WATER QUALITY IN IRELAND 2007-2009

Edited by
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Office of Environmental Assessment

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This Report is dedicated to the memory of our colleague
Michael Neill (1948-2010)

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FOREWORD

This report is the sixth in the series of three-year reviews of water quality in Ireland that have been undertaken by the Environmental Protection Agency (EPA) since 1995. A number of earlier reports were published by our predecessors, An Foras Forbartha, from 1970 to 1980 and the Environmental Research Unit, covering the period 1987 to 1990. Ireland is one of the few countries in Europe with such a detailed, scientifically based time series of water quality, which now spans four decades.

This report presents a review of Irish ambient water quality for the years 2007 to 2009. The aim of the report is to present a detailed overview of the main aspects of the quality of the aquatic environment in Ireland, to assist in the protection and enhancement of this key national resource. The data will provide a basis for Programmes of Measures to restore and maintain water quality.

The EPA has worked with a range of agencies to deliver a national assessment, based on the criteria and standards set out in the Water Framework Directive (2000/60/EC). The EPA published a national monitoring programme in June 2006 to meet the requirements of the WFD and the regulations implementing the Nitrates Directive (S.I. No. 788 of 2005).

The water quality data are presented in two ways: against the new ecological status criteria of the Water Framework Directive (WFD) and reporting on water quality, in the manner of previous EPA reports, so that trends can be seen.

The WFD assessment scheme for **water status**, that includes water quality, is a complex but comprehensive ecological approach, to aquatic resource management, in which the scope has been broadened to include a wide range of supporting parameters.

Thus, with many areas of aquatic systems to be covered, the report marks a transition phase towards a new, multi-agency programme.

The water quality data and other information have been generated by EPA field and laboratory based teams in the Office of Environmental Assessment, supplemented by information from

- Local authorities,
- Central and Regional Fisheries Boards (now Inland Fisheries Ireland)
- Marine Institute
- Radiological Protection Institute of Ireland
- Sea Fisheries Protection Authority
- Waterways Ireland and the Irish Coast Guard

We wish to convey sincere thanks and appreciation to our colleagues in these agencies.

The EPA looks forward to working with the Department of Environment, Heritage & Local Government and with the network of agencies to deliver the next phase of the Water Framework Directive and to meet the targets set out in the Directive for 2015 and 2021. This report makes clear that the targets are ambitious. Significant pollution remains an issue, for example in at least 20 river sites, in 25 lakes and in nine estuarine water bodies.

As previously stated by EPA, the achievement of future WFD targets will require a review of current water governance and the evolution of a regional network of agencies, based on the River Basins, in order to provide a more effective balance of national integration and local implementation.

Micheál Ó Cinnéide
Director
Office of Environmental Assessment

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CHAPTER FOUR

WATER QUALITY OF LAKES

Deirdre Tierney, Gary Free, Bryan Kennedy, Ruth Little, Caroline Plant, Wayne Trodd and Caroline Wynne

INTRODUCTION

This chapter is based on the results from the first three years of the Water Framework Directive (WFD) lake monitoring programme (2007-2009) and provides an integrated assessment of the biological, physico-chemical and hydromorphological quality elements monitored in Irish lakes. Results are summarised at the level of individual River Basin Districts. For continuity with previous reports, the lakes are also classified, based on their trophic status, by the number and surface area in each trophic category. In all, 222 lakes were examined representing over 988 km^2 of lake surface water or approximately 65 per cent of the surface area covered by lakes in the country.

The information on these lakes was derived from investigations carried out by the EPA, Local Authorities and the Central and Regional Fisheries Boards*.

The results of the long-term monitoring on selected representative acid-sensitive lake systems are also given, as is summary information on bathing water compliance for the nine designated freshwater bathing areas.

Lake Monitoring History

The first national survey of lakes was undertaken in the mid-1970s (Flanagan and Toner, 1975). Subsequent lake monitoring and assessments have been undertaken by An Foras Forbartha, the Environmental Research Unit (ERU), the EPA, the Local Authorities and the Central Fisheries Board (Inland Fisheries Ireland). The number of lakes, the sampling frequency and the parameters measured, have varied to suit different objectives over the years. The mid-1990s saw the commencement of research into lake ecology, under a series of EPA research grants designed to prepare for the forthcoming ecological assessment of lakes which would be required under the WFD (e.g. Free *et al.,* 2007; Irvine *et al.,* 2001; McCarthy et al., 2001).

In 2001 The EPA published a discussion document on the National Lake Monitoring Programme in anticipation of the monitoring needs under the WFD (Bowman and Toner, 2001). In the 2004-2006 water quality report 449 lakes were reported upon. However, as before, the number of lakes, sampling frequency and parameters measured varied among lakes.

In 2007 the WFD lake monitoring programme commenced with a more comprehensive assessment of lakes, albeit fewer in number, covering more physico-chemical and biological quality elements at specified and more consistent frequencies.

In this chapter the results of the 2007-2009 Irish WFD lake monitoring are presented. These relate mainly to the primary pressure on lakes: nutrient enrichment. In order to provide continuity with previous triennial reports, the 'traditional' trophic status assessment methods previously used for assessing lake water quality are compared with the results of the newer ecological status assessment methods developed for the Water Framework Directive. Some additional information on the long-term monitoring of lake acidification is also included.

Trophic Status Methodology

Enrichment of lakes is caused by increased inputs of nutrients, primarily phosphorus. Initially this results in increased growth of rooted plants, particularly those species tolerant of enrichment. Increased phytoplankton growth may follow (as indicated by increasing chlorophyll levels) and ultimately nuisance algal blooms may occur. As eutrophication progresses, the increasing density of algal cells in the water reduces water clarity (transparency), which in turn reduces the area colonised by submerged plants due to light exclusion. This can lead to a progressive reduction in the maximum depth at which they can grow and eventually even to their elimination. Increased plant and phytoplankton

* The Central and seven Regional Fisheries Boards have been incorporated into, and replaced by, Inland Fisheries Ireland (IFI).

production can also result in reduced oxygen levels, especially if the lake is prone to stratification.

The OECD lake classification scheme was established in 1982 (OECD, 1982). This scheme focussed primarily on total phosphorus, chlorophyll and water transparency as general indicators of enrichment. The scheme used annual average values of the aforementioned parameters to classify lakes into five primary trophic classes representing levels of eutrophication.

Traditionally, lake water quality in Ireland has been assessed using a modified version of the standard OECD scheme based on the annual maximum chlorophyll *a* concentration (see Table 4.1). The Irish scheme classified lakes into six water quality or trophic status categories using maximum levels of planktonic algae measured during the period. The broad eutrophic category of the standard OECD scheme was divided into three sub-categories and the ultra-oligotrophic category of the original OECD scheme was merged with the oligotrophic category. This modification of the OECD scheme was first implemented in 1983 and is set out in Table 4.1 together with corresponding indicators for each category related to water quality and the probability of pollution.

The highest chlorophyll *a* concentrations recorded are taken as estimates of the annual maximum values. These are based on average values per sampling occasion where there is more than one sampling site. These maximum values are used to assign a trophic status to the individual lakes. The average of the annual maxima for the period 2007-2009 has been used for the overall assessment of trophic status of each lake.

The ultimate aim of such schemes is to predict the likely ecological response of a given lake to nutrient inputs and to predict any impacts on the lake's 'beneficial uses' – e.g. water supply, angling, other leisure uses, biodiversity, ecosystem services and inherent ecological value. The modified OECD scheme has not been transferred to the WFD classification scheme; but this chapter compares the old and new systems for lake assessment.

WFD Lake Ecological Status Methodology

Under the WFD, ecological status is derived by taking the lowest status classes for a range of specified biological and physico-chemical and hydromorphological quality elements. The methods for biological and physico-chemical quality elements are dealt with below.

For lakes that are deemed to be at high status for biological and physico-chemical quality elements, hydromorphological condition must all agree. If hydromorphology is not also of high status the lake is downgraded to good status. Neither can lakes be considered to be of high status where the alien species zebra mussel (*Dreissena polymorpha*) or roach (*Rutilus rutilus*) are present. The presence of either of these species will result in a high status lake being downgraded to good status.

Status based on biological quality elements

Biological status was based on the response of the three biological quality elements; aquatic flora (macrophytes and phytobenthos), phytoplankton and fish, to the primary pressure on Irish lakes; nutrient enrichment.

