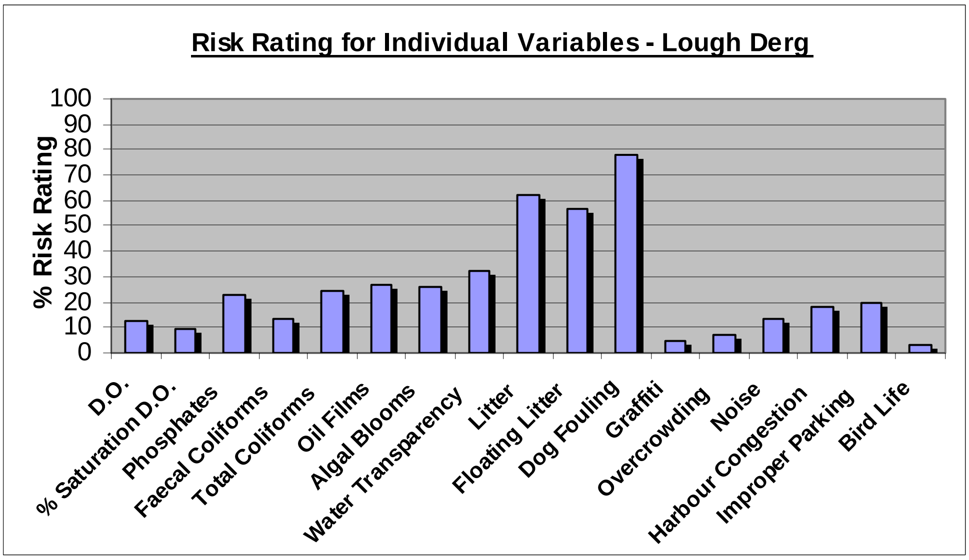



**Figure 4.4 – Average Sustainability Risk Rating for Individual Variables - Lough Derg Study Area**

Three variables standout as being particularly problematic at the Lough Derg study area. These are litter, dog fouling and floating litter. These are all variables which can be associated with the behaviour of visitors to the area. The remaining variables which are problematic are largely associated with water quality, although none of these ratings stand out in particular. However, with coliforms, oil films, algal blooms and transparency all presenting some risk, the water quality problems here are associated with issues of perception as well as presenting a health risk to users. In addition, deeper analysis of the data for these variables indicate that while the incidence of oil films, for instance, are associated with local visitor behaviour, the remaining water quality variables are largely influenced by more regional factors such as agricultural activity and the disposal and treatment of domestic waste water. Variables that performed notably well include graffiti, overcrowding and bird life. On the whole, the ratings for noise were relatively low (at 12%). However, further analysis of the situation regarding noise does highlight the close correlation between this variable and the presence of high powered motor craft and jet skis.

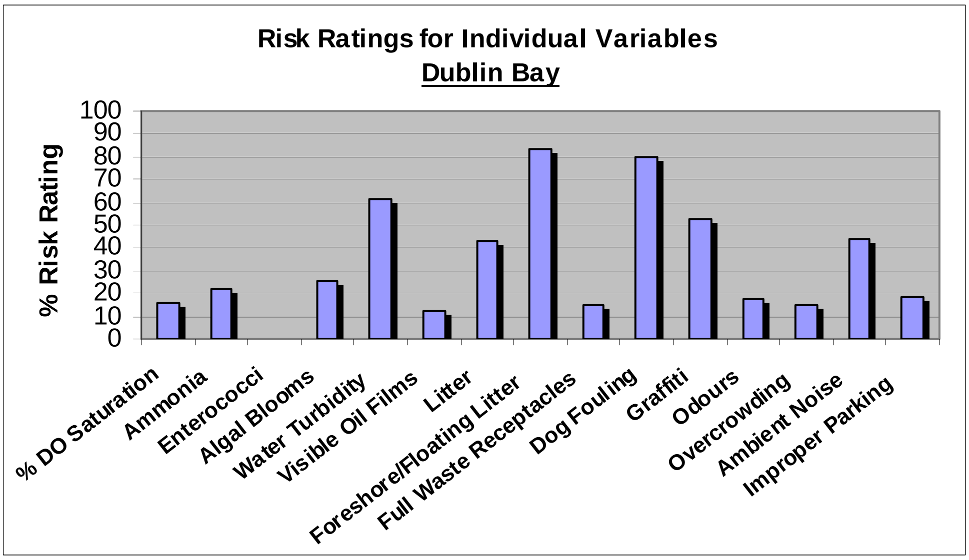



**Figure 4.5 - Average Sustainability Risk Ratings for Individual Variables – Dublin Bay Study Area**

Six variables stand out as being problematic at the Dublin Bay study area. Similarly to Lough Derg, these variables include litter, dog fouling and (foreshore) floating litter. However, in contrast to Lough Derg the variables graffiti and noise are also particularly problematic. In terms of water quality a notable feature of the above charts is the high risk rating (61%) associated with 'water turbidity' at Dublin Bay. If this rating is contrasted with the zero risk rating for enterococci (an indicator of microbial contamination), it can be seen that the issues associated with water quality at Dublin bay would appear to be related more to perception than potential health risk.

### 4.2.4 Sustainability Risk Ratings by Tourist/Recreation Season

A further feature of the methodology is the generation of sustainability risk ratings with respect to high and low tourist (or visitor) seasons. This research has shown that this particular manipulation of data provides a useful indication of the relationship between tourist season and the behavior of a given variable. Such an approach can provide useful information regarding the level of recreational activity occurring and its influence on the performance of a particular area with respect to a particular variable. The sustainability risk ratings generated for the Lough Derg and Dublin Bay study areas, with respect to tourism (or visitor) season, are presented in Figures 4.6 and 4.7 below.

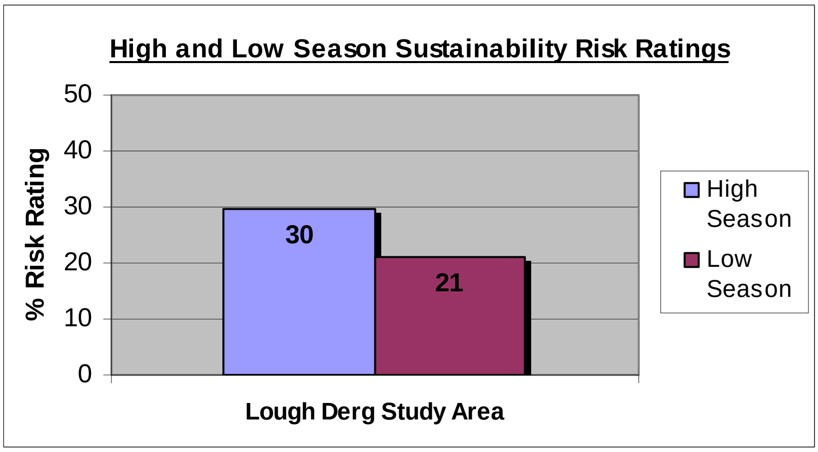



**Figure 4.6 - Combined High and Low Season Sustainability Risk Ratings for the Lough Derg Study Area**

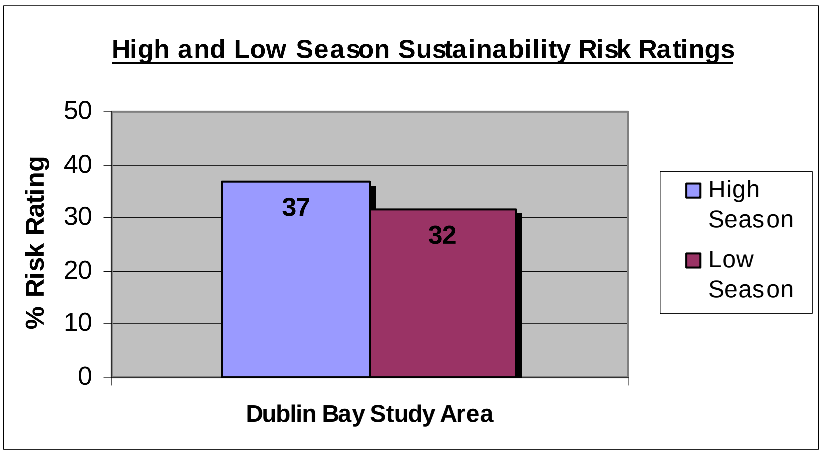



**Figure 4.7 - Combined High and Low Season Sustainability Risk Ratings for the Dublin Bay Study Area**

The above charts show that only a marginally greater sustainability risk rating was recorded during the high season at the Dublin Bay study area. The difference between the high and low season ratings for the Lough Derg area is greater, though still less than 10 percentage points. The principal significance of this is that it indicates that the sustainability issues arising at both locations are largely a year round problem. This implies that there is no direct association between greater recreational and tourist activity occurring during the high season months and a greater risk to the environmental sustainability of the areas studied. The results here therefore suggest that the factors which predominantly influence the sustainability ratings at Dublin Bay and, to a lesser extent, Lough Derg can be attributed largely to the behaviour of year round users of the amenity areas in question as well as local management practices.

#### 4.2.5 Ratings for The Individual Study Sites

The results presented in the preceding sections for the Lough Derg and Dublin Bay study areas represent the amalgamation of data recorded in respect of the three separate study sites within each study area (Terryglass, Dromineer and Meelick and Seapoint, Monkstown and Dun Laoghaire). Sustainability risk ratings for each of the individual study sites were also generated. These results are presented in Section 4.3.

The main significance of presenting the sustainability risk ratings for each of the six study sites is that it makes it possible to compare and contrast the sustainability (or environmental performance) of these sites. The research has shown that this aspect of the methodology has provided useful information regarding the nature and location of sustainability issues within each of the general study areas.

### 4.2.6 Significance of Further Data and Trend Analysis

Year round monitoring of variables at regular intervals and at multiple sites has provided a comprehensive set of data for each variable. Presentation of such date by means of line charts (in the case of quantitative data) and frequency tables (in the case of qualitative data) presents a valuable illustration of the behaviour of these variables. In due course, the detailed analysis of significant trends in the recorded data has been shown to provide further insight into the significance and implications of individual values recorded in respect of environmental variables. Such trend analysis has also provided a means of gaining insight into the possible factors behind poor risk ratings where they occurred. This research has therefore demonstrated that such trend analysis can provide valuable additional information required to allow for more effective strategies to be put in place to address these issues. The data with respect to all individual variables and relevant trend analysis are presented at length in Section 4.4 below.

## 4.3 Results and Interpretation for Individual Study Sites

The various combined and individual sustainability risk ratings generated for the Lough Derg and Dublin Bay study areas are presented in the preceding section along with the principal research findings. This section presents combined (mean) and individual risk ratings for each of the three study sites in each study area. These sites are Terryglass, Dromineer and Meelick Bay in Lough Derg and Seapoint, Monkstown and Dun Laoghaire Harbour at Dublin Bay.

### 4.3.1 Overall Risk Rating for Lough Derg and Dublin Bay Study Sites

Risk ratings were generated for each of the three specified sites at each of the Lough Derg and Dublin Bay study areas. These ratings provide a useful comparison of the level of environmental sustainability determined for each location. The ratings are presented in the two charts which follow (Figures 4.8 and 4.9).

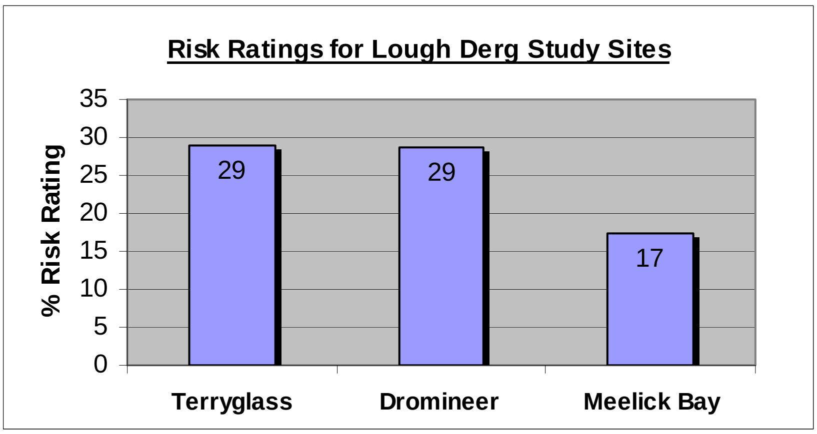



**Figure 4.8 – Overall Sustainability Risk Ratings for the Three Lough Derg Study Sites**

*<u>Comment:</u>*

A feature of the above chart for the Lough Derg sites is the equal risk ratings for Terryglass and Dromineer. In both cases the generated risk rating is considered to be relatively poor. The two sites are similar in physical make up and they are popular with both land based day-trippers and people involved in various types of boating activity. To a large extent, therefore, the environmental quality of these sites is affected by the same factors. However, review of the risk ratings for the individual variables (see Section 4.3.3 below) does reveal that poor house keeping issues such as dog fouling and litter were a particular problem at Dromineer. This may reflect the proximity of the nearby town of Nenagh and also the existence of residential housing and facilities such as a pub and a shop adjacent to Dromineer. On the other hand, at Terryglass harbour congestion and coliform contamination, together with site upkeep problems, played an important part in pushing up the risk rating. These factors are probably a reflection of the relatively small harbour at Terryglass and also the Terryglass River which flows into the harbour which was shown to contain high levels of coliform contamination (see Section 4.4 for further analysis and explanation of the factors contributing to the risk ratings).

The risk rating generated for Meelick Bay was significantly lower but is still considered less than satisfactory. The lower rating reflects the more isolated and natural character of this location. Nevertheless, Meelick Bay was seen to suffer badly from dog fouling and litter problems. However, the risk ratings for other prominent factors such as noise, water quality and overcrowding were generally very low at this site (see Section 4.3.3.1 below).

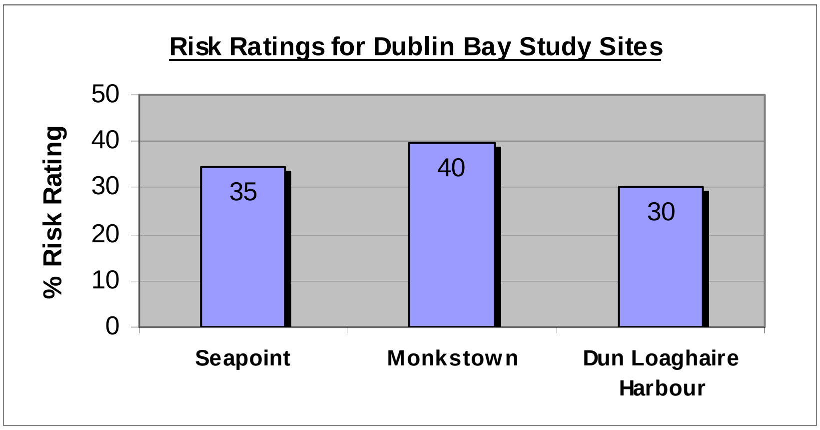



**Figure 4.9 – Overall Sustainability Risk Ratings for the Three Dublin Bay Study Sites**

*Comment:*

The risk ratings for the Dublin Bay sites were noticeably higher than those for the Lough Derg sites with the 40% rating for Monkstown being particularly high. Analysis of the ratings for individual variables (see Section 4.3.3 below) shows that very poor results for litter, dog fouling and graffiti were the main factors behind the average rating at Monkstown. Issues regarding water quality and noise were also a feature at this location but no sustainability risk was recorded with respect to traffic or overcrowding. These findings reflect the proximity of Monkstown to the DART railway line and also the popularity of the area which is likely to be linked, in part, to the ample provision of parking and green space. In contrast to Monkstown, very little parking or green space provided at Seapoint. However, this area remains a very popular bathing area and was also shown to suffer from high levels of litter, dog fouling and graffiti, though litter levels were significantly lower than at Monkstown. This was the main factor behind the lower risk rating (35%) generated for Seapoint. Not surprisingly improper parking was also an important factor in the overall risk rating for Seapoint. The risk rating for Dun Laoghaire Harbour (30%) was the lowest of the three Dublin Bay sites. Generally the risk ratings for individual variables recorded at Dun Laoghaire Harbour (see Section 4.3.3.2) were significantly lower than those recorded at Seapoint and Monkstown. However, floating litter and dog fouling were major factors behind the risk rating at this location.

### 4.3.2 Risk Ratings for Sustainability Categories (Lough Derg & Dublin Bay)

The following charts present combined risk rating results for a number of ‘sustainability categories’ for the six Lough Derg and Dublin Bay study sites. These sustainability categories comprise of a number of environmental variables considered relevant to the category (see Methodology Chapter, Section 3.3.3 for further details).

#### *4.3.2.1 Lough Derg Sites*

Sustainability risk ratings, by category, are presented in Figures 4.10, 4.11 and 4.12 below.

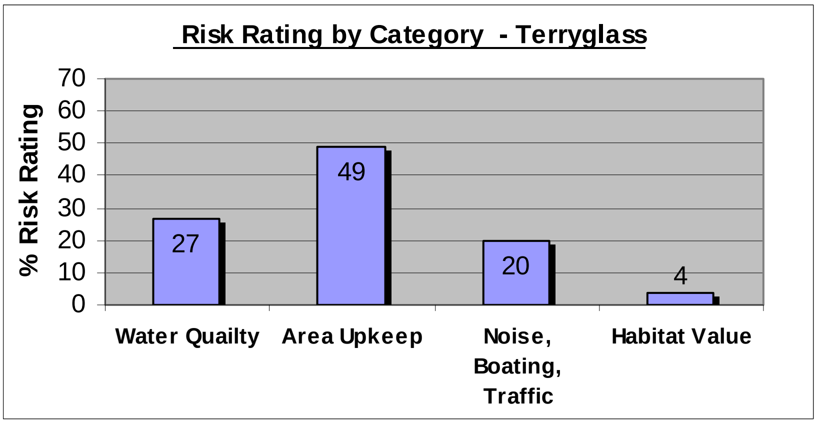



**Figure 4.10 – Risk Ratings for Sustainability Categories at Terryglass Harbour**

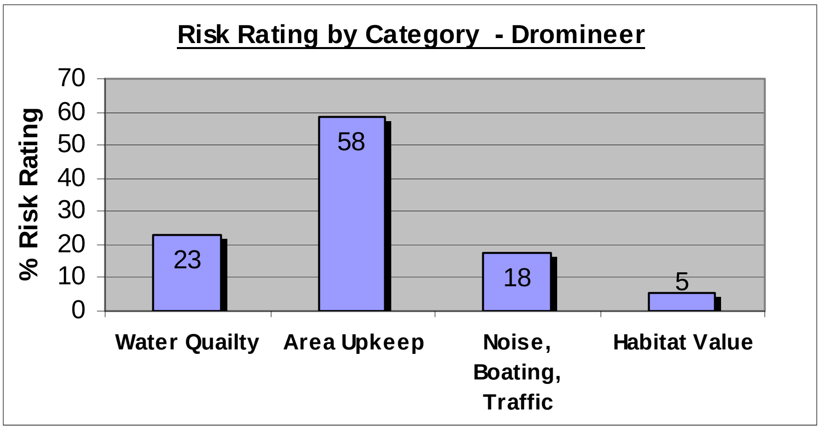



**Figure 4.11 – Risk Ratings for Sustainability Categories at Dromineer Harbour**

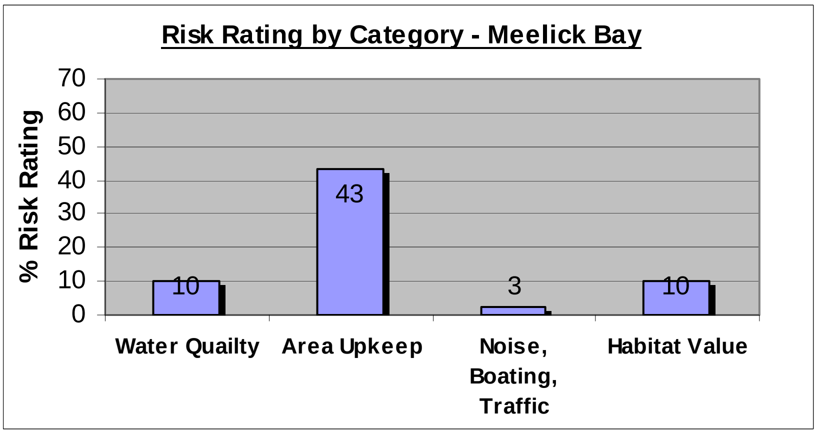



**Figure 4.12 – Risk Ratings for Sustainability Categories at Meelick Bay**

*Comment:*

A feature of the charts above for the Lough Derg sites is the similar proportions in the risk rating levels for the four sustainability categories at Terryglass and Dromineer. At all three sites it is the variables associated with the 'site upkeep' category which was found to present the greatest risk to sustainability at each site. At Terryglass and Dromineer, this is followed by 'water quality' and 'noise, boating and traffic'. Perhaps surprisingly, the variables assigned to the 'habitat value' category present the lowest risk to environmental sustainability at Terryglass and Dromineer but not at Meelick

Bay. At Dromineer the risk rating associated with the area upkeep category is particularly high at 58%.

The variables assigned to the site upkeep category, such as dog fouling, noise and litter, are those associated with public behaviour at each site. This result therefore further indicates that it is poor management of the amenity areas in question that has the greatest influence on the overall risk ratings recorded for the Lough Derg study area (see previous section). As proposed in the previous section, a positive consequence of this situation is that it should be possible to significantly reduce the risk ratings at each of the three sites with appropriate management intervention. Although the risk ratings for 'water quality' are lower than those for 'site upkeep', they are nonetheless still quite significant, particularly at Terryglass and Dromineer. Furthermore, in contrast to the 'site upkeep' variables, the analysis of trends in the water quality data for the Lough Derg sites shows that much of the poor water quality is associated with activities external to the specific sites and ultimately much harder to address at a local level.

The category 'noise, boating and traffic' had the third highest risk rating for Terryglass and Dromineer. Here it was mainly issues to do with high-powered motorboats, harbour congestion and improper parking that contributed to these risk ratings. Again management intervention could address some aspects of this problem area, though it would appear that solving the harbour congestion problem at Terryglass would require an expansion of the birthing facilities. As expected these issues were not of significance at Meelick Bay. Encouragingly, the 'habitat value' category of the Lough Derg Sites returned the lowest risk ratings at Dromineer and Terryglass. It would appear that this is largely a reflection of the physical nature of these sites where much of the surrounding natural lakeside habitat has not been compromised by the development of these amenity areas. In addition, this finding suggests that operation of various craft at these sites does not interfere to any significant degree with either water quality or bird life. Somewhat surprisingly, the rating for 'habitat value' at Meelick Bay was higher that at the other two sites. This higher rating was largely a reflection of lower dissolved oxygen levels in the water at Meelick Bay which may be due to the shallow nature of the lake at this location which could inhibit the mixing of waters adjoining the lakeshore with those of deeper areas of the lake.

#### *4.3.2.2 Dublin Bay Sites*

Sustainability risk ratings, by category, are presented in Figures 4.13, 4.14 and 4.15 below:

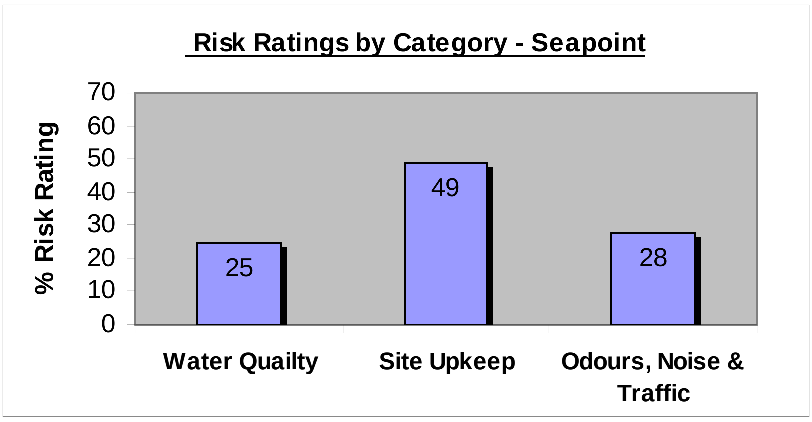



**Figure 4.13 – Risk Ratings for Sustainability Categories at Seapoint Bathing Area**

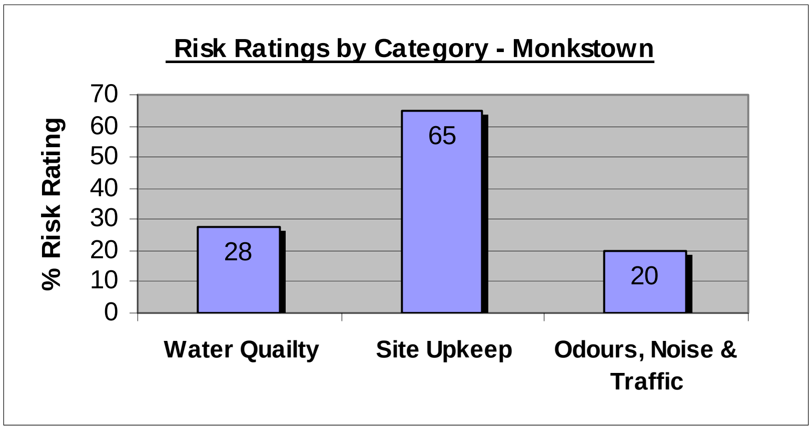



**Figure 4.14 - Risk Ratings for Sustainability Categories at Monkstown Amenity Area**

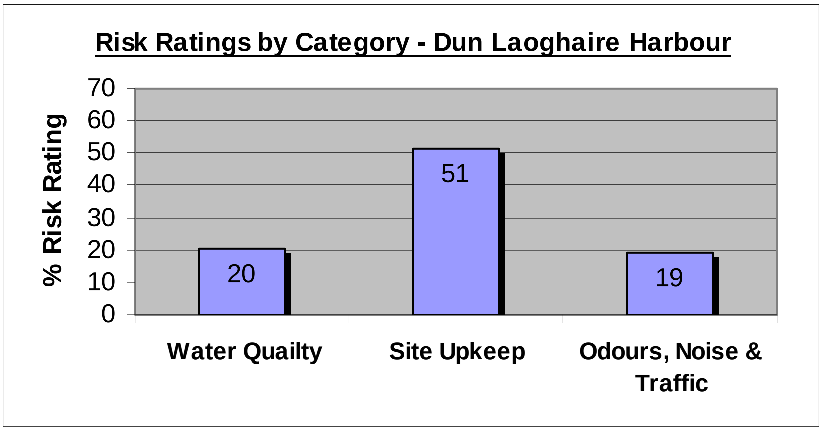



**Figure 4.15 - Risk Ratings for Sustainability Categories at Dun Laoghaire Harbour and Pier**

*Comment:*

As with the Lough Derg sites the amenity value category is again the most prominent feature of the above risk rating charts. The implications of this, which are discussed above, also apply here. A noteworthy feature of the risk rating chart for Seapoint is the high risk rating recorded for the 'odours, noise and traffic' category. Improper parking is the main variable behind this rating and this result largely reflects the confined nature of Seapoint and the complete lack of on site parking for users of this amenity area. Intervention with respect to this issue is considered impractical due to the confined, urban nature of the site. In contrast to Seapoint, the main issue contributing to the ‘odours, noise and traffic’ category are noise from the nearby roads and railways and odours from decomposing algal material. No problems associated with traffic were recorded at Monkstown which most likely reflects the provision of a generous and free parking facility at this location.

In line with the Lough Derg sites, water quality also presents a problem at all three Dublin Bay sites. However, review of the risk ratings for the individual variables (see Section 4.3.3 below), shows that whereas it is principally oil pollution that contributes to the water quality risk rating at Dun Laoghaire Harbour, it is the occurrence of algal blooms and a high level of water turbidity that contributes to the rating at Monkstown and Seapoint. The main significance of this is that the occurrence of oil pollution in Dun Laoghaire Harbour can be considered a local management failing, whereas the water quality problems at Monkstown and Seapoint are due more to external factors and therefore are likely to be much more difficult to address. Note that no risk rating was generated for a ‘habitat value’ category at the Dublin Bay sites. This was due to the lack of suitable criteria for assigning habitat related data to risk categories (see the Methodology Chapter, Section 3.4 for further details).

### 4.3.3 Risk Ratings for Individual Variables (Lough Derg & Dublin Bay Study Sites).

Risk ratings are presented in the charts below for all variables which were recorded on the basis of or assigned to low, medium and high categories. These charts illustrate clearly the relative importance of each variable with regard to the environmental sustainability of each study site.

#### *4.3.3.1 Lough Derg Sites*

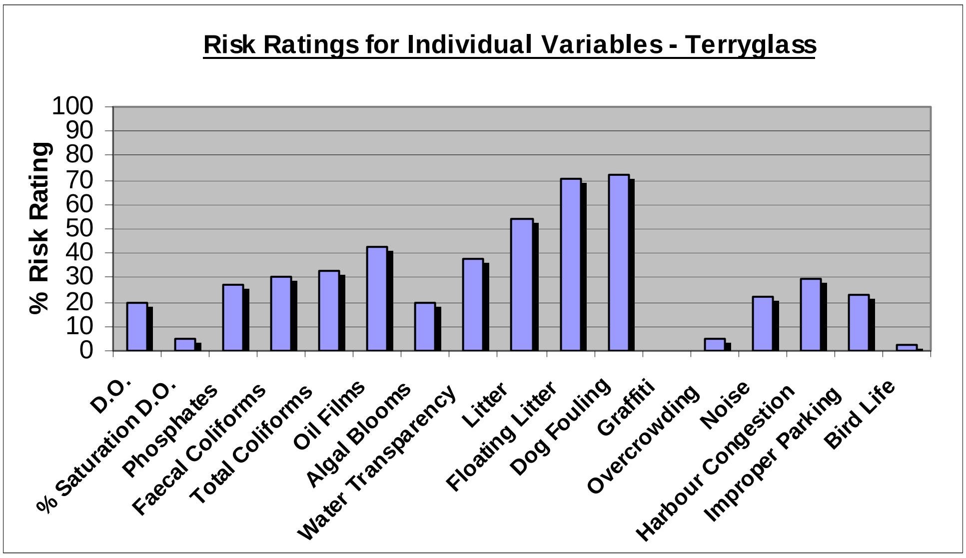



**Figure 4.16 – Sustainability Risk Ratings for Individual Variables Recorded at Terryglass Harbour**

<u>*Comment:*</u>

Litter, floating litter and dog fouling stand out in the above chart as the environmental variables which present the greatest risk to sustainability at Terryglass. This is most likely a reflection of the popularity of this site combined with less than adequate management or upkeep of the area. Many of the variables associated with water quality also have relatively high risk ratings ( >20% ). In particular, the levels of phosphates, coliforms, algal blooms and water transparency are considered to be less than satisfactory. However, with regard to these variables it is important to note that they are primarily associated with general water quality problems in Lough Derg. This issue is discussed in greater detail in the data analysis section (Section 4.4). The risk rating for oil films (42%), on the other hand, is very much a local issue with on site observations confirming that most oil pollution originated from motor boats moored in the harbour. The rating for percentage saturation of dissolved oxygen is low at Terryglass which is a significant positive finding as this variable is an important general indicator of the quality of the water habitat. In this regard, the low risk rating recorded for bird life is also a positive feature particularly with regard to the natural habitat value of this amenity area. The risk ratings for noise and harbour congestion on the other hand are relatively high. These areas were shown to be a particular problem at Terryglass during the high season where a shortage of berthing space combined with the popularity of the area for users of high powered motorboats generated high levels of harbour congestion and ambient noise.

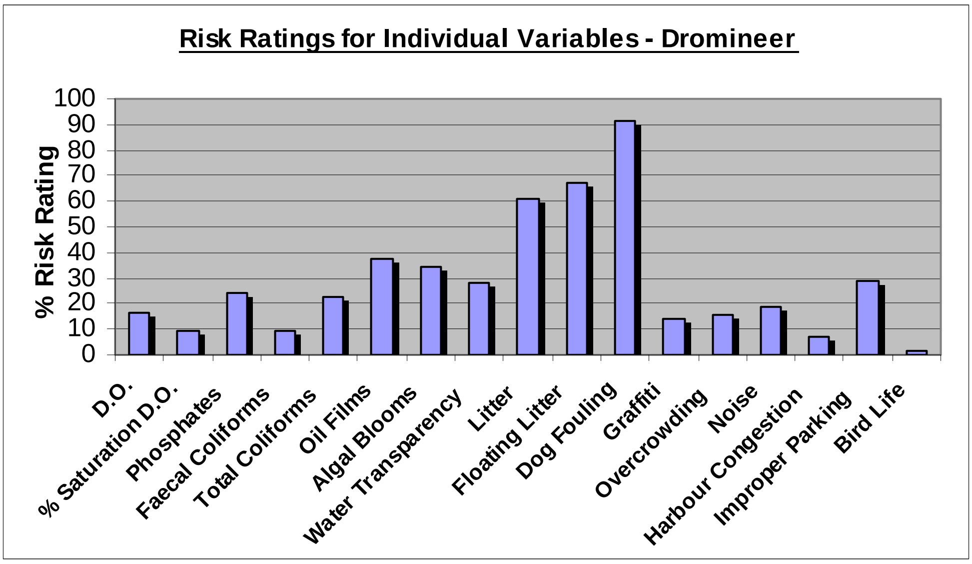



**Figure 4.17 – Sustainability Risk Ratings for Individual Variables Recorded at Dromineer Harbour**

<u>*Comment:*</u>

This chart clearly identifies the main threats to the environmental sustainability of the Dromineer amenity area. Litter and floating litter both have risk ratings over 60% with the risk rating for dog fouling being over 90 %. The risk ratings for variables associated with water quality are similar to those recorded at Terryglass, though the rating for faecal coliforms was notably lower at Dromineer. The ratings for water quality variables at Dromineer also tends to reflect more the general condition and pressures facing water quality in Lough Derg rather than any local factors. However, an exception to this again is the poor rating for oil films (38%). In line with the much greater provision of marina berthing facilities at Dromineer, the rating for harbour congestion here was considerably lower. Perhaps surprisingly, given the closer proximity of Dromineer to the urban centres of Nenagh town and Limerick city, the rating here for noise was also lower than that at Terryglass. In contrast, the rating for improper parking (22%) was surprisingly high given the extensive parking areas provided at Dromineer. As with Terryglass, the risk rating for bird life was very low, with significant levels of bird species richness consistently observed at this location.

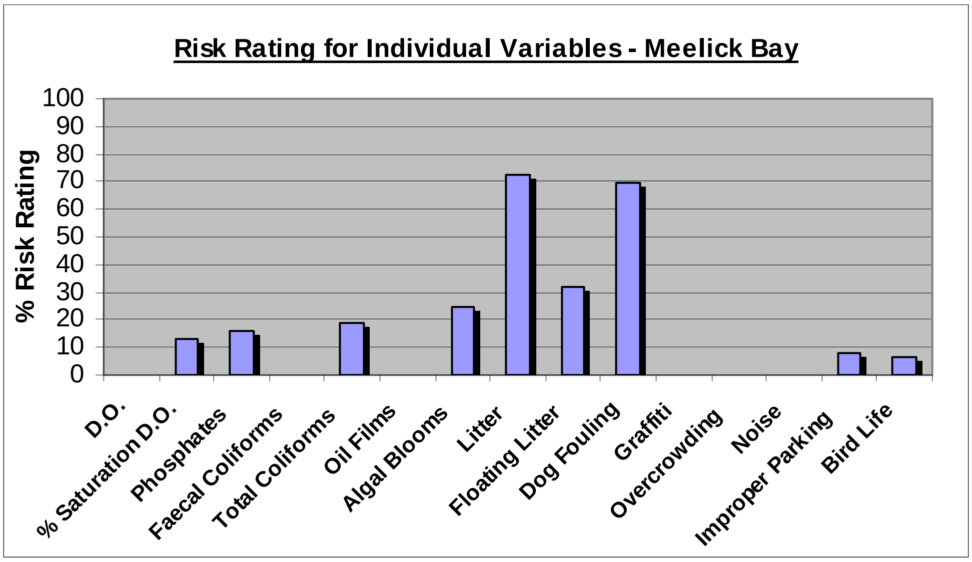



**Figure 4.18 – Sustainability Risk Rating for Individual Variables Recorded at Meelick Bay**

Comment:

Two features stand out in the above chart (Figure 4.18) for Meelick Bay. Firstly, over half the variables scored ratings of zero or below 10%. Such variables include noise, graffiti, overcrowding, oil films, bird life and dissolved oxygen. These low or zero ratings are a reflection of the isolated, tranquil location of this site and the absence of any marina facilities. However, in spite of these characteristics, this area still suffers badly with regard to litter and dog fouling. In addition, the risk levels recorded for algal blooms and total coliforms, though again linked to the general condition of Lough Derg, remain a cause for concern.

#### 4.3.3.2 *Dublin Bay Sites*

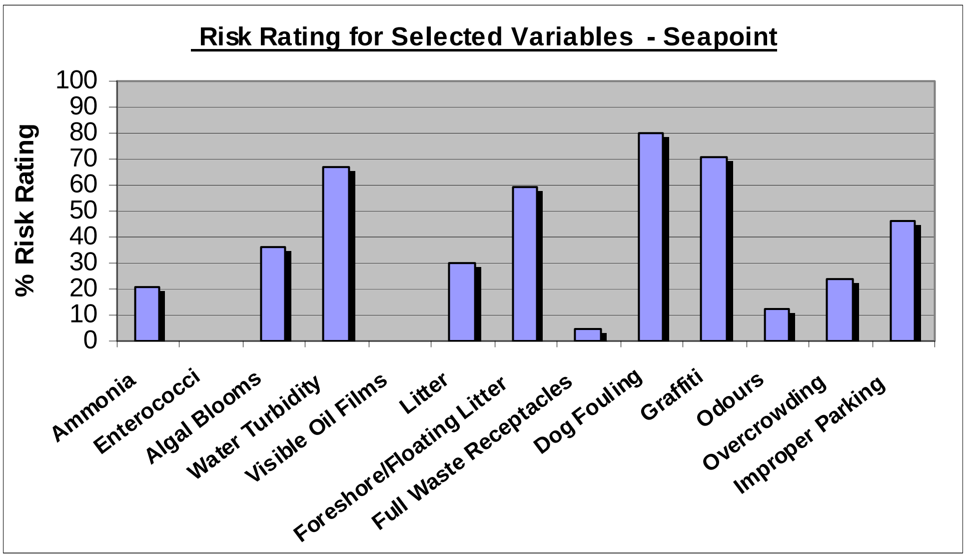



**Figure 4.19 – Sustainability Risk Ratings for Individual Variables Recorded at Seapoint Bathing Area**

Comment:

The above chart (Figure 4.19) presents a poor picture with respect to foreshore litter, dog fouling and graffiti. Algal blooms and water turbidity are also key problems at this location with risk ratings of 36 and 67% respectively. Relative to the other locations studied, the risk rating for general litter at Seapoint was relatively low. Observations indicated that this was largely due to frequent litter removal and the provision and emptying of numerous rubbish bins by the local authority. Although the risk rating for ammonia was relatively high at 20% it is interesting to note the zero rating for enterococci (a key indicator of microbial contamination). The ammonia rating likely reflects the general problems with nutrient loading from domestic wastewater in Dublin Bay (see Section 4.4 for further details) but the zero rating for enterococci runs against the general concerns held by users of Seapoint that the water quality presents a significant health risk here. Considering the high risk rating for water turbidity, it is therefore likely that the poor appearance of the water at Seapoint influences, incorrectly, the health risk perceptions of the public. Other results of note in the above chart include the high rating for improper parking which is not unexpected given the popularity of this area and the very limited provision of parking. Odours and overcrowding were minor though still significant problems at Seapoint. The odour problems were largely linked to the decay of algal matter associated with the frequent algal blooms observed at this location.

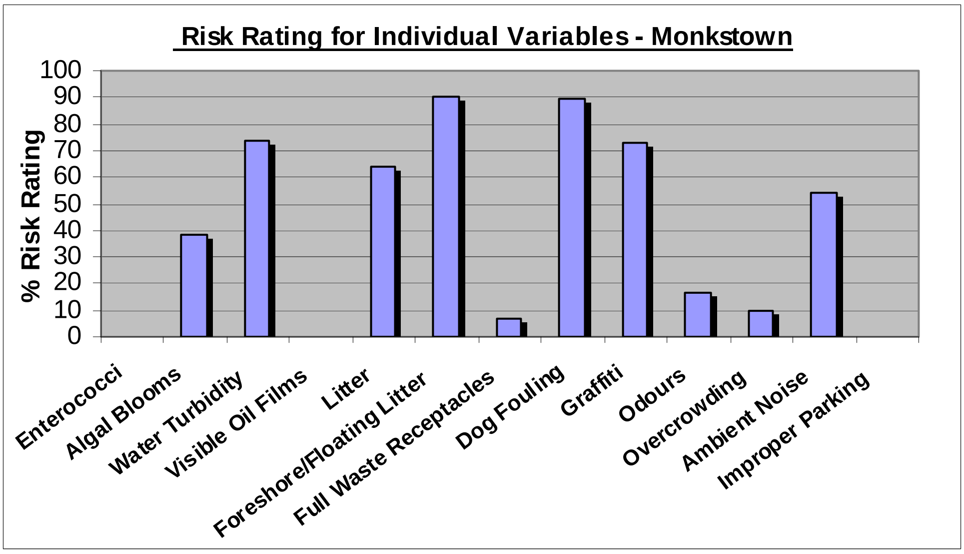



**Figure 4.20 – Sustainability Risk Ratings for Individual Variables Recorded at Monkstown Amenity Area**

<u>*Comment:*</u>

The individual risk ratings for Monkstown are quite similar to those generated for Seapoint. Here it is also litter, dog fouling, graffiti, water turbidity and algal blooms which present the greatest risk to the environmental sustainability. Zero risk ratings for enterococci and visible oil films are also recorded at this location with similar implications regarding the perceptions of water quality and health risk. In contrast to Seapoint, a zero rating for improper parking was recorded at Monkstown. As discussed in previous sections this is not surprising given the ample parking which exists at this area. The risk rating for odours was very similar to that recorded at Seapoint. This would be largely expected as both sites suffer from the same problems with algal blooms. A notable feature of the chart for Monkstown is the high risk rating generated in respect of noise. As discussed in Section 4.4 the poor rating for noise is attributable mainly to the close proximity of the DART commuter railway line and the Dun Laoghaire to Blackrock Coastal road. Nevertheless, some incidences of boating activity were observed during the summer months which did factor in the noise risk ratings.

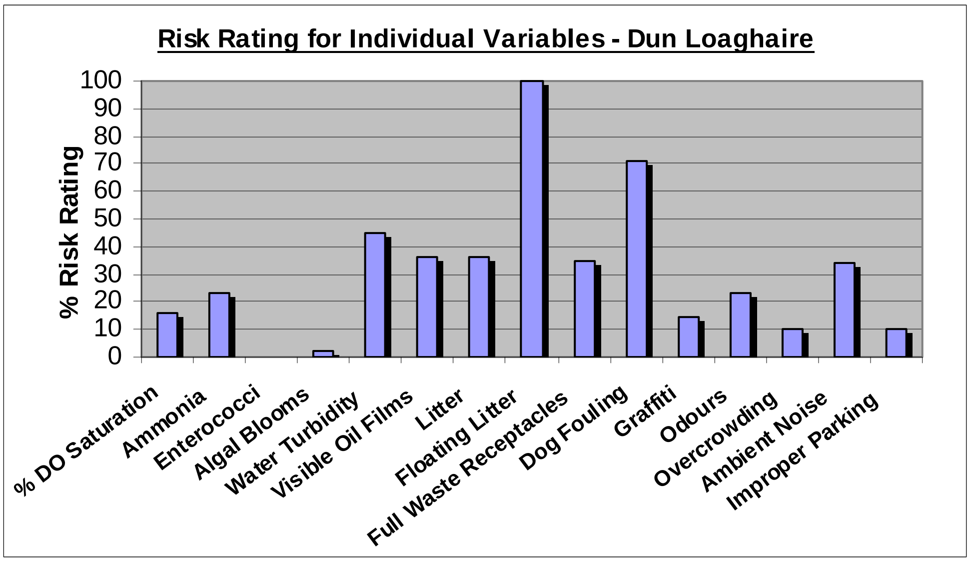



**Figure 4.21 - Sustainability Risk Ratings for Individual Variables Recorded at Dun Laoghaire Harbour and West Pier**

<u>*Comment:*</u>

Although many of the risk ratings for the variables recorded at Dun Laoghaire Harbour (and West Pier) are lower that those for Seapoint and Monkstown, two variables stand out as being particularly problematic at Dun Laoghaire. These are floating litter with a 100% risk rating and dog fouling with a 71 % rating. The problems with floating litter are presumably exacerbated by heavy use of the harbour and its enclosed nature but the rating nevertheless represents a very poor result for this variable. The dog fouling rating can be attributed to the popularity of the West pier as a location for walking dogs though receptacles for cleaning up after dogs are provided along the pier. Interestingly, the rating for litter was relatively low in spite of the fact that the rating for full waste receptacles was relatively high. Oil pollution was another problem at Dun Laoghaire, particularly in the inner section of the harbour where much of the visible oil films appeared to be originating from the small commercial fishing pier. The oil pollution problem was also the main factor behind the risk rating for odours. The noise variable scored a relatively high risk rating. This is considered particularly significant as the recording location for this variable was somewhat removed from urban noise and the rating was primarily influenced by noise associated with high powered motor craft in particular. In general the ratings for the water quality variables were relatively low. However, the problems associated with visible oil films and water turbidity meant that the appearance of the water in Dun Laoghaire was not always satisfactory.

### 4.3.4 Seasonal Comparison of Combined Risk Ratings

The following charts (Figures 4.22 and 4.23) present combined risk ratings for each site which are generated using data specific to the low and high seasons as defined (see Methodology Chapter, Section 3.5). The main function of this analysis is to illustrate whether factors contributing to sustainability risk were more pronounced during the high or low season. This provides some indication of the seasonal nature of identified problem areas or otherwise.

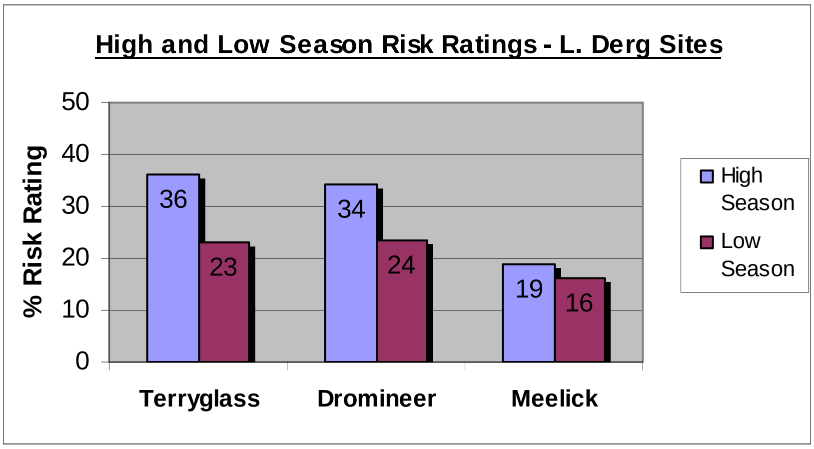



**Figure 4.22 – Combined Sustainability Risk Ratings (for High and Low Seasons) for Terryglass, Dromineer and Meelick Bay**

*Comment:*

Review of the above chart (Figure 4.22) reveals a significant difference in the discrepancies between the low and high season risk ratings for the there study sites at Lough Derg. The larger discrepancies at Terryglass and Dromineer suggest that these sites are subject to greater environmental pressures during the high season. This indication is not unexpected given the nature of these sites as popular recreation and tourism destinations. Likewise, at Meelick Bay, the absence of any significant difference between the high and low risk ratings is in line with expectation given that little difference was observed between the level of recreation activity occurring at this location during the high and low season. Further analysis of the situation at Terryglass and Dromineer (see Section 4.4) reveals that the main factors behind the higher risk ratings recorded during the high season were associated with boating and traffic variables. The risk ratings for the variables associated with site upkeep, such as litter and dog fouling, were more consistent over the course of the year.