Both chlorophyll and the macrophyte classification tool have been intercalibrated at EU level, while the fish assessment method is currently being intercalibrated. The intercalibration process is a legal obligation. Its aim is to ensure that ecological boundaries are harmonised between member states. The outcome should be that the different biological classification tools that have been intercalibrated will respond similarly to the same anthropogenic pressure. Therefore, if each member states applied their classification tool for the same biological element to the same waterbody, the same ecological status class would be returned. The outcome of the lake chlorophyll and macrophyte intercalibration has been published in a Commission decision and translated into national legislation making the boundaries legally binding. At the time of publication methods for fish status classification were still being intercalibrated – and thus, depending on the outcome, fish status classes may change. Additional pressures such as acidification, abstractions, barriers to fish migration, will be taken into account when suitable assessment methods become available.

Table 4.1. Modified version of the OECD scheme based on values of annual maximum chlorophyll concentration. Indications of water quality and the probability of pollution are also shown.

Classification Scheme			Category Description			
Lake Trophic Category		Annual Max. Chlorophyll mg/m^3	Algal Growth	Deoxygenation in Hypolimnion	Level of Pollution	Impairment of Use of Lake
Oligotrophic (O)		<8	Low	Low	Very low	Probably none
Mesotrophic (M)		8<25	Moderate	Moderate	Low	Very little
	Moderately (m-E)	25<35	Substantial	May be high	Significant	May be appreciable
Eutrophic:	Strongly (s-E)	35<55	High	High	Strong	Appreciable
	Highly (h-E)	55<75	High	Probably total	High	High
Hypertrophic (H)		≥75	Very High	Probably total	Very high	Very high

Status based on the chemical and physico-chemical quality elements

The supporting physico-chemical status was assigned using the Environmental Quality Standards (EQS) for total ammonia, dissolved oxygen and pH as published in S.I. 272 of 2009. In addition, interim EQS values of 10 and 25 µg/l P total phosphorus (TP) were used for the high/good and good/moderate boundary. Lake Habitat Surveys were used to assess hydromorphological pressure.

ASSESSMENT OF LAKE WATER QUALITY

Trophic Status

The details and trophic status of the lakes monitored are set out in Appendix 4.1 (on the CD accompanying this report) for each year surveyed during the review period. In all 222 lakes were examined (Over 988 km^2 in terms of lake area). The majority (180 or 81%) of the lakes examined in the period 2007-2009 were of satisfactory quality i.e. oligotrophic or mesotrophic in status (Figure 4.1). The water quality of the remaining 42 lakes was less than satisfactory. Of these, three lakes; Lough Gur, Inner and Naglack were classified as hypertrophic, i.e. the most enriched status. In terms of surface area lakes of satisfactory quality accounted for 910 km^2 (92%). A further 77 km^2 (8%) of lake area was classified as eutrophic and 1.5 km^2 (0.2%) were assigned to the hypertrophic category.

The proportion of lakes with an overall satisfactory water quality status (81.1%) in 2007-2009 is lower than in the previous 2004-2006 assessment period (85.3%). The proportion of lake surface area categorised as oligotrophic / mesotrophic (Figure 4.2) for the period 2007-2009 (92.1%) is similar to the period 20004-2006 (91.9%). A breakdown of trophic status for the 222 lakes examined in the period 2007-2009 is presented in Table 4.2.

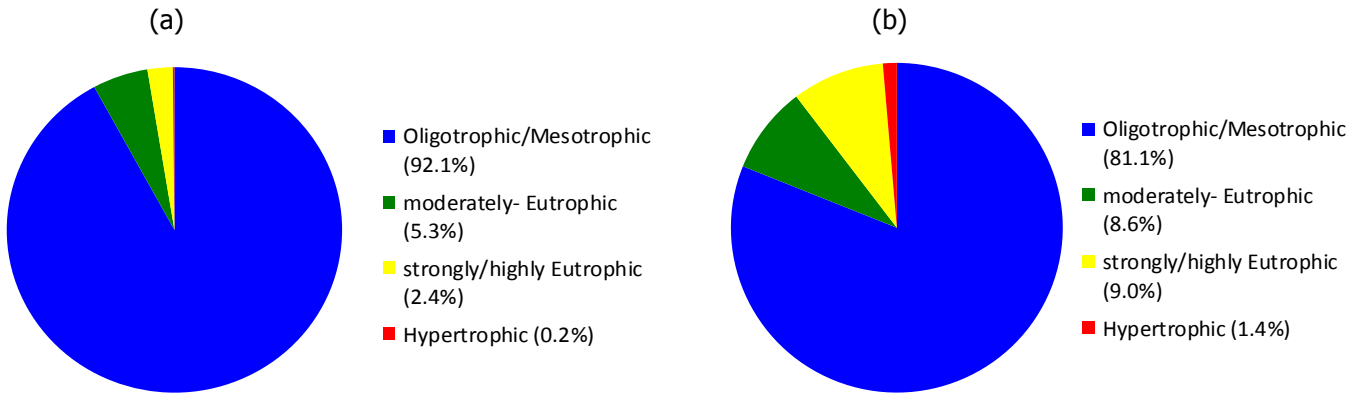


Figure 4.1. Trophic Status: (a) The percentage of lake area, and (b) percentage of lakes monitored in each trophic category.

Table 4.2. The number and percentage of lakes and the area and percentage of lake area in each trophic status for the 222 lakes examined in the period 2007-2009 is presented.

Trophic Category		Number of Lakes	% of Lakes	Surface Area km^2	% Area
Oligotrophic (O)		98	44.1	487.9	49.4
Mesotrophic (M)		82	36.9	422.1	42.7
	moderately Eutrophic (m-E)	19	8.6	52.8	5.3
Eutrophic:	strongly Eutrophic (h-E)	11	5.0	15.3	1.5
	highly Eutrophic (s-E)	9	4.1	8.8	0.9
Hypertrophic		3	1.4	1.5	0.2

Long Term trends in Water Quality based on Trophic Status

The percentage of lake area in each trophic category has remained relatively stable since 1998, based on the modified OECD scheme (Figure 4.2). There has been a small increase in the percentage area assessed as moderately eutrophic and this has been mirrored by a decline in the percentage area in the hypertrophic category.

Twenty-two lakes have been examined continuously in each review period since 1976 and a further five lakes have continuous data since 1982 (Table 4.3). Most of these lakes have relatively similar maximum chlorophyll values for the 2007-2009 period compared with the previous assessment period. The notable exceptions are Lough Gowna and L. Oughter in Cavan and L. Muckno in Monaghan, all of which have seen a decline in maximum chlorophyll values. This is believed to be due to the impact of zebra mussel populations in these lakes rather than any real improvement in trophic or ecological status, as the total phosphorus (TP) values remain elevated. Average TP values recorded for 2007-2009 for L. Gowna, Oughter and Muckno were 41, 65 and 62 µg/l, respectively. Other zebra mussel infested lakes which also showed a decline in maximum chlorophyll *a* levels include Loughs Sheelin and Kinale in Cavan and L. Key in Roscommon. The trophic status of Gortglass Lough in County Clare had deteriorated compared with the previous assessment period while most lakes remain unchanged. The majority of these lakes had attained oligotrophic or mesotrophic status, implying that for these lakes, zebra mussels have reached their maximum potential to influence chlorophyll levels.

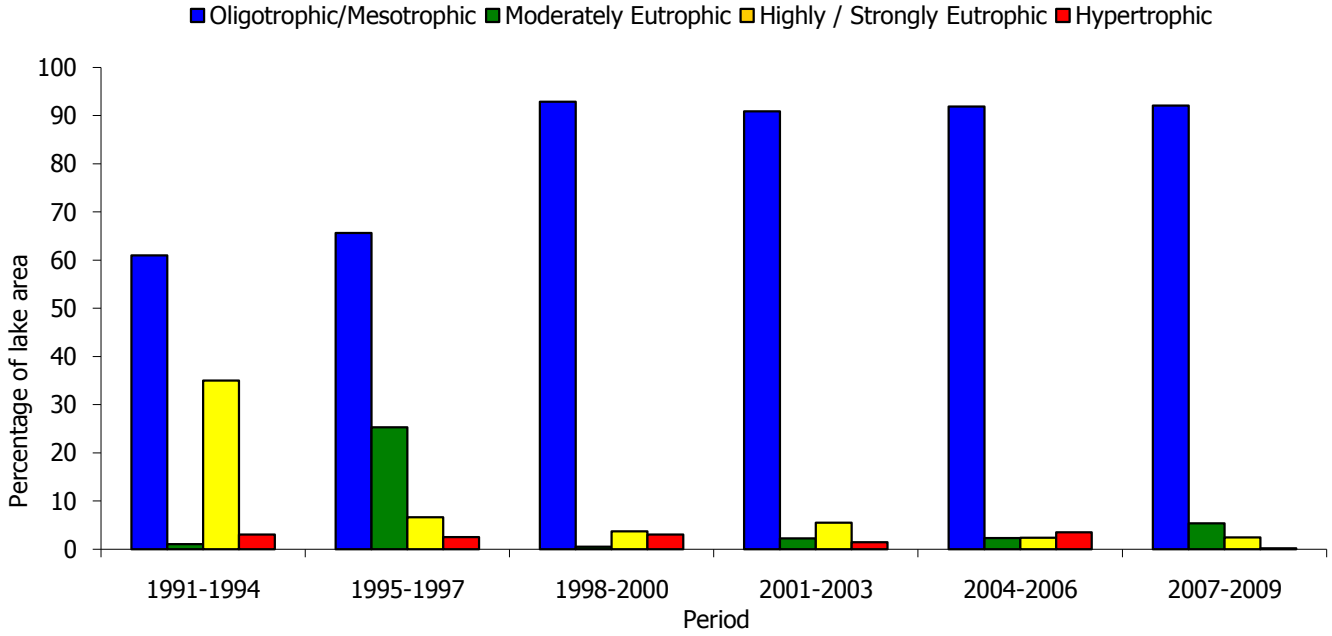


Figure 4.2. Long term trends in trophic status expressed as a percentage of total lake area examined for each of the assessment periods.

Table 4.3. Average maximum values of chlorophyll *a* (µg/l) for lakes with long term data.

Lake	County	Period of Examination								
		1976 - 1981	1982 - 1986	1987 - 1990	1991 - 1994	1995 - 1997	1998 - 2000	2001 - 2003	2004 - 2006	2007 - 2009
Arrow	Sligo	14	20	12	13	18	15	18	6	12
Carra	Mayo	9	9	9	9	10	15	7	6	6
Conn	Mayo	17	10	11	13	10	11	14	12	8
Coosan	Westmeath	5	19	-	12	13	14	16	7	7
Corrib (Lower)	Galway	28	18	10	8	11	9	8	8	8
Corrib (Upper)	Galway	11	5	9	8	11	9	13	8	7
Derg (Shannon)	N. Tipperary	14	34	41	54	27	12	10	10	10
Derravaragh	Westmeath	35	29	25	12	13	16	11	6	4
Ennell	Westmeath	47	28	19	23	16	17	21	15	17
Glendalough (Upper)	Wicklow	-	3	3	1	1	2	2	1	1
Gortglass	Clare	-	4	21	8	34	28	15	10	20
Gowna	Cavan	63	35	18	66	56	78	67	90	27
Innsicarra	Cork	34	-	61	137	43	16	29	35	40
Key	Roscommon	13	12	15	15	16	14	8	9	5
Killenure	Westmeath	16	9	-	13	11	9	6	7	5
Kinale	Cavan	40	24	24	7	6	60	33	15	9
Leane	Kerry	15	25	14	10	71	24	15	13	10
Leane (Ross Bay)	Kerry	63	57	23	17	41	30	32	25	21
Lene	Westmeath	-	5	6	7	8	8	8	14	12
Mask	Mayo	12	5	7	6	11	13	12	11	7
Maumwee	Galway	-	3	5	1	3	3	3	2	4
Muckno	Monaghan	537	54		29	24	17	48	93	65
Nahasleam (West)	Galway	-	3	3	1	2	2	3	3	3
Oughter	Cavan	11	99	68	158	132	104	86	97	34
Owel	Westmeath	290	7	8	12	11	12	11	9	11
Ramor	Westmeath	25	92	59	119	156	51	55	66	62
Ree	Longford	60	21	21	33	31	19	9	10	6
Sheelin	Cavan	-	60	37	33	48	65	44	31	26

Table 4.4. The trophic status for lakes with zebra mussel populations for the last three assessment periods (based on maximum chlorophyll) with an indication of recent changes.

		Area	Recent	Overall Trophic Status		
Lake	Location	km^2	Changes	2001-03	2004-06	2007-09
Acres	Leitrim	0.1	Improvement	s-E	h-E	M
Arrow	Roscommon	12.5	Deterioration	M	O	M
Ballykeeran	Westmeath	0.3	Deterioration	O	O	M
Boderg	Roscommon/Longford	4.3	Improvement	O	M	O
Bofin (Shannon)	Roscommon/Longford	5.1	None	O	O	O
Bunerky	Cavan	0.8	Deterioration	h-E	s-E	h-E
Conn	Mayo	50.0	Improvement	M	M	O
Coosan	Westmeath	0.8	None	M	O	O
Corrib (Upper)	Galway	85.0	None	M	M	M
Derg	Clare/Tipperary	117.5	None	M	M	M
Derravaragh	Westmeath	12.2	None	M	O	O
Derrycassan	Cavan/Leitrim	0.9	None	M	M	M
Drumlona	Monaghan	0.5	None	s-E	s-E	s-E
Forbes	Roscommon/Longford	3.4	None	O	O	O
Garadice	Leitrim	4.0	None	M	O	M
Gill	Sligo	14.3	None	M	O	O
Gowna North	Cavan	6.3	Improvement	h-E	H	m-E
Key	Roscommon/Longford	9.0	Improvement	O	M	O
Killinure	Westmeath	3.1	None	O	O	O
Kinale	Longford	2.0	None	m-E	M	M
Meelagh	Roscommon	1.2	None	O	O	O
Nablahy	Roscommon	0.78	Deterioration	M	O	M
Oughter	Cavan	13.0	Improvement	H	H	m-E
Ree	Roscommon/Longford	105.0	Improvement	M	M	O
Rinn	Leitrim	2.1	None	M	M	M
Sheelin	Cavan	17.7	None	s-E	m-E	m-E
Sillan	Cavan	1.7	Deterioration	h-E	s-E	h-E

WFD Lake Ecological Status Assessment

The first round of the WFD national lake monitoring programme assessed the ecological status of 222 lakes. The number of lakes examined in each river basin district (RBD) is presented in Table 4.5. Over half of the lakes examined (122) were located in the Western River Basin District (WRBD) and the North West River Basin District (NWRBD) reflecting the general location of lakes in Ireland. The Shannon RBD (SHRBD) had the next highest proportion of lakes at 51. The WRBD also had the greatest lake area examined (394 km^2) and 368 km^2 of lake area was examined in the SHRBD (Table 4.5).

Table 4.5. The number and surface area of monitored lakes by River Basin District for the period 2007-2009.

RBD	Number of Lakes	% of Lakes	Surface Area km^2	% Area
ERBD	16	7.2	38.8	3.9
NBRBD	5	2.3	4.4	0.4
NWRBD	61	27.5	125.7	12.7
SERBD	5	2.3	0.9	0.1
SHRBD	51	23.0	367.9	37.2
SWRBD	23	10.4	57.0	5.8
WRBD	61	27.5	394	39.8

WFD Ecological Status

In a departure from the modified OECD scheme for trophic status, lakes must now be classified using their biological quality elements and the supporting physico-chemical quality elements under the requirements of the WFD as outlined above.

National Picture: Using the new methodology, high or good status was assigned to 105 (47%) of the lakes examined (see Figure 4.3 and Table 4.6), with most of these 85 (38%) in the good status category. The majority of the remaining 117 lakes were of moderate ecological status and accounted for 53 per cent of the lakes examined. Twenty-five lakes were in either poor or bad status, most of which were located in Cavan or Monaghan. The geographical distribution of lakes in each ecological status class is illustrated in Figure 4.4.

Lakes in the high and good status categories accounted for 335 km^2 (35%) of the lake area examined (Table 4.6). A further 502 km^2 (51%) were assigned moderate status. Poor status lakes accounted for 127 km^2 (13%) of lake area examined (Table 4.6). In all, 65 per cent or 643 km^2 of lake area examined was in the moderate or worse ecological status classes (Table 4.6).

WRBD: In the WRBD 42 (69%) lakes were assigned high or good ecological status accounting for 194 km^2 (49%) of lake area monitored in the district (Figures 4.5, 4.6, 4.7 and 4.8).