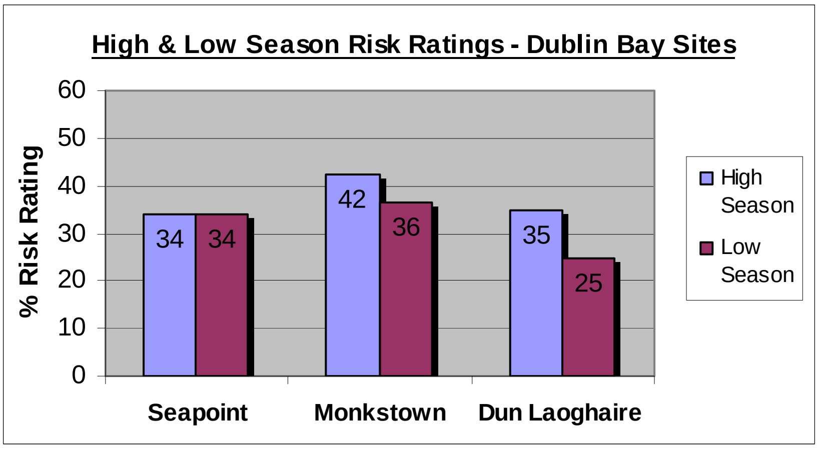



**Figure 4.23 - Combined Sustainability Risk Ratings (for High and Low Seasons) for Seapoint, Monkstown and Dun Laoghaire**

*Comment:*

The discrepancy between the low and high season risk ratings for the Dublin Bay study sites is noticeably less than that for the Lough Derg sites (with the possible exception of Dun Laoghaire Harbour and West Pier). Thus, in the case of Seapoint and Monkstown, this indicates that identified environmental pressures tend to occur through out the year regardless of tourist season. Given the urban proximity of these sites this is in line with expectation as the levels of activity occurring at these sites (with the exception of boating activity) does not increase significantly during the tourist high season. In particular, the levels of the main contributor to the sustainability risk ratings at these locations (litter, graffiti and dog fouling) were similar through out the year.

Dun Laoghaire Harbour on the other hand does show a significant difference between the high and low season risk ratings. Higher noise levels occurring in the summer months, which were observed to be associated with motor boat activity, were largely responsible for this difference.

### 4.3.5 Seasonal Comparison of Risk Ratings for Sustainability Categories

Sustainability risk ratings for the different groups of variables ('sustainability categories') are presented in this section for the high and low tourist and recreation seasons (Figures 4.24, 4.25 and 4.26).

#### *4.3.5.1 Lough Derg Sites*

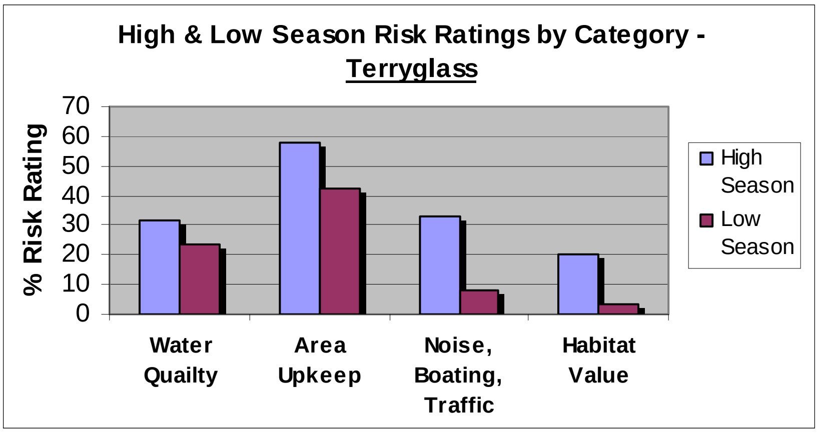



**Figure 4.24 –Risk Ratings (for High and Low Seasons) for Sustainability Categories at Terryglass Harbour.**

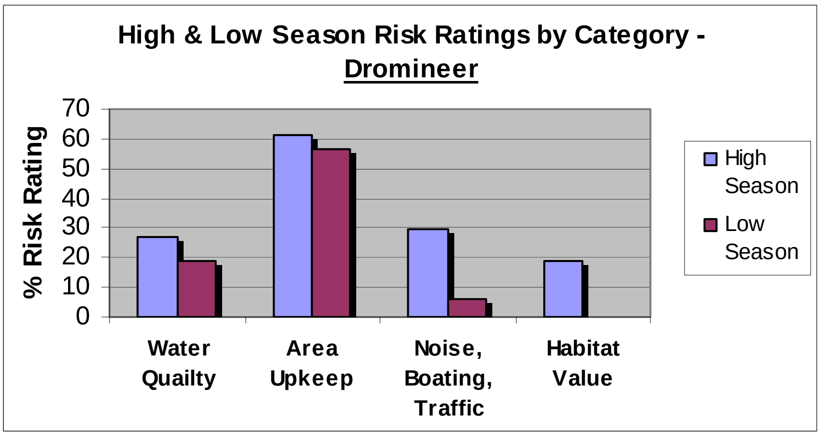



**Figure 4.25 - Risk Ratings (for High and Low Seasons) for Sustainability Categories at Dromineer Harbour.**

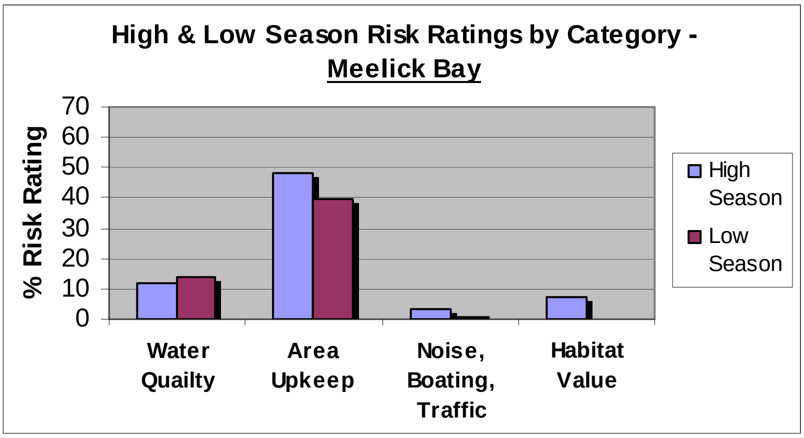



**Figure 4.26 - Risk Ratings (for High and Low Seasons) for Sustainability Categories at Meelick Bay Amenity Area**

*Comment:*

Significantly higher risk ratings were recorded during the high season for all four sustainability categories at Terryglass and Dromineer. As discussed previously, this generally reflects the greater use of these area during the summer months. In particular, the levels of harbour congestion (at Terryglass) and the use of high powered boats (at both locations) were most evident during the high season, thereby influencing the high season risk rating for the 'noise, boating and traffic' categories. Although the high season ratings for the water quality variables was significantly higher than the low season ratings, the outcome of trend analysis (see Section 4.4) suggests that this feature is not associated with greater use of these areas during the high season but rather to general trends in lake water quality in Lough Derg. An example of this is the fact that algal blooms will naturally tend to occur during the summer months. The greater high season risk rating for habitat value at both Terryglass and Dromineer was mainly due to the lower levels of dissolved oxygen recorded during the summer months. Such occurrences are known to have negative implications for fish life. With regard to the ratings for the 'site upkeep' category, high levels of floating litter recorded during the high season were a prominent factor in the discrepancy between the high and low season ratings for this category at both locations.

In contrast to Terryglass and Dromineer, the chart for Meelick Bay shows relatively little difference between the high and low season risk values for all four categories. Moreover, the rating for the water quality category is actually higher during the low season. These results are largely in line with expectation as little or no increase in use of this amenity area was recorded during the high season. As with Terryglass and Dromineer, the results for water quality are believed to be attributable to external factors occurring in Lough Derg generally. Regarding the habitat value category, it is noted that the recorded discrepancy between the high and low season risk ratings is due to natural trends in the patterns of bird life populations in the area and not due to any additional pressures associated with recreation and tourism in the area.

### *4.3.5.2 Dublin Bay Sites*

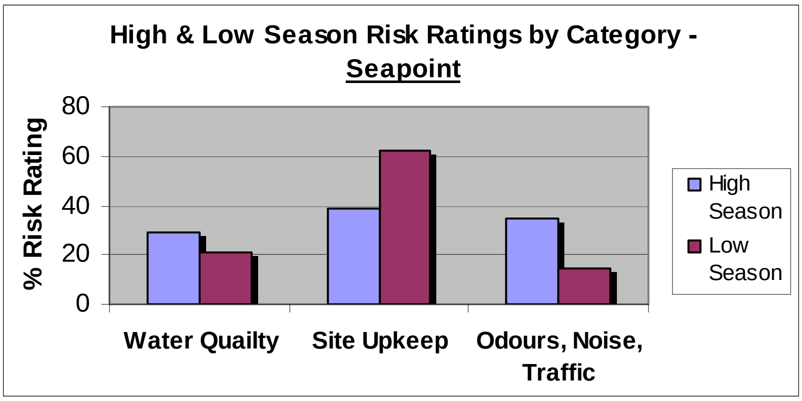



**Figure 4.27 - Risk Ratings (for High and Low Seasons) for Sustainability Categories at Seapoint Bathing Area**

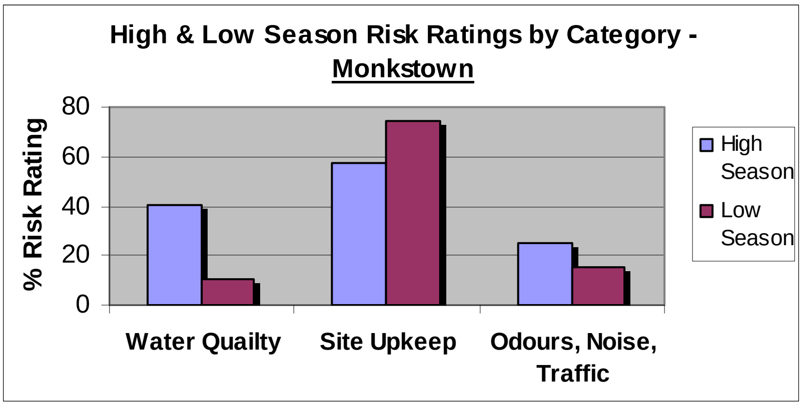



**Figure 4.28 - Risk Ratings (for High and Low Seasons) for Sustainability Categories at Monkstown Amenity Area**

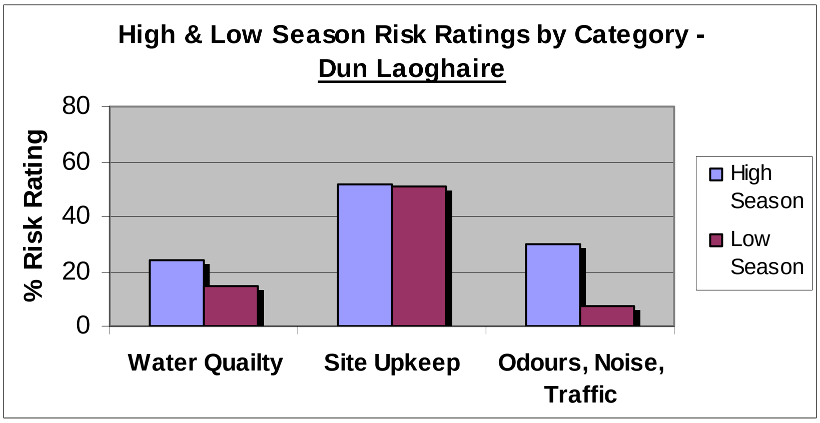



**Figure 4.29 - Risk Ratings (for High and Low Seasons) for Sustainability Categories at Dun Laoghaire Harbour (and West Pier)**

*Comment:*

The risk ratings with respect to high and low season for the three sustainability categories present a generally similar picture for all three study sites in the Dublin Bay study area. This is largely in line with expectation. However, noticeable differences include the ratings for the 'site upkeep' category. The results for this category are interesting in that at Seapoint and Monkstown it is during the low season that the highest risk to sustainability occurs. At Dun Laoghaire the risk is spread evenly between the low and high season. On site observations clearly indicate that the principal factors behind these patterns were the fact that regular cleaning and maintenance was carried out at Seapoint and Monkstown during the high season but not during the low season. Given that pressures on these amenity areas were observed to exist through out the year it is therefore no surprise that the risk ratings for this category were highest during the low season. In contrast to Seapoint and Monkstown, little maintenance or cleaning of the Dun Laoghaire site was observed at any stage of the year. Hence, the similar risk ratings with respect to the ‘site upkeep’ category for the high and low seasons.

Other points of consideration regarding the above charts include the water quality results. In this case of Seapoint and Monkstown, the factors behind the higher risk ratings during the high season were largely to do with external water quality issues in Dublin Bay such as the occurrence of algal blooms and high levels of turbidity. Although, the difference between the high and low seasons risk ratings were significantly less at Dun Laoghaire, a significant feature of the Dun Laoghaire water quality data is that local factors were prominent particularly with respect to visible oil films.

As stated the results for the ‘odours, noise and traffic’ category were largely in line with expectation with traffic at Seapoint and noise at Dun Laoghaire being the predominant factors behind the higher risk ratings during the high season. Further details are given under the relevant headings in Section 4.4 which follows.

## 4.4 Presentation of Raw Data - Trend Analysis and Interpretation

### 4.4.1 Introduction

The raw data which was recorded for the selected variables at the Lough Derg and Dublin Bay study sites is presented in this section. For quantitative variables the data is presented by way of line charts for each variable which show the values (in relevant units on the y-axis) recorded at the various sampling sites for each visit throughout the year (on the x-axis). In order not to clutter the x-axis, the months within which samples were undertaken are shown rather than the individual sampling dates. Where greater meaning of individual data values presented on the line charts are sought, the reader is referred to the relevant variable headings in Section 3.6 (Methodology Chapter) where the criteria for assigning data values to risk categories is given. In effect, these criteria illustrate the expected norms regarding the recorded values for each variable.

For qualitative variables (i.e. those recorded directly on the basis of low, medium or high risk categories), the data is shown by means of frequency charts. These are bar charts and they illustrate the frequency with which each category occurred for a given variable at a particular sampling location. Again, where further understanding of this data is required, the reader is referred to the relevant parts of Section 3.6.

With respect to the line charts (displaying the quantitative data), it should also be noted that in certain cases data for more than one sampling location at each study site is presented. The strategic selection of multiple sampling locations was one chosen means by which greater meaning could be interpreted from the data obtained at a given study site. This was particularly the case with respect to the water quality variables where the issue of probable cause of poor water quality was considered especially relevant in the general context of tourism and recreation at each study area. The analysis of differences between sampling locations (at a given study site) and seasonal patterns in the recorded data therefore formed the basis of the trend analysis exercise. This exercise is prescribed under the risk assessment methodology as development for this research (further details are given in Section 3.5 of the Methodology chapter). Where statistical tests were used to support the trend analysis the results and interpretations of such tests are given in tables which follow the associated data chart.

Finally, in accordance with the methodology developed for this research, the quantitative data for key variables at key sampling locations was converted into low, medium and high risk categories according to prescribed criteria. These criteria (for converting quantitative variable data) are discussed and presented by way of tables in Section 3.6 of the Methodology Chapter under the relevant subsection for each variable. The converted quantitative data is illustrated in a similar manner to that used for the qualitative variables. That is, by means of bar charts which show the frequency of occurrence of each risk category (low, medium or high) for each variable at the selected sampling locations.

### 4.4.2 Lough Derg Variables – Data and Analysis

#### *4.4.2.1 Frequency of Sampling*

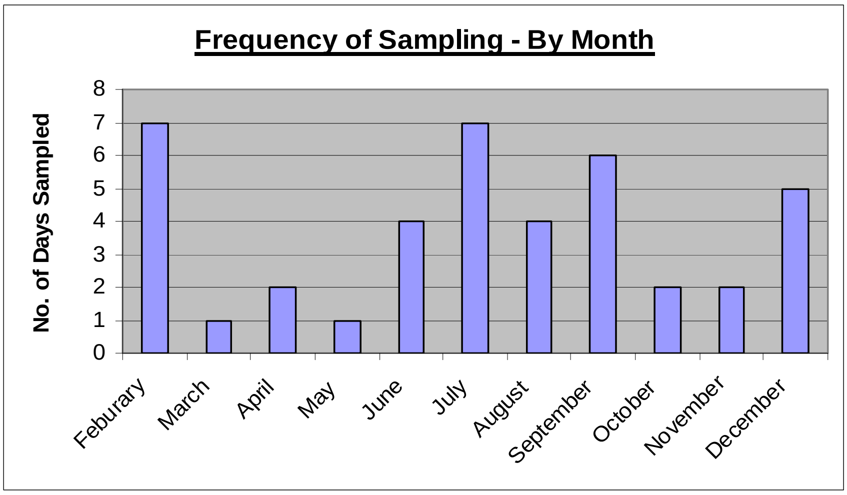



**Figure 4.30 – Frequency of Sampling Occasions by Month at the Lough Derg Study Area**

A total of 41 visits were made to the Lough Derg study sites between November 2006 and December 2007. Initial visits were made as part of the pilot study (to identify variables and prove the methodology) during the months of December 2006 and February 2007. This explains the relatively high number of visits made during these months. Apart from the pilot study, the principal focus was on the high (tourist) season and hence site visits were more frequent during the months June to September. Another factor which influenced the frequency of visits during each month included the occurrence of periods of poor weather and/or heavy rainfall. Such poor weather can influence detrimentally results or the ability to sample particularly with regard to water analysis and noise monitoring. Opportunities to sample were particularly limited during the months of June and August, 2007, due to bad weather.

### 4.4.2.2 Recorded Weather Conditions

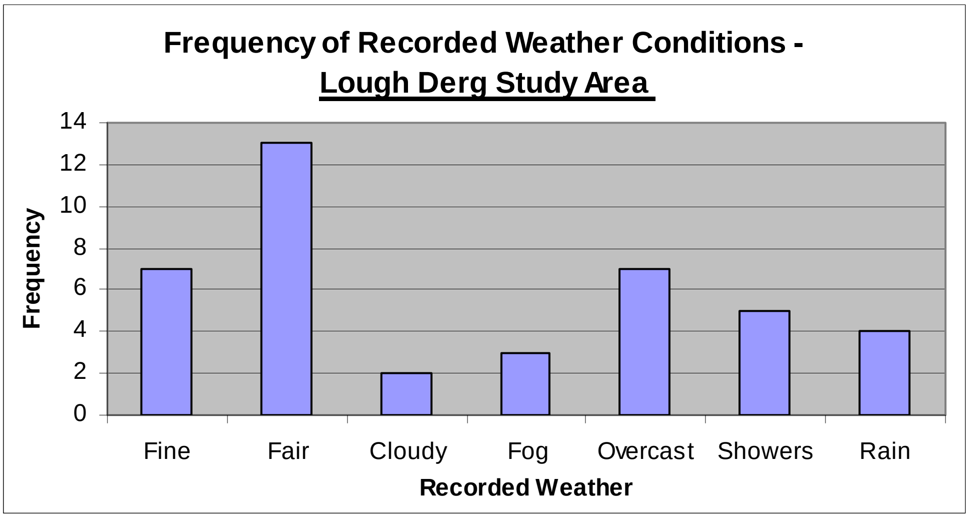



**Figure 4.31 – Frequency of Weather Conditions Recorded at the Lough Derg Study Area**

### 4.4.2.3 Water Temperature

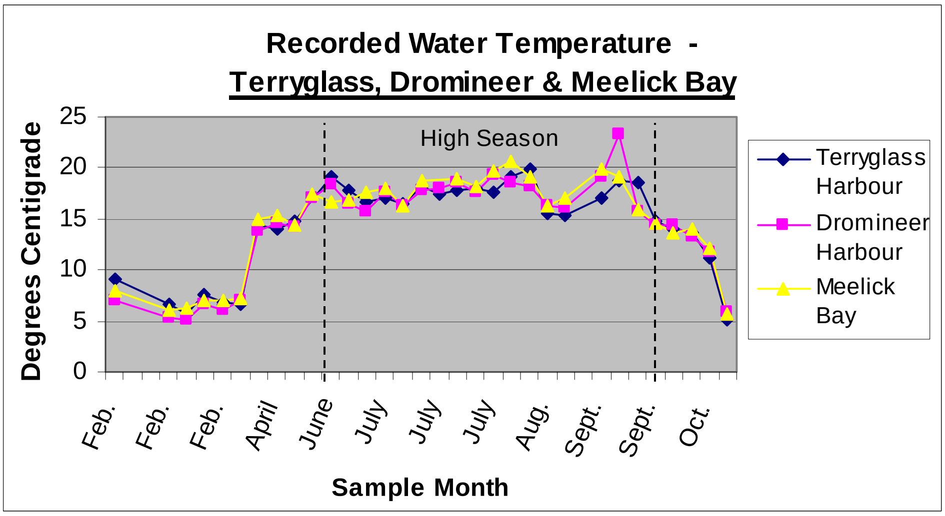



**Figure 4.32 – Chart Showing Results for Water Temperature at the Lough Derg Study Sites**

<u>*Comment:*</u>

Results for water temperature were in line with expectation with winter temperatures contrasting significantly with those recorded during the summer months. The general trend in water temperature was for the most part followed by all three sites.

### *4.4.2.4 Dissolved Oxygen*

*Raw Data Charts and Statistical Analysis:*

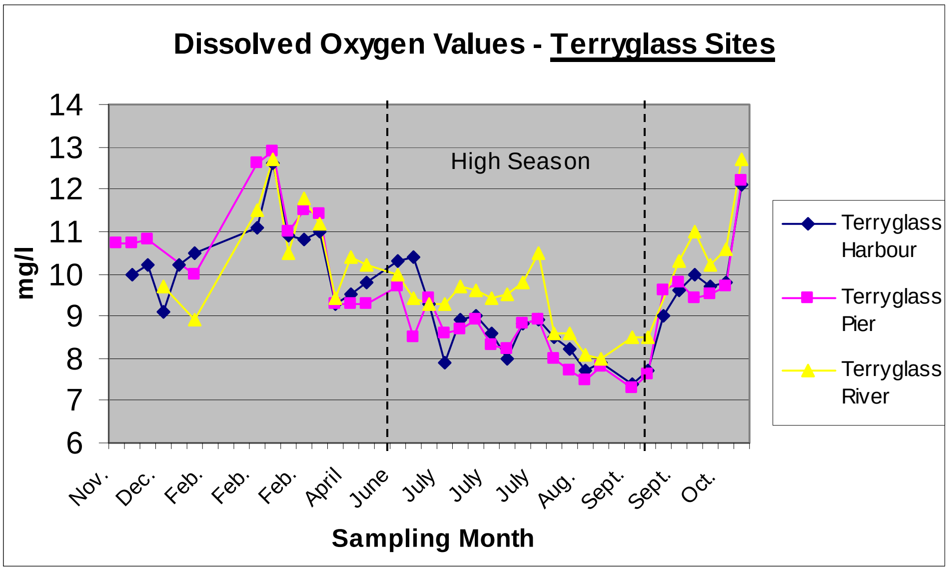



**Figure 4.33 –Dissolved Oxygen Data Recorded at three Sampling Sites at Terryglass Harbour Amenity Area**

**Table 4.1 – Statistical Analysis of Dissolved Oxygen Data at Terryglass Sampling Sites**

| Statistical Analysis (T Tests) | | | | |
|---|---|---|---|---|
| **Relationship Examined** | **Between which data sets?** | **P Value =** | **Result** | **Interpretation** |
| Significant difference | Year round data for Terryglass Harbour & Terryglass Pier | 0.42 | Difference not significant | Suggests Terryglass River does not influence DO levels in the Harbour |

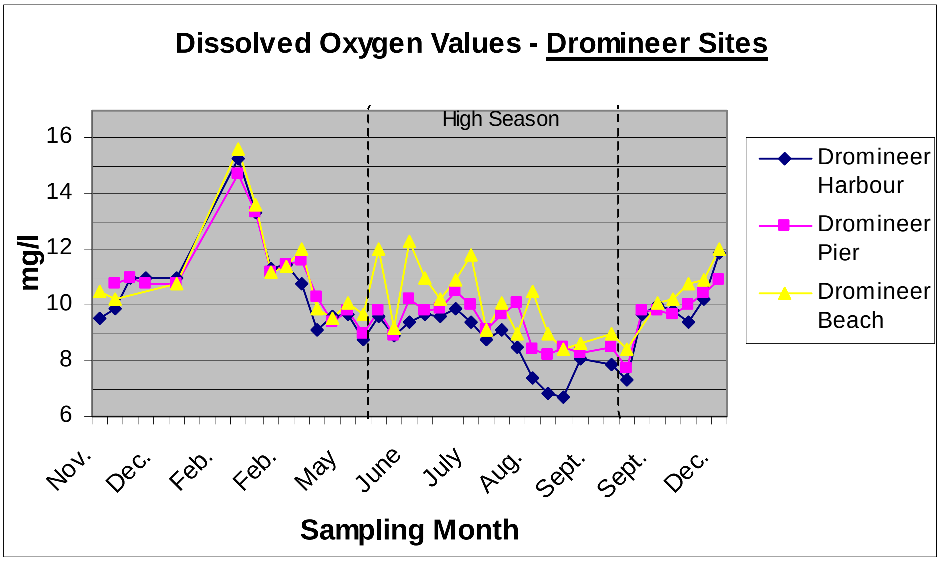



**Figure 4.34 –Dissolved Oxygen Data Recorded for Three Sampling Sites at Dromineer Harbour Amenity Area**

**Table 4.2 – Statistical Analysis of Dissolved Oxygen Data at Dromineer**

| Statistical Analysis (T Tests) | | | | |
|---|---|---|---|---|
| **Relationship Examined** | **Between Data Sets?** | **P value =** | **Result** | **Interpretation** |
| Significant difference | High season data for Dromineer Harbour & Dromineer Pier | 0.06 | Difference is not significant | No significant difference between data inside and outside of harbour; suggests pleasure craft are not affecting water quality. |
| Significant difference | Low and high season data for Dromineer Harbour and Dromineer Beach | HS P=0.41<br><br>LS P=0.0018 | Difference not significant<br><br>Difference significant | Indicates lower DO levels occurring in the harbour during the high season. Suggests pleasure craft may be affecting harbour water quality. |

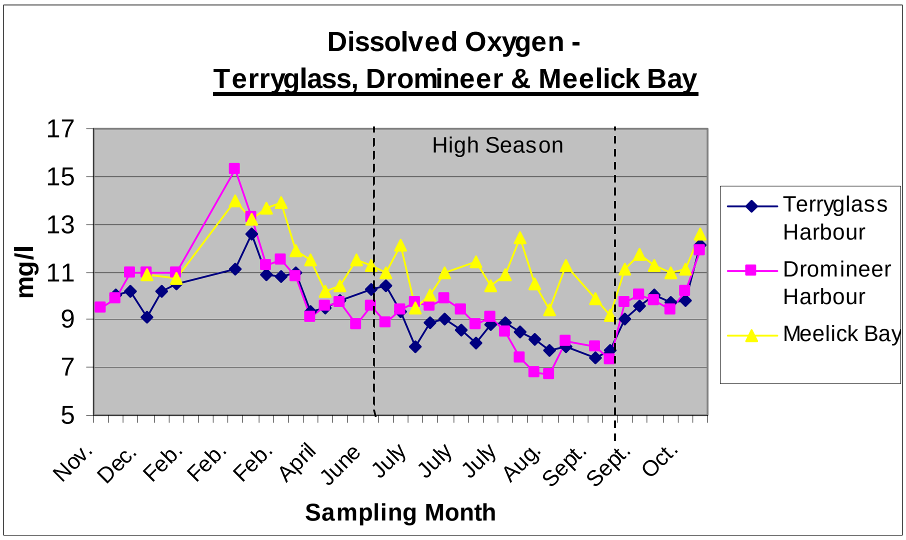



**Figure 4.35 –Dissolved Oxygen Data (mg/l) for the Three Lough Derg Study Sites**

**Table 4.3 - Statistical Analysis of Dissolved Oxygen Data from Lough Derg Study Sites**

| **Statistical Analysis (T Tests)** | | | | |
|---|---|---|---|---|
| **Relationship Examined** | **Between which data sets?** | **P = Value** | **Result** | **Interpretation** |
| Significant difference | High season data sets for Terryglass Harbour and Meelick Bay | P = $2.52 \times 10^{-7}$ | Difference is significant | Higher water quality at Meelick Bay during high season. |
| Significant difference | Low season data sets for Terryglass Harbour and Meelick Bay | P = $3.89 \times 10^{-4}$ | Difference is significant | Higher water quality at Meelick Bay also during the low season. |

*Data Converted to Risk Categories - Example Frequency Charts:*

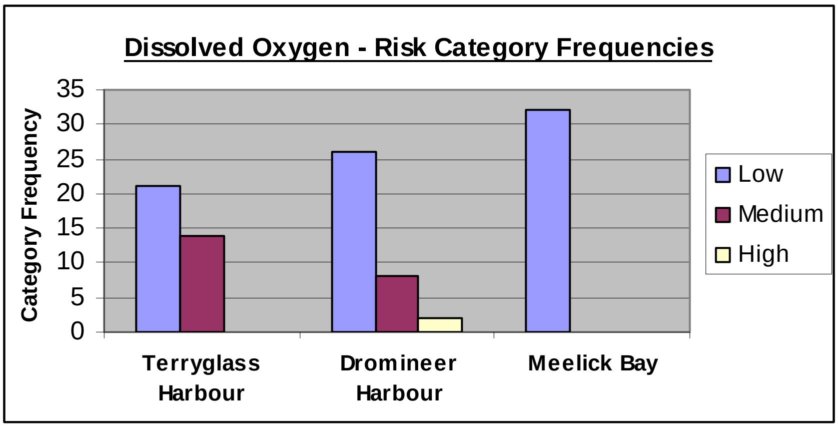



**Figure 4.36 – Dissolved Oxygen, Frequency of Assigned Risk Category for Lough Derg Study Sites**

*Interpretation and Analysis:*

Data for the Terryglass sites is largely as expected with dissolved oxygen values dropping off in the summer months as water temperature rises. The absence of a significant difference between the Terryglass Harbour and Pier values during the high season suggests that boating activity has no particular influence on the DO concentrations at Terryglass. That said, the late summer DO values for the pier and harbour are quite low and are a cause for concern. These values contrast with those returned for Meelick Bay (see Figure 4.35 and associated comment) which would indicate that some aspect of human activity is the likely cause for these low values.

The higher values for Terryglass River (this stream flows into Terryglass Harbour), particularly during the summer months, are most likely due to aeration occurring in the river as the flow runs over riffle areas and small falls. The apparent correlation between the Terryglass River values and those for Terryglass Pier and Harbour could suggest that the river water quality has an influence on the water quality in the harbour. However, the similarity between the harbour and pier data would suggest otherwise as one would expect a significant difference (not found) between these DO values if the river was influencing the DO levels in the harbour area (the presumption being that dilution would iron out any influence from the river on the Pier values).

The statistical evidence regarding the affect of boating activity on water quality in Dromineer Harbour is somewhat conflicting (see data analysis above). The lack of a significant difference between the harbour and pier data indicates that water quality in the harbour is similar to that outside which suggests that boating activity (which is concentrated in the harbour) is not affecting water quality. However, the very significant difference between the beach and harbour values during the high season indicates that poor water quality may indeed be a particular feature in the harbour, possibly due to the high levels of boating activity occurring there. Whichever way, the low DO values (< 8mg/l) recorded in Dromineer Harbour during August are a cause for concern and further suggests that poor water quality is associated with boating as boating activity was particularly high at the time. A second feature of significance is the much closer correlation between all three sites during the low season. This again suggests that recreational activity of some form during the high season may be causing the discrepancies in values between the three sites at this time.

Summer values for Dissolved Oxygen at Meelick Bay are visibly and (statistically) significantly higher than those for Terryglass Harbours. This indicates higher water quality at Meelick Bay. This would be expected due to the more isolated location of Meelick Bay and the non-proximity of Meelick to inflowing rivers which is a known source of anthropogenic pollution (largely from the agricultural sector and/or domestic waste water discharge). Although the difference between Meelick Bay and Terryglass/Dromineer is lower during the low season (suggesting that boating activity may be causing the higher difference during the high season), this difference is nevertheless not statistically significant. It is therefore not possible to draw any conclusions regarding possible associations between high season boating activity and the lower DO levels recorded at this time.

Regarding the assigned risk category charts, these illustrate a tendency to higher risk categories during the high season at both Terryglass and Dromineer harbours. Meelick Bay on the other hand returned low risk categories exclusively during both the high and low seasons. This highlights unsatisfactory conditions with respect to dissolved oxygen levels at Terryglass and Dromineer during the high season.

### 4.4.2.5 Dissolved Oxygen – Percentage Saturation.

Raw Data Charts and Statistical Analysis:

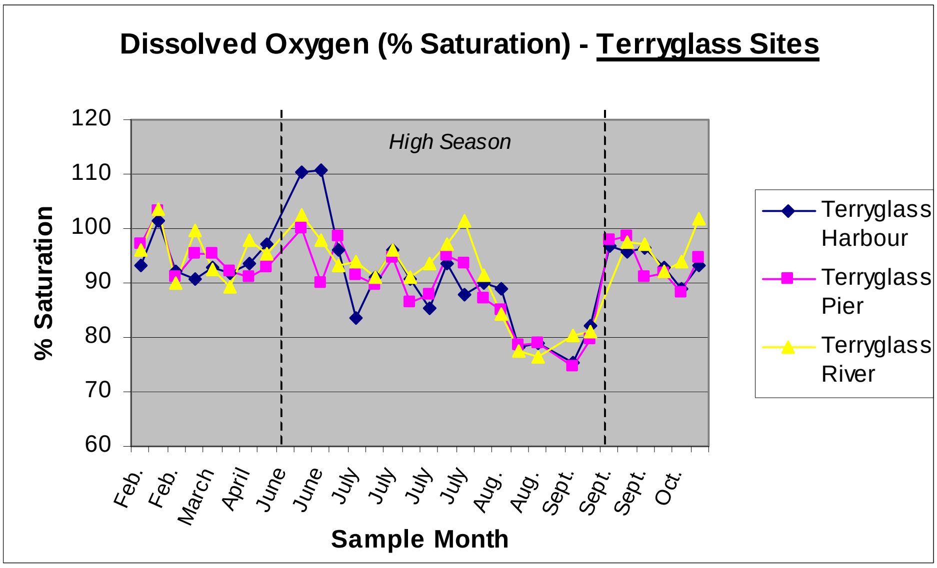



**Figure 4.37 – Dissolved Oxygen (% Saturation) Data for Terryglass Sampling Sites**

**Table 4.4 – Statistical Analysis of Dissolved Oxygen (% Saturation) Data for Terryglass Sampling Sites**

| Statistical Analysis (T Tests) | | | | |
|---|---|---|---|---|
| **Relationship Examined** | **Between Which Data Sets?** | **P Value** | **Result** | **Interpretation** |
| Significant difference | High season data for Terryglass Pier & Terryglass Harbour | = 0.59 | Difference is not significant | No significant difference for % sat (DO) levels between TG harbour & pier (during either the HS or LS) suggests no effect by boating on water quality |
| Significant difference | Low season data for Terryglass Pier & Terryglass Harbour | = 0.84 | Difference is not significant | |

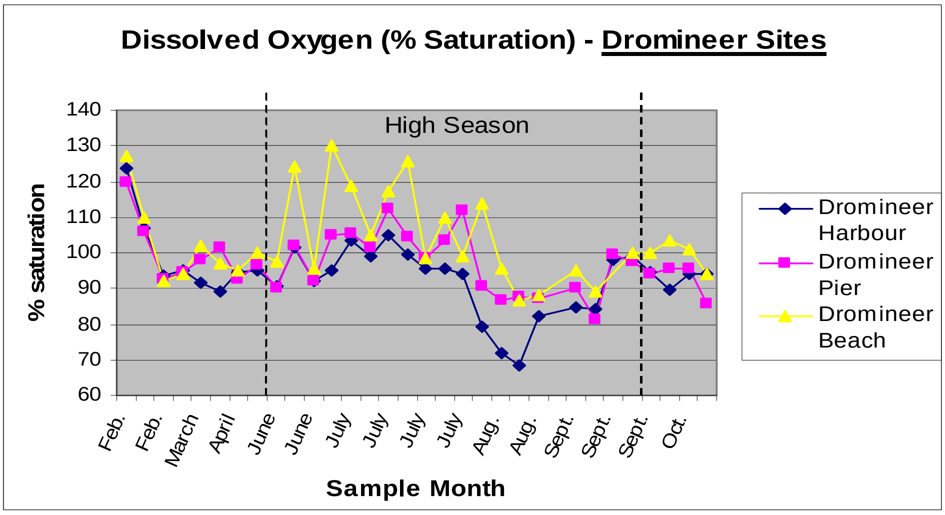



**Figure 4.38 - Dissolved Oxygen (% Saturation) Data for Terryglass Sampling Sites**

**Table 4.5 – Statistical Analysis of Dissolved Oxygen (% Saturation) Data for Dromineer Sampling Sites**

| **Statistical Analysis (T Tests)** | | | | |
|---|---|---|---|---|
| **Relationship Examined** | **Between Data Sets?** | **P Value** | **Result** | **Interpretation** |
| Significant difference | High Season data for Dromineer Harbour & Dromineer Pier | 0.076 | Difference is not significant | No significant difference between data inside and outside of harbour; suggests pleasure craft are not affecting water quality. |
| Significant difference | High Season Data for Dromineer Harbour & Dromineer Beach | 0.0018 | Difference is significant | Suggests better water quality at the beach area. Possible influence of mixing. |

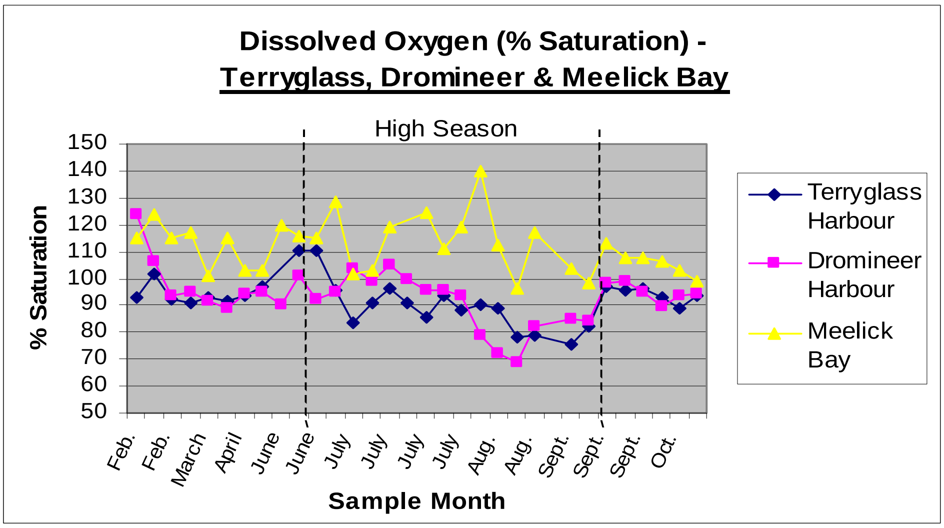



**Figure 4.39 - Dissolved Oxygen (% Saturation) Data for Key Lough Derg Sampling Sites**

**Table 4.6 - Statistical Analysis of Dissolved Oxygen (% Saturation) Data for Key Lough Derg Sampling Sites**

| Statistical Analysis (T – Tests) | | | | |
|---|---|---|---|---|
| **Relationship Examined** | **Between which Data Sets?** | **P Value =** | **Result** | **Interpretation** |
| Significant difference | High season data for Meelick Bay and Dromineer Harbour | $1.36 \times 10^{-6}$ | Difference **is** significant | Confirms lower water quality at Dromineer |
| Significant difference | High season data for Meelick Bay and Terryglass Harbour | $7.43 \times 10^{-7}$ | Difference **is** significant | Confirms lower water quality also at Terryglass |
| Significant Difference | High and low season data for Dromineer Harbour | 0.078 | Difference is not significant | Suggests boating activity is not affecting water quality at Dromineer |
| Significant Difference | High and low season data for Terryglass Harbour | 0.14 | Difference is not significant | Suggests boating activity is not affecting water quality at Terryglass |

*Risk Category Criteria and Example Frequency Charts:*

Data for Terryglass Harbour, Dromineer Harbour and Meelick Bay has been grouped into low, medium and high risk categories according to the criteria given in Section 3.6 (see Methodology Chapter). A detailed explanation of the source and relevance of the criteria is also given in Section 3.6. The frequency of each recorded category for both high and low seasons are given in the chart below:

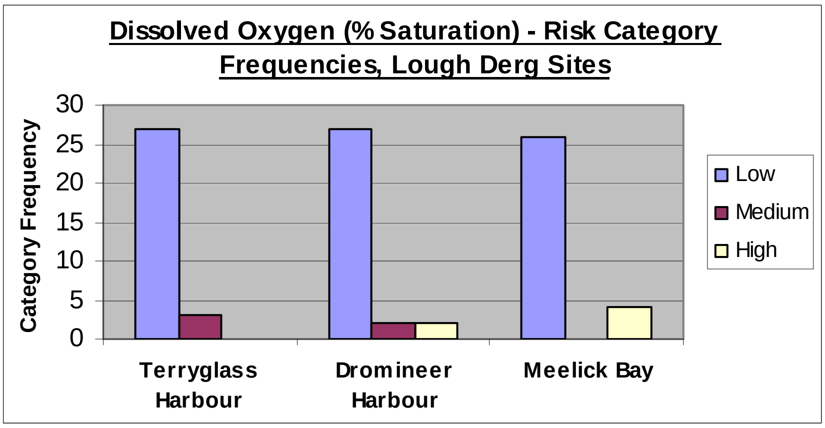



**Figure 4.40 - % Saturation of Dissolved Oxygen, Frequency of Assigned Risk Category for Key Lough Derg Sampling Sites**

<u>*Interpretation and Analysis:*</u>

No significant trends can be identified from the data set for Terryglass presented in the chart above. However, close correlation between the values for Terryglass River and the those for Terryglass Harbour and Pier would suggest that either the river water quality is strongly influencing the water in adjoining harbour and bay or that all variations observed are due to external weather factors such as rainfall or temperature. Values falling below 80% during the late summer are a cause for concern

The recorded values for Dromineer harbour are consistently lower during the high season. However, the difference between the harbour values and those recorded on the lakeside of the pier are not statistically significant. The greater (and statistically significantly) difference between values recorded at Dromineer Beach and Dromineer harbour during the high season maybe due to the greater distance of the beach area from the harbour (suggesting that boats moored in the harbour are in fact contributing to lower water quality) or simply due to greater potential for aeration of the water column at the beach area due to this area being more exposed to wave action

The data chart for Meelick Bay and associated statistical analysis clearly highlights the higher water quality occurring at this location during both the high and low seasons. However, the absence of any significant difference between percentage saturation (DO) values recorded at Terryglass and Dromineer during the high and low seasons strongly suggests that boating activity has no significant affect on water quality with respect to this particular variable or parameter. With this in mind it is likely that the higher values recorded at Meelick Bay are due primarily to the location of this area, away from possible human influence, particularly inflowing rivers. Both Terryglass and Dromineer are situated close to the entry points of rivers.

The risk category charts for percentage saturation of dissolved oxygen present a more favourable picture for Terryglass and Dromineer than that presented by the risk category charts for dissolved oxygen. This demonstrates the more robust nature of the percentage saturation variable as it accounts for natural drops in dissolved oxygen due to warmer water temperatures (see ‘Background Information’ discussion earlier in the Methodology Section). Nevertheless, the occurrence of medium and high risk categories, particularly at Dromineer, are a cause for concern. Judging by the yearly trends, the high risk categories recorded for Meelick Bay are likely to be due to natural processes causing super-saturation of the water column with respect to dissolved oxygen.