(a) (b)

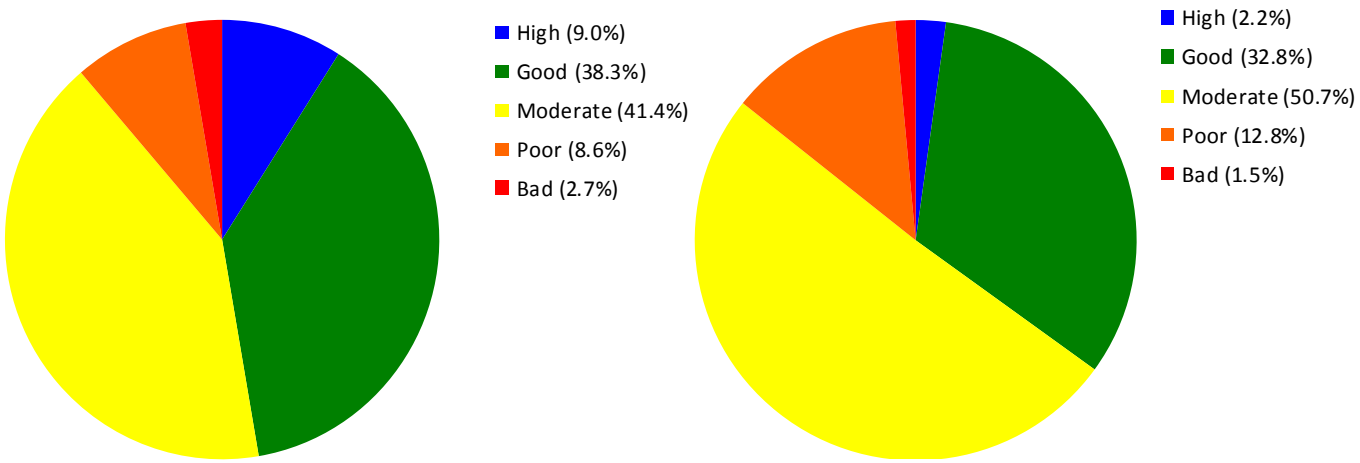
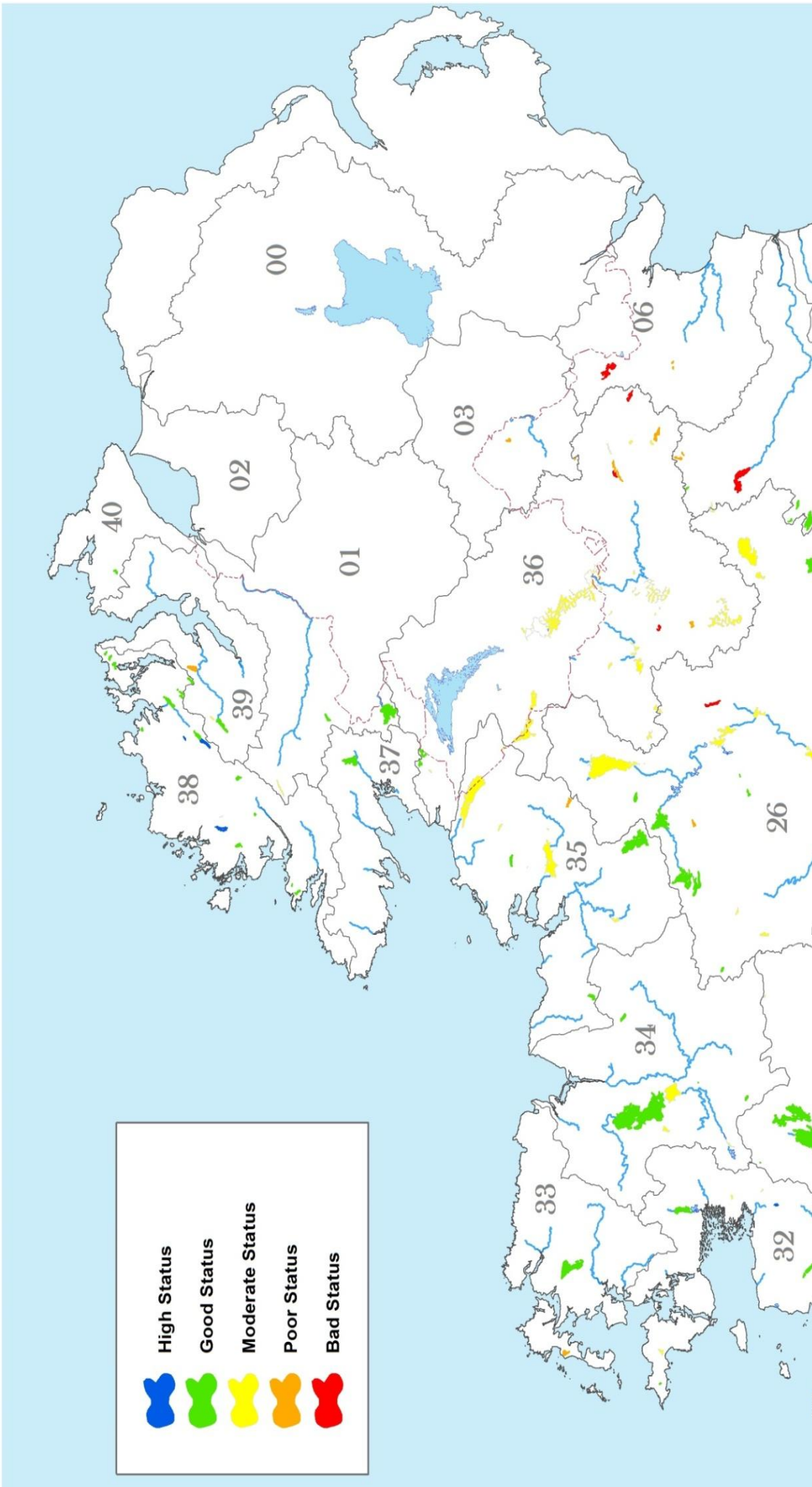


Figure 4.3 Final WFD Ecological Status: (a) percentage of lakes and (b) percentage of lake area surveyed assigned to each ecological status category.

Table 4.6. Final WFD Ecological Status: The breakdown of ecological status of the 222 lakes examined in the period 2007-2009 by number of lakes and surface area and percentage total assigned to each ecological status class.

Ecological Status	Number of Lakes	% of Lakes	Surface Area (km^2)	% Area
High	20	9.0	21.7	2.2
Good	85	38.3	323.8	32.8
High & Good	105	47.3	345.5	35.0
Moderate	92	41.4	501.6	50.7
Poor	19	8.6	126.8	12.8
Bad	6	2.7	14.6	1.5
Moderate or Worse	117	52.7	643.0	65.0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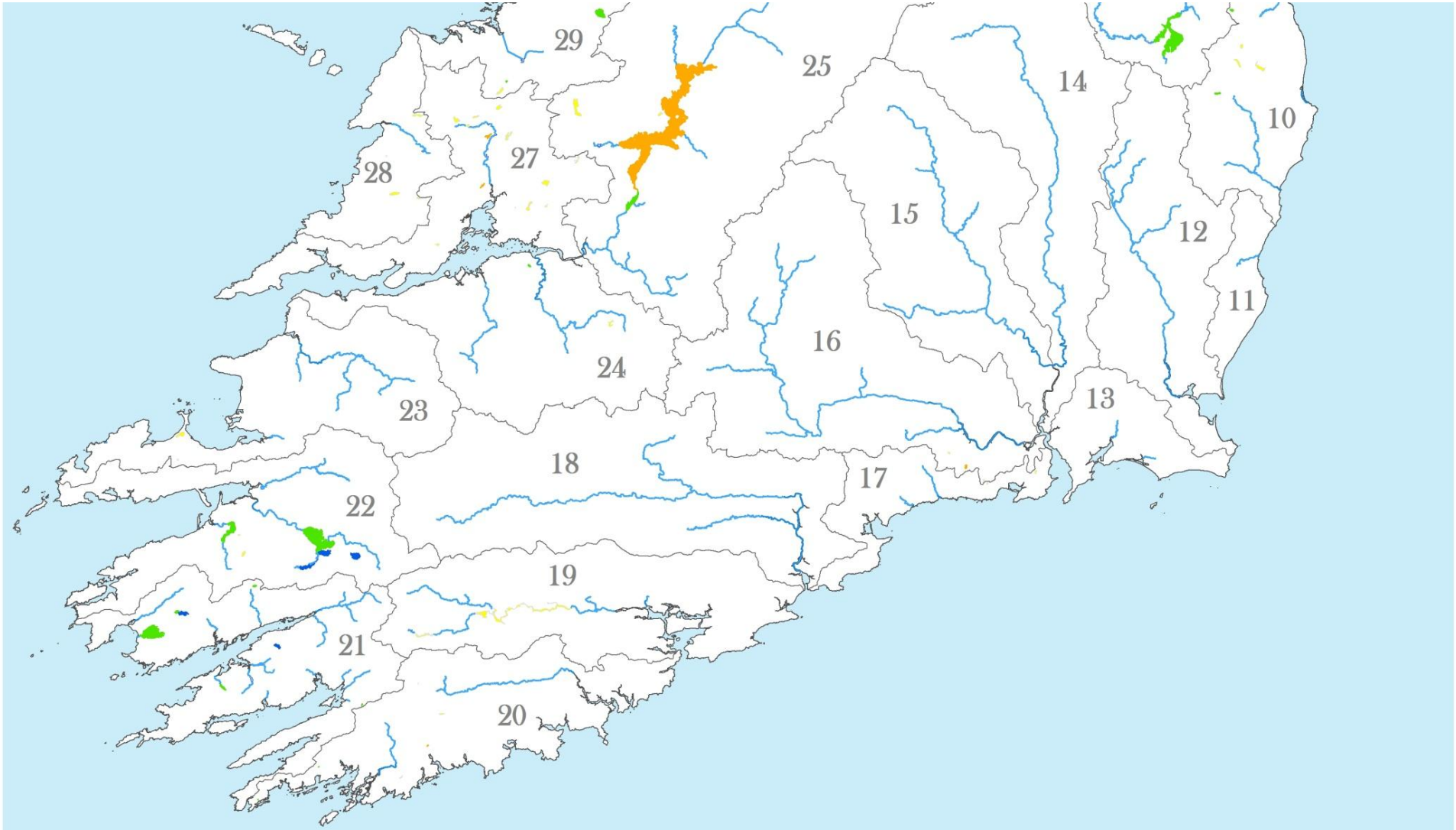


Figure 4.4. The WFD ecological status class of monitored lakes in Ireland based on a "one-out-all-out" approach using physico-chemical, biological and hydromorphological quality elements.