### *4.4.2.6 Ortho-Phosphates*

*Raw Data Charts and Statistical Analysis:*

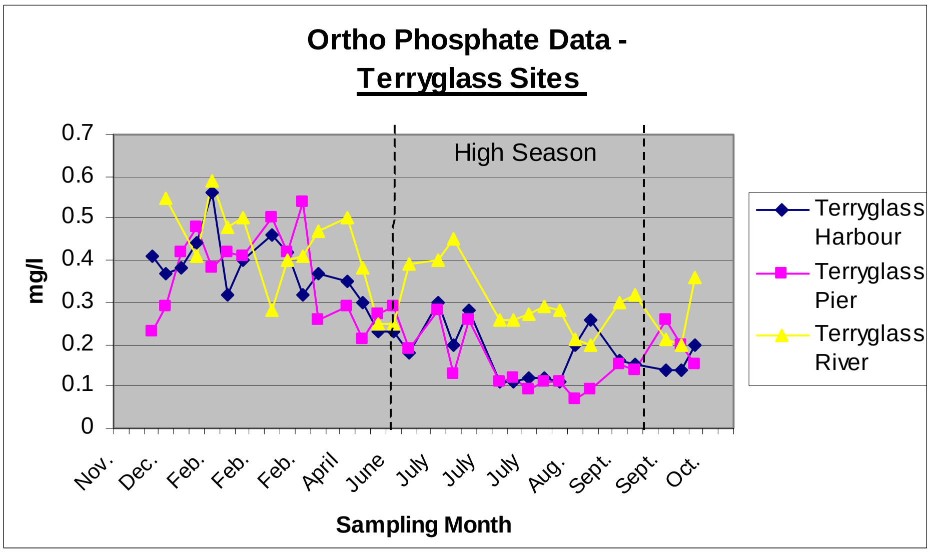



**Figure 4.41 – Ortho-Phosphate Data for Key Sampling Sites at Terryglass Amenity Area**

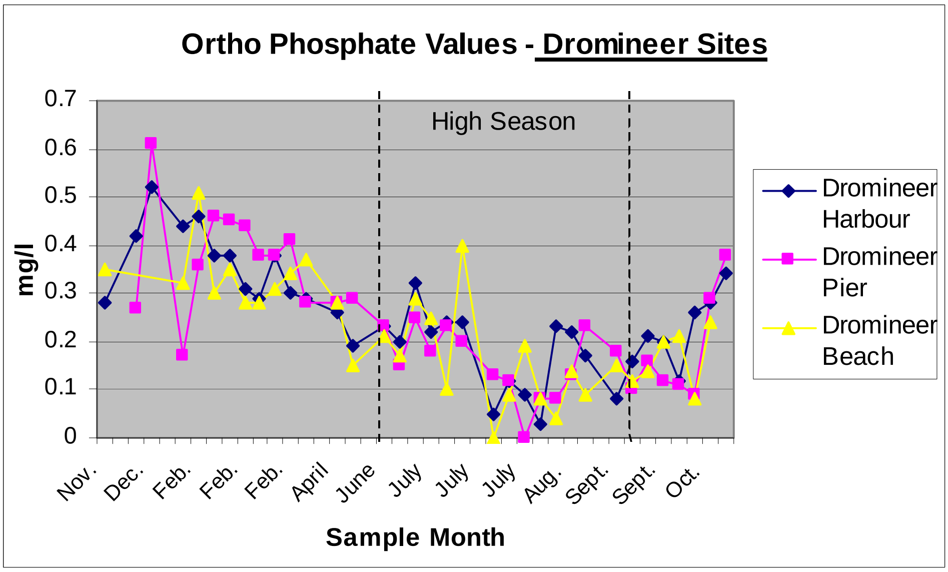



**Figure 4.42 - Ortho-Phosphate Data for Key Sampling Sites at Dromineer Amenity Area**

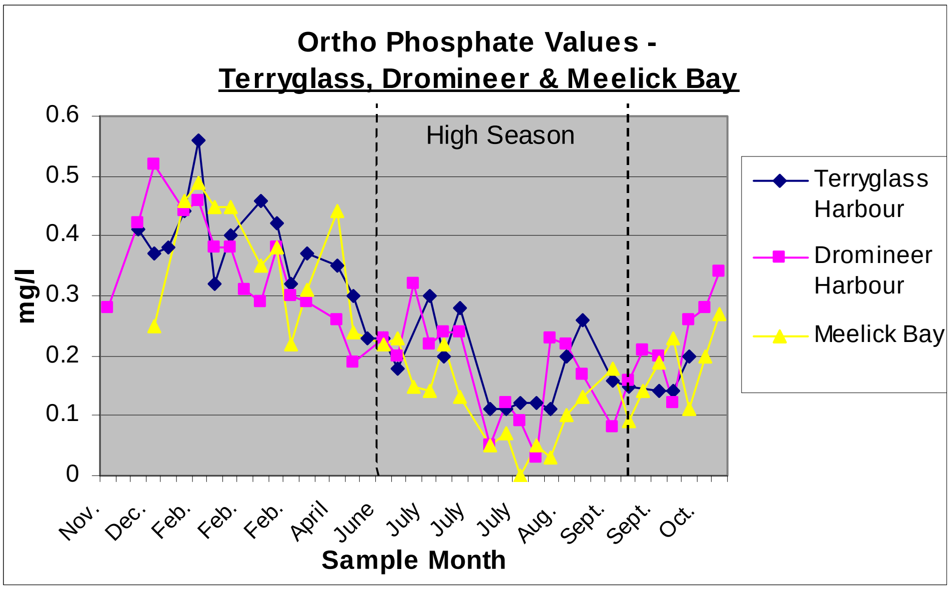



**Figure 4.43 – Ortho-Phosphate Data for Key Locations at Lough Derg**

**Table 4.7 – Statistical Analysis of Ortho-Phosphate Data for Key Locations at Lough Derg**

| **Statistical Analysis (T Tests)** | | | | |
|---|---|---|---|---|
| **Relationship Examined** | **Between Data Sets?** | **P Value** | **Result** | **Interpretation** |
| Significant difference | High Season Data for Meelick Bay & Dromineer Harbour | = 0.067 | Difference is not significant | Similar phosphate levels at Meelick and Dromineer |
| Significant difference | High Season Data for Meelick Bay and Terryglass Harbour | = 0.015 | Difference is significant | Higher Phosphate levels at Terryglass suggesting poorer water quality |

*Example Risk Category Frequency Charts:*

Ortho-Phosphate data for Terryglass Harbour, Dromineer Harbour, Dromineer Beach and Meelick Bay have been grouped into low, medium and high risk categories according to the criteria given in Section 3.6 (Methodology Chapter). The frequency of each recorded category for both high and low seasons are given in the charts below:

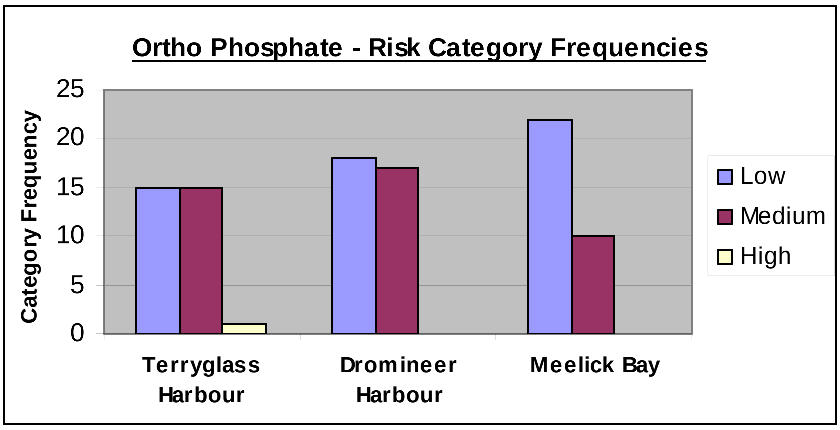



**Figure 4.44 – Ortho-Phosphates, Frequency of Assigned Risk Category for Key Lough Derg Sampling Sites**

*Analysis and Interpretation:*

The raw data charts for ortho-phosphates show no real trends or points of significance with respect to the high and low tourism seasons or to recreational activity in general. The downward and upward trends in values for all sample sites can be explained by the natural tendency for phosphorus to accumulate in lake waters during the winter months, when plant growth is greatly reduced, and to gradually deplete as phosphorus is absorbed by various plant life during the spring and summer growing season (Bowman & Toner, 2001; Clenaghan, 2003). In line with various studies carried out by the EPA (Bowman, 1996, 2000; Bowman & Toner, 2001; Neill, 2005), it is likely that the principal source of phosphorus in the lake water is from agricultural runoff and domestic wastewater entering the lake via inflowing rivers. This association is back up by the findings of this research which show consistently higher ortho-phosphate values occurring in the Terryglass River. The absence of a significant difference (see data analysis table) between Meelick Bay and Dromineer Harbour indicates that phosphorus levels are not being influenced by tourism at Dromineer. On the other hand, the presence of a significant (though relatively slight) difference between Meelick Bay and

Terryglass Harbour (Terryglass values being higher) is probably explained by the presence of the Terryglass river flowing directly into Terryglass Harbour.

In general, phosphate levels are relatively good (low) at all three study areas during the summer season and are not a real cause for concern. However, during the winter months the levels are significantly higher. These levels are a cause for concern (see assigned risk categories below) but it is very likely that they reflect the general issues regarding water quality and trophic status of Lough Derg as a whole (see background information given for this variable in the Methodology Chapter, Section 3.6.3).

Unlike the basic data charts, the risk category frequency charts above serve to highlight the problems associated with ortho-phosphate levels in the lake. In this respect, the charts show a predominance of low and medium risk categories occurring at Terryglass and Dromineer harbours. Also of interest is the occurrence of medium and high risk categories at Meelick bay. This is largely contrary to expectation as it indicates lower water quality occurring at Meelick than at Dromineer and Terryglass with respect to this particular parameter.

### *4.4.2.7 Faecal Coliforms*

*Raw Data Charts and Statistical Analysis:*

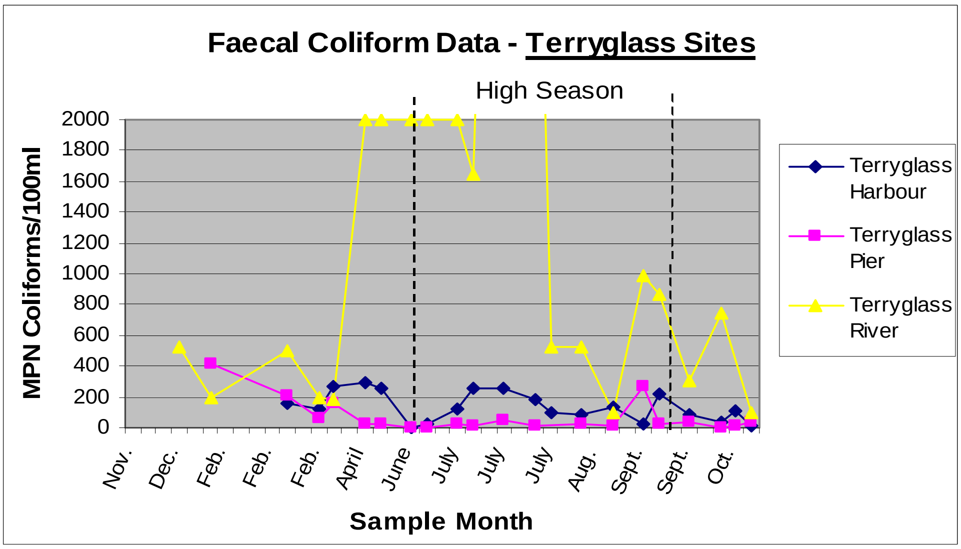



**Figure 4.45 – Faecal Coliform Data for Key Sampling Sites at Terryglass Amenity Area**

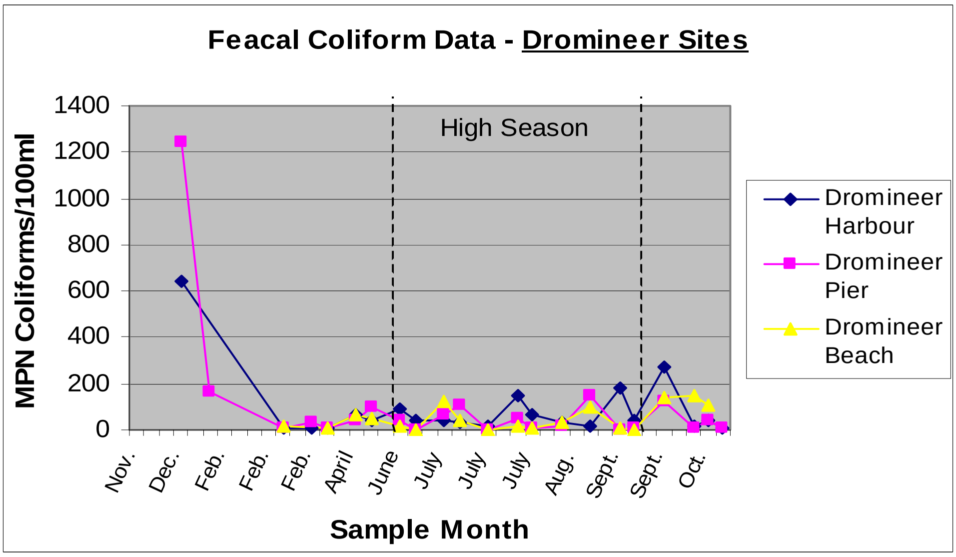



**Figure 4.46 – Faecal Coliform Data for Key Sampling Sites at Dromineer Amenity Area**

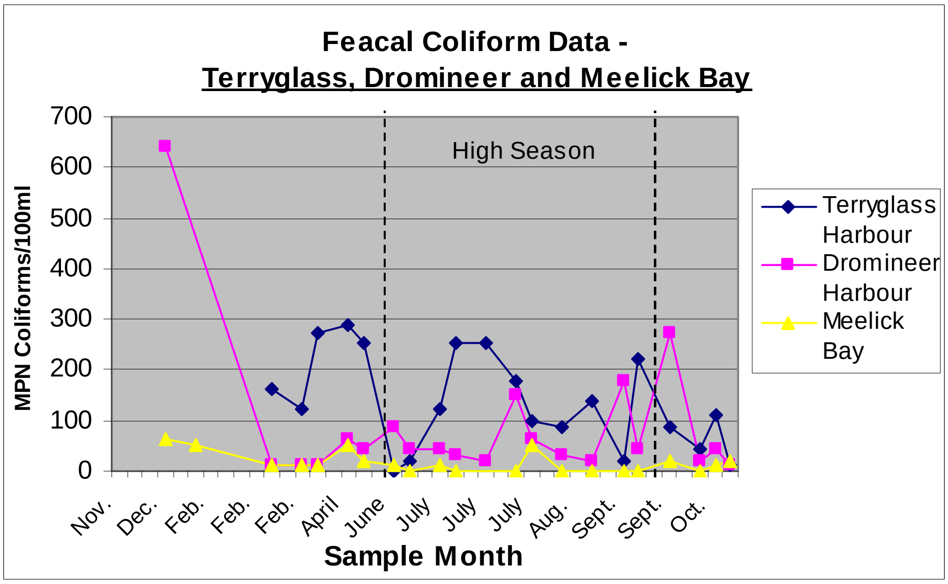



**Figure 4.47 - Faecal Coliform Data for Key Locations at Lough Derg**

**Table 4.8 - Statistical Analysis of Faecal Coliform Data for Key Locations at Lough Derg**

| Statistical Analysis (T Tests) | | | | |
|---|---|---|---|---|
| **Relationship Examined** | **Between Data Sets?** | **P Value =** | **Results** | **Interpretation** |
| Significant difference | All year data for Terryglass Harbour and Meelick Bay | $1.58 \times 10^{-5}$ | Difference is significant | Indicates higher water quality at Meelick Bay |
| Significant difference | All year data for Dromineer Harbour and Meelick Bay | 0.035 | Difference is significant | Indicates higher water quality at Meelick Bay |

*Example Risk Category Frequency Charts:*

Faecal Coliform data for Terryglass Harbour, Dromineer Harbour, Dromineer Beach and Meelick Bay has been grouped into low, medium and high risk categories according to the criteria given in Section 3.6 (of the Methodology Chapter). The frequency of each recorded category for both high and low seasons are given in the charts below:

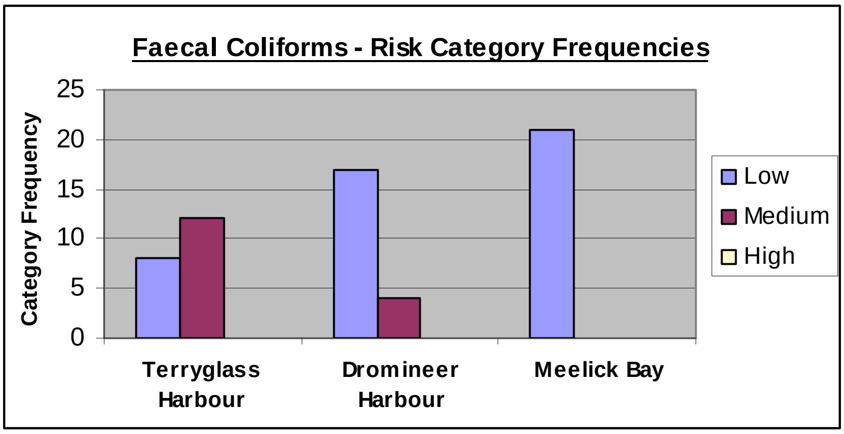



**Figure 4.48 – Faecal Coliforms, Frequency of Assigned Risk Categories for Key Lough Derg Sampling Sites**

*Analysis and Interpretation:*

The most significant feature of the above data charts is the very high faecal coliform levels recorded in the Terryglass River during both the high and low seasons. Unpolluted water would be expected to have Faecal Coliform levels below 100/100mls) (EPA, 2001). The levels recorded at the other sampling sites are more respectable. However, the levels recorded in Terryglass and Dromineer harbours nevertheless indicate intermittent faecal pollution occurring throughout the year, particularly in Terryglass Harbour. This is in contrast to the levels recorded at Meelick Bay which were consistently below 100 Coliforms/100mls. In addition, the difference between the Meelick Bay data set and that for both Dromineer and Terryglass harbours was deemed to be statistically significant (see Table 4.8).

Given the very high faecal coliform levels occurring in the Terryglass River, it is not surprising that Terryglass Harbour is subject to similar though less severe faecal contamination. A significant interpretation of this data is that faecal contamination occurring in Terryglass harbour, though nevertheless a cause for concern, is most likely emanating from the inflowing Terryglass River and not, therefore, from moored cruiser boats. The lower levels which were recorded in Dromineer (which caters for similar, if not, higher numbers of cruiser boats) backs up this assertion. With specific regard to the Terryglass river, it is quite possible that the faecal contamination is originating from agricultural activity (land spreading of slurry or poor storage of animal wastes for example) but the possibility that contamination is also arising from Terryglass village (where a number of holiday cottage complexes are located) can not be ruled out. During the period of sampling at Terryglass, works were ongoing to install a small scale sewage treatment works for the village as the existing system was reported to be unsatisfactory (North Tipperary County Council, 2004).

Statistical analysis of the data confirms that water quality, with respect to faecal contamination, is significantly higher at Meelick Bay than at either Terryglass or Dromineer. This likely reflects the more remote location of Meelick Bay away from any inflowing rivers which, as discussed, are a potential source of faecal contamination from agricultural activity in particular.

Although the faecal coliform levels recorded at Terryglass and Dromineer are not particularly high (they are largely consigned to low and medium risk categories) and are unlikely to be attributable to recreation activity, these finding nevertheless indicate a cause for concern. This is largely because of the nature of any faecal contamination which can be associated with possible pathogenic (disease causing) bacteria occurring in the water. This presents a substantial risk to recreational users of these waters.

Medium risk categories occur at both Terryglass and Dromineer Harbours and at Dromineer Beach indicating unsatisfactory conditions at these locations with respect to this parameter. Terryglass Harbour shows a predominance of medium risk categories which most likely reflects the probable influence of the highly contaminated Terryglass River on this location Meelick shows no risk with respect to faecal coliforms indicating little or no faecal contamination. Although it is likely that the medium risk categories occurring at Dromineer and Terryglass harbours are not attributable to the tourism industry itself, these finding nevertheless indicate a serious cause for concern. This is largely because of the nature of faecal contamination and its association with possible pathogenic (disease causing) bacteria occurring in the water. This obviously presents a substantial risk to users of these waters.

### *4.4.2.8 Total Coliforms*

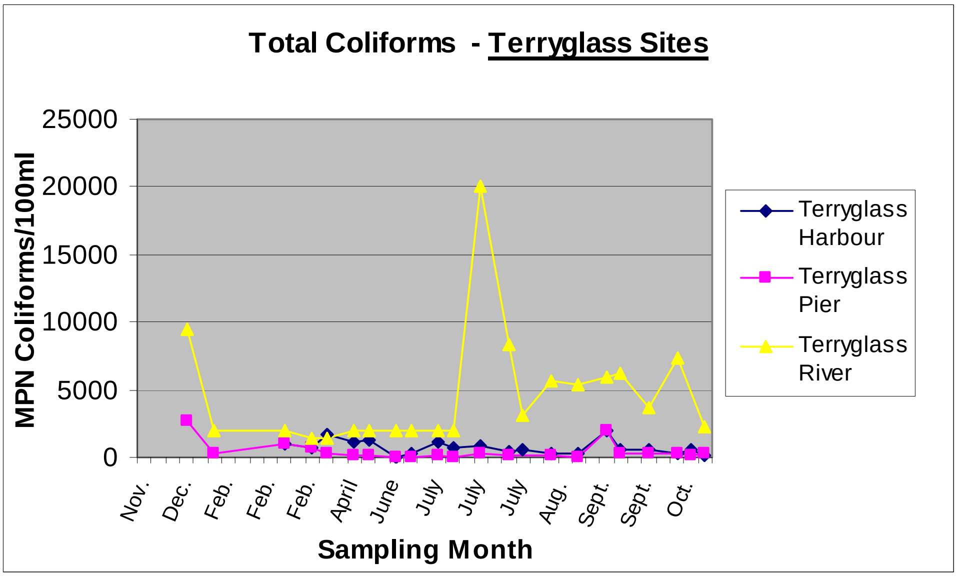



**Figure 4.49 - Total Coliform Data for Key Sampling Sites at Terryglass Amenity Area**

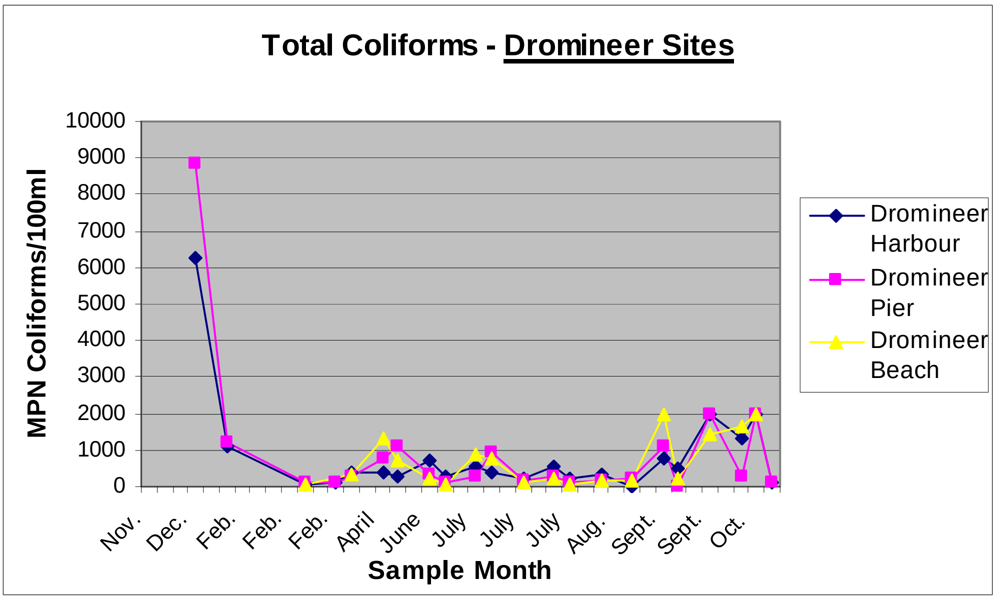



**Figure 4.50 - Faecal Coliform Data for Key Sampling Sites at Dromineer Amenity Area**

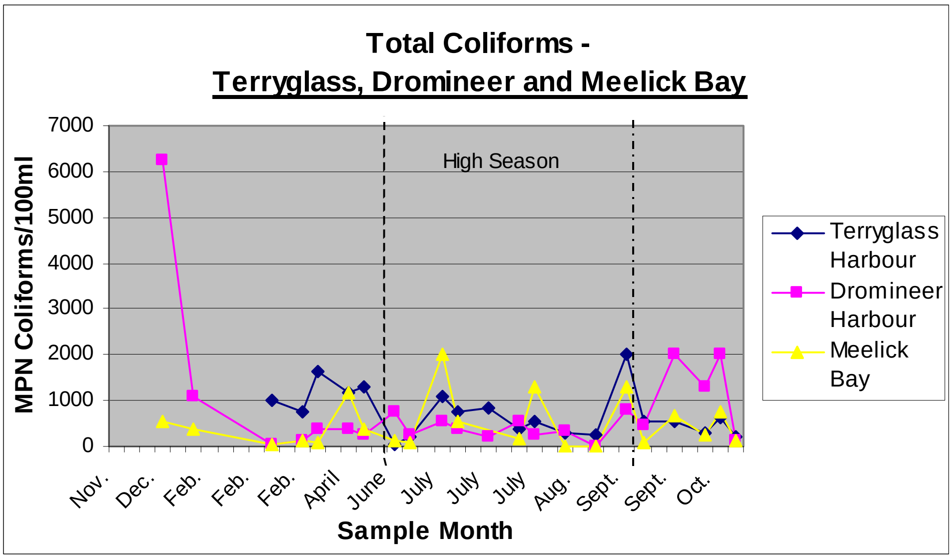



**Figure 4.51 - Faecal Coliform Data for Key Sampling Locations at Lough Derg**

**Table 4.9 - Statistical Analysis of Total Coliform Data for Key Locations at Lough Derg**

| Statistical Analysis (T Tests) | | | | |
|---|---|---|---|---|
| **Relationship Examined** | **Between Which Data Sets?** | **P Value** | **Results** | **Interpretation** |
| Significant difference | Year round data for Terryglass Harbour and Meelick Bay | = 0.151 | Difference is not significant | Indicates higher water quality at Meelick Bay than at TG Harbour |
| Significant difference | Year round data values for Dromineer Harbour and Meelick Bay | = 0.255 | Difference is not significant | Indicates higher water quality at Meelick Bay than at DR Harbour |

*Categorised Data Charts for Total Coliforms:*

Total Coliform data for Terryglass Harbour, Dromineer Harbour, Dromineer Beach and Meelick Bay was grouped into low, medium and high risk categories according to the criteria given in Section 3.6.5. The frequency of each recorded category for both high and low seasons are given in the chart below:

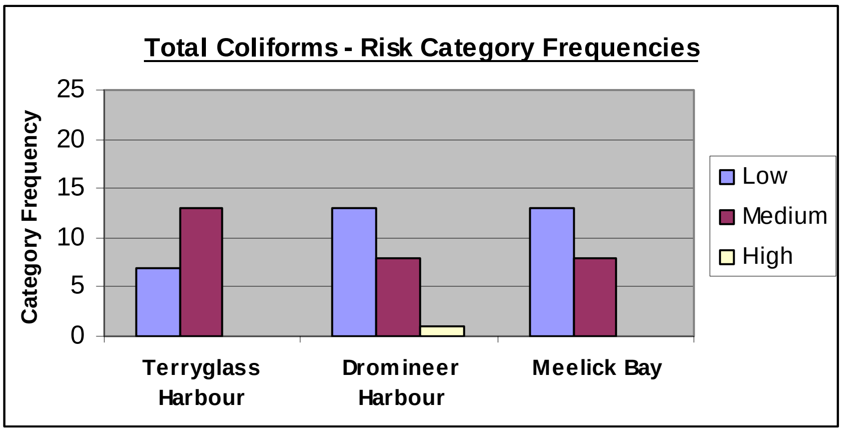



**Figure 4.52 – Total Coliforms, Frequency of Assigned Risk Category for Key Locations at Lough Derg**

*Analysis and Interpretation:*

The data recorded for 'Total Coliforms' reflects that recorded for Faecal Coliforms with intermittent microbial pollution evident at both Terryglass and Dromineer Harbours throughout the year. However, in contrast to the data for faecal coliforms, there was no significant difference between the recorded levels for Terryglass and Dromineer Harbours. Similarly, there was also no significant difference between the set of values recorded for Meelick Bay and Terryglass and Dromineer harbours (see Table 4.9). In this respect, the levels of total coliforms recorded at Meelick Bay were less satisfactory than those for faecal coliforms, with incidences of relatively high microbial contamination occurring at Meelick Bay on a number of occasions throughout the year. Given the nature of faecal and total coliform parameters it can nevertheless be assumed that the microbial contamination occurring at Meelick bay is not faecal in origin and thus not of any real significance in the context of recreational use and sustainability risk. As with faecal coliforms, a relatively high frequency of medium risk categories are recorded at both Terryglass and Dromineer for total coliforms. One high risk category was also recorded for Dromineer Harbour. Notably, and in contrast to the categorised charts for faecal coliforms, the charts here also show a number of medium risk categories occurring at Meelick Bay.

#### *4.4.2.9 Floating Oil Films*

Data for 'Floating Oil Films' is presented in the following charts. As a qualitative variable, the data was recorded and is presented in terms of the frequency of each risk category (low, medium and high) recorded on site according to the prescribed criteria (see Section 3.6.7).

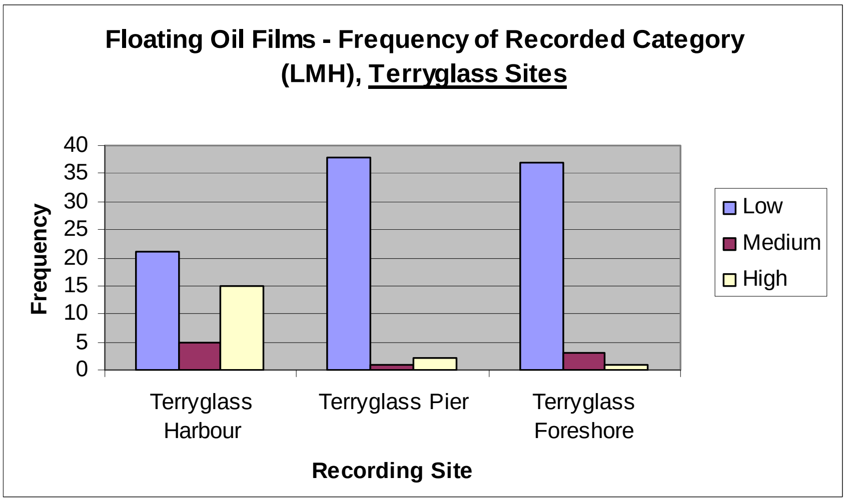



**Figure 4.53 – Floating Oil Films, Frequency of Recorded Risk Category for Key Recording Sites at Terryglass Amenity Area**

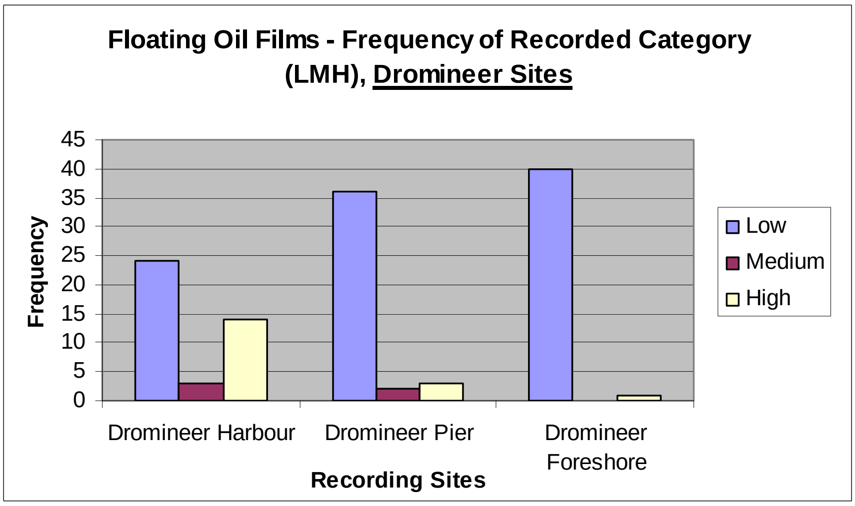



**Figure 4.54 - Floating Oil Films, Frequency of Recorded Risk Category for Key Recording Sites at Dromineer Amenity Area**

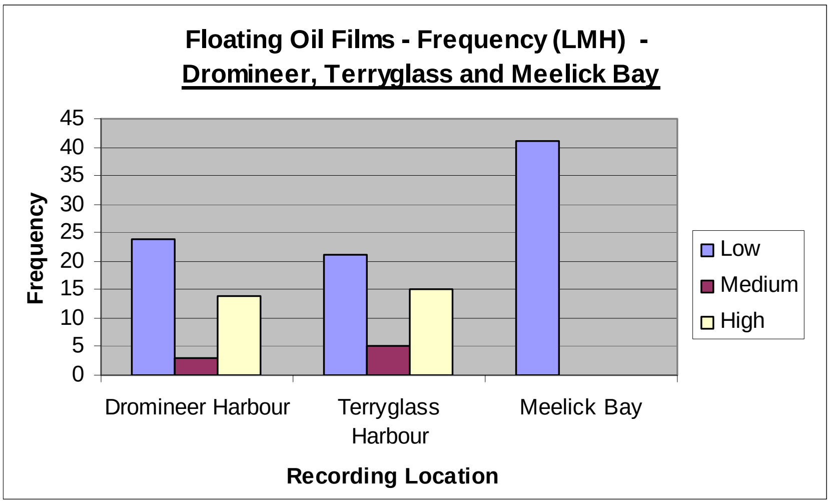



**Figure 4.55 Floating Oil Films, Frequency of Recorded Risk Category for Key Recording Sites at Lough Derg**

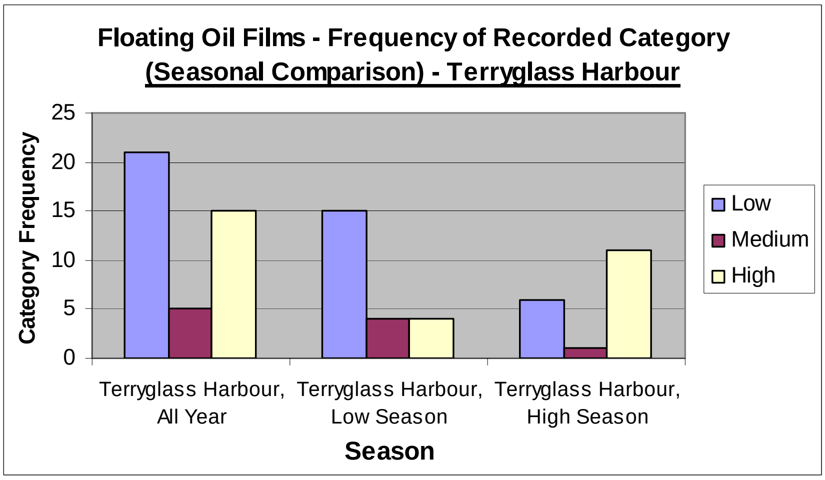



**Figure 4.56 - Floating Oil Films, Frequency of Recorded Risk Category (Low & High Season) for Terryglass Harbour**

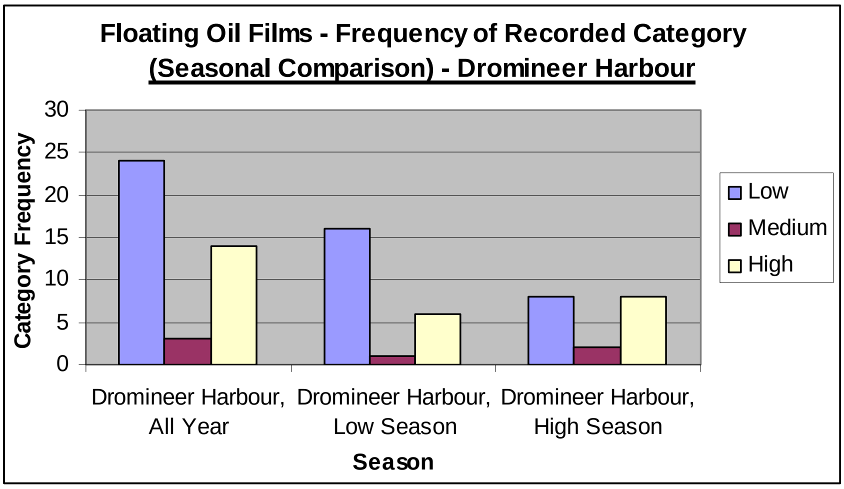



**Figure 4.57 - Floating Oil Films, Frequency of Recorded Risk Category (Low & High Season) for Dromineer Harbour**

*Analysis and Interpretation:*

A significance feature identifiable from the above charts is the fact that the recorded high risk levels of visible oil films are largely restricted to the harbour areas of both Terryglass and Dromineer. Although this may be expected due to the presence of various motorised craft within the harbours, it nevertheless confirms the localised nature of this problem. Meelick Bay in contrast shows no visible oil contamination. Regardless of origin, the levels of visible oil films recorded at Terryglass and Dromineer are considered a cause for concern due to the unsightly nature of oil pollution and its potential effects on aquatic life.

With regard to the seasonal comparison charts, it is noteworthy that although high levels of floating oil films are more prevalent at Terryglass and Dromineer during the high season, high levels do also occur during the low season. Conversely the same feature is true for recorded low levels of floating oil films. This suggests that although high levels of oil pollution is associated with greater boating activity during the high season, serious oil pollution can occur at any time of the year. Observations made during surveys showed that older boats moored and left for the winter were often associated with oil leaks and subsequent pollution. A further interesting observation from the floating oil data is the prevalence of either high or low levels, with medium levels being relatively rare. This suggests that any oil leakage, even if small, tends to generate a significant visible effect.

### *4.4.2.10 Algal Blooms*

Data for 'Algal blooms' is presented in the following charts. As a qualitative variable the data was recorded and is presented in terms of the frequency of each risk category (low, medium and high) recorded on site according to the prescribed criteria (see Section 3.6.8).

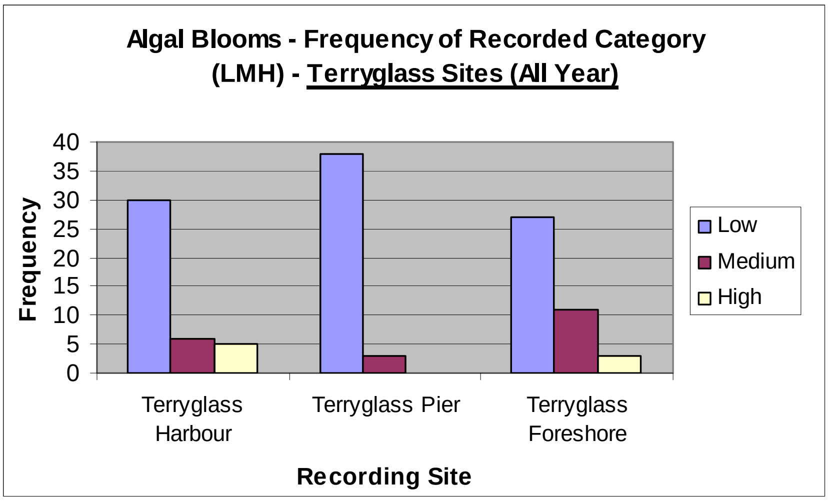



**Figure 4.58 – Algal Blooms, Frequency of Recorded Risk Category for Key Recording Sites at Terryglass Amenity Area**

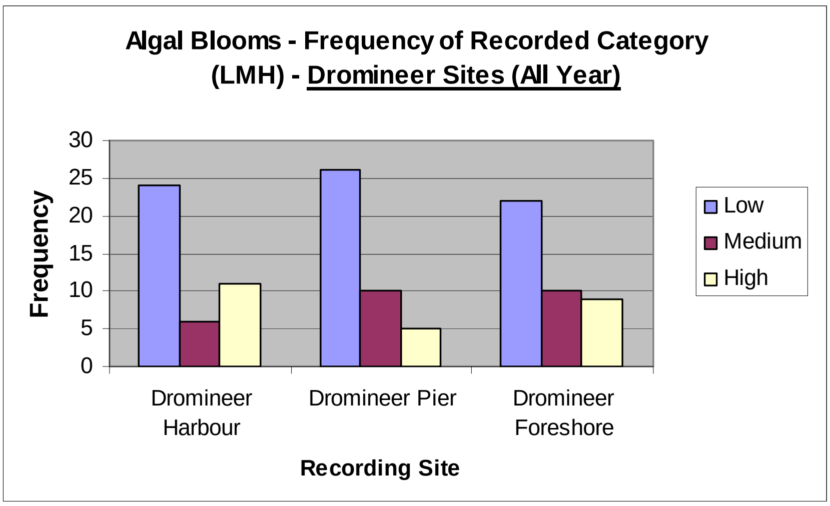



**Figure 4.59 – Algal Blooms, Frequency of Recorded Risk Category for Key Recording Sites at Dromineer Amenity Area**

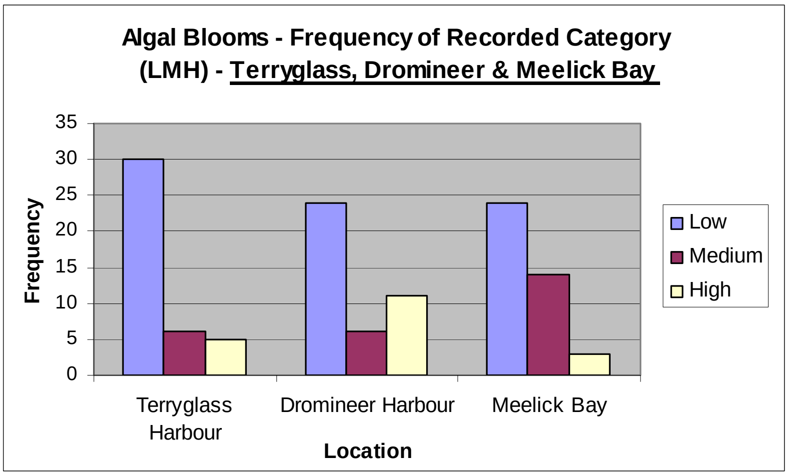



**Figure 4.60 – Algal Blooms, Frequency of Recorded Risk Category for Key Lough Derg Recording Sites**

*Data Charts with Seasonal Comparison:*

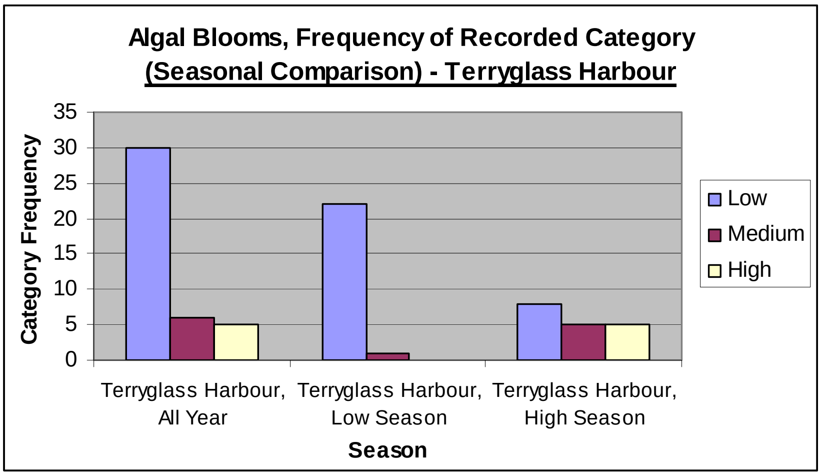



**Figure 4.61 – Algal Blooms Frequency of Recorded Risk Category (Low & High Season) for Terryglass Harbour**

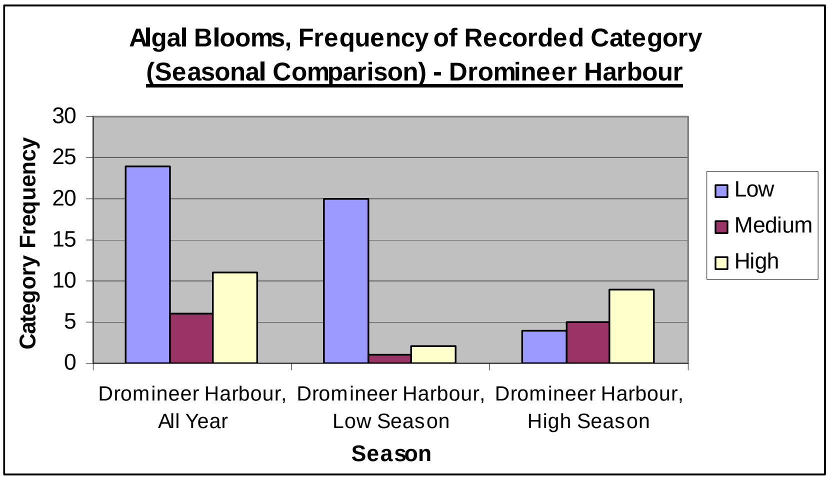



**Figure 4.62 - Frequency of Recorded Risk Category (Low & High Season) for Dromineer Harbour**

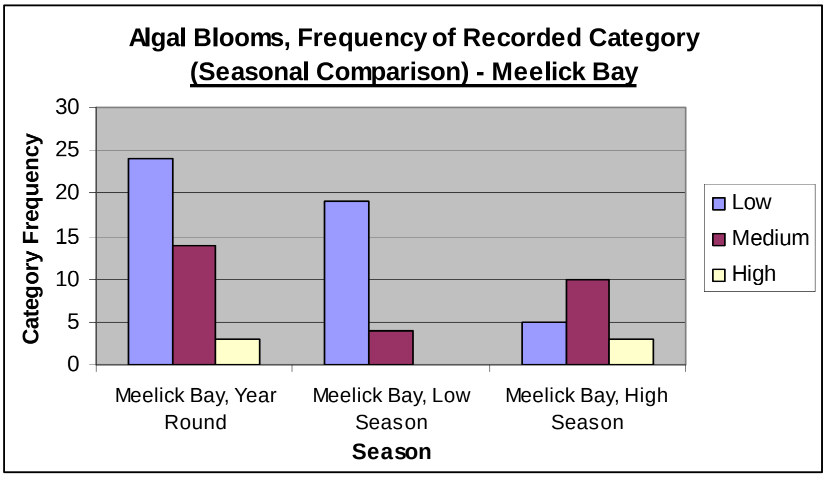



**Figure 4.63 – Algal Blooms, Frequency of Recorded Risk Category (Low & High Season) for Meelick Bay**

*Comment:*

High levels of algal blooms were recorded on 11 occasions at Dromineer Harbour and on 5 occasions at Terryglass Harbour. Medium levels were recorded on six occasions at both Terryglass and Dromineer Harbours. The results for Dromineer Beach and Terryglass foreshore were similar to those for Dromineer and Terryglass harbours respectively, with the frequency of high levels being slightly less and that for medium levels being slightly greater for both cases. This frequency of recorded high and medium levels at both Terryglass and Dromineer indicates that algal blooms continue to be a problem and has negative implications for tourism sustainability. Although fewer high levels were recorded at Meelick bay, the relatively high frequency of medium levels recorded here indicates that the algal bloom problem affects much of the lake system and is not necessarily a localised problem. Nevertheless, it is considered reasonable to assume that the enclosed nature of Terryglass and Dromineer harbours together with potential additional nutrient input sources does explain the higher levels of algal blooms occurring here.

From the seasonal comparison charts it can be seen that the majority of recorded medium and high levels occurred during the high season. Although this is largely to be expected given the seasonal nature of algal blooms (discussed in Section 3.6.8), it nevertheless compounds the negative implications of such algal blooms with respect to tourism sustainability.

#### *4.4.2.11 Water Transparency*

Water transparency data is presented below for the harbour and pier sampling sites at Terryglass and Dromineer. No data was recorded for Meelick Bay or the foreshore/beach areas of Terryglass and Dromineer as there was no access to deeper water at these locations.

<u>*Raw Data Charts and Statistical Analysis:*</u>

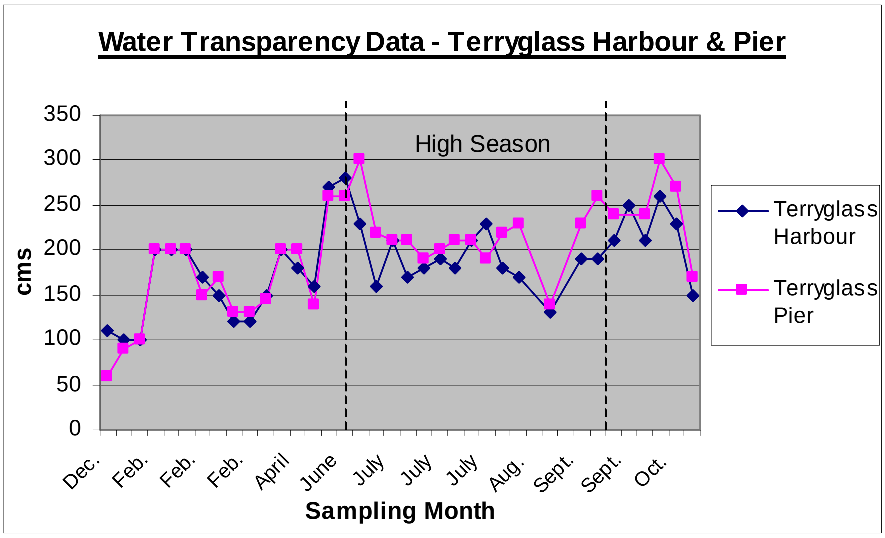



**Figure 4.64 – Water Transparency Data (cms) for Terryglass Harbour and Pier**

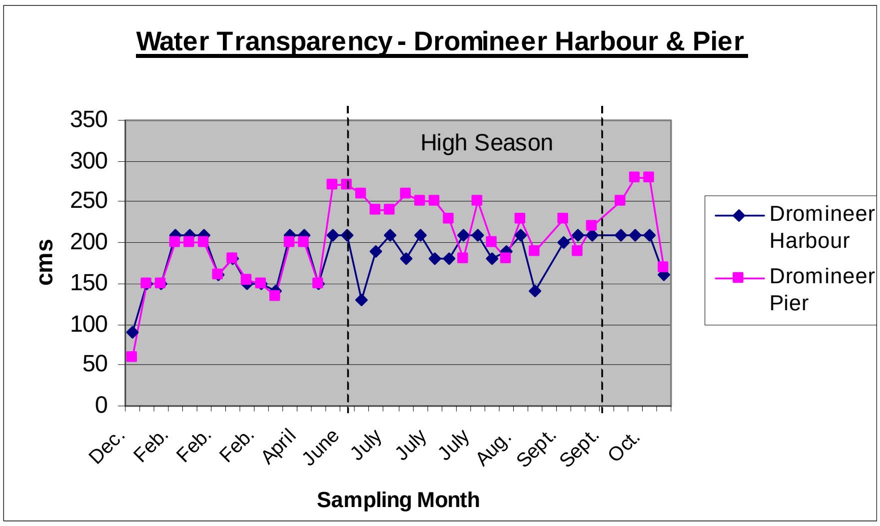



**Figure 4.65 - Water Transparency Data (cms) for Dromineer Harbour and Pier**

**Table 4.10 – Statistical Analysis of Water Transparency Data at Dromineer**

| Statistical Analysis (T Tests) | | | | |
|---|---|---|---|---|
| **Relationship Examined** | **Between Data Sets?** | **P Value =** | **Result** | **Interpretation** |
| Significant difference | All Year Data for Dromineer Harbour & Dromineer Pier | 0.00029 | Difference **is** significant | Lower transparency of water in harbour possibly due to motor craft |
| Significant difference | Dromineer Harbour, High & Low Seasons | 0.18 | Difference is not significant | No difference between high and low seasons at D. Harbour counters interpretation above |

*Example Categorised Data Chart:*

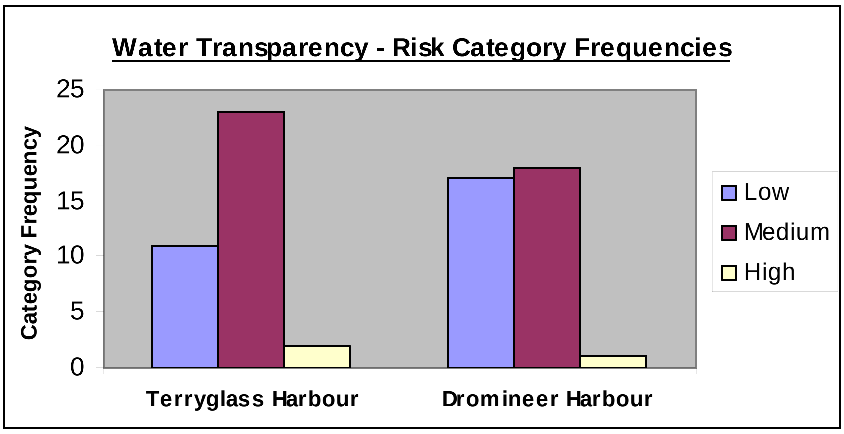



**Figure 4.66 – Water Transparency, Frequency of Assigned Risk Category for Terryglass and Dromineer Harbours.**

*Analysis and Interpretation:*

This parameter displays a high degree of variability irrespective of season or location. The close correlation between the values for Terryglass Harbour and Pier suggests that water transparency is not significantly influenced by boating or other activities associated with the tourist high season. On the other hand, a significant difference does exist between the values recorded for Dromineer Harbour and Pier. However, any suggestion that boating activity in Dromineer is affecting transparency is largely offset by the fact that there is no significant difference between the transparency values for Dromineer Harbour recorded during the high and low seasons.

An interesting feature of the above charts is that the only recorded high risk levels for water transparency (i.e. transparency below 1 metre) were for samples taken during the low season. This conflicts with the general consensus that water transparency tends to reflect the level of algae suspended in the water column. If this were the case then the lowest transparency values would be expected to be recorded during the summer when algae growth is at a maximum. In this respect, on site observations indicate that stormy weather also has a strong influence on the levels of turbidity in the water column.

Review of the risk category data charts for this variable shows a high proportion of medium risk levels assigned for both Terryglass and Dromineer harbours. These medium risk levels were in both cases distributed fairly evenly across both the high and low seasons.

### *4.4.2.12 Litter Counts*

Litter count data is presented below for the Terryglass, Dromineer and Meelick Bay amenity areas.

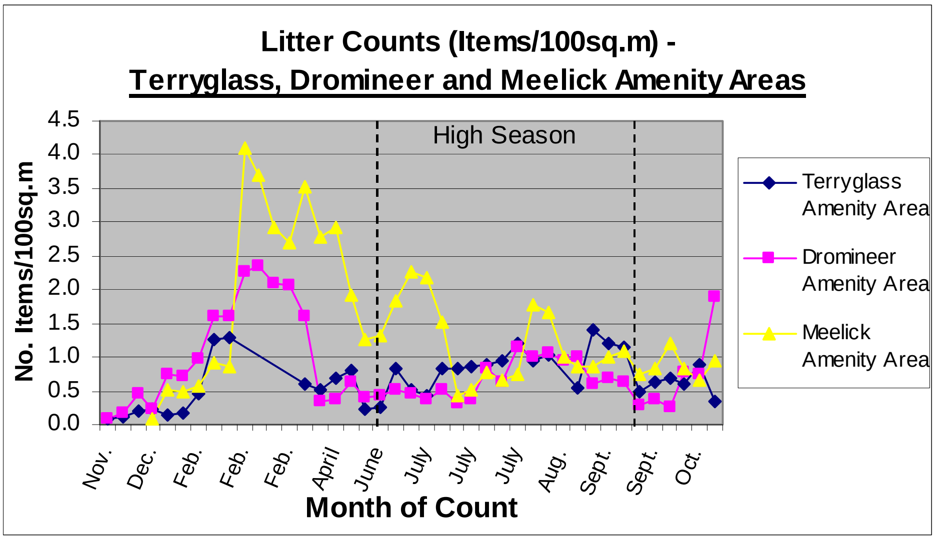



**Figure 4.67 – Litter Count Data for Terryglass, Dromineer and Meelick Amenity Areas**

*Categorised Data Charts:*

The frequency of each assigned risk category for the litter count data is illustrated in the following chart for the Terryglass, Dromineer and Meelick Bay amenity areas.

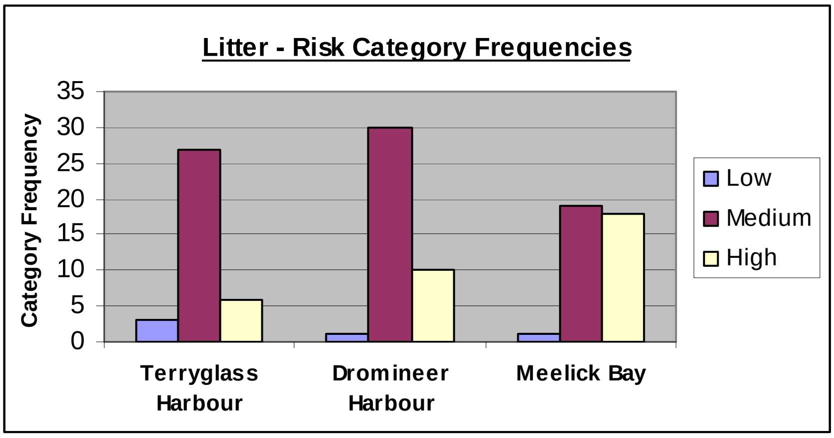



**Figure 4.68 – Litter Counts, Frequency of Assigned Risk Categories for the Lough Derg Study Sites**

*Analysis and Interpretation:*

A notable feature of this data is the prevalence of litter at all three sites throughout the year. In particular, it is obvious that particularly high levels occurred in early spring, outside of the tourist season. By way of explanation, it was noted that outside of the summer months there was no litter removal carried out by the local authority. This led to gradual accumulation of litter at all three sites throughout the autumn, winter and spring months as is evident from the data chart above. In addition, it was noted that a prevalence of windy conditions during the late winter washed large quantities of floating litter again on to all three amenity areas. This was particularly the case with Meelick Bay and is illustrated by the large spikes in the data recorded during the month of February. A further consideration regarding the litter data above is that significant levels of littering were recorded at the three sites during the high season in spite of frequency litter clearing by local authority staff. The practice of littering, therefore, is considered a serious problem and is only being kept under some sought of control by frequent litter clearing.

The prevalence of high levels of litter recorded at Meelick Bay conflicts with expectation given the isolated and unfrequented nature of this location. This feature points towards poor management of the Meelick Bay amenity area and also the vulnerability of the area to litter blowing in from the lake. Regarding this latter issue, it is not clear exactly what the source of litter in Lough Derg is. However, litter originating from the lake appears to occur in large quantities. This is considered another source of concern regarding the general sustainability of the Lough Derg area as a tourist destination.

Two significant features are evident with regard to the risk category charts. Firstly, the lack of low risk categories at all three sites and, secondly, the prevalence of high risk categories at Meelick Bay. The lack of low risk categories clearly indicates an ongoing problem with litter occurring throughout the year. Interestingly, the prevalence of high risk categories for litter at Meelick Bay contrasts sharply with the data returned for other variables which almost exclusively showed low risk levels.

### *4.4.2.13 Floating Litter*

Floating litter count data is presented below for the Terryglass, Dromineer and Meelick Bay amenity areas.

<u>*Raw Data Charts:*</u>

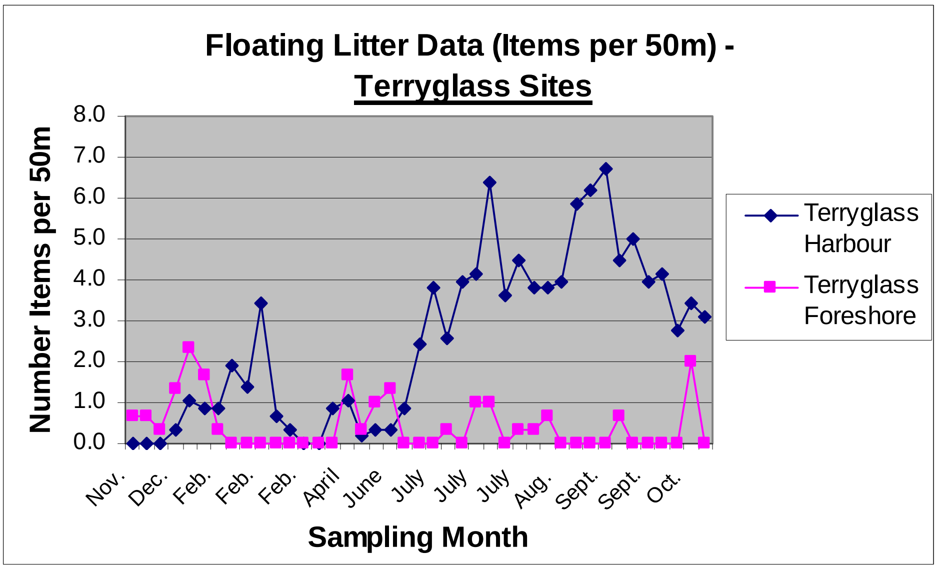



**Figure 4.69 – Floating Litter Data for Terryglass Amenity Area Sampling Sites**

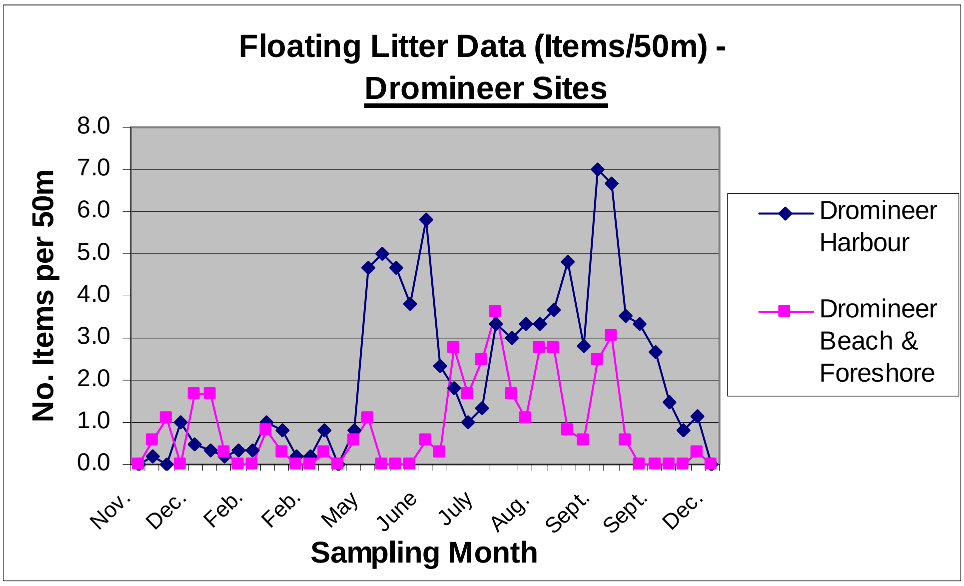



**Figure 4.70 - Floating Litter Data for Dromineer Amenity Area Sampling Sites**

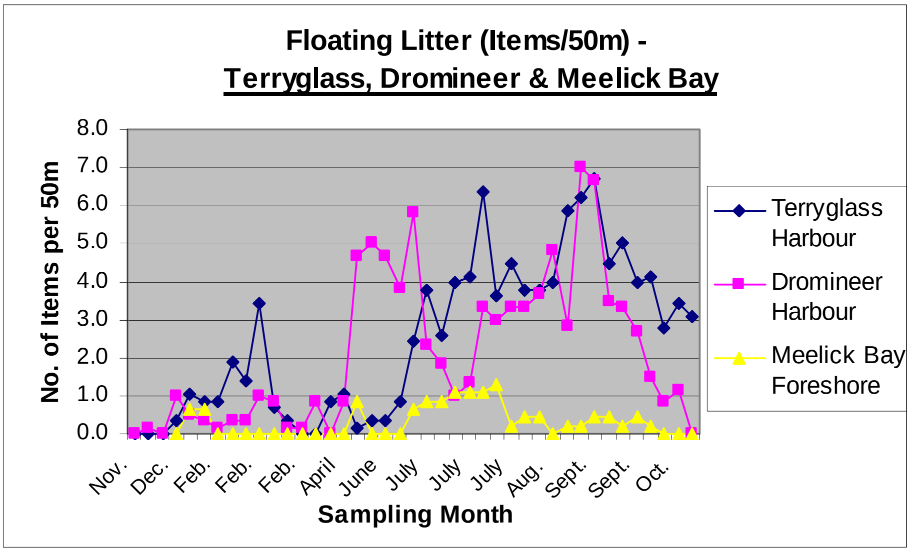



**Figure 4.71 - Floating Litter Data for Key Lough Derg Sampling Locations**

_Categorised Data Charts:_

Floating litter data for Terryglass, Dromineer, Meelick Bay was assigned to low, medium and high risk categories according to the criteria given in Section 3.6.12. The frequency of each recorded category for both high and low seasons is given in the chart below:

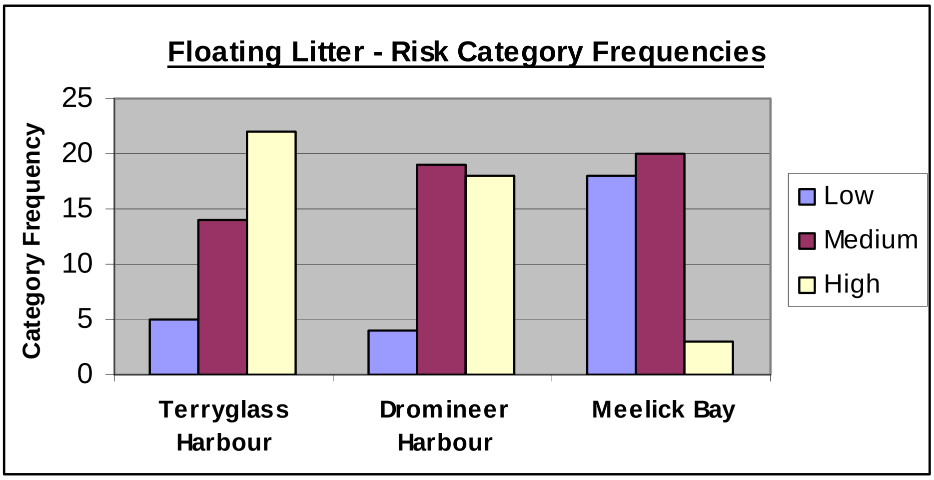



**Figure 4.72 – Floating Litter, Frequency of Assigned Risk Categories, for Key Locations at Lough Derg**

*Analysis and Interpretation:*

This variable shows a marked increase up to and during the high season with levels dropping off steadily with the beginning of the low season. This is particularly the case within the harbour areas of Terryglass and Dromineer. Meelick Bay in contrast shows a decrease, if anything, in the levels of floating litter during the high season. These trends would therefore indicate that this variable is largely influenced by the increased level of boating activity which occurs during the high season. The frequency data for assigned risk categories bear these trends out with high risk categories for this variable occurring frequently at both Terryglass and Dromineer harbours. Medium risk categories predominate at Terryglass. The frequency trends of assigned risk categories for Meelick Bay is more variable though a general feature is predominance of medium levels with some high levels also occurring. These occur predominantly during the low season.

In summary, it is evident from the above data that the levels of floating litter occurring at all surveyed sites are unacceptable from a point of view of sustainability. The levels occurring within Terryglass and Dromineer harbours are considered particularly poor. This problem is further compounded by the fact that the data trends suggest that these unacceptable levels are linked to high season recreational activity.

### *4.4.2.14 Dog Fouling and Dog Count Data*

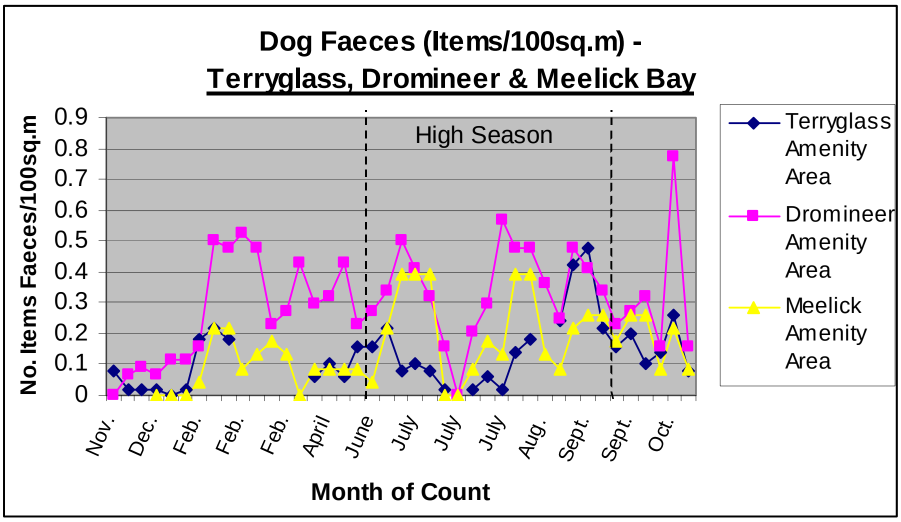



**Figure 4.73 – Dog Fouling Data (Dog Faeces) for The Lough Derg Study Sites**

**Table 4.11 – Statistical Analysis of Dog Fouling Data at Lough Derg Sites**

| Statistical Analysis (T Tests) | | | | |
|---|---|---|---|---|
| **Relationship Examined** | **Between which data sets?** | **P Value** | **Results** | **Interpretation** |
| Significant difference | High and low season data for Terryglass, Dromineer and Meelick Bay amenity areas | TG: = 0.151<br>DR: = 0.278<br>MB: = 0.036 | Difference is significant for MB. Not Significant for TG and DR | Dog fouling not linked to higher recreation activity at Dromineer and Terryglass. |

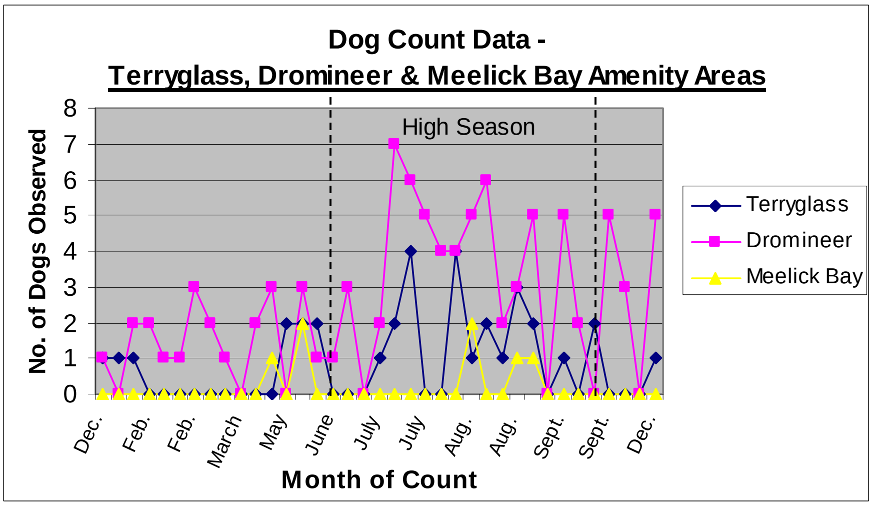



**Figure 4.74 – Dog Count Data for the Lough Derg Study Sites**

*Categorised Data Charts:*

The chart illustrating the frequency of each assigned risk category for the dog fouling data follow for Terryglass, Dromineer and Meelick Bay amenity areas.

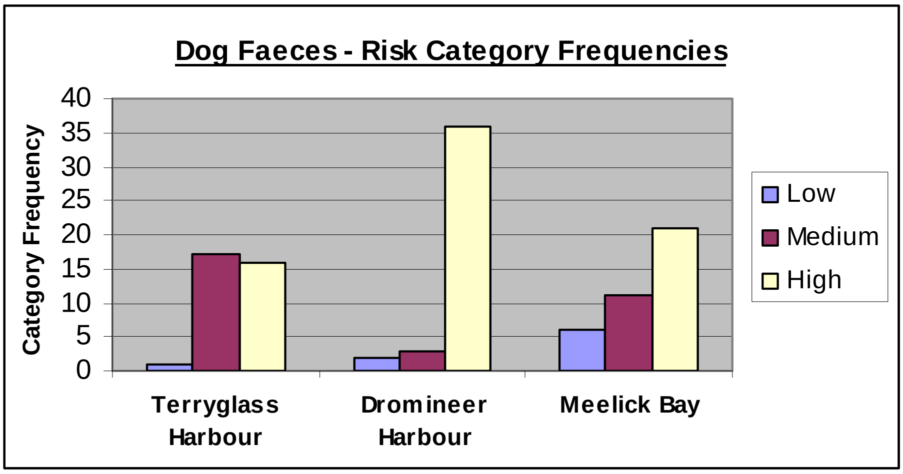



**Figure 4.75 – Dog Faeces, Frequency of Assigned Risk Categories for the Lough Derg Study Sites**

*Analysis and Interpretation:*

Both data charts above show relatively high levels of dog faeces occurring throughout the year, particularly at Dromineer and Meelick Bay. An interesting observation here concerns the reasons behind the high levels occurring at Dromineer and Meelick and the relatively close correlation between these two sets of data. Observations made during monitoring showed that at both Dromineer and Meelick a small number of dogs, without owners, were seen in these areas on repeated occasions. It is probably reasonable to assume that these dogs came from nearby houses as they were in good condition and did not appear to be strays. Both Dromineer and Meelick also appeared to be particularly popular locations for walking dogs. Thus it is likely that a large proportion of dog faeces occurring at Dromineer and Meelick originates very locally and is not affected to any significant extent by levels of general tourism or recreation.

This assertion is substantiated at Dromineer by the statistical analysis (see Table 4.11) which shows no significant difference between high and low season data for Dromineer. In the case of Terryglass the analysis shows that high season levels were not significantly different to those during the low season. Nevertheless, the data for Terryglass does show particularly high levels of dog faeces occurring during the latter part of the summer months. As these higher levels coincided with particularly high levels of cruiser activity with relatively levels of observed dog ownership, it is conjectured that these higher dog fouling levels are likely to be linked to ownership of dogs by cruiser users. Such an occurrence would denote an association between lake based recreation activity and a greater risk in terms of dog fouling.

The risk category chart highlights serious issues with regard to the prevalence of dog fouling at all three study areas. In particular, the data for Dromineer falls almost exclusively into the high risk category. Even Meelick Bay, which is an isolated and seldom visited location, has predominantly high risk levels of dog fouling. Of note, also, is the fact that high levels of dog fouling were recorded during both the high and low seasons. This suggests that the issue of dog fouling has its origins in the behaviour of local residents and is not linked to any great extent to seasonal increases in tourism and recreational activity.

### *4.4.2.15 Graffiti*

*Raw Data Chart:*

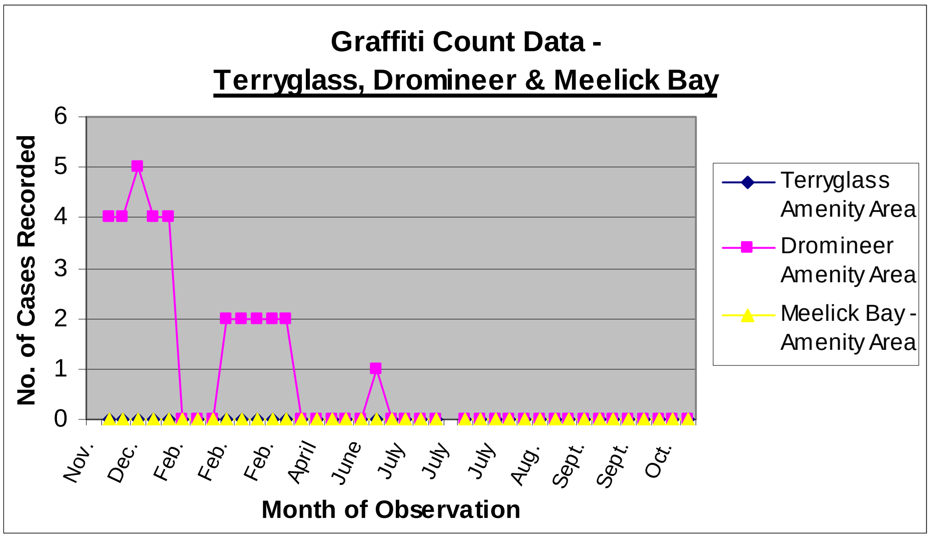



**Figure 4.76 – Graffiti Count Data for the Lough Derg Study Sites**

*Assigned Risk Category Frequency Chart:*

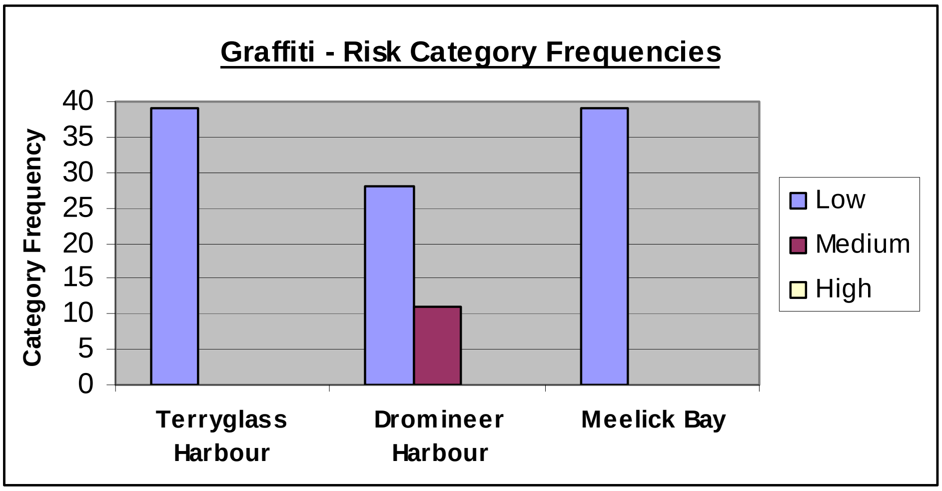



**Figure 4.77 – Graffiti Counts, Frequency of Recorded Risk Categories for the Lough Derg Study Sites**

*Analysis and Interpretation:*

The above charts show that incidences of graffiti were only evident at Dromineer Amenity Area and here predominantly during the low season months. This pattern probably reflects the less remote location of Dromineer and the fact that darker evenings along with fewer ordinary members of the public probable encourages those intent on creating graffiti. The assigned risk category chart highlights clearly both the scale and frequency of the problems with graffiti at Dromineer. Note also that low risk categories predominated during the high season at Dromineer.

### *4.4.2.16 Bird Counts*

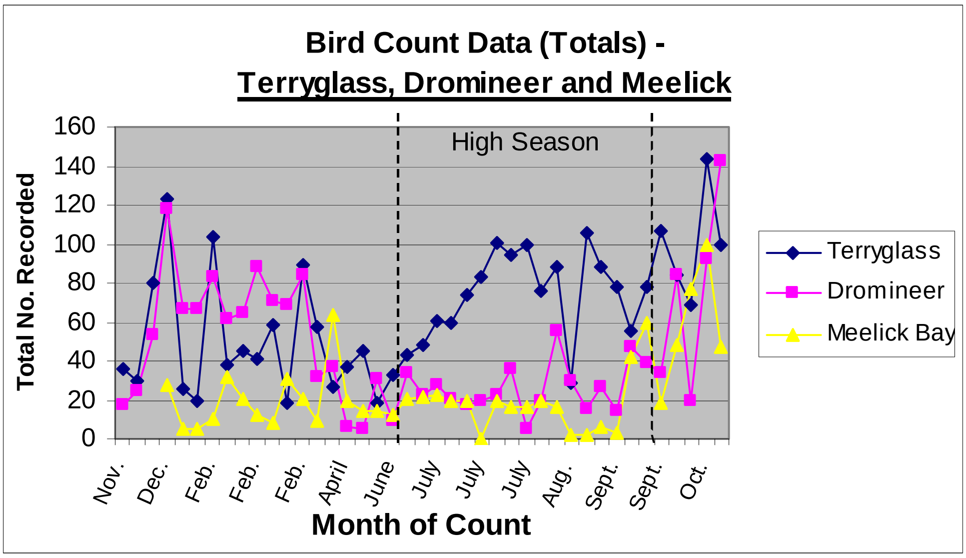



**Figure 4.78 – Total Bird Count Data for the Lough Derg Study Sites**

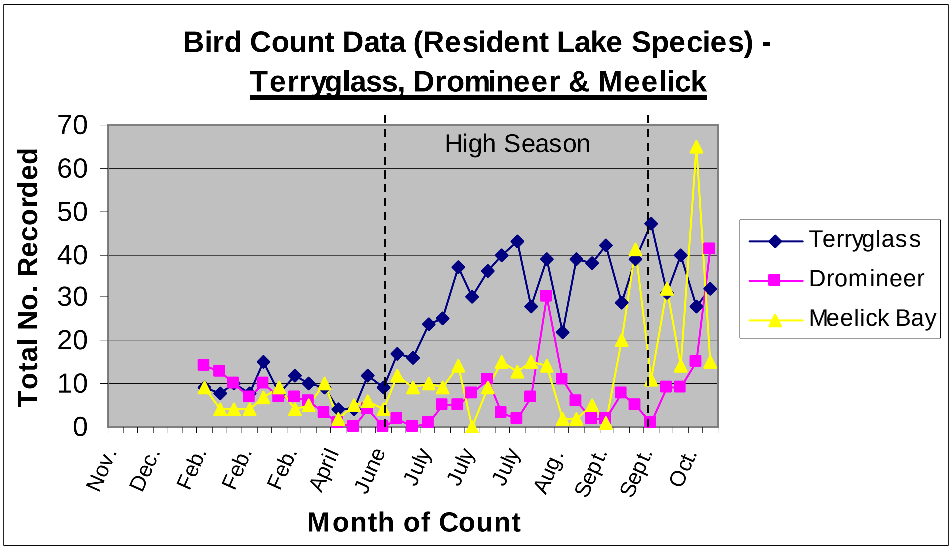



**Figure 4.79 - 'Resident Lake' Bird Species Count Data for the Lough Derg Study Sites**

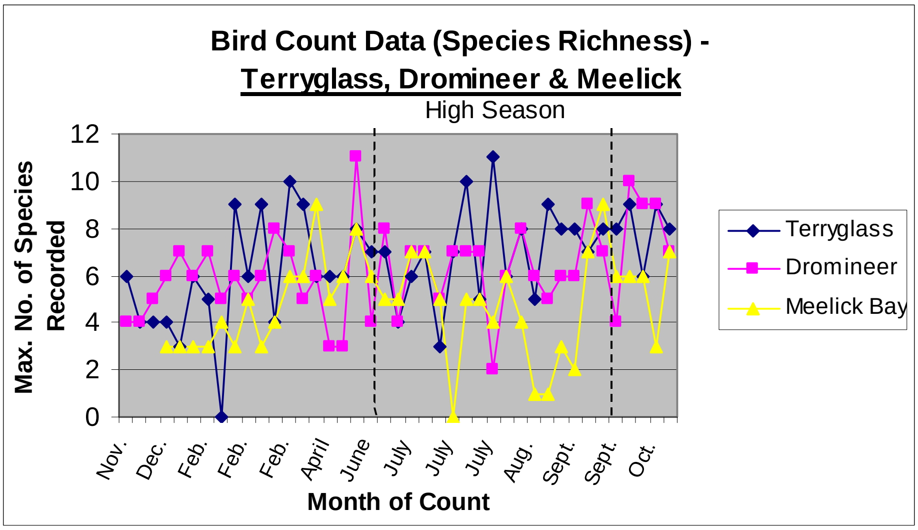



**Figure 4.80 – Bird Species Richness Data for the Lough Derg Study Sites**

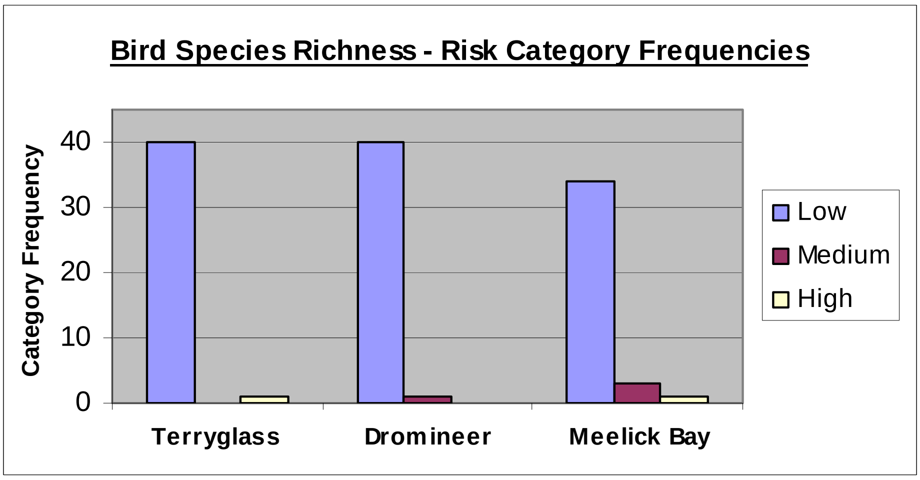



**Figure 4.81 – Bird Species Richness, Frequency of Assigned Risk Categories for the Lough Derg Study Sites**

*Analysis and Interpretation:*

The three basic data charts above highlight in many ways the complexities associated with the interpretation of bird count data in environmental assessment as outlined in the Methodology Chapter. Comparison of the first two charts highlight the distorting nature (on a data set) of including species which are naturally attracted to areas frequented by humans. Thus the chart for ‘total bird’ counts shows much higher numbers occurring during the winter months than the chart for ‘resident lake species’. From observation it was determined that the differences between these charts was mainly due to the presence of large flocks of gulls, mallards and tufted duck at Dromineer and Terryglass during the winter months. On site observations indicate that the gulls and mallards were attracted to the harbour areas of Terryglass and Dromineer for either shelter or the possibility of food thrown by members of the public. This behaviour accounts for the much greater numbers of birds occurring at Terryglass and Dromineer during the winter months than at the more natural and isolated location of Meelick Bay. Recorded numbers during the winter months were also increased by the presence of flocks of tufted duck which are resident to the area at this time but migrate in spring and summer for breeding purposes. This behaviour occurred at all three sites (Terryglass, Dromineer and Meelick Bay) and this largely accounts for the higher numbers of birds recorded under the heading ‘total birds’ at Meelick Bay than under the heading ‘resident lake birds’.

Even with the exclusion of migratory birds and also those attracted to human presence (i.e. ‘resident lake species’ only), the data for this variable still displays some interesting and significant trends. Firstly, it can be seen that bird numbers increased dramatically during the high season at Terryglass. This contrasts with little or no increase at Meelick Bay. On site observations made at the time of surveys put this increase largely down to greater populations of ‘coots’, and to a lesser extent other species, as a result of extensive breeding.

Regardless of the ecological reasoning behind these trends it must be noted that the tourism development and recreational activity occurring at Terryglass does not therefore appear to be negatively affecting the natural breeding capabilities of a variety of lake bird species. Given the data for Dromineer and Meelick Bay, it may be the case that the combination of boating and amenity infrastructure along with adjacent areas of more natural lakeshore habitat, which exists at Terryglass, provides ideal breeding and feeding grounds for natural lake bird life. Dromineer on the other hand is significantly more developed which perhaps discourages the more natural species of lake bird life.

With regard to the data chart depicting ‘species richness’, it can be noted that although the levels for each site are more random and variable in nature (that is, no clear trends are evident), there is less discrepancy between locations and between high and low seasons. However, the highly variable nature of species richness (ranging from 0 species to 9 species) occurring at Meelick Bay leaves little basis for interpretation of the variations recorded at Terryglass, Dromineer or any other (this assertion is based on the assumption that the data for Meelick Bay is indicative of excellent ecological condition with little negative human interference).

Perhaps the most significant interpretation that can be extracted from the species richness data is the fact that species richness does not decrease to any significant extent during the high season when recreational activity is greatest. In addition, the species richness values recorded at Terryglass and Dromineer are, if anything, generally higher than those recorded at Meelick Bay. These trends adds weight to the assertion above that the development/natural habitat mix occurring at Terryglass and, possibly to a lesser extent, Dromineer does not appear to have any negative affect on the habitat value for bird life in these areas. This is considered a significant finding in the context of lake tourism development and environmental conservation.

With regard to the assigned risk categories (applicable to 'species richness'), the charts highlight the relatively high values for species richness that were recorded at Terryglass and Dromineer and indicate that conditions for bird life at these locations do not present an issue with respect to sustainability.

#### *4.4.2.17 Ambient Noise - $L_{Aeq}$*

Ambient noise levels were recorded in terms of two separate but related parameters as described in the Methodology Chapter (Section 3.6.19). These parameters are known as $L_{Aeq}$ and $L_{A90}$. Results and analysis for the $L_{Aeq}$ parameter are given in this section while those for $L_{A90}$ parameter are given in the following section.

*Data and Analysis for Ambient Noise - $L_{Aeq}$*

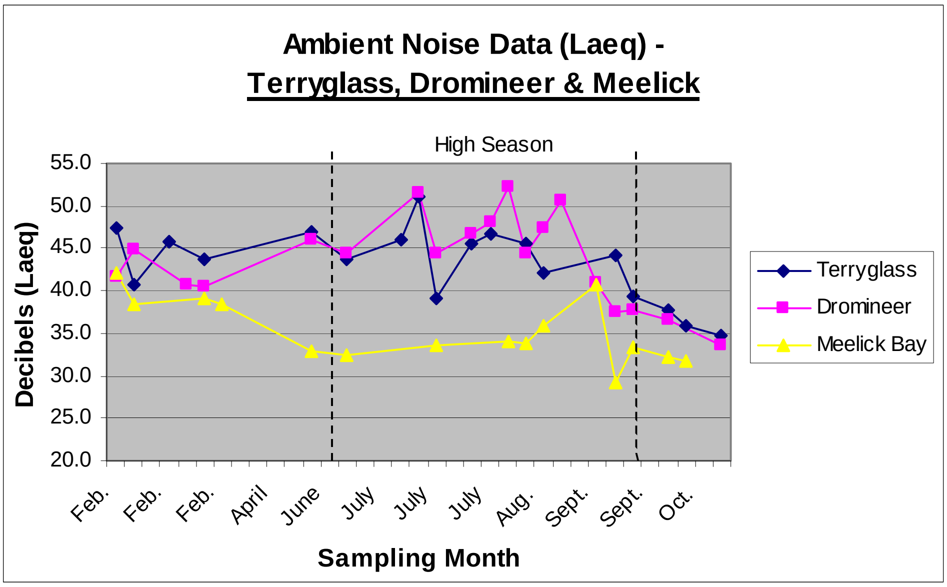



**Figure 4.82 – Ambient Noise Data ($L_{Aeq}$) for the Lough Derg Study Sites**

**Table 4.12 – Statistical Analysis of Ambient Noise Data ($L_{Aeq}$) for the L. Derg Study Sites**

| Statistical Analysis - (T Tests) | | | | |
|---|---|---|---|---|
| **Relationship Examined** | **Between Which Data Sets?** | **P Values** | **Result** | **Interpretation** |
| Significant difference | High season data for: 1) Terryglass and Meelick Bay, and 2) Dromineer and Meelick Bay | TG v MB: $3.22x10^{-6}$ DR v MB: $1.26x10^{-6}$ | Diff. is significant Diff. is significant | Ambient noise levels during the high season are significantly higher at Terryglass and Dromineer than at Meelick Bay. |
| Significant difference | High and low season data sets for Terryglass, Dromineer and Meelick bay. | TG = 0.039 DR = 0.0022 MB = 0.24 | Diff. is significant Diff. is significant Diff. is not significant | Average high season noise levels are higher at Terryglass and Dromineer. No significant difference between high and low season levels at Meelick Bay. |

*Assigned Risk Category Frequency Chart* ($L_{Aeq}$) *:*

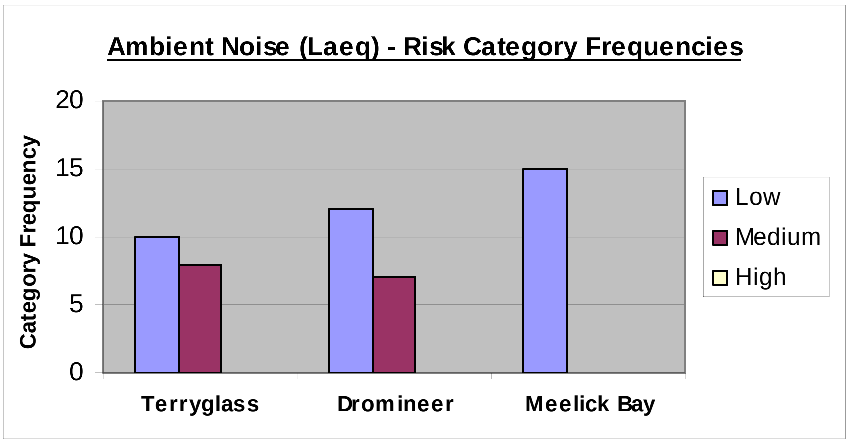



**Figure 4.83 - Ambient Noise Data ($L_{Aeq}$), Frequency of Assigned Risk Categories for the Lough Derg Study Sites**

*Analysis and Interpretation:*

With respect to the $L_{Aeq}$ raw data chart, the most prominent feature is the marked difference between the noise levels occurring at Meelick Bay and those at Terryglass and Dromineer. This is particularly the case during the high season and the statistical significance of this difference has been verified by the T test analysis given in Table 4.12. With respect to ambient noise levels, Meelick Bay is considered to represent a very natural and peaceful noise environment which provides an excellent frame of reference for this variable. Thus, the recorded data can be interpreted as highlighting the presence of noise over and above that which could be considered entirely natural. When considering the source of the higher noise levels at Terryglass and Dromineer it is interesting to note that the difference in noise levels at these locations between high and low seasons is not that obvious or marked. However, statistical analysis confirms that the average high season noise level is significantly higher at both locations. Two immediate conclusions can be drawn from this. Firstly, anthropogenic noise is increasing the level of ambient noise at Terryglass and Dromineer and secondly, this increase is more marked during the high season. Further interpretation of this would suggest that recreational activity, particularly boating in its various forms, is associated with a clear increase in the ambient noise levels during the high season at Terryglass and Dromineer. This interpretation is born out by observations during the noise surveys which clearly linked the use of jet skis and power boats in particular with marked increases in ambient noise level.

The significance of this increase in noise level at Terryglass and Dromineer is highlighted by the risk category frequency charts for this parameter ($LA_{eq}$). These charts show a prevalence of medium risk categories occurring at Dromineer and Terryglass during the high season. This contrasts with the chart for Meelick bay where all the recorded data values fell into the low risk category. On site observations attribute the medium risk categories occurring at Terryglass during the low season as being mainly associated with the use of agricultural machinery in adjacent lands.