This reflects generally the low level pressures in this RBD but the remaining 19 lakes assigned moderate or worse ecological status accounted for over 200 km^2 (51%) of the lake area examined in the district.

NWRBD: In the NWRBD, 26 lakes (43%) were assigned high or good ecological status accounting for 27 km^2 of lake area monitored (22%) in the district (Figures. 4.5, 4.6, 4.7 and 4.8). These lakes were located in Co. Donegal in areas of low intensity agriculture, large tracts of natural vegetation and generally low levels of urbanisation. Thirty-five lakes in this RBD (57%) were assigned moderate or worse ecological status or 99 km^2 of the lake area examined (79%). The majority of these lakes were located in Cavan and Monaghan, both counties with high intensity farming but poorly draining soils.

SWRBD: The SWRBD had 14 lakes (61%) assigned to the high or good ecological status categories and nine lakes (39%) were assigned ecological status of moderate or less.

ERBD: The ERBD had no lakes of high ecological status (Figure 4.14). Nine lakes (27 km^2) were assigned good ecological status and seven lakes (12 km^2) were assigned to moderate or worse ecological status (Figures 4.5 and 4.6).

NBRBD: Lakes examined in the NBRBD were assigned either poor or bad ecological status and all of these lakes were located in County Monaghan.

SERBD: All lakes assessed in the SERBD were of moderate or poor ecological status, largely due to total phosphorus and chlorophyll possibly related to intensive agriculture. All of these latter were abstraction lakes.

Table 4.7. WFD Ecological Status: Poor and bad ecological status lakes by RBD and county.

RBD	Lake	County	Ecological Status
Eastern	Drumkeery	Cavan	Poor
	Ramor	Cavan	Bad
	Upper Lough Skeagh	Cavan	Poor
Neagh Bann	Corcaghan	Monaghan	Poor
	Emy	Monaghan	Poor
	Monalty	Monaghan	Poor
	Muckno or Blayney	Monaghan	Bad
	Naglack	Monaghan	Poor
North West	Drumlona	Monaghan	Poor
	Drumore	Monaghan	Poor
	Egish	Monaghan	Bad
	Fern	Donegal	Poor
	Garty	Cavan	Poor
	Glasshouse	Cavan	Bad
	Inner	Monaghan	Bad
	Sillan	Cavan	Poor
South East	Knockaderry Reservoir	Waterford	Poor
Shannon	Ballybeg	Clare	Poor
	Cavetown	Roscommon	Poor
	Derg SH	North Tipperary	Poor
	Dromore	Clare	Poor
	Rinn	Leitrim	Bad
	Ballinlough	Cork	Poor
West	Belhavel	Leitrim	Poor

West	Cross	Mayo	Poor

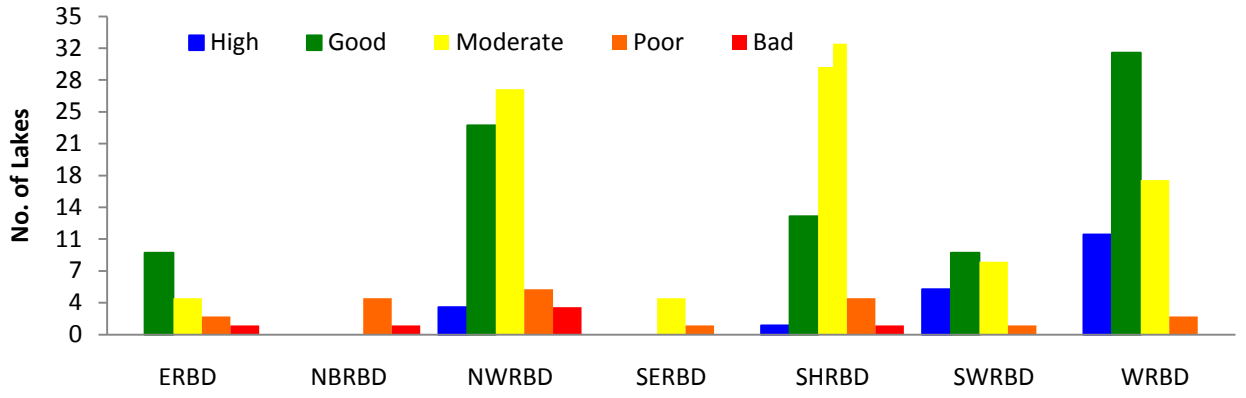


Figure 4.5. The number of lakes assigned to each ecological status class for each River Basin District

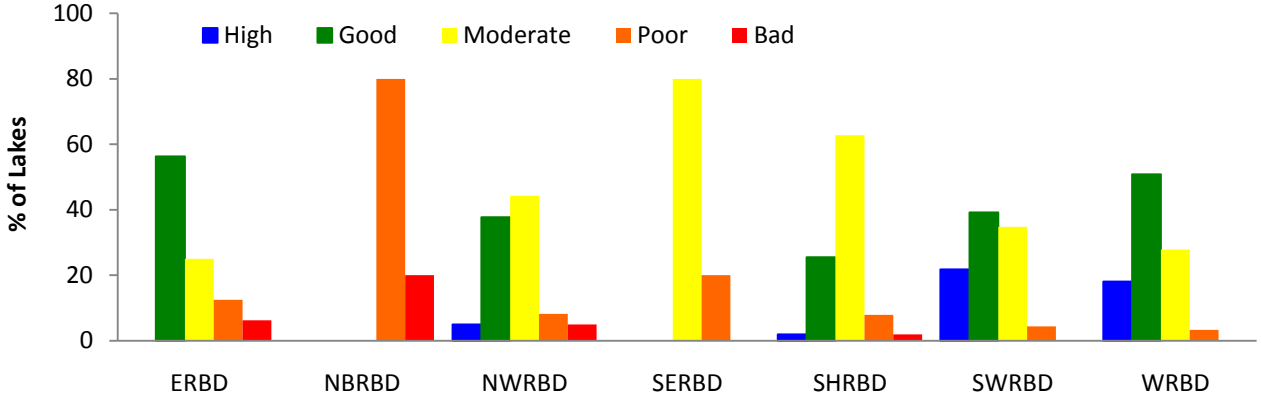


Figure 4.6. The percentage of lakes assigned to each ecological status class for each River Basin District.

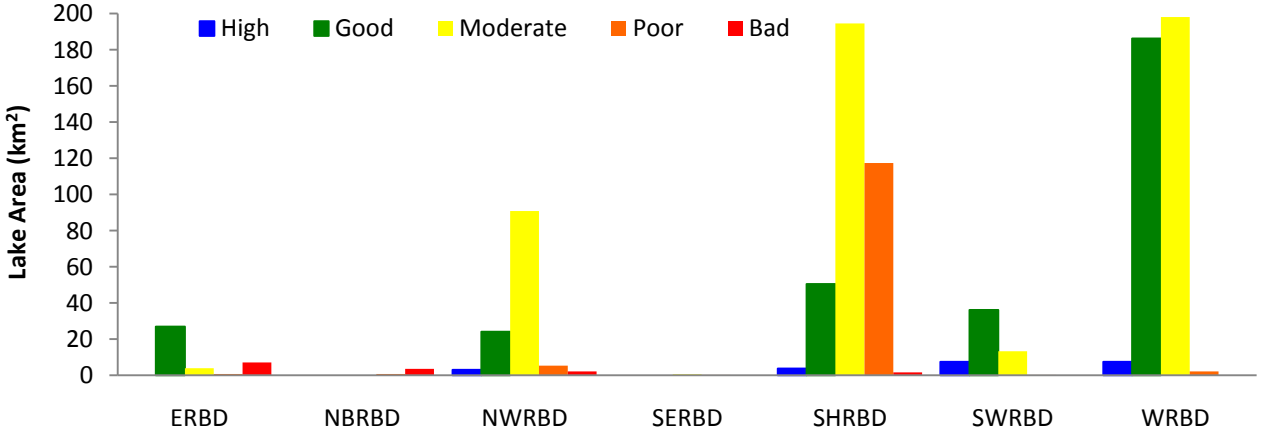


Figure 4.7. The lake area (km^2) assigned to each ecological status class for each River Basin District.