### *4.4.2.18 Ambient Noise – $L_{A90}$*

*Data and Analysis for Ambient Noise – $L_{A90}$*

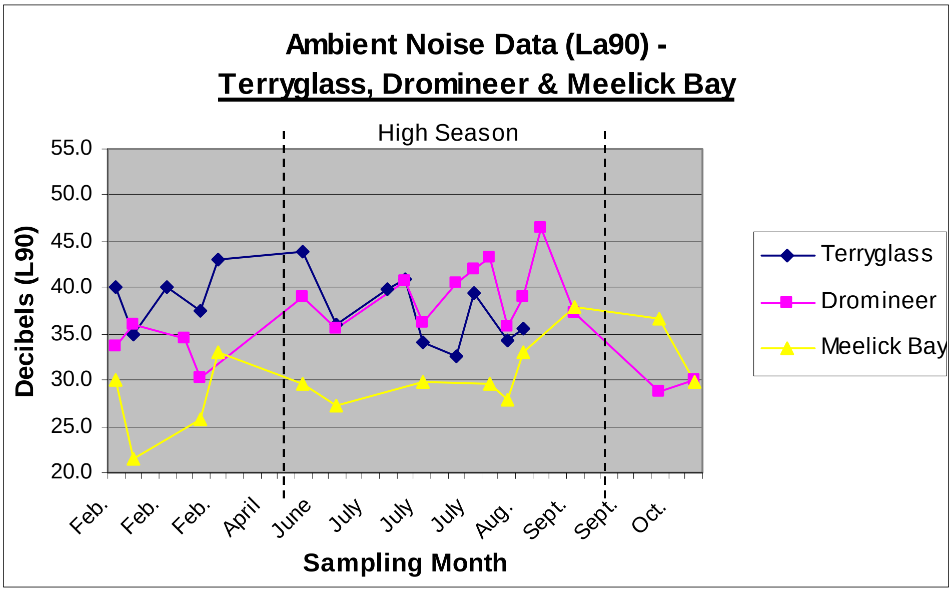



**Figure 4.84 - Ambient Noise Data ($L_{A90}$) for the Lough Derg Study Sites**

**Table 4.13 – Statistical Analysis of Ambient Noise Data ($L_{A90}$) for the L. Derg Study Sites**

| **Statistical Analysis - (T Tests)** | | | | |
|---|---|---|---|---|
| **Test for?** | **Between Which Data Sets?** | **P Values =** | **Result** | **Interpretation** |
| Significant difference | High season data for:<br>1) Terryglass and Meelick Bay, and<br>2) Dromineer and Meelick Bay | TG v MB: 0.0034<br><br>DR v MB: 0.00024 | Diff. is significant<br><br>Diff. is significant | Ambient noise levels during the high season are significantly higher at Terryglass and Dromineer than at Meelick Bay. |
| Significant difference | High and low season data sets for Terryglass, Dromineer and Meelick bay. | TG:<br>= 0.37<br>DR:<br>= 0.006<br>MB:<br>= 0.32 | Diff. is not significant<br>Diff. is significant<br>Diff. is not significant | Average high season noise levels are higher at Terryglass only.<br>No significant difference between high and low season levels at Meelick Bay or Terryglass |

*Categorised Data Charts for $L_{A90}$*

$L_{A90}$ noise data for Terryglass, Dromineer and Meelick Bay were grouped into low, medium and high risk categories according to the criteria given in Section 3.6 (see Methodology Chapter). The frequency of each recorded category for both high and low seasons are given in the chart below:

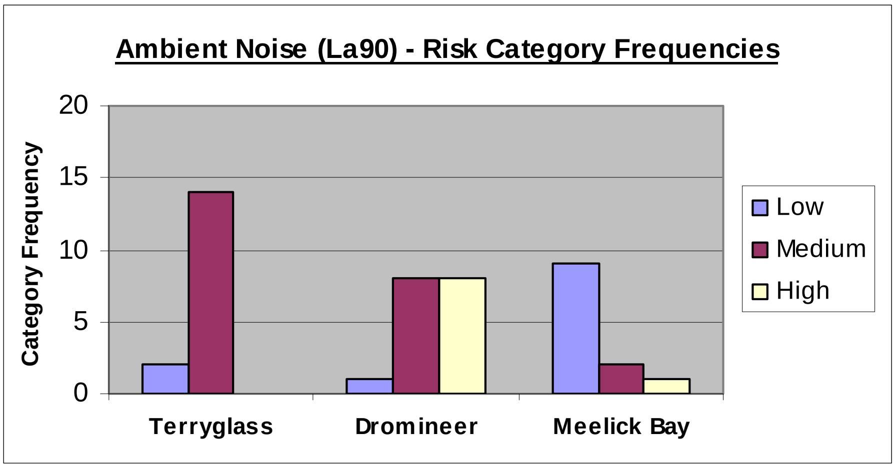



**Figure 4.85 – Ambient Noise ($L_{A90}$), Frequency of Assigned Risk Category for the Lough Derg Study Sites**

*Analysis and Interpretation:*

With regard to the data recorded for the second noise assessment parameter ($La_{90}$) a number of significant features are evident. Firstly, the values recorded at all three sites display a greater level of variability throughout the year (than the values for the LAeq parameter) and the distinction between the data for Meelick Bay and that for Terryglass and Dromineer is less obvious. Nevertheless, the statistical analysis (see Table 4.13) does indicate that the $La_{90}$ noise values are also significantly higher during the high season at Dromineer and Terryglass than at Meelick Bay. However, looking at the charts this difference is not as marked as that for the $LA_{eq}$ data. Also in contrast to the

$LA_{eq}$ data, the $La_{90}$ data shows no significant data between the high and low season data sets for Dromineer.

The discrepancies between the $L_{Aeq}$ and $L_{A90}$ data sets outlined above is most likely due to the fact that the $La_{90}$ parameter tends to record background noise only. Hence, in the case of Dromineer, this parameter has failed to pick up the more random noise events which were associated with recreational activity at this location. Thus the $La_{90}$ data showed no significant difference between the high and low seasons. The $LA_{eq}$ parameter on the other hand measured the average noise levels and therefore was able to pick up and record these less continuous but still very significant noise events. In conclusion, it is felt that the $LA_{eq}$ parameter has provided a more representative assessment of the observed noise environment at the three locations than the $La_{90}$ parameter.

#### *4.4.2.19 Parked Cars*

*Raw Data Chart:*

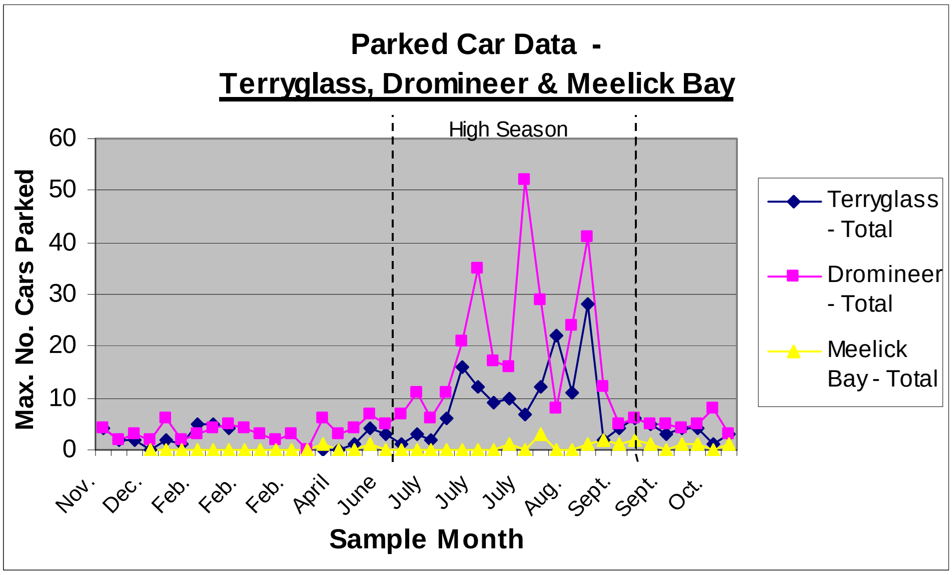



**Figure 4.86 – Parked Car Counts for the Lough Derg Study Sites**

*Comment:*

This data was largely in line with expectation. Values at Dromineer and Terryglass during the summer months were more variable with the higher values tending to coincide with periods of good weather and weekends. The values during the winter months were typically low with little variation. This trend occurred all year round at Meelick Bay.

### *4.4.2.20 Boating Counts*

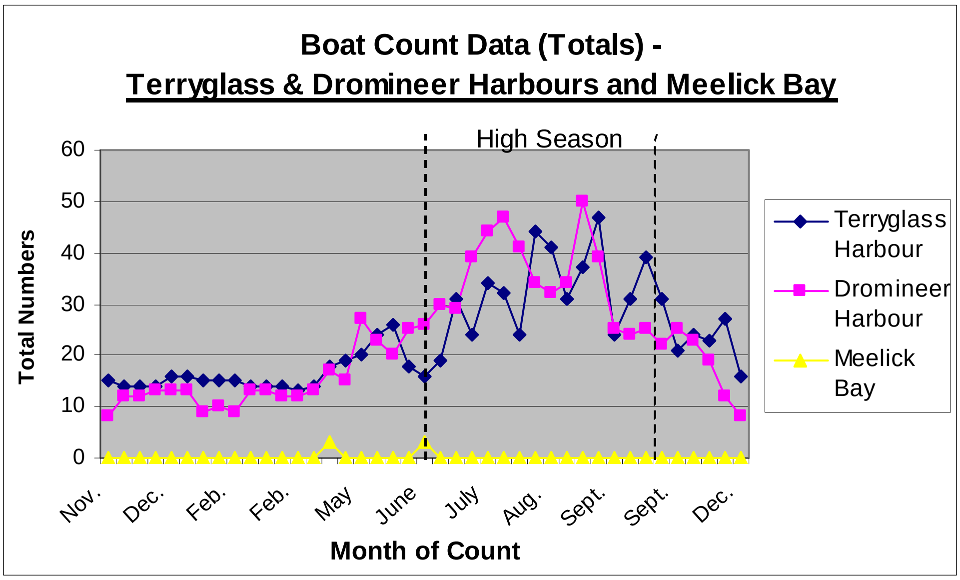



**Figure 4.87 – Total Number of Boats Recorded (Moored and Motoring) at the Lough Derg Study Sites**

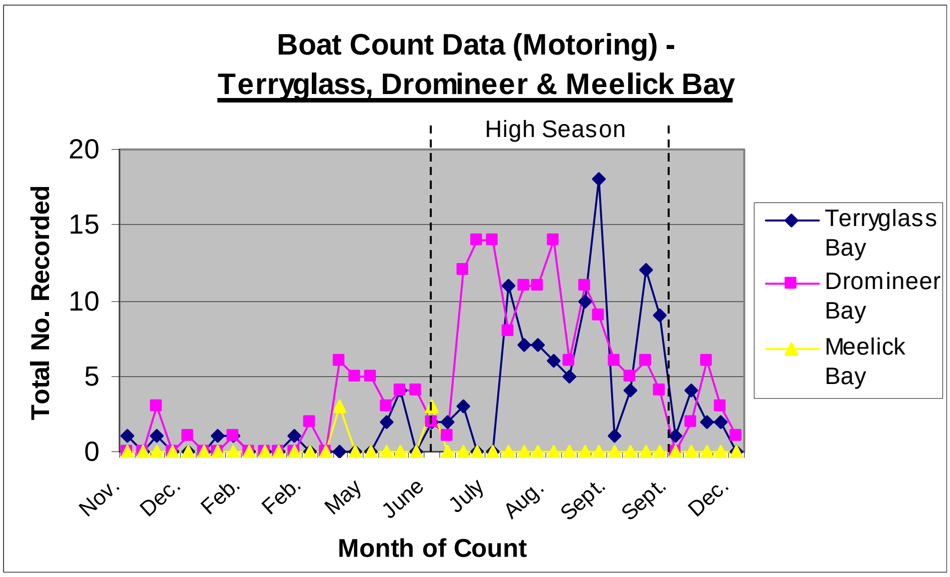



**Figure 4.88 – Number of Motoring Boats Observed at the Lough Derg Study Sites**

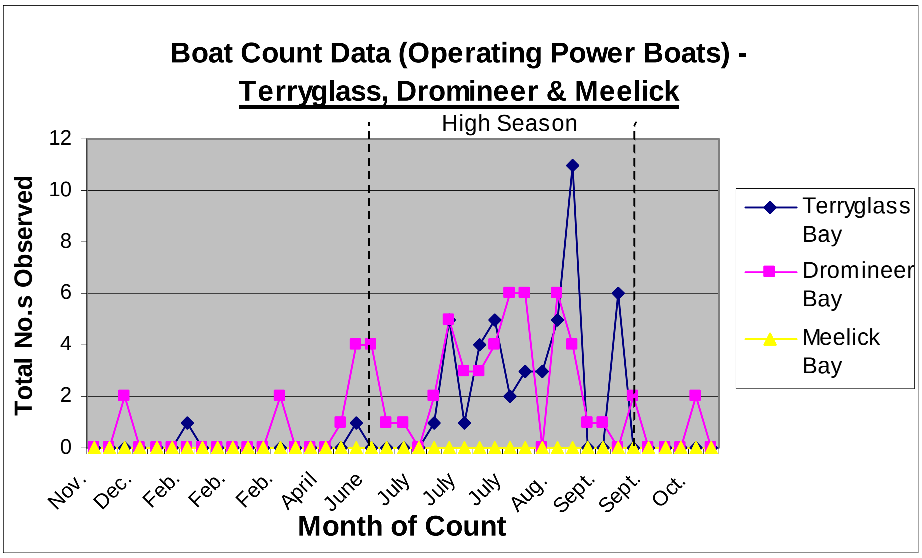



**Figure 4.89 – Number of Power Boats in Operation at the Lough Derg Study Sites**

*Comment:*

The data in the above three charts was largely in line with expectation. A residual and relatively consistent number of moored boats were recorded at Terryglass and Dromineer harbours during the winter months. These were observed to be boats tied up for the winter as very little activity was recorded with respect to motoring boats during the winter. During the summer months, both the number of moored and motoring boats increased significantly though a relatively high degree of variability in the data was recorded. The initial increase in motoring boat activity at Terryglass and Dromineer during April and May was attributable to angling boats taking advantage of the mayfly season. The use of power boats was largely confined to the summer months and little or no boating activity was recorded at Meelick Bay.

### *4.4.2.21 Harbour Congestion*

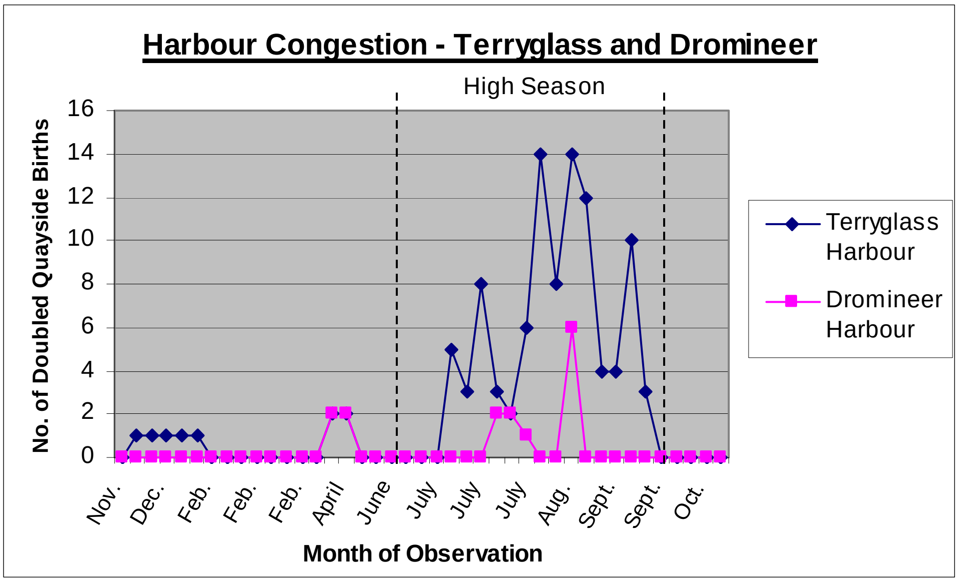



**Figure 4.90 – Harbour Congestion Data for Terryglass and Dromineer Harbours**

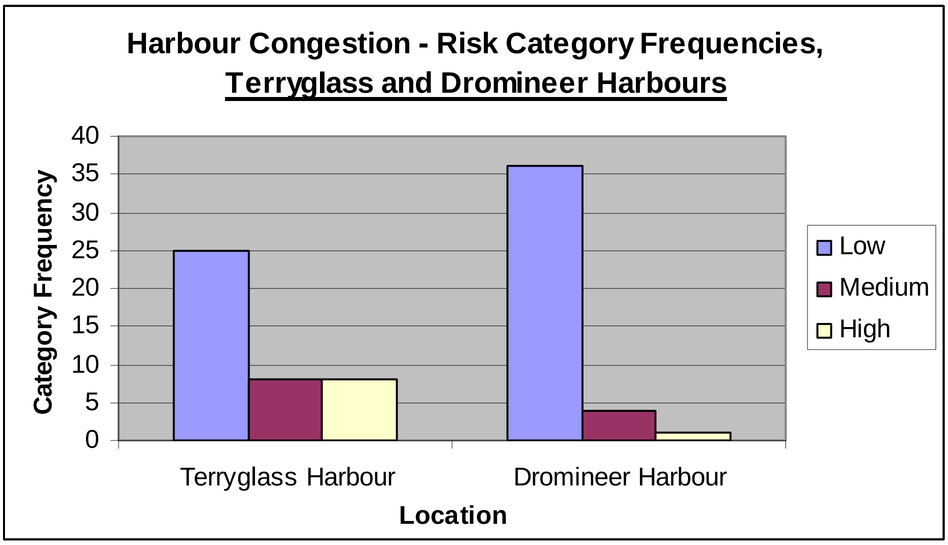



**Figure 4.91 – Harbour Congestion, Frequency of Assigned Risk Categories for Terryglass and Dromineer Harbours**

*Comment:*

The data presented in the charts above was largely in line with expectation. Incidences of harbour congestion occurred almost exclusively during the high season. The higher levels of harbour congestion recorded at Terryglass Harbour reflect the more limited availability of berthing space at this location, together with its popularity with visiting cruisers due to its scenic location and proximity to the popular village of Terryglass. The incidences of harbour congestion recorded during the low season were largely attributable to situations where boat owners tied up beside each other for reasons other than the lack of availability of berthing space.

### 4.4.3 Dublin Bay Variables – Data and Analysis

Data for the Dublin Bay study sites (Seapoint, Monkstown and Dun Laoghaire Harbour) is presented in this section. The manner of presentation is the same as that used for the Lough Derg data presented in Section 4.4.2 above. Again, the reader is referred to the relevant headings in Section 3.6 of the Methodology Chapter where greater insight is required with respect to the significance of data values presented in this section.

#### *4.4.3.1 General Conditions Data*

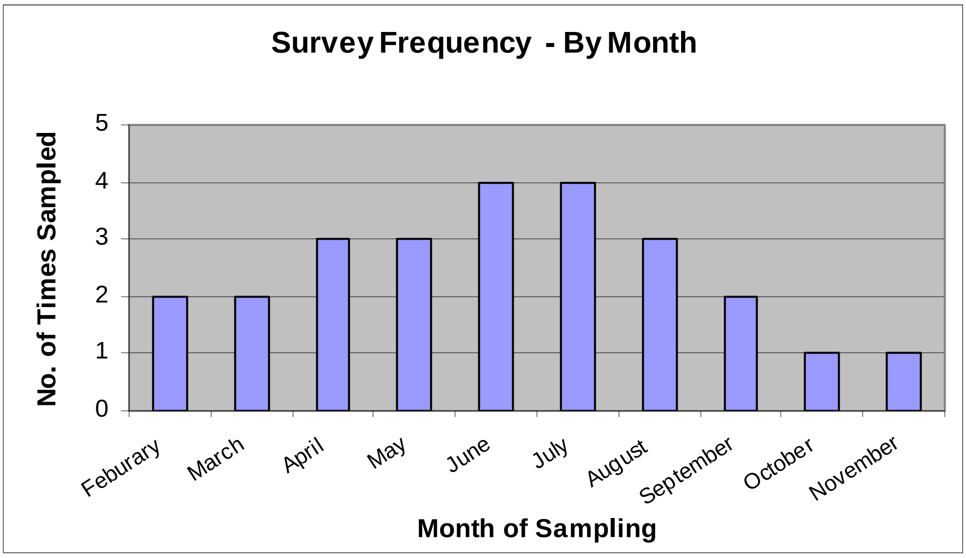



**Figure 4.92 – Frequency of Survey or Sampling Visits Undertaken at the Dublin Bay Study Area by Month**

25 sampling visits were made to the Dublin Bay study sites. These sites were carried out between February 2008 and November 2009. The frequency of visits was highest during the summer months. This provided additional data of conditions when recreational activity was at its highest level.

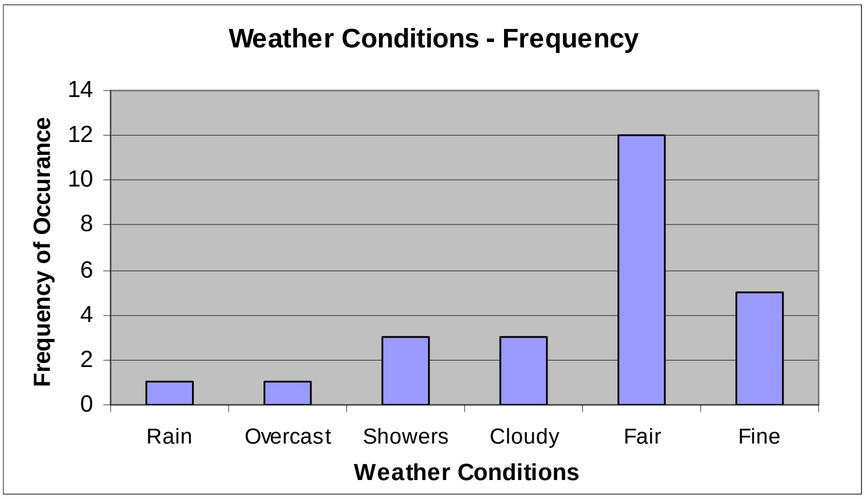



**Figure 4.93 – Frequency of Weather Conditions Recorded at the Dublin Bay Study Sites**

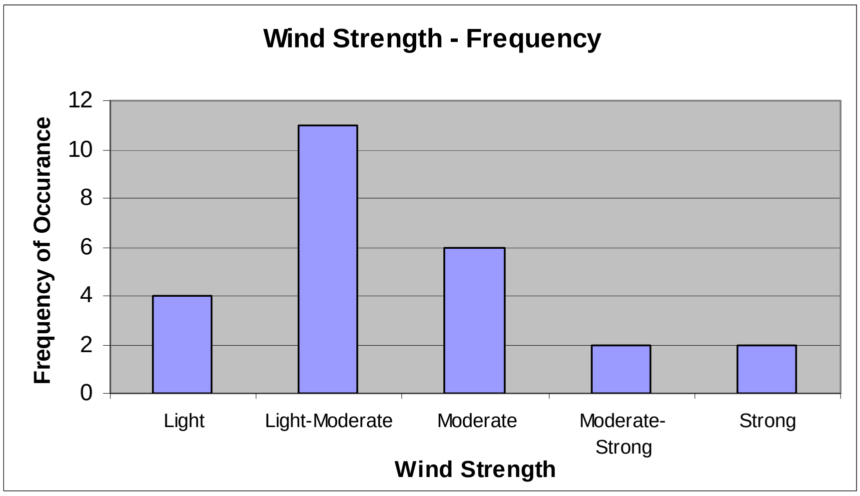



**Figure 4.94 – Frequency of Recorded Wind Strength (by Category) at the Dublin Bay Study Sites**

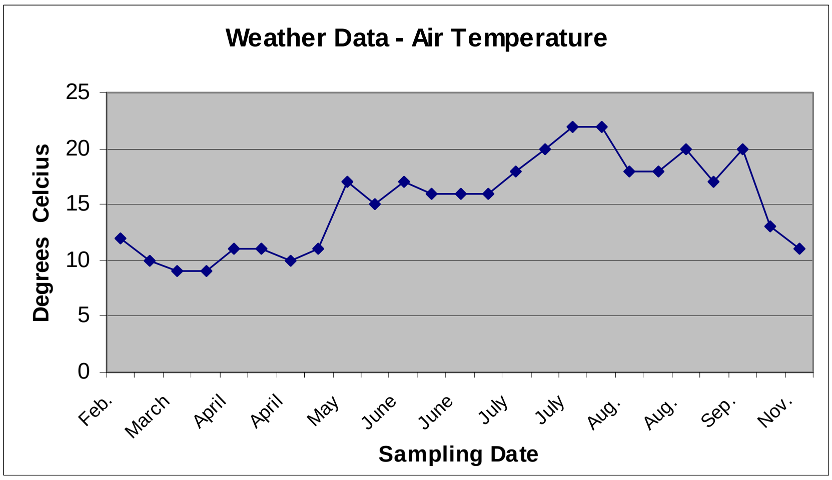



**Figure 4.95 – Air Temperature (°C) Data Recorded at the Dublin Bay Study Sites**

*Comment:*

In spite of generally poor weather conditions occurring over the Summer of 2008, it was nevertheless possible to concentrate site visits during times of relatively fair weather. This again allowed for assessment of conditions when recreational activity was relatively high. This also provided greater opportunity for undertaking noise assessment as the methodology for this parameter requires that wind strength is less than moderate (see chart above).

### *4.4.3.2 Water Temperature Data Chart*

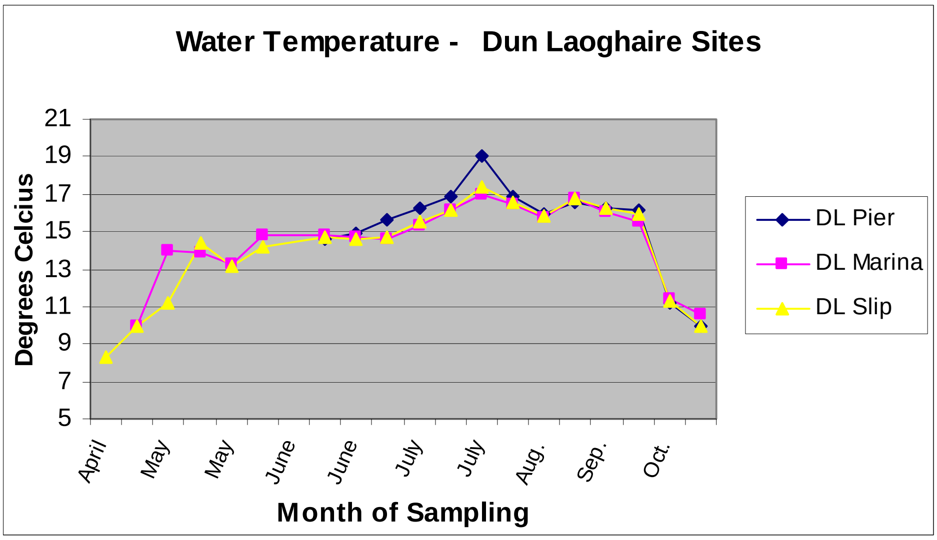



**Figure 4.96 – Water Temperature Data for Dun Laoghaire Harbour Sampling Sites**

*Analysis and Interpretation:*

The recorded water temperature values follow a predictable pattern with a gradual increase towards the summer months and a more distinct drop off in temperature at the end of September when colder and windier weather coincided with longer nights. Of passing interest is the fact that the summer water temperatures were consistently lower in the inner reaches of Dun Laoghaire harbour (that is, at the slip and marina sampling points) than further out at the West pier. This is somewhat contrary to expectation as normally one would expect the water temperature to be lower nearer to the mouth of the harbour where greater mixing with colder external water would presumably occur due to tidal and wave action. One potential implication of the higher temperatures observed at the inner harbour sites is that this could put additional pressure on dissolved oxygen levels as water temperature is inversely related to the solubility of dissolved oxygen (see background information under ‘Dissolved Oxygen’ in the Methodology Chapter). As noted in the discussed in the Methodology Chapter this could have adverse implications for marine organisms which require high levels of dissolved oxygen in the water column.

#### *4.4.3.3 Dissolved Oxygen Data*

Data for the variable 'dissolved oxygen' is presented in the chart below. Due to the dependence of this variable on seasonal water temperature fluctuations (see Methodology Chapter, Section 3.6.1) no detailed analysis of the high and low season data was deemed warranted. Furthermore, due to the absence of relevant external standards pertaining to acceptable levels of dissolved oxygen in marine waters, it was decided not to generate and assign risk categories for this particular variable. With respect to dissolved oxygen, the focus was instead on the related variable 'percentage saturation of dissolved oxygen'. Relevant standards are available for this variable as detailed in Section 3.6.2.

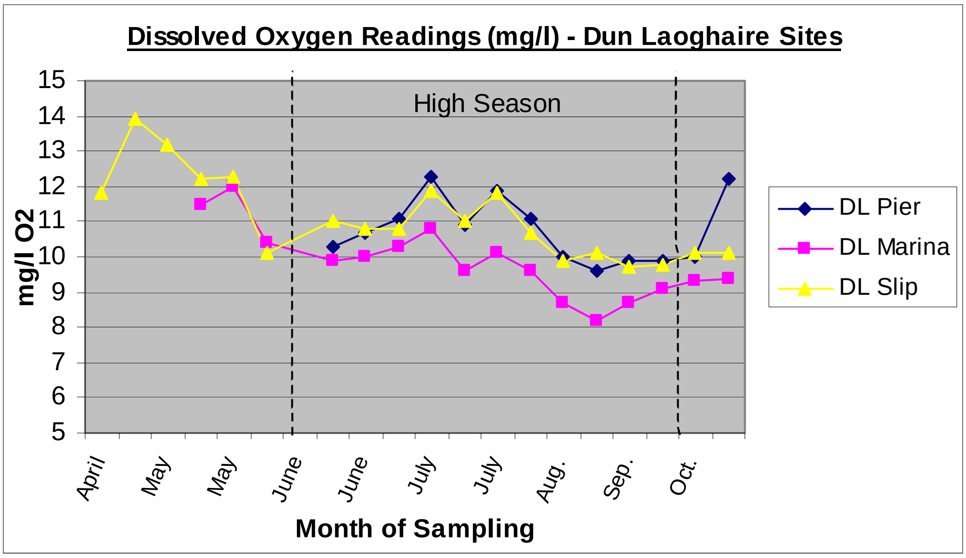



**Figure 4.97 – Dissolved Oxygen Data for Key Sampling Sites at Dun Laoghaire Harbour**

*Analysis and Interpretation:*

The general pattern of dissolved oxygen readings are largely as expected with values dropping off towards the end of the summer months as water temperatures reached their peak. Again in line with expectation, values were seen to begin to recover again with the onset of autumn. That said, two features of interest in the data are the close correlation between the Pier and Slipway readings and the consistently lower readings which are evident in the Marina readings during the high season. The aforementioned similarity in the Pier and Slipway readings would suggest that water quality at these two locations is similar. This being in spite of their relative lack of proximity. The fact that the marina readings are consistently lower could suggest that water quality is lower at this location. This presents the obvious but not necessarily true assertion that the reduction in water quality here is associated with large numbers of various pleasure craft in use at this location. This trend is mirrored in the percentage saturation data presented below and because this parameter is generally considered a more robust indicator of water quality this issue is therefore discussed in more detail under the heading of Percentage Saturation below.

### *4.4.3.4 Percentage Saturation of Dissolved Oxygen Data*

The data recorded for percentage saturation of dissolved oxygen is presented in the chart below.

*Data Charts and Analysis:*

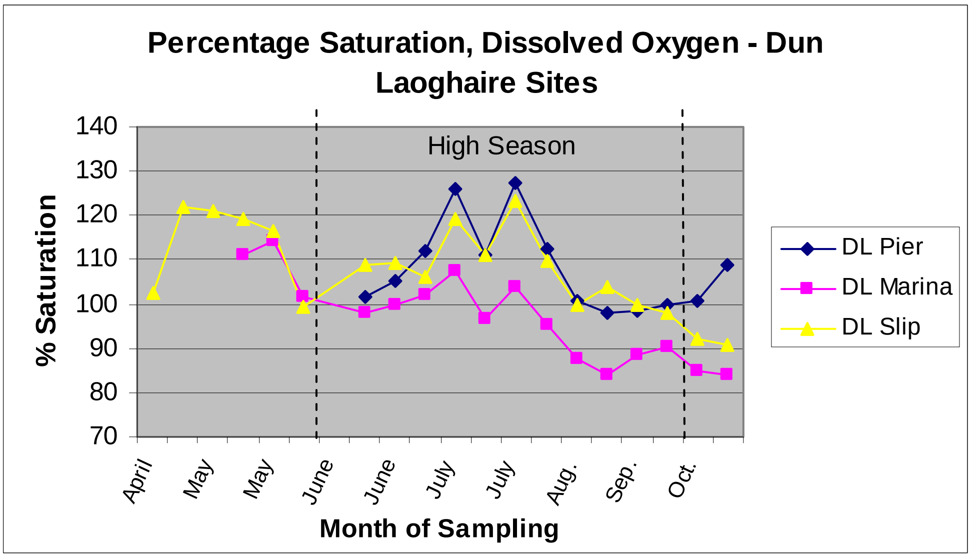



**Figure 4.98 - % Saturation of Dissolved Oxygen for Key Sampling Sites at Dun Laoghaire Harbour**

**Table 4.14 – Statistical Analysis of Dissolved Oxygen (% Saturation) Data for Key Sampling Sites at Dun Laoghaire Harbour**

| **Statistical Analysis - (T Tests)** | | | | |
|---|---|---|---|---|
| **Relationship Examined** | **Between Which Data Sets?** | **P Values =** | **Result** | **Interpretation** |
| Significant difference | High season data for Dun Laoghaire slipway and marina | DL Pier v DL Marina = 0.00481<br><br>DL Pier v DL Slip = 0.7852 | Difference is significant<br><br>Difference is not significant | Suggests lower water quality in the Marina area (possible due to leisure craft).<br>Suggests inner harbour location of slipway does not affect water quality. |

*Assigned Risk Category Frequency Charts:*

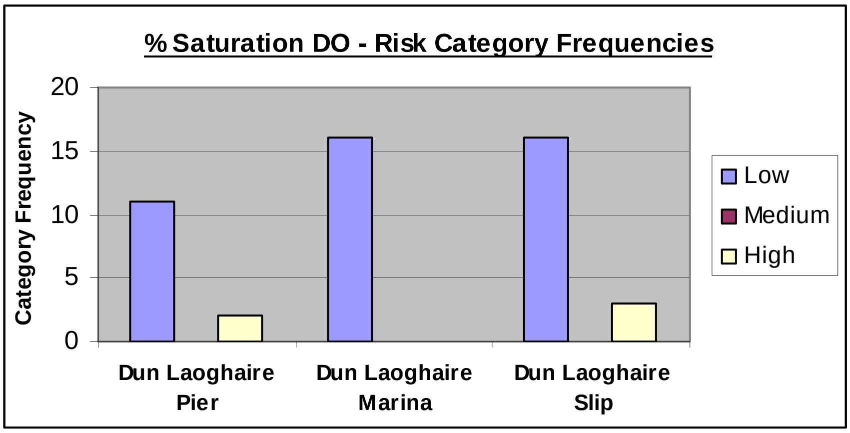



**Figure 4.99 - % Saturation (Dissolved Oxygen), Frequency of Recorded Risk Categories for Key Sampling Sites at Dun Laoghaire Harbour**

*Analysis and Interpretation:*

The basic data for percentage saturation of dissolved oxygen (see Figure 4.98) presents a mixed picture with a wide range of values being recorded through out the year. In spite of this variability the vast majority of values fell within the acceptable range according to the risk criteria outlined in the Methodology chapter (see Section 3.6.2). Review of the assigned risk category charts illustrate this fact with the majority of values being recorded as low risk. Indeed, only three samples at Dun Laoghaire Slip and two at Dun Laoghaire Pier were assigned as high risk (three of these occurring within the high season). Interestingly no values fell within the assigned medium risk category, though this probably reflects more the narrow range of this category as defined in the methodology (see Section 3.6.2). Nevertheless, the high risk values recorded at Dun Laoghaire Pier and Slipway during July and August are a cause for concern.

Nevertheless, with regard to the raw data chart, the high level of variability during both the high and low seasons makes it difficult to draw any useful interpretations regarding the possible seasonal affect of recreational activity on percentage saturation levels and its implications regarding more general water quality. That said, one consistent feature is evident in the data. This is the lower values recorded at the Marina throughout the high season. This trend was also evident in the Dissolved Oxygen data presented in Section 4.4.3.3 above and the interpretation of both is interrelated and somewhat complex. Thus initial interpretation of this pattern would suggest that the lower percentage saturation and dissolved oxygen readings at the Marina are indicative of poorer water quality at this location (the implications of this being that the high use levels of recreational pleasure craft is associated with this reduction in water quality). However, this assertion is not born out by data for the other water quality variables presented below. Furthermore, the lower values recorded at the Marina do stay within the low risk range with respect to percentage saturation and the upper end values at the Pier and Slip fall into the high risk range. This would then suggest that the pattern of consistently higher values recorded at the Pier and Slip may atypically, though feasibly, be associated with poorer water quality (as a result of over production of oxygen by marine vegetation for example, see the background information in the methodology chapter under these variables for more information on the interpretation of these variables as indicators of water quality status). Nevertheless, other factors such as super saturation of oxygen following windy weather could also provide an explanation of the higher values. In conclusion, interpretation of the data for this variable is not conclusive with respect to water quality. However, the assigned risk categories outlined in the charts above and their implications to sustainability remain valid.

#### *4.4.3.5 Ammonia (Total)*

*Data and Statistical Analysis:*

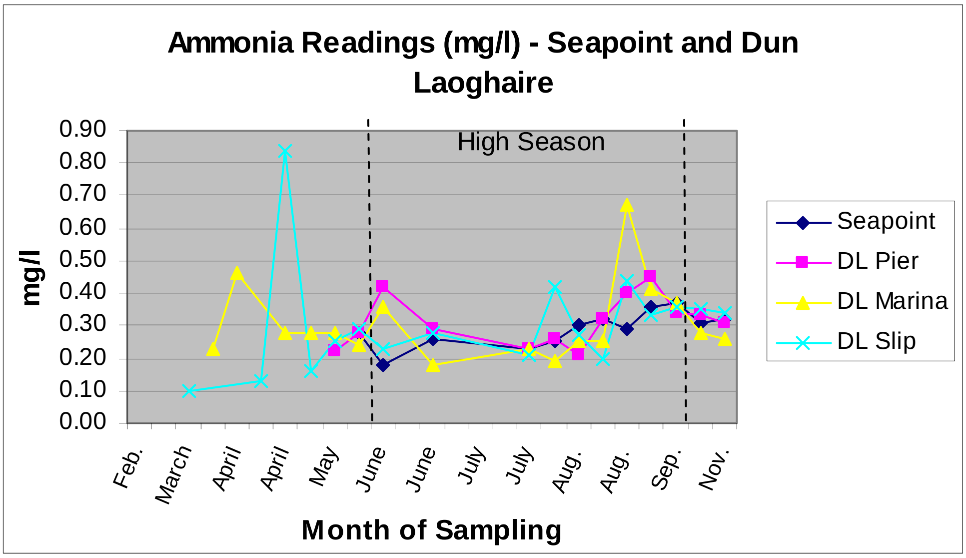



**Figure 4.100 – Ammonia Data for Seapoint and Dun Laoghaire Sampling Sites**

**Table 4.15 – Statistical Analysis of Ammonia Data for Key Sampling Sites at Dun Laoghaire**

| **Statistical Analysis - (T Tests)** | | | | |
|---|---|---|---|---|
| **Relationship Examined** | **Between Which Data Sets?** | **P Values** | **Result** | **Interpretation** |
| Significant difference | High and low season data for Dun Laoghaire Marina | = 0.51 | Difference is not significant | No significant increase in ammonia levels during the high season. |
| Significant difference | High and low season data for Dun Laoghaire slipway | = 0.97 | Difference is not significant | No significant increase in ammonia levels during the high season. |

*Assigned Risk Category Frequency Chart:*

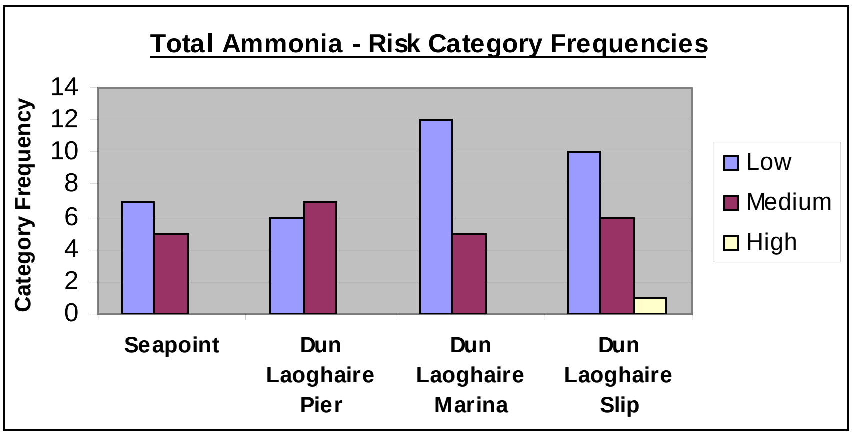



**Figure 4.101 – Ammonia, Frequency of Assigned Risk Categories, Seapoint and Dun Laoghaire Sampling Sites**

*Analysis and Interpretation:*

The raw data for total ammonia presents no marked trends or patterns of significance. However, one possibly relevant pattern is the general increase in values towards the end of the high season. At first glance this could be thought to be associated with the general increase in motor boat activity that was also recorded at this time (see Figure 4.134 in Section 4.4.3.23 below). However, the ammonia levels at Seapoint are also seen to increase at this time. No boating activity was recorded at Seapoint and therefore it is considered more likely that the rise in values at both Seapoint and in Dun Laoghaire Harbour is associated with a more general increase in ammonia levels in the region at this time. The cause of this increase remains unclear but either increases in the level of poorly treated domestic wastewater or a greater rate of algae decomposition (though no particular increase in the level of algal blooms was observed at this time) are possibilities.

Aside from possible interpretations of the raw data trends, the categorised data indicates that the proportion of ammonia values which reached unsatisfactory levels (that is, assigned as medium risk) was relatively high at all four locations. Interestingly, in this respect, Dun Laoghaire Pier, would normally be assumed to have the best water quality (due to its location), returned the highest proportion of values assigned as medium risk. This contrasts with the relatively low proportion of medium risk categories recorded at Dun Laoghaire marina where one might expect poorer water quality due to the presence of a large number of pleasure craft at this location. In a general sense, the risk category charts indicate a mixed situation regarding ammonia levels with a generally even split between low and medium risk categories. With regard to the seasonal split between low and medium risk categories, again the situation is very mixed with for example Seapoint showing a greater proportion of low risk values in the high season but Dun Laoghaire Marina showing a greater proportion of low risk values in the low season.

Aside from the prevalence of medium risk values and the sustainability issues associated with this, there is no clear information attainable from the ammonia analysis.

### 4.4.3.6 Enterococci

*Raw Data Charts:*

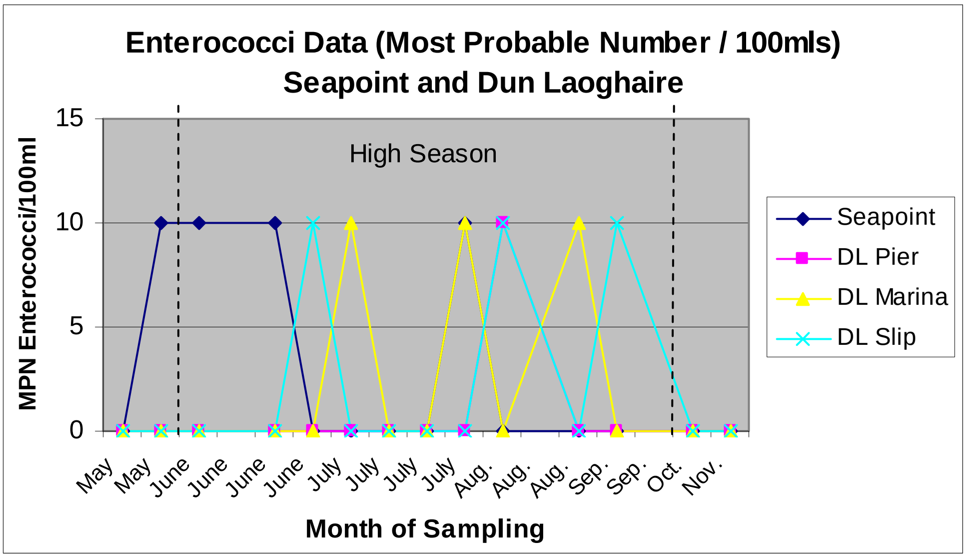



**Figure 4.102 – Enterococci Data for Seapoint and Dun Laoghaire Sampling Sites**

*Assigned Risk Category Data Chart:*

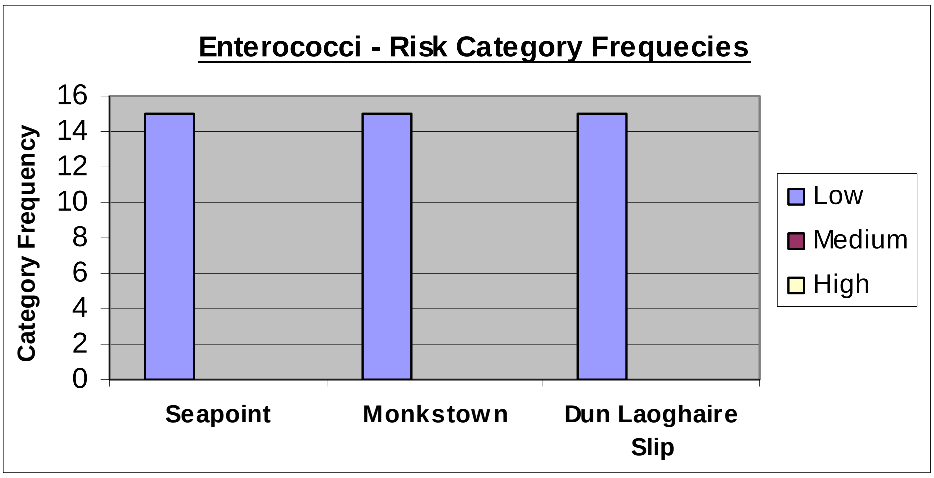



**Figure 4.103 – Enterococci, Frequency of Assigned Risk Category for Key Dublin Bay Sampling Locations**

<u>*Analysis and Interpretation:*</u>

All of the enterococci readings fell within the low risk category as outlined in the risk category criteria table in Section 3.6 (see this section for further explanation). Thus the levels of recorded enterococci are not considered an issue with regard to sustainability at Dun Laoghaire and Seapoint. Because, enterococci is widely considered to be an important marker of marine water quality (EPA, 2001; FEE, 2008) this finding has wider and positive implications regarding the general water quality status of these important coastal recreation and tourism areas. If further interpretation can be drawn from the enterococci data it is from the general observation that the, albeit slightly, higher readings were generally recorded at Seapoint and also at Dun Laoghaire Marina and Slip (the values at Dun Laoghaire Pier being better). This suggests that low level microbial contamination is evident at these locations. Because Seapoint is a widely used bathing area, this is perhaps a cause of some concern particularly if levels were seen to increase in the future. With respect to the Dun Laoghaire values, the data does shows that where slight microbial contamination occurs it is most likely at the marina or slip areas. This suggests that the marina area at least appears to have some vulnerability to this form of contamination with the possibility that it is associated with the improper disposal of sewage waste from pleasure craft using the marina. Although, the levels of contamination are currently not considered to be a problem, the data trend would affirm the need for monitoring of the situation into the future.

#### *4.4.3.7 Water Transparency Data*

Data for this quantitative parameter was recorded at Dun Laoghaire Marina only. This was due to impracticalities associated with recording this parameter at the other locations.

*Raw Data Chart and Analysis:*

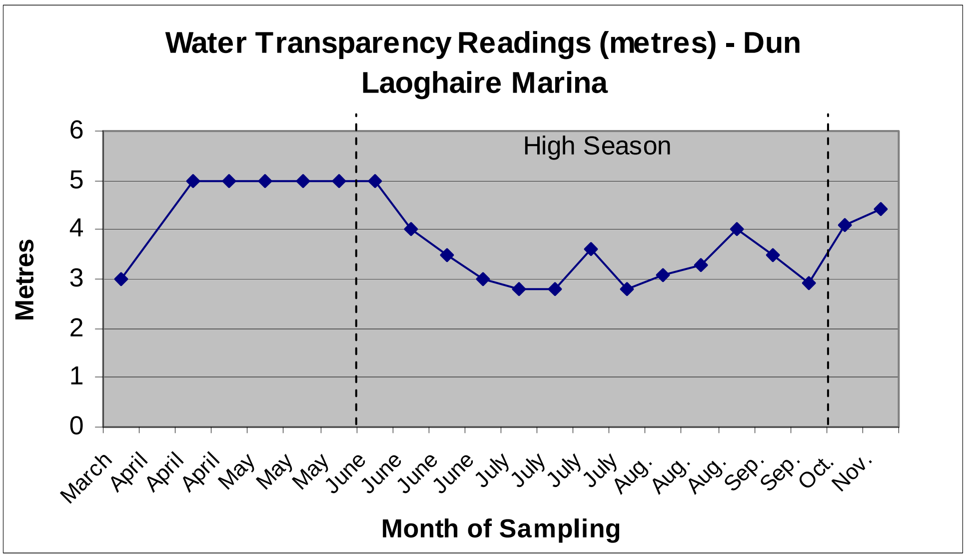



**Figure 4.104 – Water Transparency Data for Dun Laoghaire Marina**

**Table 4.16 – Statistical Analysis of Water Transparency Data for Dun Laoghaire Marina**

| **Statistical Analysis - (T Tests)** | | | | |
|---|---|---|---|---|
| **Relationship Examined** | **Between Which Data Sets?** | **P Values =** | **Result** | **Interpretation** |
| Significant difference | High and low season data for Dun Laoghaire Marina | 0.002414 | Diff. is significant. | Water Transparency was significantly lower during the high season. Suggests possible influence by pleasure craft |

*Assigned Risk Category Data Chart:*

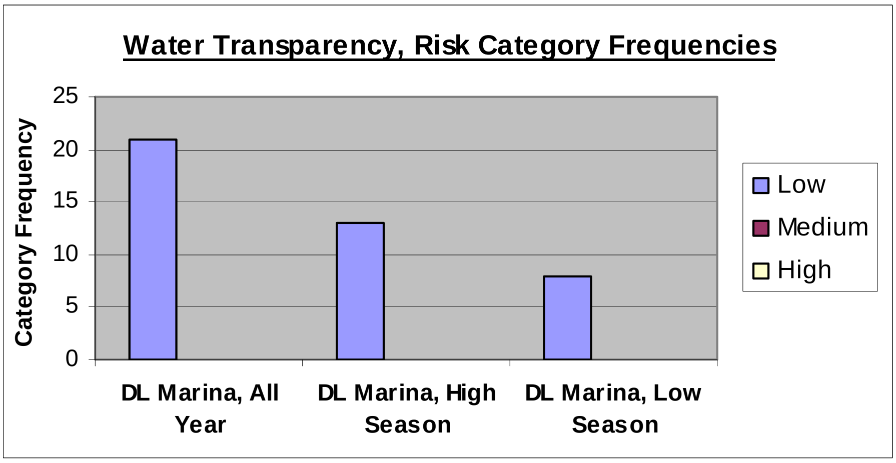



**Figure 4.105 – Water Transparency, Frequency of Assigned Risk Categories, Dun Laoghaire Marina, High and Low Seasons**

*Analysis and Interpretation:*

Although all recorded values fall within the low risk category, the year round trend does indicate a significant discrepancy between the high and low season values (see Table 4.16). In this respect, the statistical analysis confirms the significant difference between the average high and low season transparency levels in the marina. In the absence of other plausible explanations for this data trend, the assumption is made that this trend is due to the much higher numbers of boats operating within the marina during the high season. Although the disposal of wastewaters from pleasure boats may contribute to a reduction in water transparency, it is considered that the movement of boats and use of motors is probably the principal factor in the drop in transparency. Nevertheless, the transparency values remained within the low risk category. Thus, although the suspected association between transparency levels and boating activity is considered a finding of significance, the assertion here is that current levels of boating activity are sustainable with respect to this parameter.

### *4.4.3.8 Water Turbidity*

Data for the variable ‘water turbidity’ is presented in the chart below. This variable is related to the variable ‘water transparency’ and details of this relationship can be found in the Methodology Chapter under the relevant headings. As a qualitative variable, the data for water turbidity was recorded directly into risk category groups (low, medium & high) according to the criteria specified in the Methodology (See Section 3.6.10).

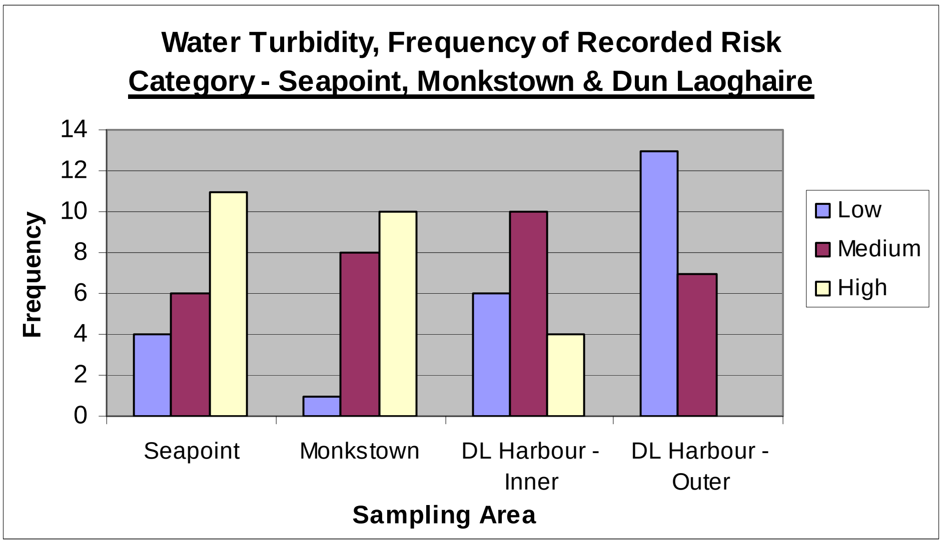



**Figure 4.106 – Water Turbidity, Frequency of Recorded Risk Categories for Key Dublin Bay Sampling Locations**

*Analysis and Interpretation:*

The most significant feature of the data presented above is the high proportion of high and medium risk categories recorded at Seapoint and Monkstown. Although, it is quite likely that the observed turbidity levels are a natural and largely harmless consequence of the physical and biological make up of Dublin bay (see Methodology Chapter for further information in this respect), it nevertheless means that the aesthetic appearance of the sea water at these locations is seriously compromised on many occasions. This inevitably presents sustainability issues at these locations.

In contrast, the data for Dun Laoghaire Harbour shows a mixed picture with low levels of turbidity most frequent in the outer section of the harbour but a significantly high proportion of medium and high risk categories observed in the inner section. These observations are most likely explained by the deeper water found at the outer section where the relative shelter and flushing by the tides prevents the build up of suspended solids in the water column. In the inner harbour there is presumably less flushing from the tide and the waters are more shallow. Together with the action of passing motor craft it is likely that this situation contributes to the levels of suspended solids in the water column in the inner reaches of the harbour. Incidentally, it is at this location where a greater density of water based activities occurs which is heightens the sustainability issues presented by the relatively high risk turbidity levels found here.

### *4.4.3.9 Floating Oil Films*

Data for the variable ‘floating oil films’ is provided in the charts below. This is a qualitative variable and therefore the data was recorded and is presented directly in terms of the frequency of each risk category as recorded on site.

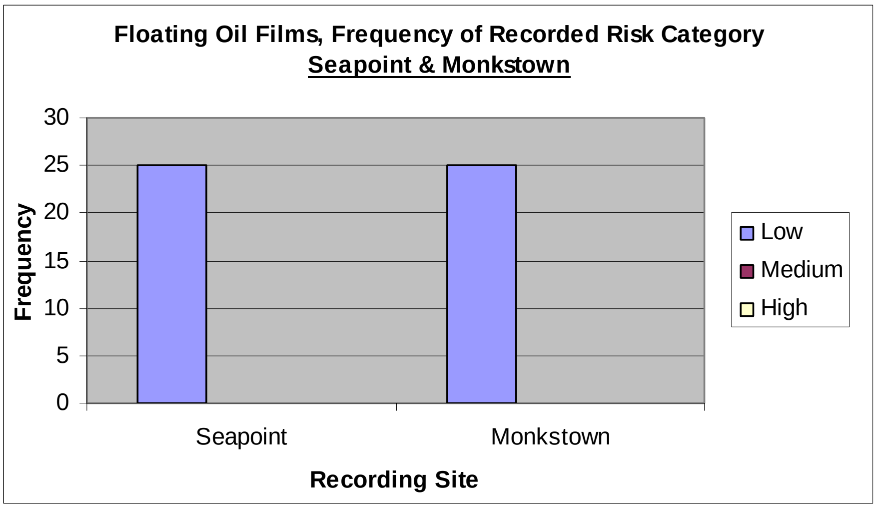



**Figure 4.107 – Floating Oil Films, Frequency of Recorded Risk Categories, Seapoint and Monkstown**

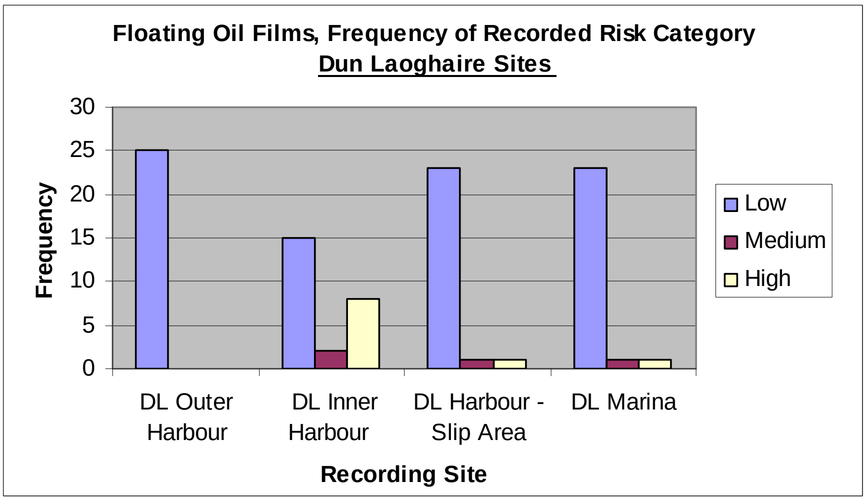



**Figure 4.108 - Floating Oil Films, Frequency of Recorded Risk Categories, Dun Laoghaire Sites**

*Analysis and Interpretation:*

The only incidences of medium or high risk categories for this variable were recorded within the confines of Dun Laoghaire harbour. The risk categories recorded at Seapoint and Monkstown were exclusively low which is a positive finding with respect to the sustainability of these locations. The data for Dun Laoghaire harbour on the other hand does present cause for concern. Interestingly, the large majority of high and medium categories occurred at the inner harbour area and not the marina and slip area as might be expected due to the large number of pleasure craft using these facilities. The data, together with on site observation, strongly indicate that the main source of oil pollution occurring within the harbour is associated with commercial fishing boats which use the pier between the marina and the inner harbour. At this location, some incidences of oil pollution were quite severe with extensive areas of floating oil films (>2000$m^2$ in area) clearly visible and strong odours prevalent. Thus, in spite of the near absence of oil pollution originating from the use pleasure craft, the prevalence of oil films arising from commercial fishing activity is nevertheless in direct conflict with the sustainability of the recreation and tourism industry at this location.

#### *4.4.3.10 Algal Blooms*

Data for the variable 'algal blooms' is provided in the charts below. As a qualitative variable the data was recorded and is presented directly in terms of the frequency of each risk category as recorded on site.

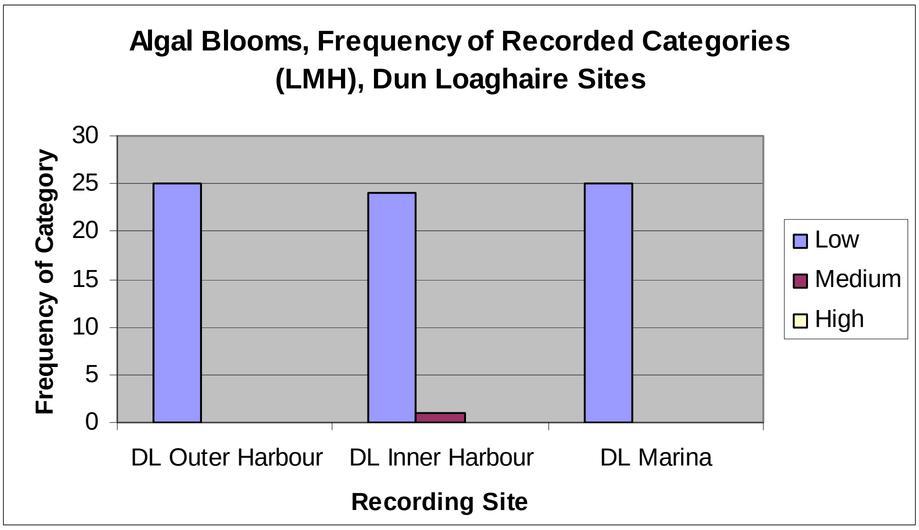



**Figure 4.109 – Algal Blooms, Frequency of Recorded Risk Categories for Key Dun Laoghaire Recording Sites**

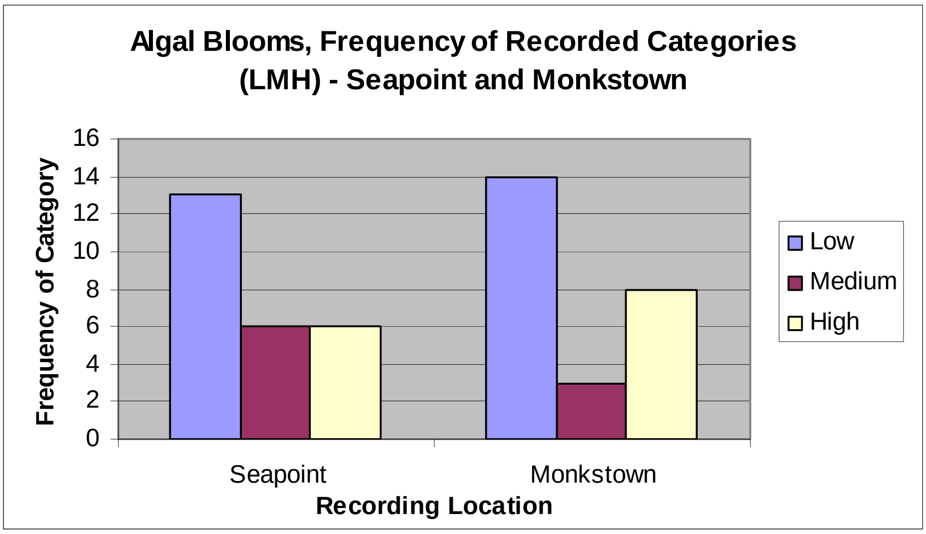



**Figure 4.110 - Algal Blooms, Frequency of Recorded Risk Categories for Seapoint and Monkstown Recording Sites**

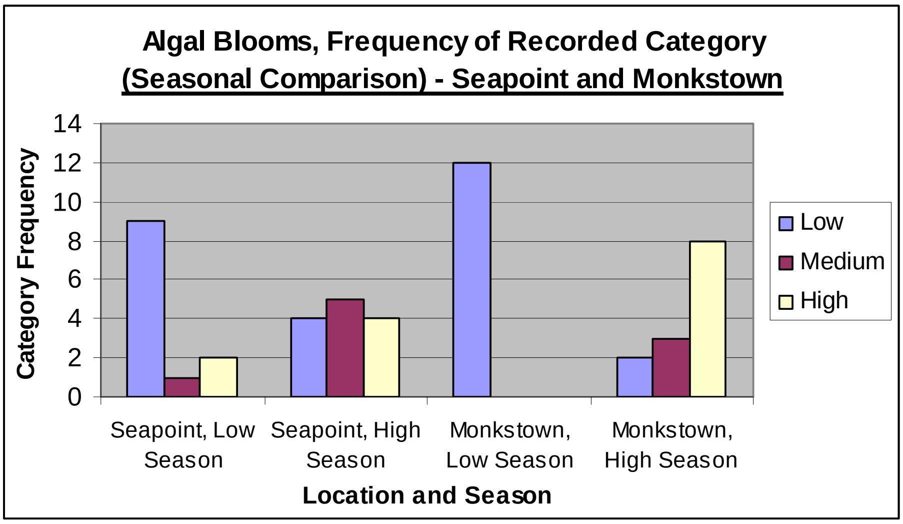



**Figure 4.111 - Algal Blooms, Frequency of Recorded Categories for Seapoint and Monkstown (Season Comparison)**

*Analysis and Interpretation:*

The data for algal blooms presents a near mirror image to that for 'floating oil films'. In this case it is Seapoint and Monkstown where the medium and high risk categories are most prevalent. Thus, while algal blooms do not present as an issue within Dun Laoghaire Harbour, the recorded levels at Seapoint and Monkstown are indicative of underlying water quality problems and at odds with the sustainability of these recreation areas. In addition, the seasonal comparison of these two sites (see Figure 4.111) shows that that the problems with algal blooms occurs primarily during the high season (particularly at Monkstown) when recreation and tourism activity along with expectation are at their highest.

### *4.4.3.11 Litter Counts*

*Raw Data Charts and Analysis:*

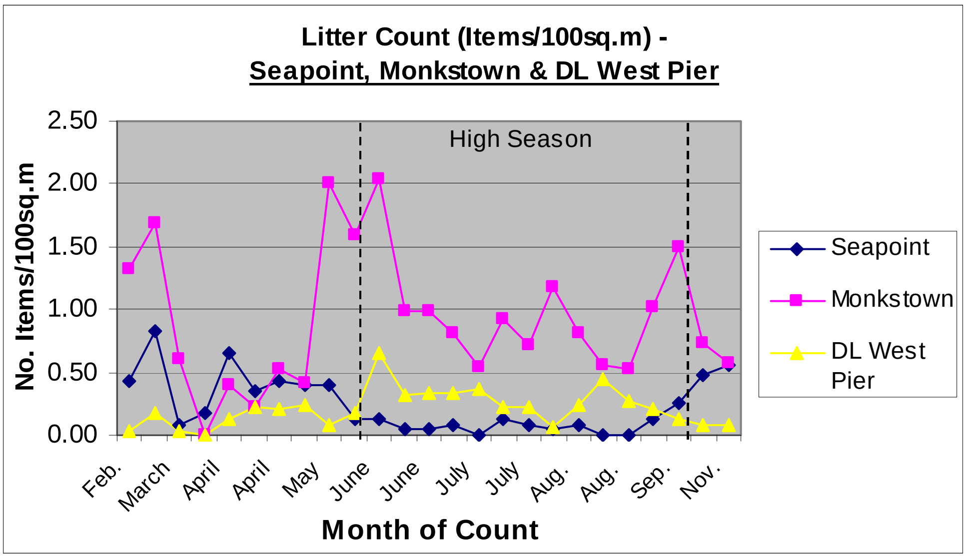



**Figure 4.112 – Litter Count Data for Key Dublin Bay Recording Locations**

**Table 4.17 – Statistical Analysis of Litter Count Data for Key Dublin Bay Recording Locations**

| Statistical Analysis - (T Tests) | | | | |
|---|---|---|---|---|
| **Relationship Examined** | **Between Which Data Sets?** | **P Values =** | **Result** | **Interpretation** |
| Significant difference | High and low season data for Seapoint | 0.000201 | Difference is significant. | Test confirms lower litter levels at Seapoint during the high season |
| Significant difference | High and low season data for Monkstown | 0.5632 | Difference is not significant. | Test confirms no significant difference between high and low season litter levels at Monkstown. |
| Significant difference | High and low season data for Dun Laoghaire West Pier | 0.00183 | Difference is significant. | Test confirms higher litter levels at Dun Laoghaire West Pier during the high season |

*Assigned Risk Category Frequency Chart:*

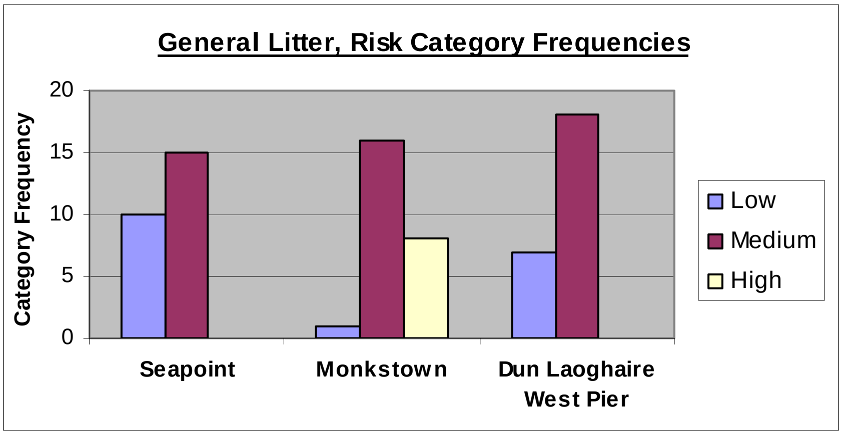



**Figure 4.113 – Litter Counts, Frequency of Assigned Risk Categories for Key Dublin Bay Survey Sites**

*Analysis and Interpretation:*

As discussed earlier in the results section for Lough Derg (Section 4.4.2), the analysis and interpretation of litter count data trends was complicated by litter management practices of the relevant local authorities. Although the undertaking and timing of litter collection is not strictly relevant to the results of this methodology, it nevertheless can provide explanation for differing observations. Thus review of the basic data chart reveals that average litter levels drop significantly during the high season (see statistical analysis in Table 4.17). This is most plausible explained by litter clean ups which were observed to be undertaken at regular intervals by local authority staff during this time. In contrast, the data for Dun Laoghaire West Pier shows litter levels increasing significantly during the high season. This area is under management by the Dun Laoghaire harbour company and no litter cleanups were seen to be undertaken by this authority. The data for Monkstown presents a very mixed picture. Generally, litter levels were relatively high but with great variability through out the year. In addition, no significant difference exists between the low and high season average levels at Monkstown. It would appear that this area falls between the jurisdiction of Dun Laoghaire harbour company and local authority and is being overlooked in terms of litter clean up. As a popular location for year round walking and picnicking litter is consequently a particular problem at this location.

The risk category data confirms the litter problems at Monkstown with a high proportion of medium and high categories recorded (during both the high and low seasons). This data also indicates unsatisfactory levels of litter occurring at Seapoint and Dun Laoghaire West Pier. Trends to note here include the fact that higher proportion of medium risk categories occurring at Seapoint and the West Pier during the low and high season respectively (not shown).

### *4.4.3.12 Floating Litter*

*Raw Data Charts and Analysis:*

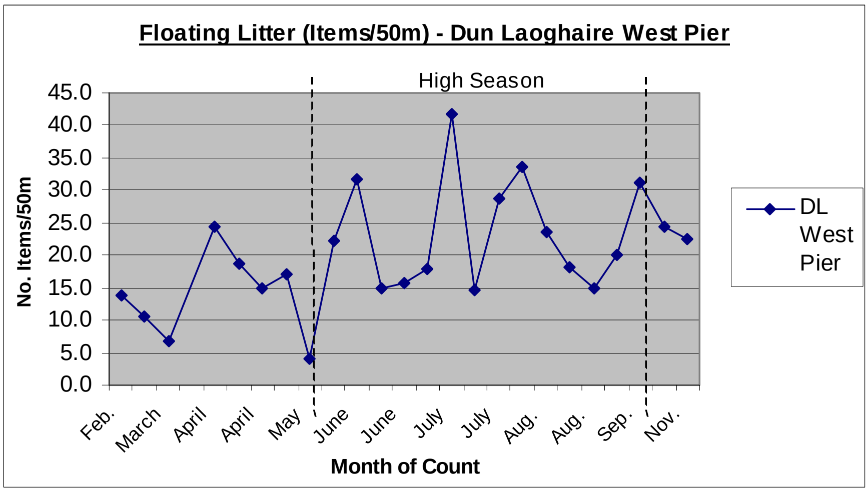



**Figure 4.114 – Floating Litter Data, Dun Laoghaire West Pier**

**Table 4.18 – Statistical Analysis of Floating Litter Data for Dun Laoghaire West Pier**

| **Statistical Analysis - (T Tests)** | | | | |
|---|---|---|---|---|
| **Relationship Examined** | **Between Which Data Sets?** | **P Values =** | **Result** | **Interpretation** |
| Significant difference | High and low season data for Dun Laoghaire West Pier | 0.0346 | Difference is significant. | Test confirms average floating litter levels were significantly higher during the high season. |

*Assigned Risk Category Data Charts:*

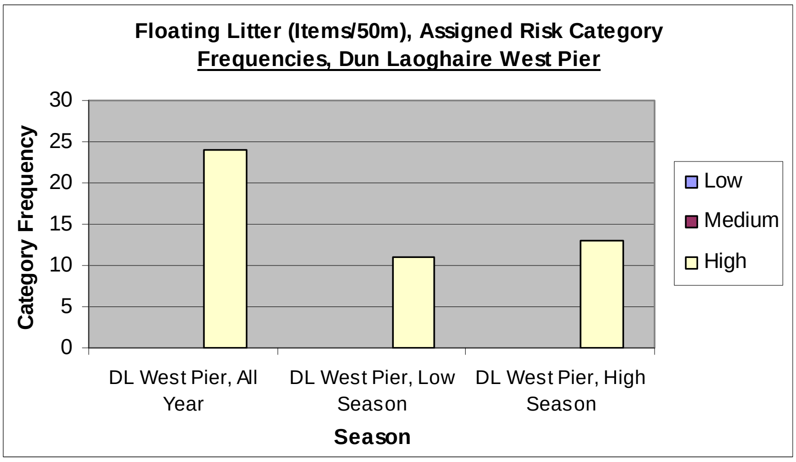



**Figure 4.115 - Floating Litter, Frequency of Assigned Risk Categories for D. Laoghaire West Pier (Season Comparison)**

*Analysis and Interpretation:*

Floating litter levels at Dun Laoghaire West Pier were notably high on almost all sampling occasions. As no removal of floating litter from the harbour was observed at any time during the year, it is considered that the higher average levels occurring during the high season (see statistical analysis in Table 4.18) are most likely associated with the extra recreational activity, including boating, that occurred during this time. Needless to say, the levels recorded here were assigned exclusively to the high risk category and are indicative of very unsatisfactory conditions with respect to this variable.

### *4.4.3.13 Foreshore Litter*

*Raw Data Charts:*

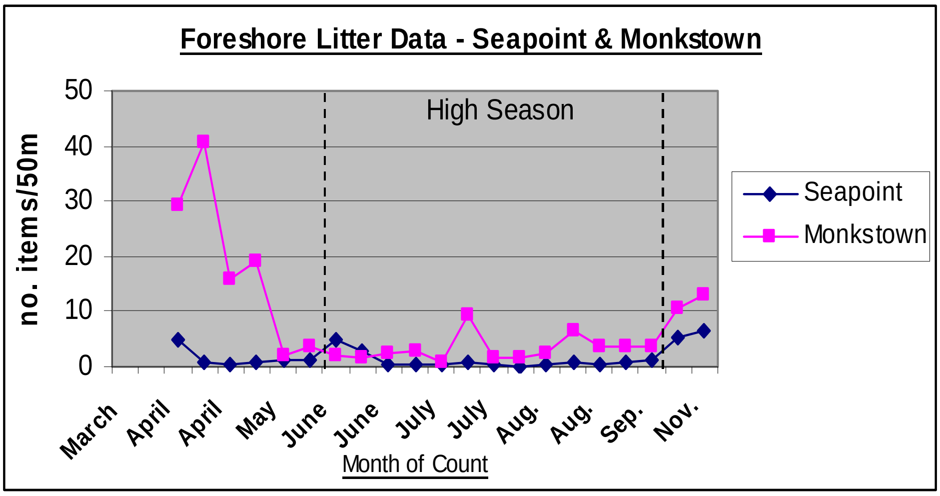



**Figure 4.116 – Foreshore Litter Data for Seapoint and Monkstown**

*Assigned Risk Category Frequency Charts:*

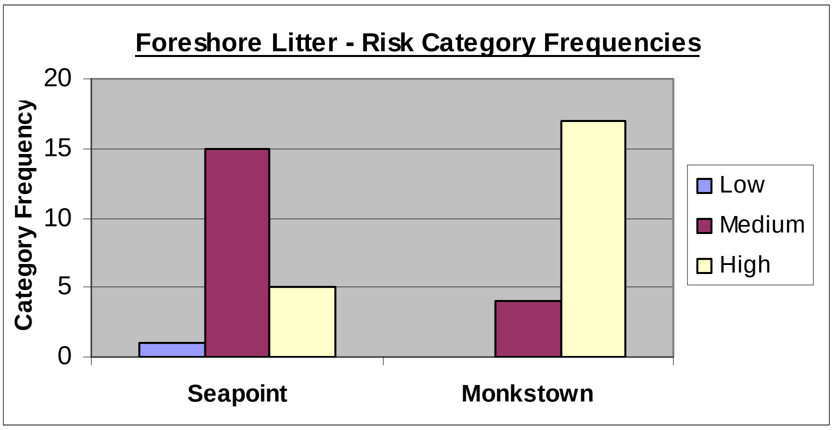



**Figure 4.117 – Foreshore Litter, Frequency of Assigned Risk Categories for Seapoint and Monkstown**

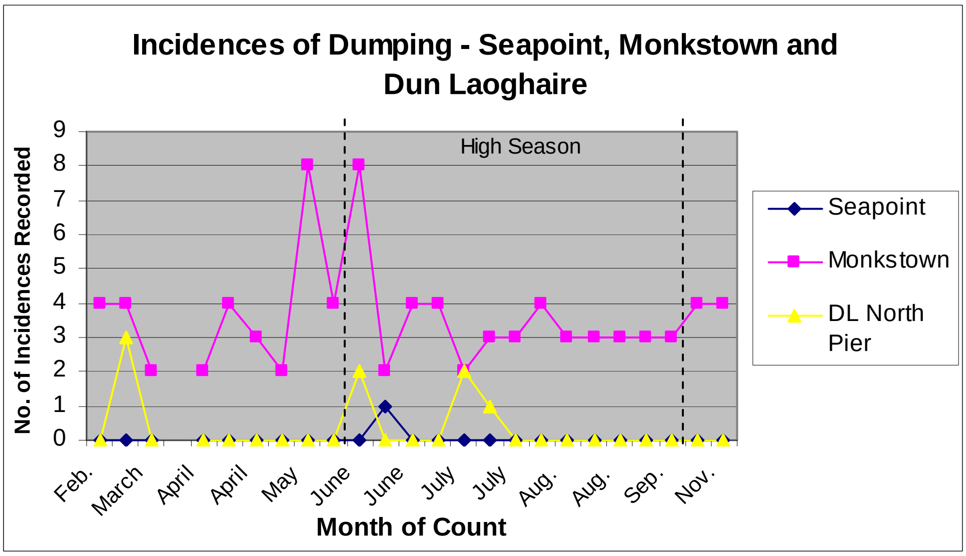
*<u>Analysis and Interpretation:</u>*

The recorded foreshore litter levels show a high degree of variability at Monkstown with very high and variable levels occurring in the winter and with lower, more consistent levels occurring during the high season. Levels here were seen to increase again after the high season. The reasons for this trend are not clear however some beach clean up measures were quite likely at the start of the high season. Nevertheless, the risk category frequency chart for Monkstown show that high risk levels of foreshore litter were still prevalent during the high season. All in all the data for this variable shows a very unsatisfactory situation ongoing at Monkstown.

The data for Seapoint was more consistent with little distinction between high and low season levels. However, review of the risk category chart for Seapoint indicates that levels here, though not as poor as at Monkstown, were still largely unsatisfactory. The seasonal comparison shows that the situation during the summer months was slightly better with a higher proportion of medium risk levels (as apposed to high risk levels) occurring at this time. Although, this trend can presumably be at least partly accounted for by the litter clearing work of local authority staff during the high season, questions still remain regarding the effectiveness of this litter management as the levels remained largely unsatisfactory.

### *4.4.3.14 Incidences of Dumping*

<u>*Data and Analysis:*</u>




<u>*Comment:*</u>

The main problem with rubbish dumping was recorded at the Monkstown amenity area. Small (in number) but visually intrusive levels of rubbish dumping was recorded through out the year at this location. On two occasions during the months of May and June, noticeably higher levels were recorded, though these were subsequently cleared by the local authority. No identifiable trend with respect to recreation levels or tourist season was recognised.

### *4.4.3.15 Dog Fouling and Dog Counts*

*<u>Raw Data Charts:</u>*

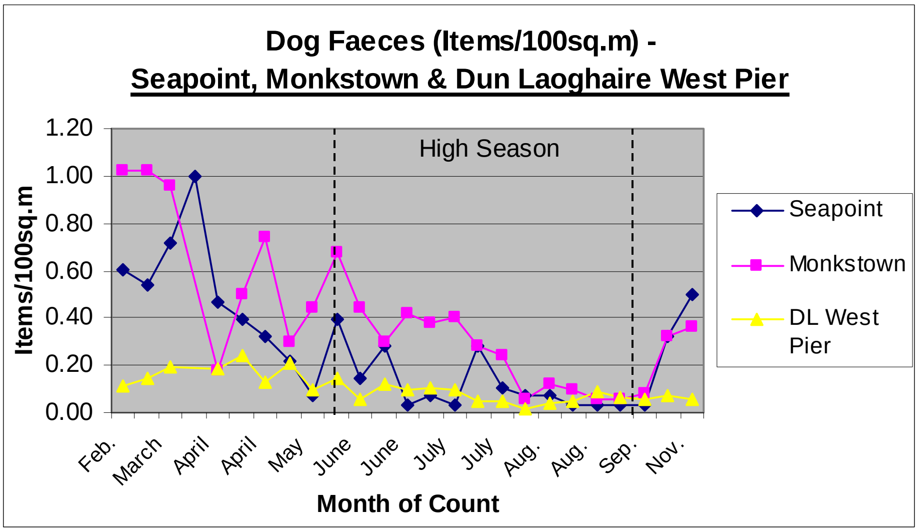



**Figure 4.118 – Dog Fouling (Faeces) Data for Dublin Bay Study Sites**

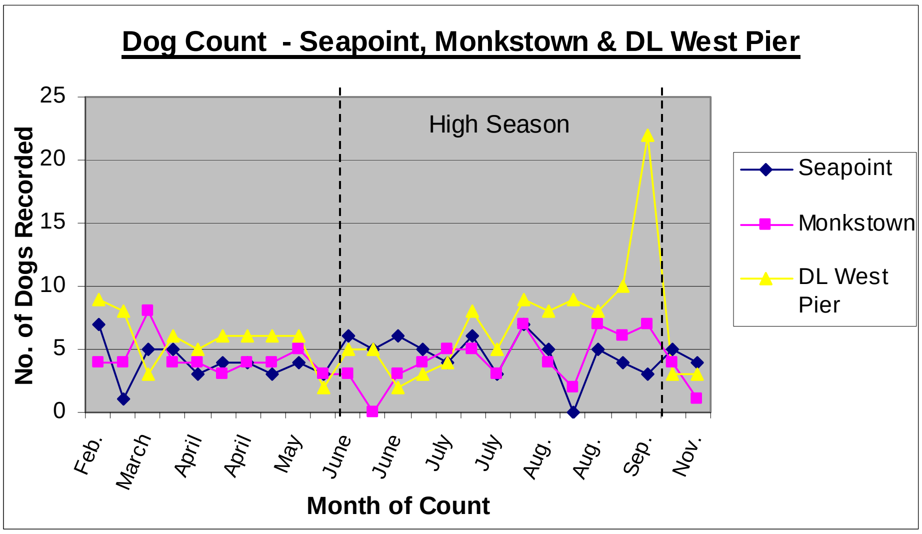



**Figure 4.119 – Dog Count Data for Dublin Bay Study Sites**

*Assigned Risk Category Frequency Charts:*

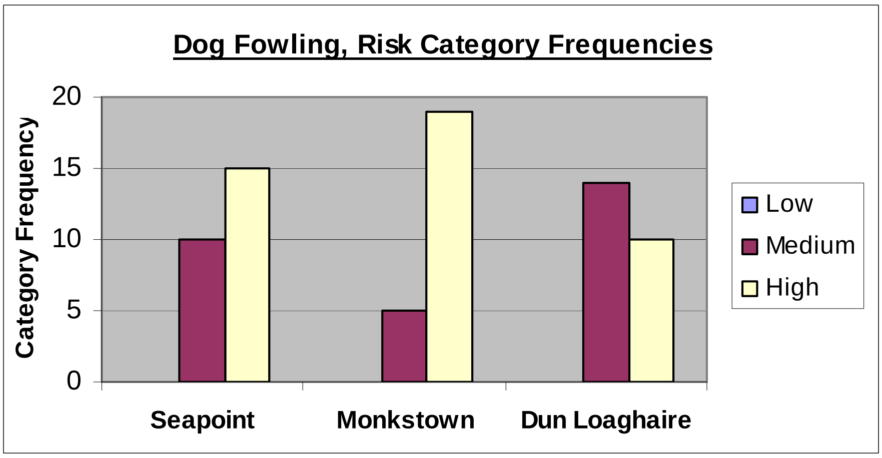



**Figure 4.120 – Dog Fouling, Frequency of Assigned Risk Categories, Dublin Bay Study Sites**

*Analysis and Interpretation:*

The basic data chart illustrates an interesting trend with regard to all three sites assessed. That is, in spite of considerable variability, there is in all cases a distinct decrease in dog fouling levels as the high season progresses. This trend is most pronounced at Seapoint and Monkstown where recorded levels during the winter months were very high and a marked increase is recorded again following relatively low levels at the end of the high season. In the absence of any known or observed efforts to remove dog fouling from these areas by local authorities, these data trends remain difficult to interpret with any certainty. This difficulty is further compounded by the data for dog counts (see chart above) which, in line with expectation, shows similar, if not higher, numbers of dogs being walked during the high season months. Two possible explanations are entertained. Firstly, it is possible that the greater number of people using these facilities during the summer months ‘encourages’ dog owners to clear up after their dogs at this time.

Equipment for such clean up is readily available at Dun Laoghaire West Pier where interestingly there is less dog fouling (than Monkstown or Seapoint) in spite of a higher number of recorded dogs present. Secondly, with warmer weather occurring during the high season, the rate of decomposition of dog faecal matter would be expected to be higher. However, the effect that this would have on the time taken for removal (through decomposition) of dog faeces has not been established.

Aside from the data patterns discussed above, the risk category data charts highlight a very poor situation regarding dog fouling with a high proportion of high risk categories occurring at all three sites. In light of the health risks associated with dog faeces and the visual connotations, this situation is considered to be highly unsatisfactory.

### *4.4.3.16 Incidences of Graffiti*

*Data Chart:*

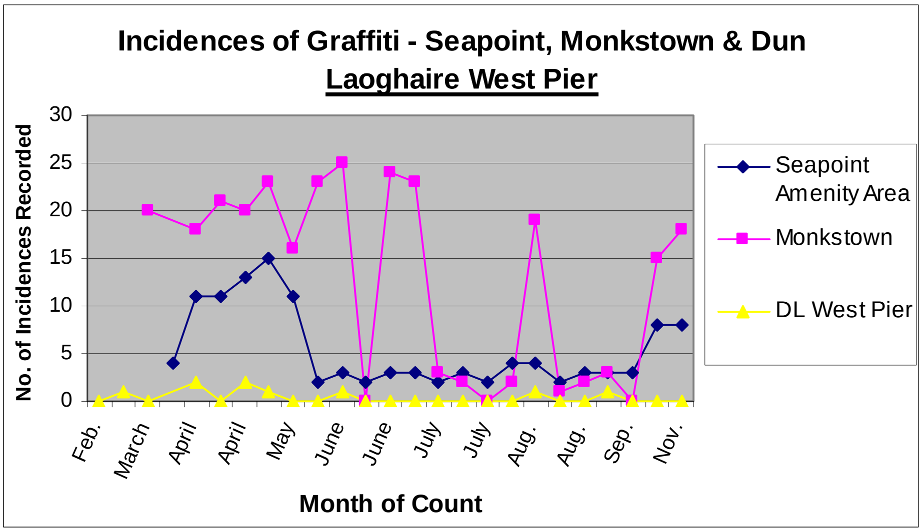



**Figure 4.121 – Graffiti Data for Dublin Bay Study Sites**

*Assigned Risk Category Frequency Chart:*

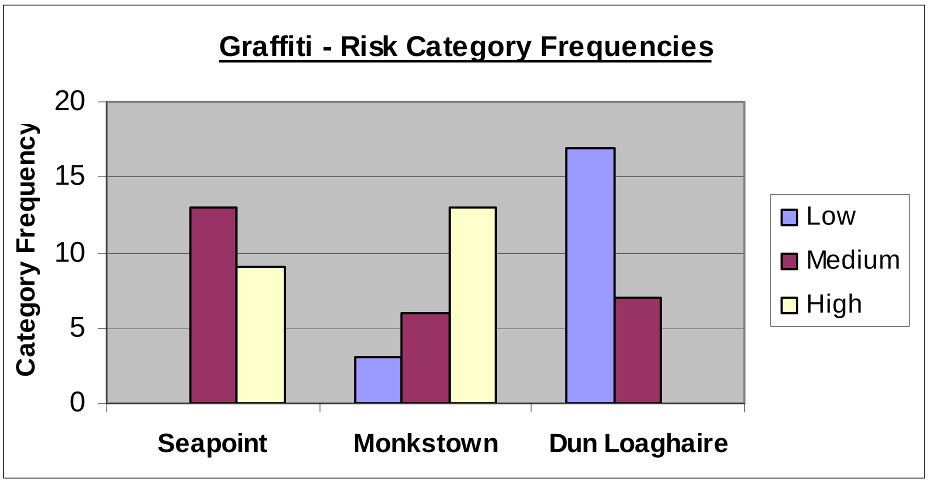



**Figure 4.122 – Graffiti, Frequency of Assigned Risk Categories, Dublin Bay Study Sites**

*<u>Analysis and Interpretation:</u>*

The data for graffiti shows high levels occurring at Seapoint and, in particular, Monkstown. The problems with graffiti at these locations were particularly bad during the low season months when high risk levels were almost exclusively recorded. It was apparent that efforts were made by the local authority to clean up graffiti at the start of the high season and these efforts were reflected in the better results recorded for these locations during the high season. In spite of this, however, a relatively high proportion of high and medium risk levels were nevertheless recorded at both Seapoint and Monkstown during the high season also, the problem again being particularly bad at Monkstown.

The results for Dun Laoghaire West Pier show graffiti to be less of a problem at this location but still a cause for concern with some incidences of medium risk categories recorded during both the high and low seasons.

### *4.4.3.17 Odours*

The variable 'odours' was recorded directly into low, medium and high (risk) categories on the basis of prescribed criteria. These criteria are outlined in the Methodology Chapter (See Section 3.6.17). The following chart illustrates the frequency of each recorded category for Seapoint, Monkstown and Dun Laoghaire West Pier.

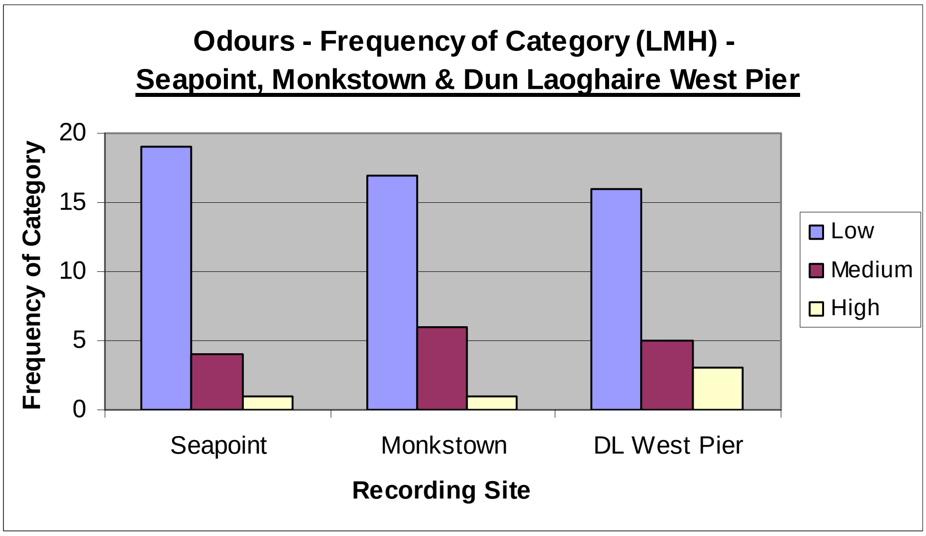



**Figure 4.123 – Odours, Frequency of Recorded Risk Category for Dublin Bay Study Sites**

<u>*Analysis and Interpretation:*</u>

A similar proportion of high, medium and low categories was recorded at each of the three sites. Although, much the largest proportion of recording were assessed as low risk, a significant proportion of medium categories and a small number of high risk categories were also recorded at all three sites. This implies that odours do present an impediment to sustainability in the context of tourism and recreation. The medium and high levels of odours recorded at Monkstown and Seapoint were attributed to decomposing algal matter whereas odours recorded at Dun Laoghaire West Pier were attributed to oil pollution originating from the commercial fishing quay.

### *4.4.3.18 Incidences of Full Waste Receptacles – Data and Analysis*

*Raw Data Chart:*

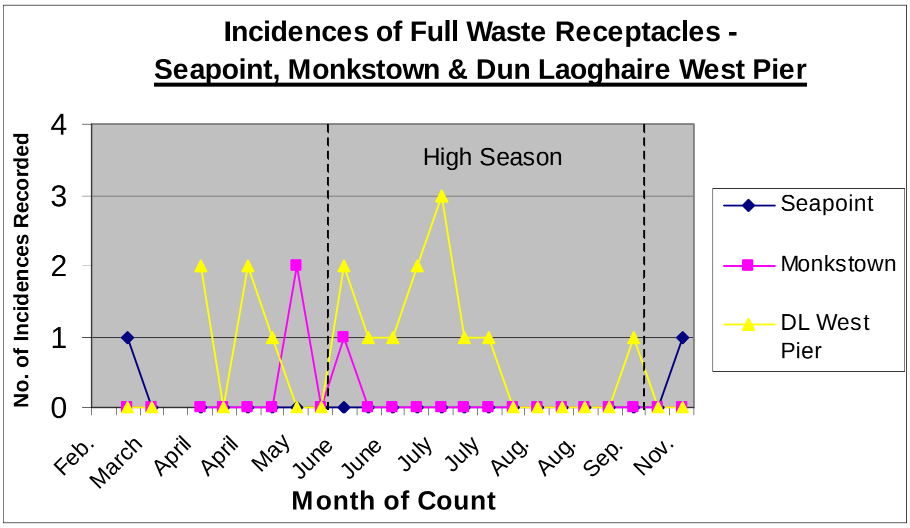



**Figure 4.124 – Full Waste Receptacles Data for Dublin Bay Study Sites**

*Assigned Risk Category Data Chart:*

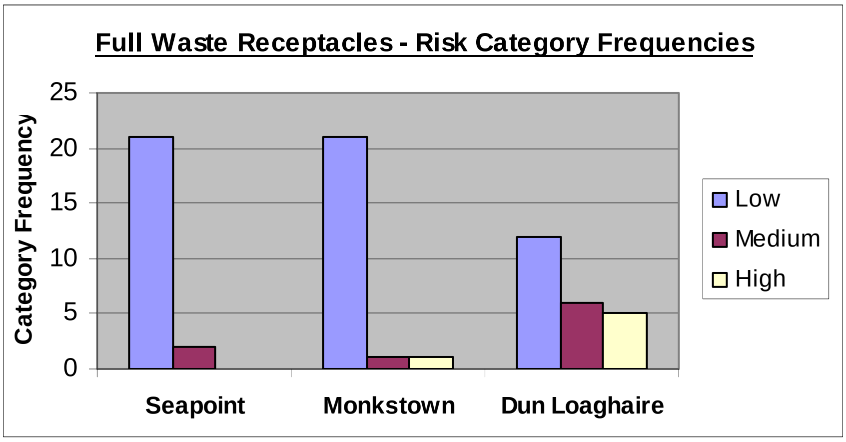



**Figure 4.125 – Full Waste Receptacles, Frequency of Assigned Risk Categories, Dublin Bay Study Sites**

*Comment:*

Data for this variable was largely variable. No particular trends regarding high or low recreation seasons were identifiable. The risk category frequency chart illustrates the relatively greater extent of this problem at Dun Laoghaire West Pier. Note that despite the data above showing Dun Laoghaire to be worst affected with regard to full waste receptacles, the data given for litter counts (see Section 4.4.3.12) shows that Monkstown is worst affected regarding actual litter on the ground.