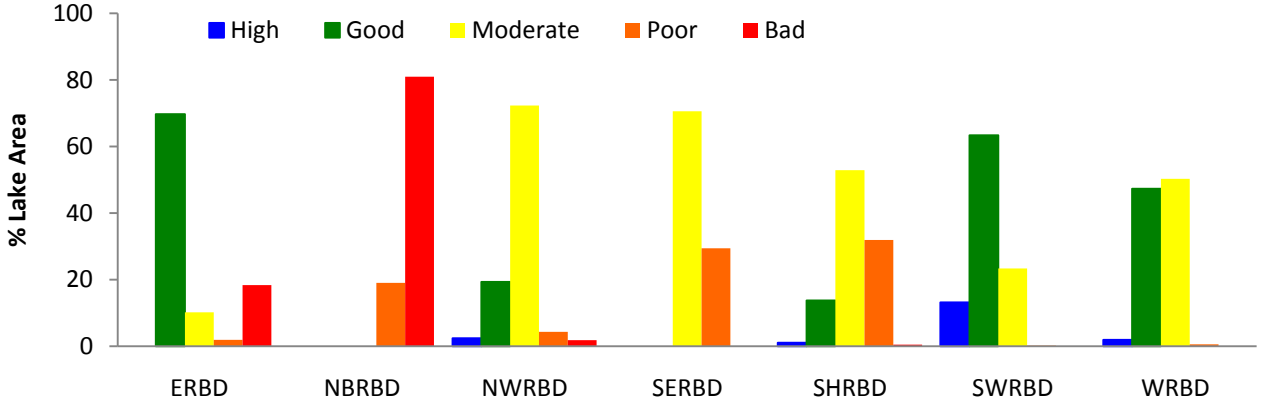


Figure 4.8. The percentage lake area assigned to each ecological status class for each River Basin District.

Seven lakes are designated as heavily modified waterbodies (HMWB). A different set of criteria apply to these lakes for assigning ecological potential rather than ecological status. Lakes for which the ecological potential assigned did not match the ecological status were reviewed in light of their modifications and the quality elements that were driving status. Two HMWBs, Pollaphuca and Lough Salt were upgraded from moderate ecological status to good ecological potential because the driving element, macrophytes, could be restricted by the modifications.

Hydromorphological pressures from abstractions or obstructions that impact one or more biological quality elements have not been considered here, nor has the pressure, acidification, with the exception of where the response was manifested in low pH values. In the future, both pressures should be included: pending the development and intercalibration of classification tools responding to such pressures.

Drivers of Ecological Status

The fact that the lowest status quality element, whether, biological, physico-chemical or hydromorphological determines the final ecological status on the so-called 'one-out-all-out' basis means that in some cases just one quality element will determine the final ecological status – possibly disagreeing with the status assigned by other quality elements. The principle is a precautionary one in the sense that most sensitive quality element should respond first to the pressures affecting the ecological status of the water body. Appendix 4.1 lists the results obtained for individual quality elements on a lake by lake basis and provides the fine detail showing the extent of agreement between the quality elements assessed. This also shows which quality element is ultimately responsible for a given lake's ecological status when there are differences between the results for different quality elements. The following summarises some of the main differences between quality elements.

High status is dependent on agreement between the physico-chemical quality elements status and biological status. The hydromorphological conditions of all high status lakes must also be assessed – and if a lake has significant hydromorphological alterations it cannot be considered to be at high status and must be downgraded to good status. In addition, any high status lake containing the alien species zebra mussel (*Dreissena polymorpha*) or roach (*Rutilus rutilus*) could not be considered to be at high status and is automatically downgraded to good status. Three lakes with high status for biological and physico-chemical quality elements were downgraded by their hydromorphology and while 54 of the monitored lakes contained populations of zebra mussel, none of them was at high ecological status and therefore no lake was downgraded on this basis. Of the 222 lakes monitored, only 20 lakes met all these criteria and could be considered at high ecological status (Appendix 4.1).

Eighty-five lakes were assigned good ecological status and for 39 of these lakes (46%) the biological and physico-chemical elements both indicated good status. The physico-chemical quality elements determined the ecological status of 21 of these lakes (25%). Good ecological status was assigned to 20 lakes (24%) based on their biological quality elements and two other lakes, designated as HMWB, were of good ecological potential.

Ninety-two lakes were assessed to be at moderate ecological status. There was agreement between the biological status and physico-chemical quality elements status for 48 of these lakes (52%). Moderate ecological status for 11 lakes (12%) was determined by their physico-chemical quality element status. Biological status determined the status of the remaining 32 lakes (35%).

The status of lakes in the poor and bad ecological classes is determined solely by the biological status as there are only three classes for the physico-chemical quality element status. All but three lakes in this status class were moderate status for the physico-chemical quality elements.

OECD Trophic Status vs WFD Ecological Status

Some 180 lakes were considered to be either of oligotrophic or mesotrophic status based on OECD classification scheme using maximum chlorophyll *a*, accounting for 910 km^2 of lake area. The chlorophyll metric used under the WFD classification is based on the average chlorophyll concentration over the 3-year period but this method also incorporates other biological and physico-chemical elements in addition to chlorophyll.

When WFD ecological status is contrasted against trophic status, 105 (59%) of the 180 oligotrophic or mesotrophic lakes were assigned either good or high ecological status; while 67 were assigned moderate ecological status (Table 4.8). Six lakes and two lakes, categorised as satisfactory under the modified OECD scheme, were assigned poor and bad ecological status, respectively. Five of these latter eight lakes were considered to be at moderate status based on physico-chemical quality element status but were less than moderate based on their biological quality elements.

Of the 67 satisfactory lakes (oligotrophic or mesotrophic lakes) 29 were assigned moderate ecological status based on both physico-chemical quality elements status and biological status. In this oligotrophic-mesotrophic group, 27 lakes were of moderate ecological status based on their biological quality elements alone but at good or high status for their physico-chemical elements, while the remaining 11 lakes were of moderate status based on their physico-chemical quality elements.

The 75 satisfactory lakes under the OECD scheme which are now assigned moderate ecological status under the WFD represent 564 km^2 of lake area examined. This results in an apparent dramatic decrease in the area of lake considered to be in a satisfactory condition based on trophic status compared with satisfactory ecological status (high or good) based on the new WFD methods.

The discrepancy between the traditional water quality assessment, the modified OECD lake quality scheme and the WFD ecological status arises as the former only considers chlorophyll levels and the latter incorporates a more holistic approach which includes a wider range of physico-chemical quality elements, additional biological elements together with more intensive monitoring.

Table 4.8. WFD Ecological Status classes compared with OECD trophic status classes for 222 lakes (2007-2009).

	Trophic Status 2007-2009						Totals:
Ecological Status	O	M	m-E	s-E	h-E	H	
High	17	3					20
Good	58	27					85
Moderate	23	44	18	4	2	1	92
Poor		6	1	6	5	1	19
Bad		2		1	2	1	6
Totals:	98	82	19	11	9	3	222

BIOLOGICAL STATUS

The status of the biological quality elements combines with physico-chemical status on a one-out-all-out basis to provide WFD ecological status as outlined above. The following provides a more detailed breakdown of biological status on a national and RBD basis and physico-chemical status is described in the subsequent section.

National: Of the 222 lakes monitored, 115 or 52 per cent were of high (20%) or good (32%) biological status (Figure 4.9) with most of these located in the WRBD. The NWRBD and the SHRBD had 12 per cent and 10 per cent of the high and good status lakes monitored nationally in their region. The remaining 107 of lakes (48%) were in moderate or worse status. The NWRBD and the SHRBD had 16 per cent and 13 per cent of these, respectively. All lakes in the NBRBD were in poor or bad biological status and all lakes in the SERBD were of moderate or poorer biological status. Figure 4.10 illustrates the national geographical distribution of lakes in each biological class.

In terms of lake area, 334 km^2 or 34 per cent of the total lake area monitored was assigned high or good biological status (Figure 4.11 & Table 4.9). The remaining 654 km^2 or 66 per cent of lake area examined was assigned moderate or worse biological status with in excess of two-thirds of this area located in the SHRBD and WRBD.