### *4.4.3.19 Incidences of Bird Life Disturbance*

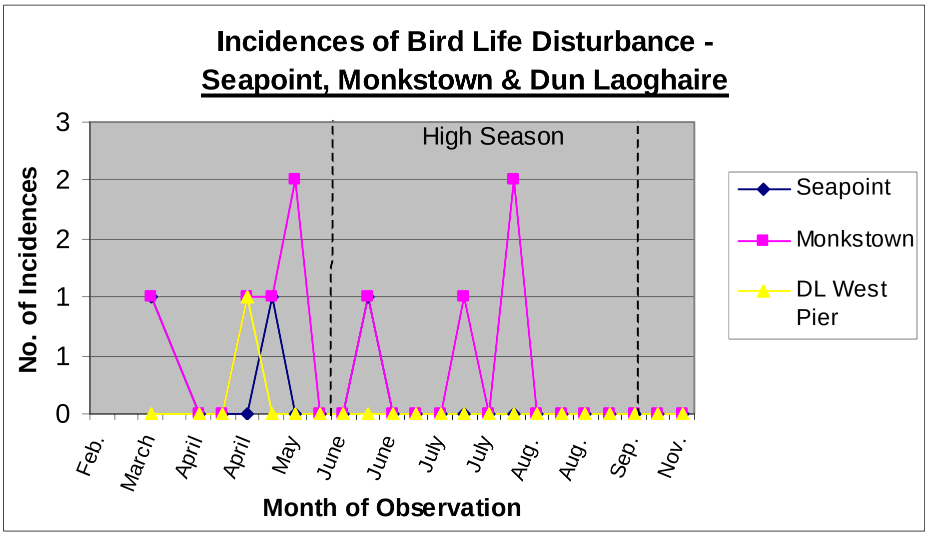



**Figure 4.126 – Bird Life Disturbance Data for Dublin Bay Study Sites**

*Comment:*

The beach and foreshore area at Monkstown was where most incidences of bird life disturbance were recorded. This was mainly associated with dogs chasing birds. However, such disturbances were as likely to occur during the low season as during the high season.

### *4.4.3.20 Bird Counts*

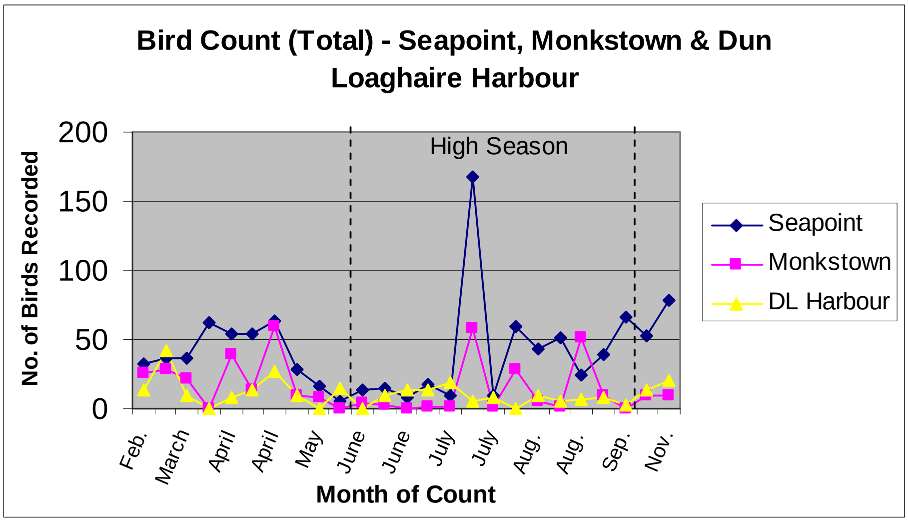



**Figure 4.127 – Total Bird Count Data for Dublin Bay Study Sites**

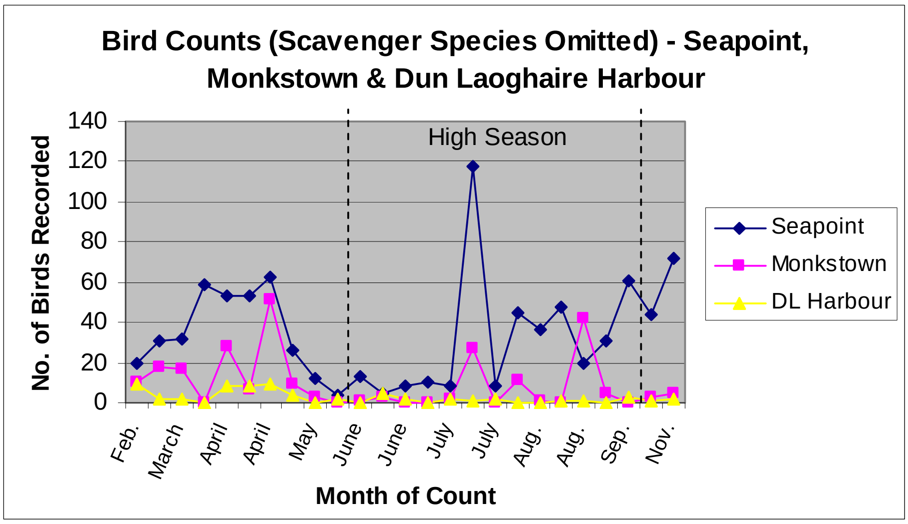



**Figure 4.128 – Bird Count Data (Scavenger Species Excluded) for Dublin Bay Study Sites**

*Comment:*

The bird count data varied considerably throughout the year, particularly at Seapoint and Monkstown, but was not out of line with expectation for this variable. The greater numbers observed generally at Seapoint and Monkstown can be attributed to the existence of rocky and sandy foreshore areas at these locations. Such areas are known to attract various wintering and resident bird species searching for food under rocks, seaweed and in the substrate. On the other hand only relatively small numbers of birds were observed at Dun Laoghaire Harbour. Although, Dun Laoghaire Harbour is a focus for recreational activity , it was not possible to infer any significance from this trend as the habitat at this location differs dramatically from that at Seapoint and Monkstown. Nevertheless, many of the birds observed during the summer months in Dun Laoghaire Harbour were scavenger species such as crows and seagulls (this trend is highlighted by the second chart which excludes scavenger species) which may to a certain extent reflect the availability of discarded food from recreational users of the harbour. The variability in the data observed for Seapoint and Monkstown can be largely attributed to weather and tide factors and the breeding, migratory and flocking habits of the birds observed. Again, these factors make it difficult to identify any trends of significance in the data.

### *4.4.3.21 Parked Car Counts*

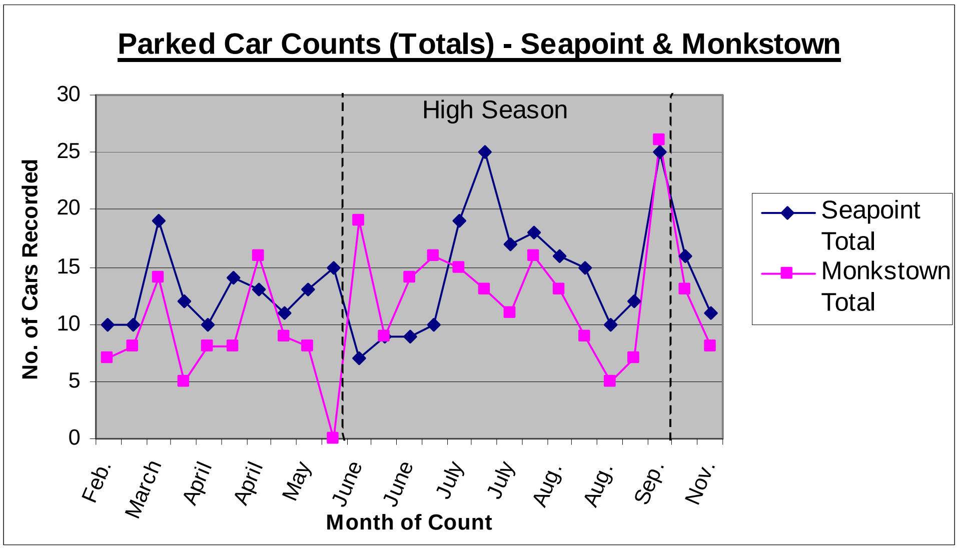



**Figure 4.129 – Parked Car Data (Totals) for Seapoint and Monkstown Amenity Areas**

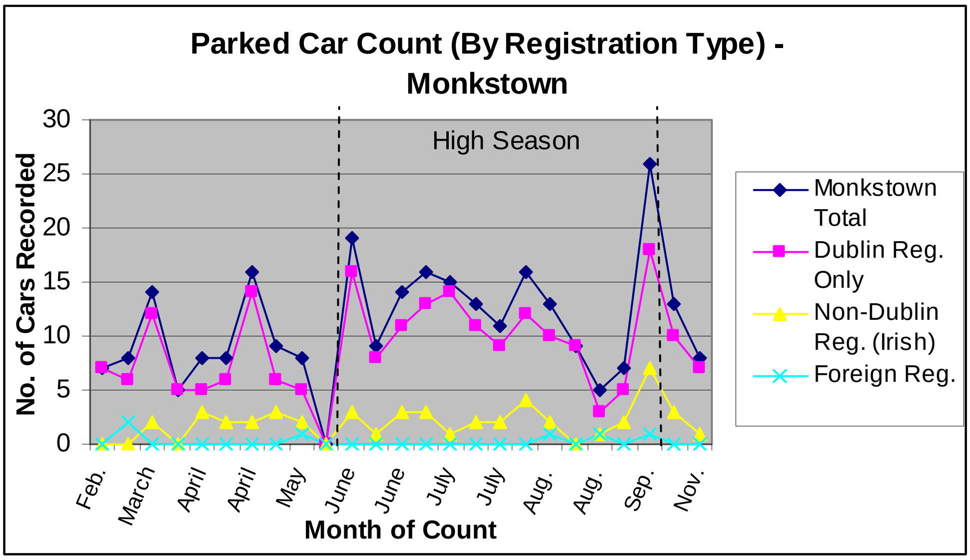



**Figure 4.130 – Parked Car Data (by Registration Category) for Monkstown Amenity Area**

*Comment:*

The data for parked cars at both Seapoint and Monkstown displayed a high degree of variability through out the year with little discernable difference between the high and low recreation seasons. Review of the second chart (Figure 4.130) indicates that it is likely that this reflects the local nature of recreation at these locations. That is, observations indicate that most visitors to these amenity areas are from the local area (this is borne out by the large proportion of local registration number plates in the car count data) and use these areas year round for all weather activities such as walking. Nevertheless, the intermittent spikes in the car count data can be attributed to occasions of fine weather during the summer months.

#### *4.4.3.22 Improper Parking*

<u>*Raw Data Charts:*</u>

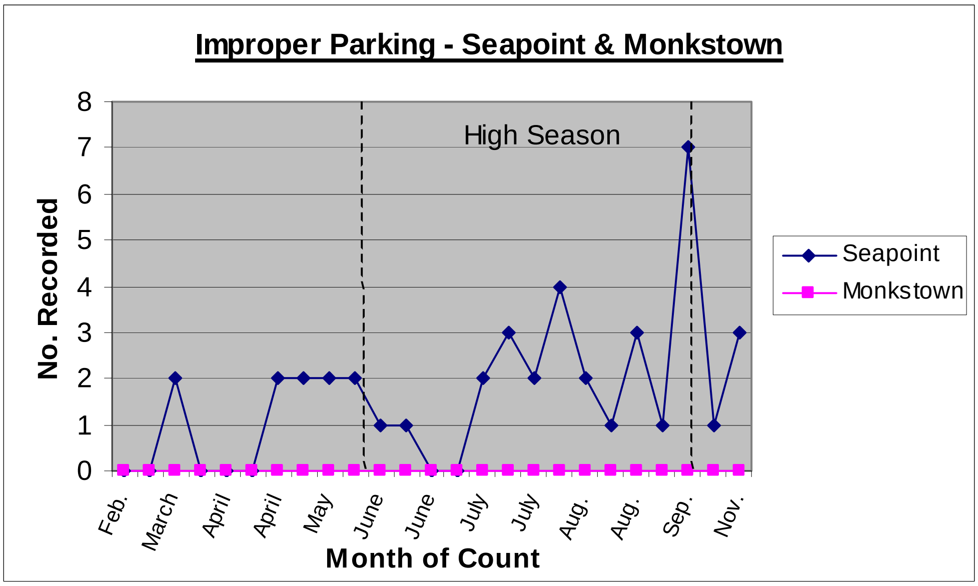



**Figure 4.131 – Improper Parking Data for Seapoint and Monkstown Amenity Areas**

*Assigned Risk Category Frequency Charts:*

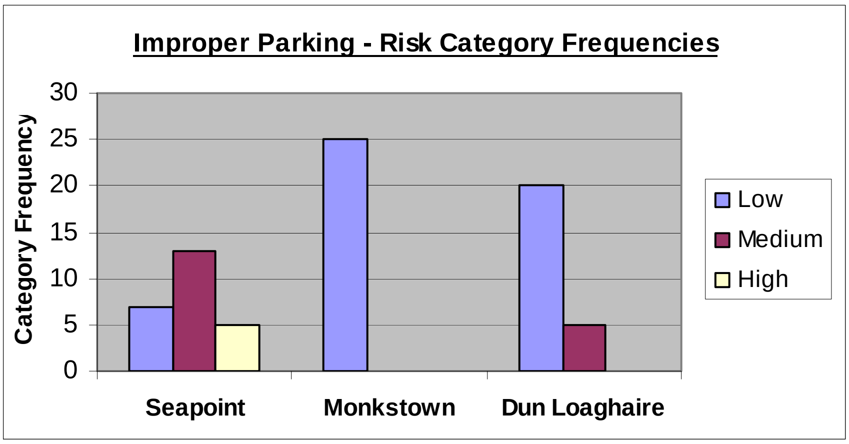



**Figure 4.132 – Improper Parking, Frequency of Assigned Risk Categories for Dublin Bay Study Sites**

*Comment:*

The main trend of note regarding this variable is the contrast between the data for Monkstown and Seapoint. This presumably reflects the ample parking available at Monkstown and the limited parking at Seapoint which is shared by residents and visitors to the area. Although, improper parking was highest during the summer months it is notable that improper parking at Seapoint occurred well outside of the high recreation season as well. Not surprisingly, the categorised data for Seapoint shows a significant level of medium and high risk levels which serve to highlight the problem with parking at this location.

### 4.4.3.23 Boating Data

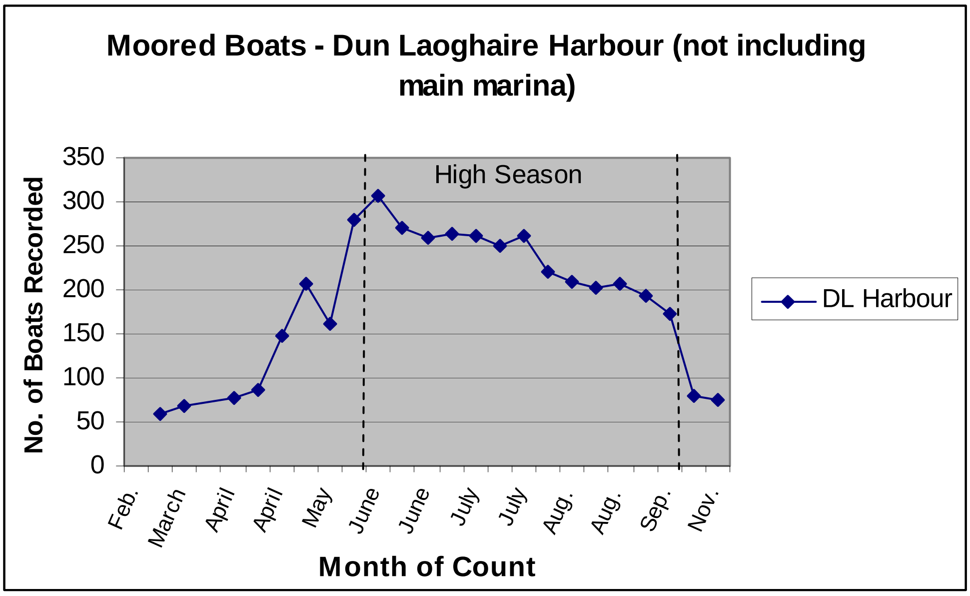



**Figure 4.133 – Moored Boats Count Data for Dun Laoghaire Harbour**

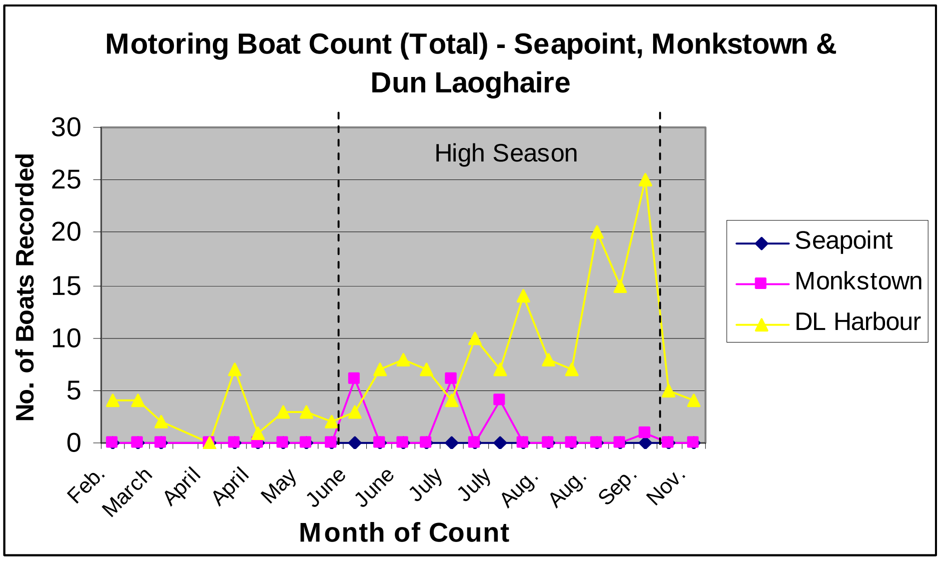



**Figure 4.134 – Motoring Boat Count Data for Dublin Bay Study Sites**

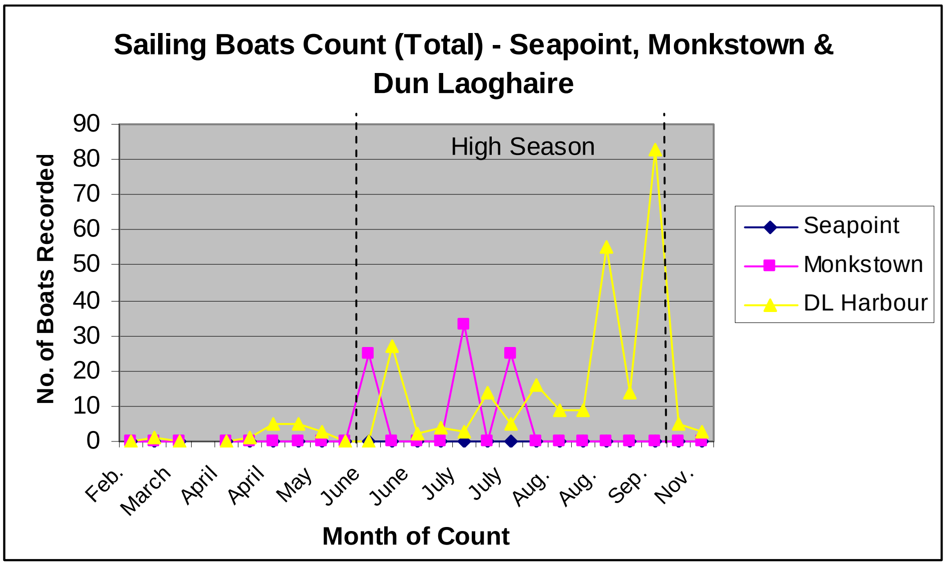



**Figure 4.135 – Sailing Boats Count Data for Dublin Bay Study Sites**

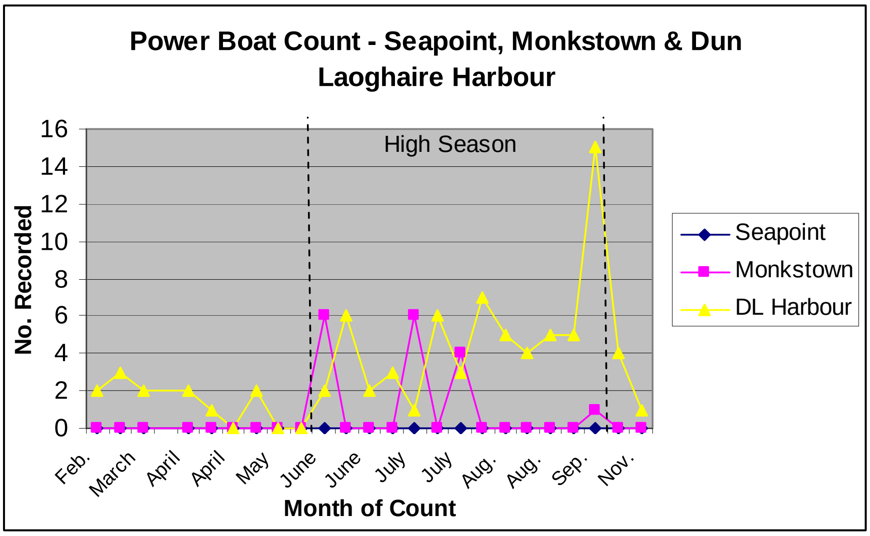



**Figure 4.136 – Power Boat Count Data for Dublin Bay Study Sites**

*Comment:*

The data for moored boats was largely predictable and served as an aid for determining the beginning of the high recreation season at Dun Laoghaire Harbour. In this respect, it was observed that most of the wintered cruisers were launched for the summer sailing season during April and May.

The number of motoring boats varied significantly from week to week but a general upward trend during the high season was observed at Dun Laoghaire Harbour. This trend fell away dramatically after September. Motoring boats comprising predominantly of high powered boats were observed intermittently at Monkstown, these largely confined to the summer months. In this regard, it was noted that the Monkstown amenity area was used as a launching area for jet skis and also rigid inflatable boats belonging to the adjoining sailing school at this location. The use of high powered boats was also a feature of the Dun Laoghaire Harbour data. Numbers were significantly higher during the summer months, though power boats were also recorded during the spring, autumn and winter months. Sailing boat numbers also varied significantly but were more noticeable confined to the summer months.

### *4.4.3.24 Ambient Noise Data - $L_{Aeq}$ and $L_{A90}$*

*Raw Data Charts and Analysis:*

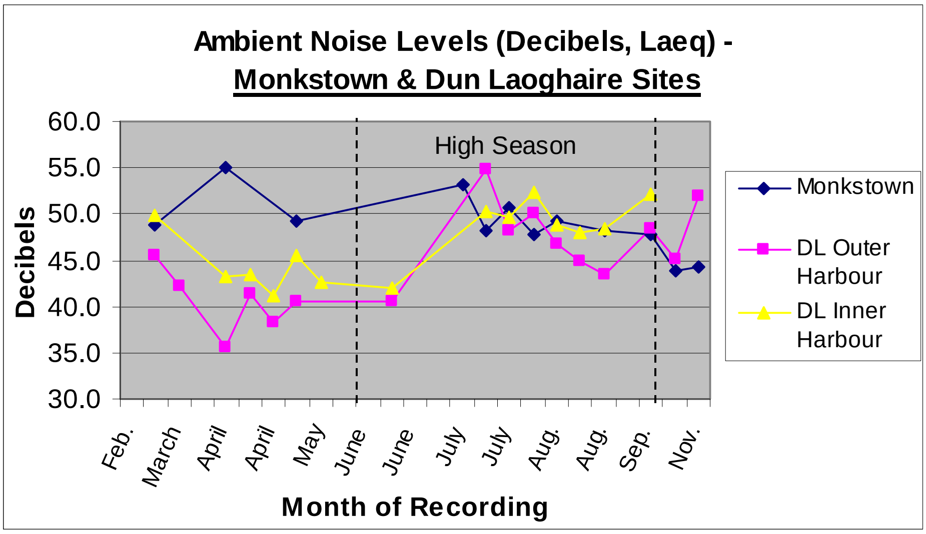



**Figure 4.137 – Ambient Noise Data ($L_{Aeq}$) for Monkstown and Dun Laoghaire Harbour**

**Table 4.19 – Statistical Analysis of Ambient Noise Data ($L_{Aeq}$) for Dun Laoghaire Harbour and Monkstown**

| **Statistical Analysis (T Tests) – $L_{Aeq}$ Data** | | | | |
|---|---|---|---|---|
| **Relationship Examined** | **Between Which Data Sets?** | **P Values =** | **Result** | **Interpretation** |
| Significant difference | High and low season data sets for Dun Laoghaire Outer Harbour | 0.02753 | Difference is significant | Average ambient noise levels are significantly higher during the high season. |
| Significant difference | High and low season data sets for Dun Laoghaire Inner Harbour | 0.03101 | Difference is significant | Average ambient noise levels are significantly higher during the high season. |
| Significant difference | High and low season data sets for Monkstown | 0.2860 | Difference is not significant | No significant difference was observed between average high and low season ambient noise levels. |

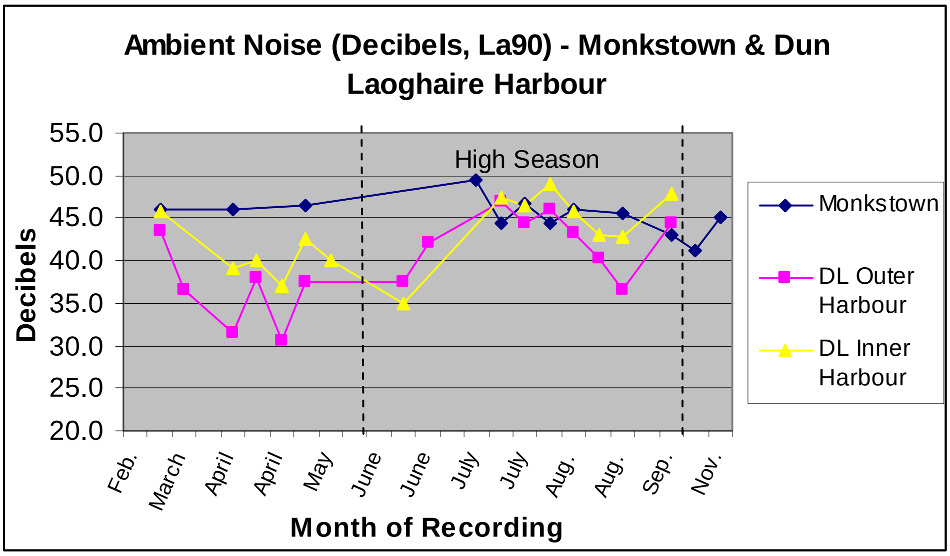



**Figure 4.138 - Ambient Noise Data ($L_{A90}$) for Monkstown and Dun Laoghaire Harbour**

**Table 4.20 – Statistical Analysis of Ambient Noise Data ($L_{A90}$) for Dun Laoghaire Harbour and Monkstown**

| Statistical Analysis (T Tests) – $L_{A90}$ Data | | | | |
|---|---|---|---|---|
| **Relationship Examined** | **Between Which Data Sets?** | **P Values =** | **Result** | **Interpretation** |
| Significant difference | High and low season data sets for Dun Laoghaire Outer Harbour | 0.06801 | Difference is not significant | No significant difference was observed between average high and low season ambient noise levels. |
| Significant difference | High and low season data sets for Dun Laoghaire Inner Harbour | 0.2285 | Difference is not significant | No significant difference was observed between average high and low season ambient noise levels. |
| Significant difference | High and low season data sets for Monkstown | 0.2136 | Difference is not significant | No significant difference was observed between average high and low season ambient noise levels. |

*Assigned Category Frequency Charts:*

Recorded values were assigned into risk categories for the $L_{Aeq}$ Parameter data only. The frequency chart is provided below:

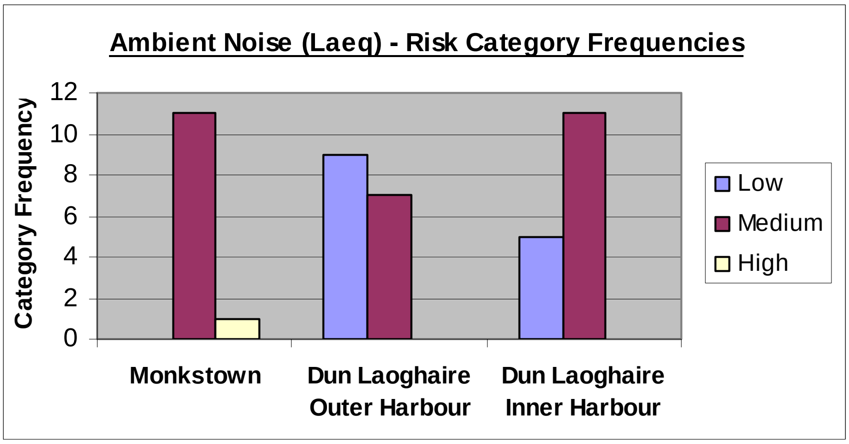



**Figure 4.139 – Ambient Noise ($L_{Aeq}$), Frequency of Recorded Risk Category for Dun Laoghaire Harbour and Monkstown**

*Analysis and Interpretation:*

Both the LAeq and La90 data showed primarily higher average noise values occurring during the summer high season months at the inner and outer sections of Dun Laoghaire harbour. However, statistical analysis of the data shows that for the La90 parameter the difference between the low and high season data for these two locations is not significant (at a confidence level of 95%). On the other hand, the difference between the low and high season data, for these locations, was shown to be statistically significant for the LAeq data. Thus in this context, the LAeq form of noise measurement has proven to be a more informative parameter distinguishing between average noise levels when little or no boating activity was observed (during the low season) and levels when significant levels of boating activity were observed (during the high season). For this reason, it was decided to focus on the LAeq parameter for interpretation of the noise data and also for the assigning of risk categories according to the criteria prescribed in the Methodology Chapter. Thus the charts presenting the frequency of assigned risk categories applies to the LAeq noise parameter only.

With regard to the LAeq noise data it is notable that the distinction observed between high and low season average noise levels at the inner and outer sections of Dun Laoghaire harbour was recorded despite the existence of considerable background noise attributable to urban activity associated with Dun Laoghaire town (such noise was observed to originate primarily from motor traffic and the DART suburban rail system). This background noise was particularly noticeable at the inner harbour sampling point. This means that the increase in noise levels recorded during the high season was over and above that caused by the background urban noise. In many ways, this adds extra significance to the noise originating from motor boat activity in Dun Laoghaire harbour during the high season. Such noise was identified at the time of sampling as the only appreciable difference between the recorded high and low season noise data. With regard to the implications of these patterns, the risk category charts serve to highlight the situation with a significantly higher proportion of medium risk categories recorded at both locations during the high season. The smaller proportion of medium risk categories recorded during the low season serves to highlight the still significant levels of noise occurring at these locations during the low season which can be attributed to background urban noise.

In contrast to the data for Dun Laoghaire harbour, the data for Monkstown shows little difference between high and low season values. This can be largely explained by the proximity of the Monkstown recording site to both the DART railway line and a busy road following the coastline north towards Dublin city centre. Noise levels at Monkstown were thus dominated by road and rail traffic which was largely the same irrespective of the time of year. Any potential increase in noise levels at this location due to recreational activity was effectively screened by this urban noise. Nevertheless, with regard to the question of sustainability, the risk category chart shows that the recorded values largely fell into the medium risk level at this location. Thus, in the context of the sustainability of recreation and tourism at Monkstown, noise levels are still a cause for concern here regardless of their origin.

## 4.5 Summary of Results and Analysis for Lough Derg and Dublin Bay Study Areas

A summary of notable findings drawn from analysis of the basic data recorded for all variables is given in this section. Further details are contained in the previous section under the relevant section headings for each variable.

### 4.5.1 Lough Derg Study Areas

Application of the methodology has demonstrated that all three sites studied at Lough Derg had potential problems regarding the environmental sustainability of tourism and recreation at these locations. In particular, the data shows that both Terryglass and Dromineer had persistent year round problems with regard to water quality, littering and dog fouling. During the summer months these problems were exacerbated by high levels of noise, floating litter and algal blooms. These findings are largely at odds with the general perception and often promoted image of Lough Derg as having an unspoilt and tranquil environment (North Tipperary County Council, 2004).

The water quality issues identified at Terryglass and Dromineer were most prominent in the harbour areas of these locations and spanned the entire set of variables recorded with respect to water quality. The data shows frequent occurrences of medium or high risk levels recorded throughout the year for dissolved oxygen, phosphates, coliforms and water transparency. In addition, high risk levels of floating oil films and algal blooms were recorded on numerous occasions during the summer high season.

Comparison of data patterns for the different sites at Terryglass and Dromineer and for the different seasons suggests that the water quality problems at these locations are not directly linked to tourism and recreational activity. Rather it appears most plausible that the excessive nutrient levels and associated problems (such as algal blooms, poor water transparency and fluctuating dissolved oxygen levels) are linked to the general nutrient enrichment problems associated with Lough Derg in general (EPA, 2004; Neill, 2005). It would also appear that these lake wide problems are being exacerbated by faecal contamination of both human and animal origin entering the lake close to Dromineer and Terryglass harbour from the Nenagh and Terryglass rivers respectively. Once again this problem, although not necessarily linked to or resulting from tourism or recreation, nevertheless presents challenges with regard to the sustainability of the tourism and recreational industry at Lough Derg.

In addition to the water quality problems recorded at Terryglass and Dromineer, problems associated with littering, dog fouling and noise levels were also shown to be prevalent at these locations. The littering problem involved both land based litter and floating litter in the harbour and foreshore areas of each location. A high proportion of medium and high risk levels of land based litter was recorded at both sites throughout the year. Interestingly, the litter problem at Dromineer was greater during the winter months. Floating litter was a particular problem in the harbour areas of Dromineer and Terryglass with a very high proportion of high risk levels recorded at both locations during the high season. Levels of floating litter recorded during the winter months were not as high but still a cause for concern nevertheless. Dog fouling proved to be a serious issue throughout the year at Dromineer and Terryglass with a high proportion of high risk levels recorded year round. The problems of dog fouling were deemed to be particularly bad at Dromineer. Noise was also an issue of concern at Terryglass and Dromineer with a significant proportion of medium risk levels recorded primarily during the high season. Together with on-site observations, analysis of the noise data suggests strongly that excessive noise levels were primarily associated with the use of either high-powered outboard engine driven boats or jet skis. The operation of lake cruiser type boats was observed to raise background noise levels significantly but generally such activity did not push ambient noise levels into the medium or high risk categories. Unlike other problem variables, it is important to note that the noise problems appear to be directly attributable to activities associated with the recreation and tourism industry.

The sustainability issues identified at Meelick, although still a cause for concern, were confined to fewer environmental parameters than at Terryglass and Dromineer. In this regard, littering and dog fouling were noted as particular problems occurring at Meelick throughout the year. Water quality issues were also identified at Meelick but these were confined to Phosphate, Dissolved Oxygen and algal bloom levels. Microbial contamination (faecal coliforms) and floating oil pollution was not a problem at Meelick. With regard to the potential source of water quality issues at Meelick, it is likely that these findings are largely indicative of the general over enrichment problems associated with Lough Derg (Neill, 2005) and are therefore not an indication of any locally sourced pollution. Moreover, the absence of any significant levels of faecal contamination at Meelick should be highlighted in a positive sense.

With regard to the remaining environmental variables recorded at Meelick Bay, satisfactory levels (low risk) were recorded on all occasions regardless of season. These variables include ambient noise, graffiti, floating litter, faecal coliforms, floating oil films, illegal parking and overcrowding. In the context of these environmental parameters, Meelick Bay represents a very natural and unspoilt environment and amenity area and provides a useful frame of reference for environmental quality when contrasted against similar sites such as Terryglass and Dromineer. The environmental quality of Meelick Bay is further enhanced by the existence of areas of natural lakeshore and woodland habitat. However, the positive aspects of Meelick Bay only serve to highlight the problems recorded at this location with respect to litter, dog fouling and algal blooms in particular.

### 4.5.2 Dublin Bay Study Areas

Results for the Dublin Bay study areas present a mixed picture with differing sustainability issues evident at the three locations studied, Seapoint, Monkstown and Dun Laoghaire Harbour and West Pier. As with the Lough Derg sites, litter and dog fouling were noted as particular problems occurring at all three sites through out the year. Water quality issues were also recorded at all three sites but the nature of the problem differed between sites. Other issues of note include the prevalence of odour problems at all three sites and the problems associated with graffiti which were particularly evident at Monkstown. Problems associated with noise were recorded at both Monkstown and Dun Laoghaire Harbour.

The situation regarding litter was quite complex due to the differing nature of the three locations. The data for general litter showed that levels at Seapoint were higher during the winter months but with medium and high risk levels still observed frequently during the summer months. In contrast and more in line with expectation, litter levels were seen to increase during the summer high season at Dun Laoghaire Pier, with a prevalence of high risk levels recorded at this time. The litter situation at Monkstown was very poor with a high portion of high and medium risk levels recorded throughout the year. The variable floating litter was only recorded at Dun Laoghaire Pier (see explanation in the Methodology Chapter, Section 3.6.12) and this data shows very high levels occurring at this location throughout the year. The variable ‘foreshore litter’ was recorded at Seapoint and Monkstown. Here the data again shows high levels occurring throughout the year, particularly at Monkstown.

The recorded situation with regard to litter was echoed somewhat by that for dog fouling. Again levels at all three locations were very poor but with higher levels occurring at Seapoint during the low season and at Dun Laoghaire West Pier during the high season. High and medium risk levels for dog faeces were recorded at Monkstown throughout the year. A general conclusion drawn from this data is that the trends reflected the year round popularity of these locations for walking dogs.

With regard to water quality, the results were more mixed with, for example, oil pollution occurring frequently but confined to the inner sections of Dun Laoghaire Harbour. In contrast, frequent problems with algal blooms and turbidity were recorded at Seapoint and Monkstown but not in Dun Laoghaire Harbour. All three areas returned largely positive results for both nutrient (ammonia) and microbial (enterococci) contamination. Review of the general water quality patterns recorded suggest that the observed issues are linked to the general status of water quality in Dublin bay, the morphology of the coastline and the nature of commercial fishing activities in Dun Laoghaire Harbour. Dublin Bay is known for having raised nutrient levels due the disposal of wastewater effluent (this is treated but still contains high levels of dissolved nutrient matter) from the Dublin City are into the bay (EPA, 2004). Excess nutrients combined with extensive shallow areas are known to encourage the growth of free floating algae and to generate high levels of turbidity (Brunton et al., 1987). Under certain weather and tide conditions both Seapoint and Monkstown appear vulnerable to this effect. On the other hand, water depths in Dun Laoghaire harbour are much deeper and the harbour is also physically protected (due to the narrow harbour mouth) from accumulations of algae in the bay. It appears that the enclosed nature of Dun Laoghaire however, leaves the harbour more vulnerable to accumulations of floating oil pollution from commercial fishing trawlers and leisure craft particularly in the inner harbour area. The enclosed nature of Dun Laoghaire Harbour was also observed to exacerbate the situation regarding floating litter as described above.

A general observation concerning the water quality results is that while water quality does not present any particular health risk to users it nevertheless generates a situation where the visual appeal or perception of water quality is often greatly reduced and thus at odds with sustainability of recreation and tourism in the area. In addition, the occurrence of accumulations of oil pollution and algal blooms in Dun Laoghaire Harbour and Seapoint/Monkstown respectively, was observed to be a primary factor in the recording of medium and high risk levels at these locations with regard to the variable ‘odours’.

With regard to the noise assessment, two main findings are apparent. Firstly, the recording locations which were most exposed to urban noise (that is, Monkstown and Dun Laoghaire inner harbour) frequently experienced medium risk levels of noise but such levels were recorded irrespective of season and were largely accounted for by urban traffic. The difference between high and low season noise levels at the more isolated location of Dun Laoghaire outer harbour on the other hand were more distinct with a noticeable increase in the proportion of medium risk noise levels at this location during the summer months. This difference between the noise data values for high and low seasons at this location was deemed to be statistically significant and it is likely that the difference can be attributed, at least in part, to noise associated with boating activity in the harbour.

# Chapter Five

# DISCUSSION and CONCLUSIONS

## 5.1 Introduction

With regard to tourism and recreation, it is clear that pursuing the goal of environmental sustainability is associated with a number of fundamental difficulties. Not least amongst these is the issue of assessment and the need to obtain and communicate data in a manner that can provide meaningful evaluation of environmental conditions and effects (Hughes, 2002). As discussed in the introduction to this thesis, a variety of techniques have been developed, or adapted, over the past number of years with the aim of assessing environmental quality and tourism impact in the context of sustainability. The most relevant of these techniques, in the context of this research, include the use of sustainability indicators (Schianetz et al., 2007; WTO, 2004), the Carrying Capacity concept (Farrel & Runyan, 1991; McCool & Lime, 2001) and the Tourism planning frameworks; Limits of Acceptable Change (LAC) and Visitor Impact Management (VIM) (Graefe et al., 1990; Newsome et al., 2002; Stankey et al., 1985). Whereas it is evident that the use of sustainability indicators and the carrying capacity concept are still the most widely recognised of these methods, LAC and VIM have recently gained significant recognition as more practical approaches to the issue (Moore et al., 2003: Newsome et al., 2002). Nevertheless, a common feature of these and other similar techniques is reliance, to a greater or lesser extent, on indicators of environmental condition. In this respect, various authors have drawn attention to the limitations associated with the use of environmental indicators and have questioned the value of their application in the field (Hughes, 2002; Lindberg et al., 1997; Ceron & Dubois, 2003). In particular, the assumption that the data provided by poorly related environmental indicators can be used to provide a reliable quantified assessment of environmental quality, effect and sustainability is now contested by many researchers (Ceron & Dubois, 2003; Green et al., 1990; Hughes, 2002; Sharpley, 2000 and Williams, 1994).

The principal aim of this research was to develop and test a risk assessment based model for assessing the environmental sustainability of tourism and recreation areas. This model is intended to provide an alternative to existing options for this type of assessment. Specifically the model and risk assessment approach is intended to address the limitations associated with existing methodologies by addressing the uncertainties which are inevitably associated with the use and interpretation of environmental data. In addition the risk assessment model is also designed to address the problems regarding the communication of findings from such data.

A key question that arises in this context is whether or not the risk assessment model, as developed, can be considered successful. A further question concerns the implications of this in the context of existing techniques and models and the potential wider application of this particular approach. These questions are addressed in the following discussion by way of reference to the principal findings arising from application of the model at the Lough Derg and Dublin Bay study areas.

## 5.2 Development of The Risk Assessment Model

The risk assessment model is based on the adaptation of established models from the fields of social science risk assessment and environmental risk assessment (Waring & Glendon, 1998; EEA, 1998; US EPA, 1992). In line with these models (see Figures 2.1 and 2.2 on page 68) a structured three-stage framework was adopted. Specifically in this case the stages are referred to as Risk Assessment, Risk Evaluation and Risk Management.

The Risk Assessment stage of the model is intended to provide a mechanism for the identification of environmental factors which may affect the sustainability of a defined tourism and recreation area and for providing insightful information regarding these factors as and where possible. Specifically, the structured and repeated measurement of environmental variables over a sustained period is intended to reduce uncertainties associated with the environmental data by providing insight into the observed behavior of such variables.

A key objective of the Risk Evaluation stage of the model is to provide a means by which quantitative data from a diverse range of environmental variables can be expressed in a manner that is both uniform and understandable by users of such data. This is achieved by converting quantitative data to risk categories according to prescribed criteria. This approach draws primarily from social science risk assessment practices and is often referred to as risk characterisation (Royal Society (1992). An underlying feature of the risk evaluation stage of the model concerns the interpretation of the significance of environmental data values using the risk characterisation process and trend analysis.

The principal objective of the Risk Management stage of the model is to provide a means by which the interpretation and characterisation of data arising from the previous two stages can be communicated in a condensed yet informative and reliable manner. This is achieved by means of the 'sustainability risk rating' system. The Risk Management stage is ultimately intended to aid and promote decision making by authorities implementing the model.

## 5.3 Strengths of the Model in the Context of Research Findings

Application of the risk assessment model at the two chosen study areas (Lough Derg and Dublin Bay) provided the means by which the validity and effectiveness of the model could be assessed. In this regard, the strengths and weaknesses of the model and associated methodology are examined and discussed first in the context of relevant findings from the field research. Consideration of the wider implications of this research, together with conclusions and recommendations follow this.

### 5.3.1 Selection of Variables

With regard to the selection of variables, it was found that the structured yet open approach prescribed for the identification of hazards and selection of monitoring methods in the Risk Assessment stage of the model ensured that a diverse and comprehensive range of environmental variables was selected for both study areas. In particular, it is felt that the lack of restrictions regarding the scope of selectable indicators (such as the use of indicator checklists which are commonly used with sustainability indicators (WTO, 2004)) ensured that preconceptions were avoided and that the variables selected were representative of the areas in question and covered all the key aspects of environmental sustainability. In this regard, the inclusion of qualitative methods of assessment allowed the focus of assessment to be extended beyond quantifiable elements of the environment to include qualitative variables such as the extent of algal blooms, overcrowding and odours. Although, it is recognised that the inclusion of qualitative variables may be at the sacrifice of scientific accuracy and rigour the findings of this research support the contention that it is a necessary solution to a situation where relying solely on quantifiable risk to environmental sustainability is considered unrealistic and self limiting (Royal Society, 1992; Waring & Glendon, 1998).

Notwithstanding the extent of variables selected as part of this research, a recognition is that with further resources the range selected could easily have been extended further to include more specialised variables such as, for example, vegetative cover and mammal and invertebrate populations. A general finding of this research is that this feature of the model and associated methodology, whereby an emphasis is placed on the scope and range of selected variables, allowed the generation of a more comprehensive picture of environmental condition and risk to environmental sustainability using a minimum of technical and financial resources. A further consideration in this respect concerns the general contention, held in emerging social science risk assessment approaches, that by selecting and monitoring as large a number of variables as possible, the potential weaknesses or inaccuracies associated with individual variables (such as qualitative variables) will be minimised and therefore increasing the reliability of the subsequent assessment (McDonald and Hrymak, 2002; Wells, 1996).

### 5.3.2 The Use of Risk Categories for Recording and Communicating Data

A key issue regarding the environmental assessment of tourism and recreation areas concerns the difficulties with interpreting the meaning or significance of individual and series of data values recorded in respect of quantitative parameters or variables (Hughes, 2002). Such difficulties may apply equally to both technical and non-technical data where an understanding of the underlying science and/or theory behind the data is often required. This issue is considered particularly important in a management context where it may be necessary to provide information to aid decision making by personnel who may have a limited knowledge or expertise regarding environmental measurement and data in general. In addition, the inclusion of qualitative variables creates a requirement for a standardised means of representing observations and recording the associated data.