WRBD: In the WRBD 43 lakes (71%) were assigned high or good biological status (Figure 4.11) covering 194 km^2 of the monitored lake surface area (49%). There were 18 lakes (30%) of moderate biological status representing 200 km^2 (55%) of the monitored lake area there.

SWRBD: In the SWRBD 15 lakes (65%) were assigned high or good status amounting to 44 km^2 (77%) of monitored lake area in the district. The SWRBD had eight lakes (35%) assigned moderate biological status – just over 13 km^2 (23%) of the monitored lake area in the SWRBD.

NWRBD: High or good biological status was assigned to 26 (43%) of lakes in the NWRBD, 27 km^2 of lake area monitored. Moderate biological status was assigned to 35 lakes (57%) in the NWRBD representing 99 km^2 (79%) of lake area monitored in the district.

SHRBD: High or good biological status was assigned to 23 (45%) of lakes in the SHRBD, representing 62 km^2 of lake area monitored. There were 28 lakes at moderate biological status representing 306 km^2 (83%) of the monitored lake area in the RBD.

ERBD: Eight lakes (50%) in the ERBD were assigned high or good biological status representing 7.5 km^2 (19%) of lake area. The other half of the 16 lakes monitored in the ERBD were assigned moderate biological status representing 31 km^2 (81%) of lake area monitored.

NBRBD & SERBD: No lakes in the NBRBD and SERBD were assigned good or high biological status (See Figures 4.11-4.14).

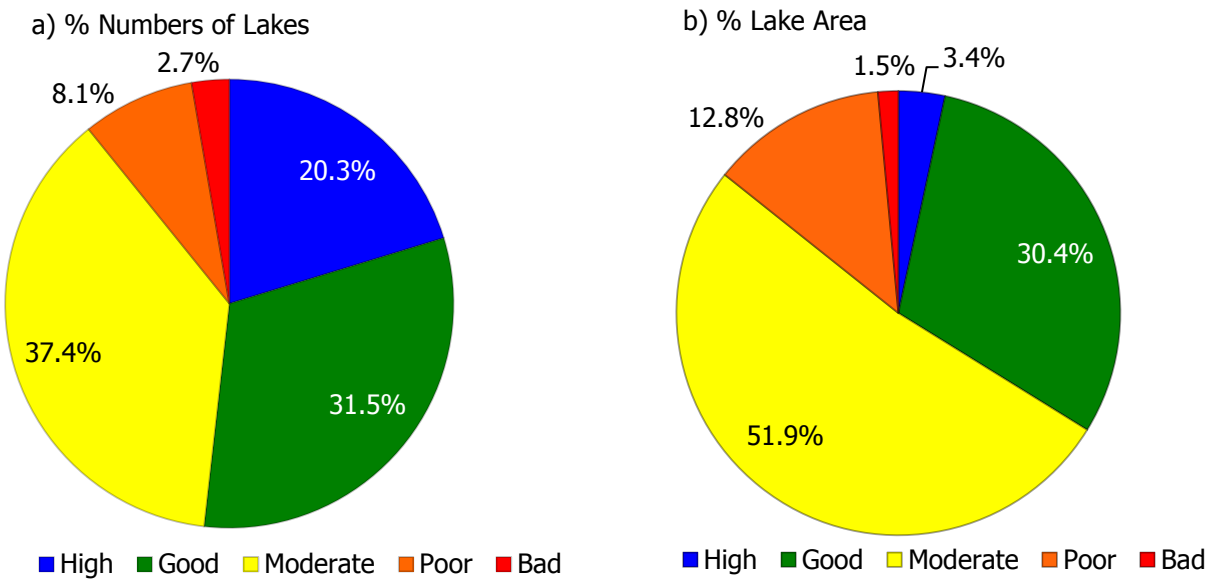
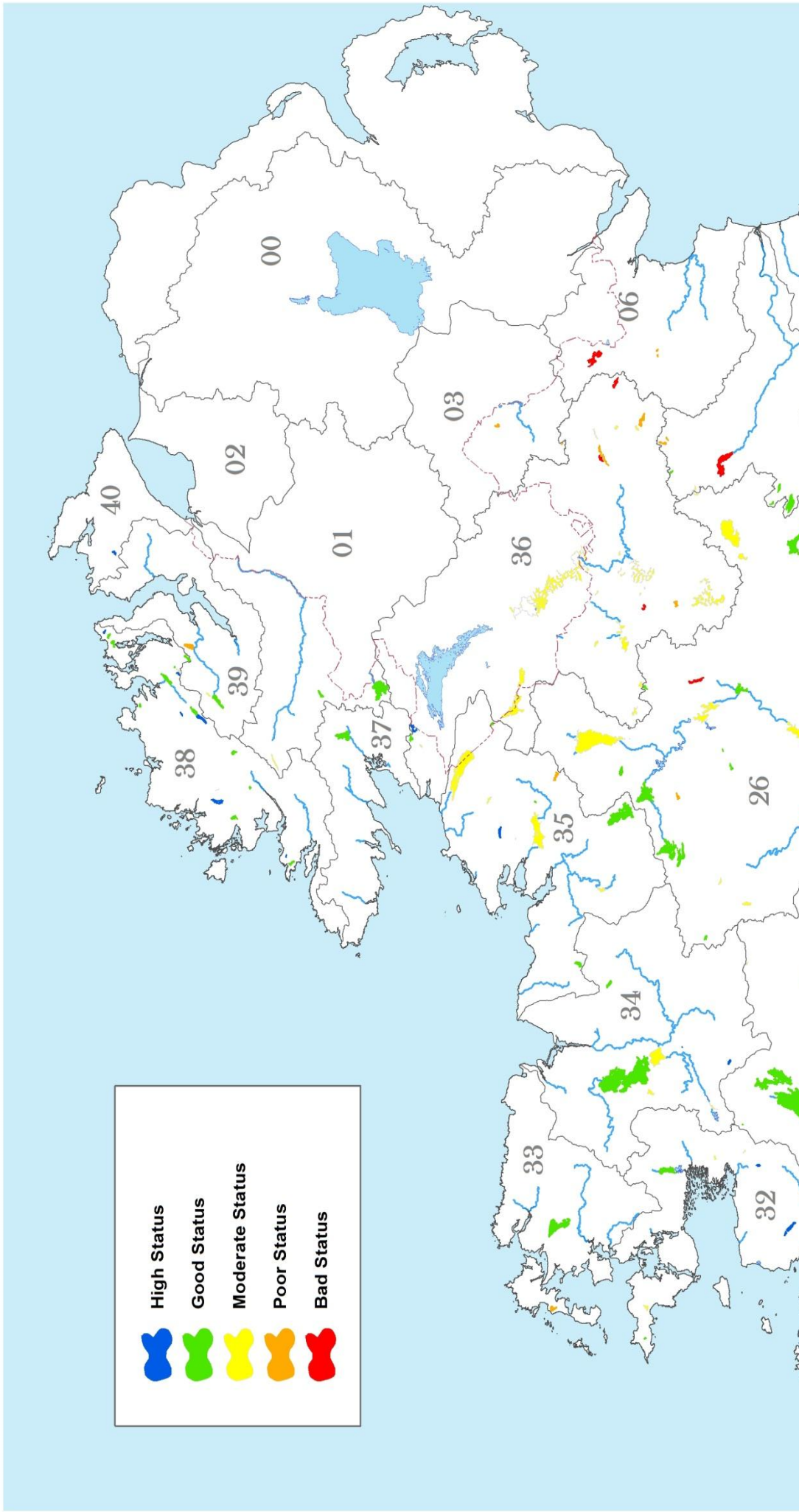


Figure 4.9. WFD Biological Status: National breakdown by a) percentage number of lakes and b) lake area assigned to each biological status category which combines with physico-chemical quality elements to yield overall ecological status.