To address these issues, the risk assessment model and applied methodology draws on emerging social science approaches to risk assessment whereby risk is ultimately considered in terms of likely outcomes rather than quantified units or probabilities (Royal Society, 2002; Waring & Glendon, 1998). In this regard, a key feature of the model is that qualitative and quantitative data values are recorded in terms of, or assigned to, a Likert type risk category scale (in the case of this research a simple three point risk category scale: low, medium and high was used). This recording or representation of the environmental data is done on the basis of prescribed criteria drawn from external standards of environmental quality where available.

In practice, it was found that with regard to quantitative variables the nature of the data recorded as part of this research served to highlight the value of this feature of the methodology. In this regard, much of the recorded quantitative data displayed a high degree of variability with often no particular trends identifiable with regard to environmental quality (see, for example, the raw data charts for faecal coliforms, phosphates, ambient noise and floating litter given in the Results Chapter). This meant that even where the meaning of an individual data value was understood (in the context of environmental quality and sustainability), it was often difficult to discern what proportion of the data values returned for a particular variable could be considered acceptable in terms of environmental quality.

With regard to the above, it was found that the use of the risk category system had three distinct benefits. Firstly, by expressing individual data values in terms of a categorised level of risk (based on non-compliance with environmental standards) the significance of such values with regard to environmental quality was readily understandable. Secondly, this system meant that the spread of data values (often displaying a high degree of variability) recorded for each variable over the monitoring period could be greatly simplified and presented in terms of the relative proportion of risk categories recorded. For comparative purposes, this proportion could also be separated according to high and low recreation seasons. Again, this was shown to greatly aid the interpretation of complex sets of recorded data. Thirdly, expressing the data from different variables in similar terms provided the basis for a useful system of comparison (that is, the sustainability risk rating system, see later in this section). In essence, it is felt that this approach allows the significance of data values, drawn from a wide spectrum of analytical disciplines to be presented in a manner understandable by those with limited expertise of such disciplines.

With regard to the qualitative variables, the main strength identified with the risk category system is that in the first place, it could be used as the basis for recording qualitative aspects of environmental sustainability. Furthermore, using this system for both qualitative and quantitative variables provided the opportunity for direct comparison between these distinct forms of data.

An issue which arose with regard to the risk category classification system was the need to identify environmental quality standards from which the criteria for assigning data to risk categories could be generated. In practice it was found that the availability and suitability of such standards varied with respect to the variables in question. Nevertheless, suitable standards were identified for the majority of variables selected and particularly for quantitative variables. In addition, it was found that the identified standards often specified two or more guide levels or standards for a given variable which could then be used to define the cut off points between the low and medium categories and the medium and high categories. Where only one level was specified in a standard for a particular variable then it was possible in many cases to combined guide levels specified by different but still relevant standards. Examples of the identified standards include the Blue Flag Beach Standard (FEE, 2008), the Irish Quality of Bathing Water Regulations (S.I. No. 155 of 1992) and Environmental Quality Standards produced by the Irish Environmental Protection Agency (EPA, 1997).

Where relevant standards directly applicable to Ireland could not be identified for a variable, then in some cases it was possible to identify relevant standards from other jurisdictions. Thus, for example, in the case of variables such as litter and dog fouling reference was made instead to a beach classification scheme developed by the UK Environment Agency and the UK National Aquatic Litter Group (EA/NALG, 2000) and a beach litter measuring system produced by a collaboration between the Keep Holland Tidy Foundation and the Royal Dutch Touring Club (ANWB and Nederland Schoon, 2006). This latter system being recommended by the Blue Flag Beach Standard (FEE, 2008). Although, the criteria set in these schemes were not directly applicable to the data values generated in this research, it was still possible to manipulate the criteria in these schemes in order to allow the generation of relevant and appropriate criteria for assigning risk levels in respect of the litter and dog fouling variables (further details of this process are given in the Methodology Chapter).

With regard to the qualitative variables, it was found that the aforementioned standards also contained general qualitative specifications regarding the acceptable levels of a variety of qualitative variables such as floating oil films. It was therefore possible to use these specifications as the basis of the criteria for recording the selected qualitative variables in terms of risk category.

### 5.3.3 Use of Trend Analysis

The identification and analysis of significant trends in the recorded data is a second key feature of the Risk Evaluation stage of the proposed model. This exercise is intended to reduce uncertainties associated with the recorded data and strengthen its interpretation by establishing a better understanding of the behaviour of variables over the course of the defined monitoring period. In the course of this research, the focus of the trend analysis exercise centred on a number of key issues. These included the possible influence of recreation activity on variables, the identification of possible external factors influencing variables and also the general behaviour of variables with respect to factors such as the time of year or weather conditions.

A general conclusion that can be drawn from the research findings is that the trend analysis exercise was shown, in practice, to provide valuable information regarding the behavioural nature of selected variables. Such information ultimately allowed a more informed and thus objective interpretation of data expressed either quantitatively (in its original form) or in terms of risk categories or risk ratings. In addition, the often complex and unpredictable nature of the data recorded as part of this research indicates that it is very likely that random or one off sampling of environmental indicators could easily mean that significant incidences of substandard environmental quality would be missed. In both instances, the value of taking repeated measurements of a range of variables over an extended period of time was clearly demonstrated. Finally in this context, the use of statistical tests of significance (such as T Tests) was found to be a useful aid to the trend analysis by helping to determine the level of confidence with which conclusions could be drawn regarding similar trends or distinctions between potentially related data sets. Specific examples of findings which highlight the strengths of the trend analysis as applied are discussed below.

With regard to the water quality variables recorded at the Lough Derg sites, a significant finding based on the trend analysis undertaken was that for most variables incidences of poor water quality could not be linked to recreational activity. Instead, the trend analysis indicated that the problems of water quality identified at these sites are more likely associated with background pollution issues occurring in Lough Derg generally. Such issues include general nutrient enrichment and faecal contamination of the lake waters associated with runoff from agricultural lands and the poor operation of wastewater treatment plants from which treated waters enter the lake system. These problems are well documented by the Environmental Protection Agency (Neill, 2005; Bowman, 2000; Bowman & Toner, 2001) and their influence on the water quality of the sites studied at Lough Derg are supported by the analysis of the data recorded for this research.

Similarly, at the Dublin Bay study sites, results from the trend analysis indicated that most of the recorded problems regarding water quality are likely to be as a result of nutrient enrichment of the bay waters and also the physical makeup of the bay. The nutrient enrichment of Dublin Bay is also well documented (EPA, 2000 & 2004) with the principal source of this contamination being the discharge of partially treated wastewater (that is, without nutrient removal) from Dublin City into the bay area (EPA, 2000). In the case of this research, the variable and year round nature of recorded ammonia levels indicated that such wastewater disposal is likely to be a principal causative factor behind the high incidences of algal blooms recorded at Monkstown and Seapoint. In addition, the shallow, sedimentary and tidal nature of the inner parts of Dublin Bay is associated with high levels of suspended sediment (Brunton et al., 1987). Again, the year round nature of recorded incidences of high water turbidity which were most prevalent at Seapoint and Monkstown suggest that it is the physical, tidal nature of Dublin bay which is most likely associated with this particular water quality issue.

An exception to the general observations regarding water quality at the Dublin Bay study area discussed above were the prevalence of floating litter and oil films within Dun Laoghaire harbour. In this case, the data trend analysis was used to show that these problems were most likely associated with higher levels of boating activity which occur during the defined high season.

With regard to litter and dog fouling, analysis of trends in the data from both the Lough Derg and Dublin Bay sites indicated that this is a year round problem and that the absence of litter clearing during the low season months tends to exacerbate the problem at this time. This analysis was based on the varying nature of the data recorded at all six study sites and the fact that litter and dog fouling levels were not observed to increase by any significant degree during the summer months. The data for graffiti at the Dublin Bay sites showed similar trends with similar implications.

With regard to the variable ‘ambient noise’ recorded at the Lough Derg study sites, statistical tests used as part of the data analysis confirmed that noise levels recorded at Terryglass and Dromineer were significantly higher during the defined high season than during the low season. The value of this exercise being the indication that higher levels of boating and general recreational activity occurring during the high season are significantly increasing the ambient noise environment and contributing to incidences of noise pollution.

With regard to noise levels at the Dublin Bay study sites, using the trend analysis it was possible to show that, despite the relative proximity of a variety of urban noise sources, the data for both of the noise sampling points at the inner and outer sections of Dun

Laoghaire harbour showed significantly higher average values during the high season. Given the relatively close proximity of a variety of background urban noise sources such as roads and commuter rail lines, this use of the trend analysis is considered significant as it highlights the likely influence on ambient noise levels associated with motor boat activity during the high season. By way of contrast, the trend analysis showed no significant difference to exist between average noise levels for the low and high seasons at Monkstown. Here it was evident that background urban noise sources were the dominant influence on noise levels throughout the year.

A general observation regarding the trend analysis was that it showed firstly that a variety of factors tend to influence the behaviour of variables for both the Lough Derg and Dublin bay study areas. Secondly, these factors can originate from number of sources both internal or external to the tourism and recreation areas in question. The value of the trend analysis exercise is highlighted in this case as this has obvious implications regarding the identification of the causes of problem issues and also regarding the nature and plausibility of measures required to address problem issues.

Finally, despite the difficulties experienced with establishing correlations between certain variables (see following section, 5.4), it was still possible to identify potential associations in some cases. For example, the high incidence of algal blooms occurring at the Lough Derg study sites during the summer months was largely in line with expectation given the high levels of phosphates recorded during the winter months (Neill, 2005). The delayed nature of the consequences of phosphate enrichment is also considered a significant finding in this respect. In addition, the data regarding floating litter (at Lough Derg) showed a clear trend of increasing quantities starting in the spring time and peaking at the end of what was defined as the high season for recreation activity. The association with recreation activity identified here is considered strong. In the same manner, the trend analysis indicated that the extent of recorded visible oil films were closely associated with the presence of motor boats and cruisers in the harbour areas of the various study sites.

### 5.3.4 Sustainability Risk Ratings

The generation of ‘sustainability risk ratings’ is a key element of the Risk Management stage of the risk assessment model. This aspect of the model is intended to further aid the interpretation and communication of generated data by representing the relative proportion of risk categories recorded for each variable as a single score. In addition, use of this risk rating system provides a means of combining the results for individual variables in order to generate an aggregated or average rating for groups of variables or for a particular location or area.

Regarding the strengths of the model, a number of observations can be drawn from the research findings regarding the generation of sustainability risk ratings. Firstly, it is felt that that the ratings generated with respect to individual variables represented a very informative tool which served to highlight problem areas in a clear and unambiguous manner. Secondly, it was found that the ratings reflected well the visual observations made during sampling visits to the various study sites. Thus, for example, the combined individual variable ratings for the Lough Derg study area clearly showed that the principal issues regarding environmental sustainability in this area are associated with litter, floating litter and dog fouling. Furthermore, the individual variable ratings for each study site (Terryglass, Dromineer and Meelick Bay) served to highlight important distinctions between these sites such as the absence of problems with regard to floating oil films, faecal coliforms and noise at the Meelick Bay amenity area. Notably, all of these issues as portrayed by the risk rating system were very much in line with observations on the ground and with the analysis of the raw data.

With regard to the Dublin Bay study area, the combined sustainability risk ratings generated for individual variables also clearly highlighted the problems in this study area. These are mainly associated with general housekeeping (or site upkeep) issues and include variables such as water turbidity, litter, floating litter, dog fouling, graffiti and noise. Again, the generation of risk ratings for individual variables recorded at the three study sites within this area (Seapoint, Monkstown and Dun Laoghaire Harbour) enabled important distinctions to be identified between these study sites such as the issue of visible oil films at Dun Laoghaire Harbour and algal blooms at Seapoint and Monkstown. In addition, it is useful to note that in the case of the Dublin Bay study area generally, the rating system demonstrated that where water quality problems exist they are more associated with physical problems such as oil pollution and floating litter rather than microbial issues which would have greater health significance. This is in contrast to generally observed perceptions of water quality in the Dublin Bay study area held by members of the public.

A final observation regarding the value of the risk rating system concerns the amalgamated risk ratings for the various study sites. The results of this research show that these combined ratings allow instant year round and seasonal comparisons to be made between the different study areas and study sites. The value of this is demonstrated by the fact that, for example, Meelick Bay recorded a relatively high risk rating score (17 as opposed to 29 for both Terryglass and Dromineer) in spite of initial high expectations and impressions of the area regarding environmental quality. In addition, the lack of contrast between the combined risk ratings for low and high recreation seasons at both Lough Derg and Dublin Bay served to highlight the year round nature of many of the problems identified regarding the environmental sustainability of the associated study sites.

## 5.4 Limitations of the Model in the Context of Research Findings

Although the risk assessment based model is intended to provide an improved approach to the assessment of environmental sustainability, in the context of tourism and recreation areas, it is recognised that a number of weaknesses or limitations can nevertheless be identified in the model and associated methodology. The principal areas where such weaknesses are to be found concern the use of qualitative variables, the conversion of quantitative data to risk based categories and the generation of sustainability risk ratings. The limitations associated with these and other aspects of the model are discussed below in the context of relevant research findings.

### 5.4.1 Use of Qualitative Variables and the Risk Category System

This limitation concerns the reliance on elements of subjective judgement regarding both the recording of qualitative variables and the conversion of quantitative data to risk categories. In the case of qualitative variables, it is recognised that the use of broad and often purely descriptive criteria for recording such variables can be questionable in terms of the repeatability of the methodology and therefore the consistency and reliability of the generated data. In the case of quantitative variables, the conversion of data values to a three point risk category scale (low, medium and high) could be viewed as an oversimplification of otherwise significant scientific data. In addition, the somewhat discretionary selection of environmental standards (which may or may not be directly related to the variable in question) for generating the conversion criteria may be open to question.

In more traditional academic disciplines this general approach is likely to be considered lacking in scientific accuracy and rigour. Even within the general discipline of risk assessment there is a tendency to regard simple, more qualitative approaches to risk assessment as being far inferior to sophisticated scientific approaches (Waring & Glendon, 1998). However, Waring & Glendon (1998) quoting from Toft (1993) argue that such a view is unwarranted and is based on a failure to recognise that all risk assessment, regardless of the level of quantification, is inherently value-laden.

In the context of this research, a general observation with respect to the use of qualitative variables was that, during sampling visits, there was usually little confusion as to which risk category should be applied to a particular observed condition. This was considered largely attributable to both the broad nature of the risk category system (that is, using just three categories) and the clarity of the criteria used. In addition, the use of quantitative guides in the recording criteria for variables such as floating oil films and overcrowding was found useful in this context. A further observation is that a focus was placed on the selection of quantitative methods of assessment for identified hazards where possible. As such the vast majority of variables selected were actually quantitative (25 out of 32, in the case of the Lough Derg study sites, and 28 out of 36 in the case of the Dublin Bay study sites) and therefore it can be argued that any inaccuracies associated with the use of qualitative variables did not predominate in the overall assessment of each study area. The research findings also served to highlight the importance of the inclusion of qualitative variables in the study. In this regard, the research results for many of the qualitative variables such as algal blooms floating oil films, water turbidity and odours showed that these represented key problems areas in the context of environmental sustainability at a number of the study sites. A conclusion drawn from this is that the value of including qualitative variables outweighs any potential lack of consistency or reliability in the data.

With regard to the conversion of quantitative data to risk categories, a significant finding in the context of this research was the generally complex pattern of the recorded quantitative. This feature of the data meant that its meaning was often ambiguous and its interpretation complicated. In this regard, the simplification of this data in order highlight the key significant features of the data was found to be a valuable tool which greatly aided the interpretation of the data.

### 5.4.2 Selection of Variables

Although the prescribed approach to the selection of variables, including the use of qualitative measures, was found to ensure that a comprehensive range of variables were identifiable, it was still noted from the research that a number of factors existed which did limit the number of variables which were ultimately selected for monitoring. These factors primarily involved practical issues such as the availability of equipment for measuring quantitative variables, the ability to identify useful criteria for qualitative variables and the relevance of the data produced by variables in a general sense.

Applicable variables in this context included for example the measurement of chlorophyll in water or the measurement of vegetative cover or animal populations.

### 5.4.3 Availability of External Standards

This limitation of the model concerns the availability and applicability of external environmental standards for setting the criteria for assigning risk levels to quantitative and qualitative data. Although this research demonstrates that relevant and workable standards were identifiable for most variables there were a number of variables for which such standards could not be identified. These variables included for example graffiti, harbour congestion, illegal parking and full waste receptacles. For such variables it was therefore necessary to generate discretionary criteria for assigning the recorded data values to the three risk categories. In order to reduce the subjectivity of this exercise reference was made, where possible, to relevant related standards such as general environmental quality expectations contained in the Blue Flag Beach Standard (FEE, 2008) and any relevant literature on the subject.

A further issue or limitation recognised under this heading is that using this model it was difficult to make any allowance, in the choice of standards, for potentially different expectations of environmental quality due in this case to the different types of recreation areas (rural and urban). This was largely due to the limited availability of suitable standards.

### 5.4.4 Trend Analysis

The principal limitation in this respect concerned the identification of associations between potentially related variables. In this regard, it is recognised that the use of statistical correlation analysis could provide a more robust assessment of such associations in the case of applicable variables. However, in practice it was found that the complexity of many of the variables meant that such an exercise was considered impractical given the resources and time available. For example, the plausibility of linking variables such as algal blooms and phosphate levels (an algal bloom precursor) was greatly complicated due to factors such as temperature, sunlight and season. Such factors all play a part in the generation of algal blooms in addition to the role of phosphate concentrations. Similarly, the link between variables such as the level of cruiser boating activity (at Lough Derg) and faecal coliforms (an indictor of faecal contamination) was found to be complicated by external factors such as agricultural runoff and weather conditions (Bowman & Toner, 2001).

Analysis of correlations, however, was undertaken in the case of some variables such as noise measurement. In this case correlations between noise level and the observance of power boats were examined. However, this analysis did not return any relationship of significance despite the clear observed increase in recorded noise levels when jet skis or other power boats were in operation. The main difficulty identified here was the relatively small number of sampling occasions carried out in respect of noise during the high season when power boats were observed to be operating. Again, this was a consequence of the model which requires the focus to be on investigating as broad a range of variables as possible. Attempts to correlate less complex variables such as litter and levels of recreational activity (car counts) or weather factors also proved difficult due, in this case, to the accumulative nature of both regular and floating litter and due to the intermittent schedule of litter clean ups by local authorities

A second limitation (or difficultly) identified with the trend analysis was the recognised need to account and control, where possible, for the influence of external factors on the environmental quality of the selected study sites. A typical example in this regard concerns the influence of external factors on the various water quality variables. In the case, the issue was addressed by selecting multiple sampling sites at contrasting locations in and around each study area. In this way, comparisons could be made between the data for zones subject to recreational use and pressures and the data for zones peripheral to these areas (including inflowing rivers). Thus, for example, at Terryglass Harbour, water quality sampling sites were selected within the harbour area, on the lake side of the main pier and just upstream of the point where the Terryglass River entered Terryglass harbour. By subsequently comparing the data from the various water quality variables sampled at these contrasting points, it was therefore possible to demonstrate that the water quality regime within Terryglass Harbour was predominantly influenced by the water quality of the Terryglass River, with respect to coliforms and phosphates, and by the lake water quality with respect to algal blooms and water transparency. Thus a conclusion drawn here was that the only water quality issue that could be confidently attributed to recreational activity at this location was floating litter and floating oil films.

In a general sense, it was found that the seasonal nature of tourism and recreational activity, together with the repeated measurement of variables, provided a means by which the behaviour of variables could be assessed both in the absence or presence of key aspects of recreation activity. Thus in the case of noise monitoring, for example, it was possible to account for the influence of external sources, such as road traffic or agricultural machinery, by simply comparing the data for the winter and summer seasons.

### 5.4.5 Sustainability Risk Ratings

With regard to the generation of 'sustainability risk ratings', a limitation identified during the course of the research concerned the inability to determine a level of statistical confidence in the individual or aggregated risk rating scores and thereby generate confidence intervals for the ratings. It was found that this was primarily due to the complex nature of the methodology and also the nature of environmental analysis. In this respect, the focus of the model is on the frequent measurement over time of a broad range of environmental variables in order to build a comprehensive picture of factors influencing the environmental sustainability of tourism and recreation areas. The data values are then categorised with the frequency distribution of generated categories forming the basis of the sustainability risk rating score. It therefore follows that in order to begin to ascertain confidence intervals with respect to individual or combined risk ratings it would be necessary to first carryout multiple measurement of individual variables on each sampling occasion such that levels of variability (standard deviations) could be established and confidence intervals calculated for this data. Such an approach would greatly increase the resources and time required and, it is believed, render the model impractical. Even at that, the dynamic nature of environmental processes mean that confidence intervals would be likely to change on a week by week basis (Bowman & Toner, 2001). This is a recognised problem with environmental analysis generally where the complex behaviour of environmental parameters means that a reliable measure of variability can be difficult to establish (Bowman & Toner, 2001). With regard to the risk assessment model, further complications also arise given the use of qualitative measurement of certain variables where the measurement of variability would be compounded by subjective factors.

A further potential limitation identified with respect to the sustainability risk ratings concerns the fact that when aggregating risk ratings for individual variables in order to produce a rating for a particular area the same weightings were applied to all the individual risk ratings. Given that certain variables may be perceived as being of greater significance in the context of sustainability, an argument exists for applying different weightings to different variables when aggregating risk ratings. However, it is recognised that any such application of different weightings would involve further additions of subjectivity to the process. Thus when combining risk ratings an emphasis is placed on the strength of using a large number and range of variables, as opposed to focusing on any differences in their respective perceived levels of importance.

Given the issues raised above, it is important to note that the risk rating score is not intended to represent a mathematical measure of the probability of an area being sustainable or not. Rather, it is intended as a representation or characterisation of the risk to environmental sustainability expressed in terms of non-compliance with accepted environmental quality standards. Considering that the concept of sustainability is largely recognised as not having any absolute measure (Ceron & Dubois, 2003; Swarbrooke, 1998), in this context the need to produce confidence intervals with regard to the sustainability risk ratings is considered unwarranted.

### 5.4.6 Resource and Time Requirement

A general limitation of the model that was recognised during the course of the research was that the processing of data was found to be relatively time consuming. Together with the need to monitor variables over a prolonged period (up to a year for one cycle of the methodology), this means that the model not only requires significant periods of time to implement but it also requires considerable man hours in terms of conducting the monitoring regime and processing all the data. In this respect, however, experience from this research did show that repetition of the methodology significantly reduced the time required for data processing as the same data templates and macros could be used for additional sets of data.

### 5.4.7 Application of the Model

With regard to the application of the risk assessment approach, Wilkinson (2007) maintains that a wide range of stakeholders should ideally be involved in the decision making process regarding the management of tourism and recreation areas. The nature of any stakeholder involvement is not prescribed as such in the concept model which means that this important input may be overlooked. However, as Wilkinson (2007) points out, this is a problem that affects all approaches to sustainable tourism management. In a similar light, empowering local people in the management process has been found to foster positive social impacts and generate support for tourism development (Simpson and Wall, 1999). The proposed concept model is not explicitly designed with public participation in mind. However, the model does recognise the important role that attitudinal surveys could play in establishing risk tolerance levels, particularly for the more subjective environmental parameters such as acceptable levels of litter or noise, for example. Such attitudinal surveys would normally involve some degree of public participation.

## 5.5 Wider Implications of Research Findings & Comparisons with Existing Methodologies

Application of the model has demonstrated the strengths of the risk assessment approach particularly with respect to the interpretation and communication of environmental data in the context of promoting the environmental sustainability of tourism and recreation areas. As reviewed in the introduction chapter, a variety of alternative methods exist for assessing the sustainability of tourism and recreation in a general sense. However, as discussed earlier, only four of the existing methods are identified at this point as being relevant in the context of this research. These alternatives are the concept of carrying capacity, the use of sustainability indicators and the tourism impact frameworks; Limits of Acceptable Change and Visitor Impact Management.

With regard to the carrying capacity concept it is important to note that the relevance of this concept to this research is seen largely in a theoretical context. Thus it is acknowledged that the carrying capacity concept provides a valuable remainder that the nature and extent of recreational use within a defined area will have inevitable repercussions regarding environmental impacts. In addition, the carrying capacity concept has received much attention in tourism literature and ultimately the sustainability objectives of this concept are similar to those which underlie the risk assessment model. However, as pointed out by authors such as Lindber et al. (1997), McCool & Lime (2001) and Krumpe & Stokes (1994), determining an empirical link between given use levels and resulting environmental impact has proven all but impossible to achieve reliably in the field. Thus, from a practical use perspective the carrying capacity concept is not considered a realistic alternative to the risk assessment approach and furthermore a deliberate decision was made not to incorporate the principles of carrying capacity into the risk assessment model.

With regard to the use of sustainability indicators it is recognised that this approach is widely prescribed for assessing the environmental aspects of the sustainability of tourism and recreation areas and is advocated by the World Tourism Authority (WTO, 2004). In addition, a variety of formal criteria are now prescribed for their selection by various authorities including again the WTO (WTO, 2004). A general consensus identified in the subject literature is that, in theory at least, the selection of sustainability indicators in such a prescribed manner should provide researchers and authorities with the necessary information to identify appropriate management strategies for promoting the environmental sustainability of tourism and recreation areas (Manning, 1999). More recently, a number of structured models have been devised for identifying sustainability indicators in various tourism contexts. These include the VICE (TMI, 2003) and ACHIEVE (Flanagan, 2007) models as discussed in the Introduction Chapter (see Section 1.7.1).

Given the above, it is acknowledged that the use of sustainability indicators as a measure of environmental sustainability can provide useful information, particularly with respect to variables that are more predictable and easier to interpret. However, much of the environmental data recorded in respect of this research proved to be relatively complex. Such complexities included the behaviour of variables over time which was often observed to be very changeable and difficult to predict. In addition, it was evident that many variables are influenced by a multiple of factors which makes it difficult to verify links between variables which otherwise appear connected and between certain variables and levels of recreational activity. Issues associated with the means of recording variables were also confirmed, thus necessitating the use of both quantitative and qualitative methods of measurement. This in turn confirmed the difficulties regarding the assessment of the combined significance of environmental data.

In effect, the complexities observed during the course of this research, regarding environmental data serve to highlight the need for a structured approach when trying to assess, interpret and communicate the cumulative influences of multiple variables on environmental sustainability. Although, the development of indicator models such as VICE (TMI, 2003) and ACHIEVE (Flanagan et al., 2007), have undoubtedly provided greater structure to the identification of sustainability indicators, it is felt that the lack of a prescribed and structured framework for dealing with the actual information generated by application of the sustainability indicator approach greatly limits the scope of this methodology as a means of assessing environmental sustainability. This view supports the opinions of various authors such as Ceron & Dubois (2003), Green et al. (1990), Twinning-Ward & Butler (2002) and Hughes (2002) who have all questioned the practical value of the sustainability indicator approach.

With regard to the above, it is felt that the tourism planning frameworks, Limits of Acceptable Change and Visitor Impact Management offer a more practical approach to the sustainable management of tourism and recreation areas. These frameworks were developed as more realistic reformulations of the carrying capacity framework where a focus was placed not on ‘how much use is too much?’ but rather on ‘what level of change is acceptable?’ (Krumpe & Stokes, 1994). In addition, both LAC and VIM advocate structured approaches to the identification, measurement and use of environmental data (Newsome et al., 2002; Glasson et al., 1995) and in this respect they share similarities with the risk assessment model developed as part of this research. Specific examples of such similarities include the focus on identifying resource conditions, relating data to defined standards and communicating the need for subsequent action where standards are not met. In addition, these methods also recognise that elements of subjectivity are inherent in both the recording of environmental data and the making of management decisions based on such data (Graefe et al., 1990; Stankey et al, 1985).

In many respects, the tourism planning frameworks, VIM and LAC, have served as a useful precedence for the development of this model, particularly with respect to those areas where they share similarities. In this regard, the risk assessment model could be viewed as a logical extension to LAC and VIM. However, the scope of this model goes beyond that of VIM and LAC and therefore a number of features of the risk assessment model distinguish this approach from these tourism impact frameworks and can be considered advantageous. These features are outlined below (see Table 5.1 for a summary of distinctions between the key alternative methodologies).

In contrast to tourism planning frameworks, the risk assessment approach advocates the selection and repeated measurement of as wide a range of relevant variables as is feasible. This is intended to allow the identification of natural and seasonal variations in the recorded environmental data and where possible to identify possible links with tourism and recreation activity. Hughes (2002) contends that such variations are at the heart of the uncertainties that plague environmental data and render the significance of individual measurement difficult to establish. With regard to variable selection, the structured approach prescribed by the risk assessment model is also considered a strength as the requirement for selecting indicators as part of the LAC or VIM process is often seen as problematic (Cole & Stankey, 1997; Krumpe and Stokes, 1994; Glasson et al., 1995). In addition, although the tourism planning frameworks permit the use of qualitative variables, unlike the risk assessment model there is no specified manner regarding their use (Newsome et al., 2002). Prescribing the selection of purely descriptive qualitative variables, as and when they are deemed appropriate, addresses the problem of recording environmental effects that are difficult to quantify and thereby maximises the number of variables that can be monitored.

A further distinguishing feature of the risk assessment model concerns the defining of standards with regard to accepted levels of environmental quality. Whereas the tourism planning frameworks prescribe the production of internal site specific standards (Newsome et al., 2002), the risk assessment approach draws on established external standards of environmental quality when defining standards to be used when assessing sustainability. In this regard, Krumpe & Stokes (1994) highlight the finding that in many instances managers applying LAC felt they had insufficient baseline data to set standards internally. Furthermore, in contrast to the tourism planning frameworks generally, all recorded data values and incidences of non-compliance with defined standards are then expressed in terms of likely consequence or categories of risk rather than discreet values. This approach recognises and partly addresses the uncertainties associated with individual environmental data values. With the risk assessment approach, it is therefore the relative proportion of the frequency of risk categories recorded for each variable that serves as the basis for management intervention, rather than single incidences of non-compliance with defined standards (Glasson et al., 1995). In order to aid communication, this frequency distribution is then expressed as a sustainability risk rating which represents both the overall level of non-compliance with environmental quality standards and the related risk to sustainability as a single score. This score, in effect, reflects the year round performance of an individual variable against defined standards and provides managers with a valuable decision making tool. In contrast to the tourism planning frameworks, the sustainability risk rating system also provides a means of communicating the combined or aggregated significance of a range of otherwise difficult to relate environmental variables. In this respect, an aggregated sustainability rating or score can be produced for a particular area that takes account of all elements assessed. In effect, the use of risk categories and the risk rating system recognises both the uncertainties associated with environmental data and the difficulties in relating environmental data to sustainability.

Although a purported aim of LAC and VIM is to incorporate scientific assessment while acknowledging the subjective nature of the decision making process (Newsome et al., 2002), there is no specified mechanism in these methodologies for addressing the uncertainties associated with the interpretation of environmental data. Hence, a recognised limitation associated with LAC and VIM is that resource condition standards are set on the basis of the environmental data recorded as part of the methodology (Glasson et al., 1995; Krumpe & Stokes, 1994). Thus where this data proves unreliable or difficult to interpret then the subsequent standards set may prove inappropriate to the general objectives set for the area in question (Glasson et al., 1995). In this regard, Newsome et al. (2002) contend that managers may in practice be reluctant to set standards. In contrast, the risk assessment approach for the most part relies on established standards of environmental quality and thereby is not exposed to this problem.

A final distinguishing feature is that the risk assessment model is intended to address all potential influences or impacts on environmental quality which may affect the sustainability of the selected area. VIM and LAC on the other hand focus on visitor impacts only (McCool, 1996; Stankey et al., 1985) and ignore other impacts which are arguably still important in the context of sustainability. On reflection, it is apparent that VIM and LAC may be more suited to niche areas of recreation where the adoption of area specific standards is considered necessary. In many regards, this view is in line with general opinion regarding these methodologies (Moore et al., 2003) and largely reflects their origins in wilderness areas of North America and continued application in these types of areas (Glasson et al., 1995).

**Table 5.1 – Summary Comparison of Key Alternative Sustainability Assessment Methods**

| | **Sustainability Indicators** | **Limits of Acceptable Change** | **Visitor Impact Management** | **Risk Assessment Model** |
|---|---|---|---|---|
| **Intended focus and general objective of the methodology** | Monitor and assess change in practices and conditions considered linked to the sustainability of tourism | Set social and resource standards based on acceptable levels of change with respect to opportunity classes or zones. Uphold such standards by way of monitoring and management intervention. | Determine general objectives for a recreational area. Identify and assess resource and social indicators. Set standards for each indicator which reflect the general objectives. | Identify and monitor environmental hazards to sustainability. Characterise data in terms of risk and communicate findings in a manner which promotes effective decision making and continual improvement. |
| **Characteristic features** | Broad and flexible approach with emphasis on selecting case relevant indicators which should provide information necessary to maintain sustainability of tourism destinations. | Selected standards relate to level of change, due to visitor use, considered acceptable. Advocates different standards for different ‘opportunity classes’ or use zones. Use of indicators key to monitoring impact. | Recognises that management is part science part subjective judgement. Objectives relate to both the visitor experience and resource protection. Use of indicators key to monitoring impact. | Structured, hazard identification based approach to selecting variables. Recorded data values presented in terms of degree of non-compliance (risk) with accepted environmental standards. Risk rating system used to aid communication. |
| **Means of selection of indicators or environmental Variables** | Primarily by referral to suggested indicator lists, supplemented by case specific indicators identified using focus groups, stakeholder meetings etc. Largely a desk based exercise. | Onus on destination managers or rangers to identify of resource and social conditions based on knowledge of issues and general experience of the area. | Indicators selected on the basis of policies, previous research, existing data etc. Indicators should reflect visitor impact. Again largely a desk based exercise | Indicators (or variables) selected by researcher using a structured and prescribed on-site hazard identification process. Selected indicators should relate directly to the identified hazards. |
| **Means of devising standards and objectives** | Setting of standards or objectives is not implicit in the methodology. Focus is on trend in indicator values over time and interpreted implications. | Normally via stakeholder input and consensus by managers. Input by public can be sought. | Standards are set by area managers for individual indicators. Such standards should reflect the general management objectives for the area. | Reference to authoritative external standards of environmental quality where applicable. Otherwise using discretionary reference to relevant subject literature. |
| **Means of Interpreting the significance of recorded data** | Significance is based on a case-by-case analysis of indicator data. | Significance of recorded data relates to compliance or otherwise with set standards for each indicator. | Significance of recorded data relates to compliance or otherwise with set standards for each indicator. | Significance of data is interpreted by reference to identified standards and defined risk category criteria. Trend analysis supports the interpretation. |
| **Means of communicating data and its significance** | Data is communicated on a case-by-case basis. No prescribed manner for doing this. | No prescribed means for communicating data and its significance (though main significance simply relates to meeting set standards). | No prescribed means for communicating data and its significance (though main significance simply relates to meeting set standards). | Data and its significance communicated using a risk rating system defined by a 0 – 100 scale. |

## 5.6 Potential Areas of Application

The risk assessment model is intended to have a degree of flexibility in terms of the types of areas to which it can be applied and also in terms of the level of expertise and resources required to implement the model. Although the strengths of alternative frameworks such as Limits of Acceptable Change and Visitor Impact Management are acknowledged, it is felt that the risk assessment approach still provides a broader approach to the issue of environmental sustainability as defined for this research. This is because the risk assessment approach deals explicitly with the problems of indicator selection, the identification of standards and the interpretation and communication of environmental data. This means there is less of an onus on those making decisions based on information stemming from application of the model to possess expertise in the field of environmental science and resource management. It is therefore considered reasonable to expect that the risk assessment model should have greater appeal to tourism and recreation managers who may lack expertise in the use and significance of environmental data. This is in contrast to tourism planning frameworks, such as LAC, which have seen application almost exclusively in national park areas by expert staff whose sole remit is the upkeep and management of these areas (Krumpe & Stokes, 1994).

In addition, it is argued that the widespread recognition of the risk assessment field and the prescribed use of existing standards of environmental quality (for defining risk category criteria) should add an element of greater authority to this methodology. In this respect, it is considered that this methodology is likely to have more mainstream application potential as the research findings indicate that the methodology is adaptable to different types of locations. In many respects it should be possible to apply this methodology to any context where environmental standards of quality exist or are capable of being generated by way of reference to such standards or relevant literature. Such contexts need not necessarily be confined to the field of tourism and recreation and could be broadened to include, for instance, nature reserves, conservation areas or even building complexes.

Although the focus of this particular research has been on site specific aspects of sustainability, it is recognised that wider issues regarding sustainability need to be considered. Such issues include resource and energy use and the production of various waste streams and are tied in with global issues such as global warming, resource depletion and the conservation of biodiversity. Notwithstanding the limits of this body of research, it must be stressed that this should not in theory prevent the inclusion of wider threats or hazards to sustainability in a broader sense to the risk assessment model. Thus, for example, as long as relevant standards can be identified or agreed regarding, for example, energy consumption patterns (including the use of private vehicles and air travel) and the nature and volumes of waste streams produced within a defined tourism and recreation area, then such standards could be used to generate risk category criteria and thus these issues can be incorporated into the risk assessment model.

With regard to the actual application of the model in new areas by persons unfamiliar with the model, it is recognised that the methodology associated with the application of the model in the context of this research may appear complex, lengthy and difficult to implement. However, it must be stressed that the model itself is considered relatively straightforward and sets out a simple step-by-step process for its implementation. Thus, following the model should not present any particular challenges, regardless of the context in which it is implemented. With regard to the level of complexity of the working methodology associated with implementing the model, and required resources, it is considered that this will ultimately depend on the scale and complexity of the area under investigation and the scope of variables selected for assessment.

## 5.7 Recommendations

Recommendations for further research focus on the recognised need to assess the repeatability and reliability of aspects of the risk assessment model and associated methodology and also on the availability of suitable environmental standards for generating risk category criteria in respect of both qualitative and quantitative variables.

With regard to the use of environmental standards, it is recognised that the risk assessment model relies to a large extent on the existence of relevant standards that are applicable to the variables being assessed. Furthermore, such standards should ideally specify greater than one level of acceptability for a given parameter such that the criteria for the three risk categories can be ascertained. These standards essentially defined the basis of the risk category system, which is in turn linked to the assessment of environmental sustainability.

In the case of the quantitative variables selected as part of this research, it was found that suitable standards were identifiable in most instances, particularly with regard to the more scientific variables such as those assessing water quality. However, difficulties were experienced in identifying workable standards with regard to quantitative variables whose significance is more perceptive in nature. Such variables include graffiti, harbour congestion, illegal parking and ambient noise, for example. In this regard, it is recommended that research be undertaken in order to determine the levels of these variables that can be considered acceptable and to allow authoritative standards or guidelines to be set. Due to the perceptive nature of these variables it is likely that such research would need to be undertaken by way of attitudinal surveys correlated with quantified observations. With regard to ambient noise, a particular recommendation is that further research is required in order to develop standards that are relevant to rural and tranquil recreational locations. A further recommendation, in this regard, is that genuine attempts should be made to establish standards for ecological variable such as bird counts, vegetation surveys and mammal populations.

In the case of the qualitative variables, it was found that some general specifications regarding acceptable levels of certain variables were given in standards such as the Blue Flag standard (FEE, 2008). However, in general a lack of standards with specific specifications for qualitative variables was noted. It is therefore recommended that further research is required in order to better establish and define what levels of these variables are considered acceptable by tourists and other users of recreation areas such that authoritative standards can be produced. As such variables are largely perceptive in nature, it is again likely that attitudinal surveys combined or correlated with structured field observations would have to form the basis of such research.

With regard to the repeatability of the methodology, two issues stand out. Firstly, the recording of qualitative variables in the field is undertaken on the basis of mostly descriptive criteria. Thus an element of subjectivity is involved in the interpretation of the criteria when assigning risk levels. As a result of this, the consistency or repeatability of this system for different users is open to question. A recommendation in this context is that this aspect of the methodology should be tested using multiple surveyors in order to establish the consistency of the criteria used and to develop improved criteria where necessary.

Secondly, the inability to establish a quantified level of confidence in the sustainability risk ratings is recognised. A recommendation in this context is that further research should be undertaken in order to establish whether it is possible to provide some measure of confidence with respect to the calculated sustainability risk rating. Given the complex nature of the methodology is likely that such research would involve further field sampling with a focus initially on a small number of key variables. Notwithstanding this recommendation, a general consideration is that any further application of the methodology, either in part or in full, will help to ascertain the reliability of the methodology and build confidence in its use.

## 5.8 Novelty of Research

This research is considered novel for a number of reasons. Firstly, the principles of social science based risk assessment have not previously been applied in a formal and structured manner to the field of tourism and recreation environmental assessment. In this regard, the development of a risk assessment based model (adapted from environmental and social science risk assessment models) for assessing the environmental sustainability of tourism and recreation areas is considered novel. In addition, this research represents the first development, application and testing of a methodology based on this model.

A number of specific elements of the model and associated methodology are also considered novel in this context. These include the use of established environmental standards and risk categories in order to express data in terms of sustainability risk and the use of a risk rating system or score in order to communicate the significance of this categorised data.

Finally, the repeated measurement of selected environmental variables over prolonged monitoring periods has provided new and valuable insight into the behaviour of such variables and the relationship between environmental conditions and tourism and recreation activity.

## 5.9 CONCLUSIONS

The aims and objectives of this research have been achieved. A risk assessment based model for assessing the environmental sustainability of tourism and recreation areas was successfully developed. This model provided the framework for the development of a detailed methodology which was implemented and tested at two chosen study areas. The research findings have highlighted the strengths and weaknesses of the risk assessment model and associated methodology and the general approach to the issue. In particular, the research findings have demonstrated that using the model enables both the interpretation and communication of sustainability performance in a manner that recognises the limitations associated with using environmental data while promoting effective and realistic decision-making. A number of key features underpin the success of the model. These are outlined below.

Firstly, the structured yet flexible approach to the identification of hazards and selection of environmental variables ensured that a comprehensive range of factors relevant to the assessment of environmental sustainability could be addressed with a minimum of financial and technical resources. Secondly, the repeated measurement of variables over an extended period of time was shown to provide crucial information regarding the nature and behaviour of individual environmental variables with respect to location, time of year and tourist season. This allowed individual data values to be put into context and therefore provided a platform for more meaningful interpretation of such values with respect to environmental sustainability and observed trends in recreational and tourist activity.

In addition, expressing the data from both qualitative and quantitative variables in terms of risk categories provides a means of representing the likely associated level of risk to sustainability in terms of the level of compliance with recognised environmental quality standards. This approach recognises the inconsistent nature of environmental data, the often subjective nature of its interpretation and the conceptual difficulties in providing an empirical measure of environmental sustainability. Using this approach, it is therefore the relative frequency of recorded risk categories (low, medium and high) for each variable, rather than individual incidences of non-compliance, which would serve as the basis for management intervention regarding environmental sustainability.

Finally, the potential difficulties associated with interpreting multiple frequency distributions of risk categories are addressed in the methodology by way of a sustainability risk rating system. Using this system, the relative proportion of recorded risk categories for each variable is expressed as a single score or rating on a percentage scale. The resulting ratings can then also be amalgamated to generate overall sustainability risk ratings in respect of groups of variables or selected study areas. Given the nature of its calculation and in line with social science risk assessment principles (Amendola, 2001) the sustainability risk rating is not intended as a definitive mathematical measure of risk but rather as a representation or characterisation of the likely level of risk to environmental sustainability expressed in terms of the level of compliance with recognised environmental quality standards. In effect, the use of both the risk category and risk rating systems means that the significance and meaning of multiple data sets, drawn from a wide spectrum of analytical disciplines, can be presented and communicated in a manner which circumvents the need to understand the theory behind such data. This is considered particularly important in a management context where those ultimately responsible for making decisions based on the methodology are unlikely to have such expertise.

Although, in the case of this research, a statistical level of confidence could not be ascertained for the sustainability risk rating (due to the complex nature of data involved), it is felt that this rating system still represents the most realistic means of communicating the significance of complex environmental data in the context of environmental sustainability. Given the requirement of this methodology to promote good management in this respect, the practical advantages of such a rating system are considered to outweigh the mathematical and statistical weaknesses inherent in this approach.

With regard to the potential use of the risk assessment model and methodology, it should be noted in the first instance that the methodology is primarily intended as a decision aid or tool which, given the strengths of this approach, should allow tourism managers or local authorities to optimise the environmental sustainability of tourism and recreation areas under their jurisdiction. However, although the generation of sustainability risk ratings are intended to function as a decision making tool, the methodology does not specify the timing or nature of management action required to address problem issues identified. Furthermore, it is also recognised that many factors affecting the environmental sustainability of tourism and recreation areas may be due to external factors and will effectively be outside of the control of those responsible for these areas. In this respect, it is considered that the onus should initially be on environmental and tourism managers to draw conclusions from the risk ratings and trend analysis and implement management actions as they see necessary. The nature of such actions is likely to depend very much on the problem areas identified and, as in the case of the study areas investigated as part of this research, may simply involve better cleaning and upkeep of the areas in question. Nevertheless, it may ultimately be necessary to restrict certain activities, such as the use of jet skis or powerboats, for example, in order to reduce sustainability risk to an acceptable level.

With regard to the above, it is felt that ultimately a lower limit for the sustainability risk ratings should be set, below which conditions are considered unacceptable and unsustainable. Such a limit would have to represent a balance between political and environmental imperatives for an area (such issues being at the core of the sustainability debate). At the very least, the generated risk ratings should be used to identify and highlight key problem areas and to provide a benchmark against which the performance of recreation and tourism areas can be assessed against each other or over time. This should also prevent the potential for long term incremental reductions in environmental standards. In this way, the methodology is intended to promote an ethos of self-regulation and continual improvement with respect to the management of tourism and recreation areas.

In conclusion, it is recognised that any methodology designed to assess the environmental effects of tourism will have weaknesses and therefore it is imperative not to underplay the difficulties faced by such methodologies and also to recognise the consensus that methods must be devised nonetheless (Ceron & Dubois, 2003; Jafari & Wall, 1994; Mader, 1998). In this respect, it is useful to bear in mind that tourism and recreation area development ultimately represents a set of trade-offs between promoting visitor access and protection of the natural environment (McCool & Lime, 2001). Environmental assessment and management therefore involves finding a balance between the relative merits of quantified data and the values that people attach to different aspects of the physical environment and its development (Newsome et al., 2002; McCool & Lime, 2001; Manning, 2003). Such a balance must be found in conditions of uncertainty (McCool & Lime, 2001) and hence it is inevitable that novel approaches to assessment, such as this, should form part of the solution.

With regard to the above, it is felt that the risk assessment methodology offers a practical, realistic and improved approach to the promotion of sustainability from an environmental perspective at established tourism and recreation areas. In contrast to other established methods, this methodology sets out, to address and deal with the difficulties regarding the interpretation, use and communication of environmental data, as highlighted by authors such as Hughes (2002), Williams (1994) and Krumpe & Stokes (1994). This approach inevitably leads to some compromise with respect to strictly scientific methods. However, this compromise largely reflects the impracticalities of relying exclusively on quantitative data and scientific methods, as identified by McCool & Lime (2001). As advocated by these authors, the risk assessment methodology offers an alternative decision making framework which is both systematic and explicit in the use of value judgement when deemed appropriate. In the light of general agreement regarding the need for mechanisms to promote the environmental sustainability of tourism (Jafari and Wall, 1994), this compromise is ultimately considered not only justifiable but also necessary.

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