Table 4.9 WFD Biological Status: The number, area and percentages of lakes in each biological status class for the period 2007-2009

	Number of Lakes	% of Lakes	Area	% area
High	45	20.3	33.4	3.4
Good	70	31.5	300.9	30.4
Moderate	83	37.4	512.9	51.9
Poor	18	8.1	126.7	12.8
Bad	6	2.7	14.6	1.5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Good Status
Moderate Status
Poor Status
Bad Status

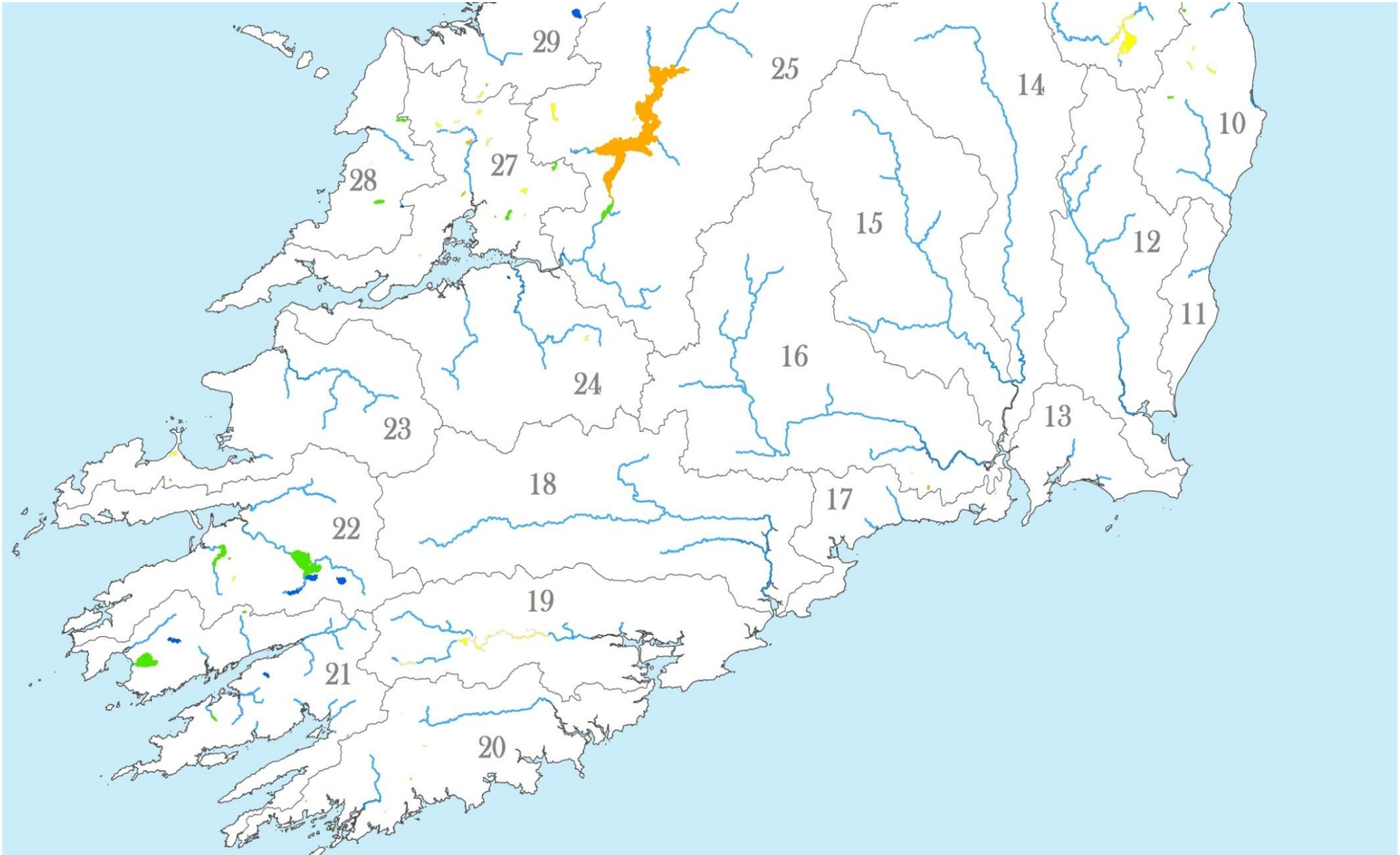


Figure 4.10. WFD Biological Status: The national geographical distribution of lakes in each biological class.

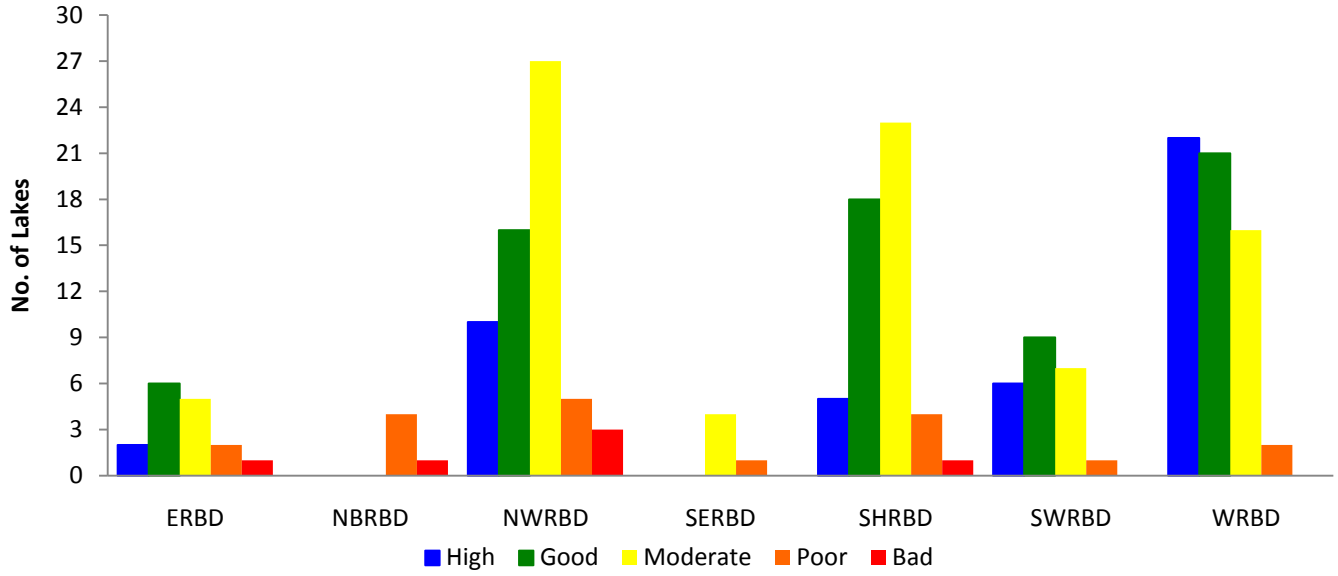


Figure 4.11. WFD Biological Status: The number of lakes assigned to each biological status class for each River Basin District.

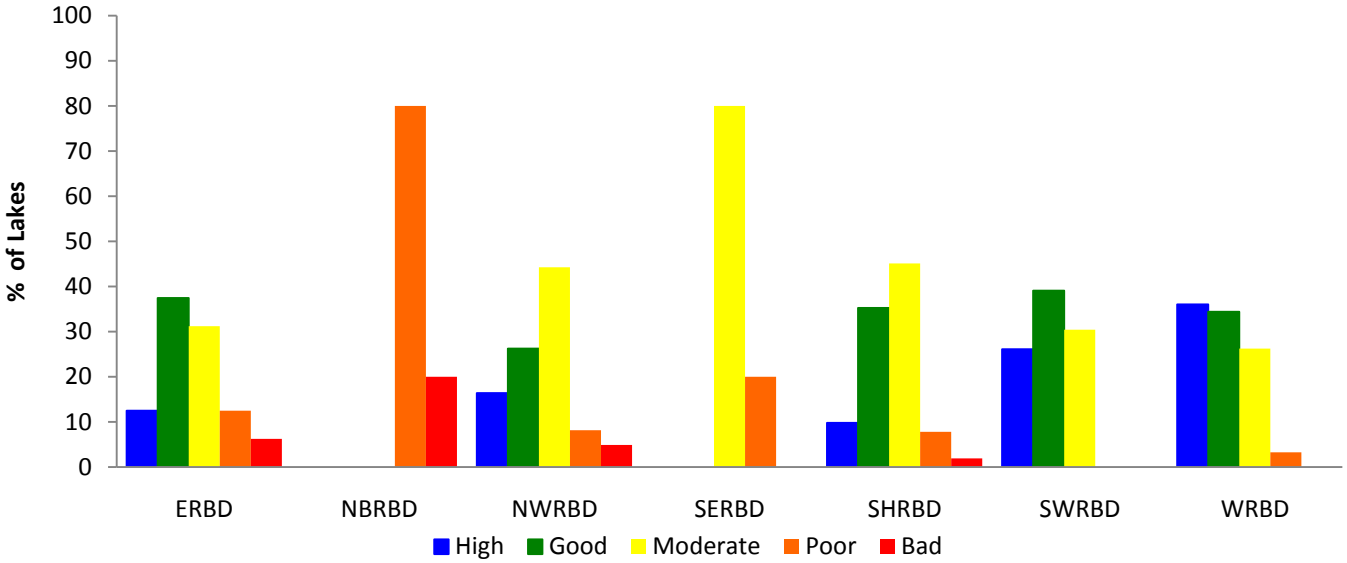


Figure 4.12. WFD Biological Status: The percentage of lakes assigned to each biological status class for each River Basin District.

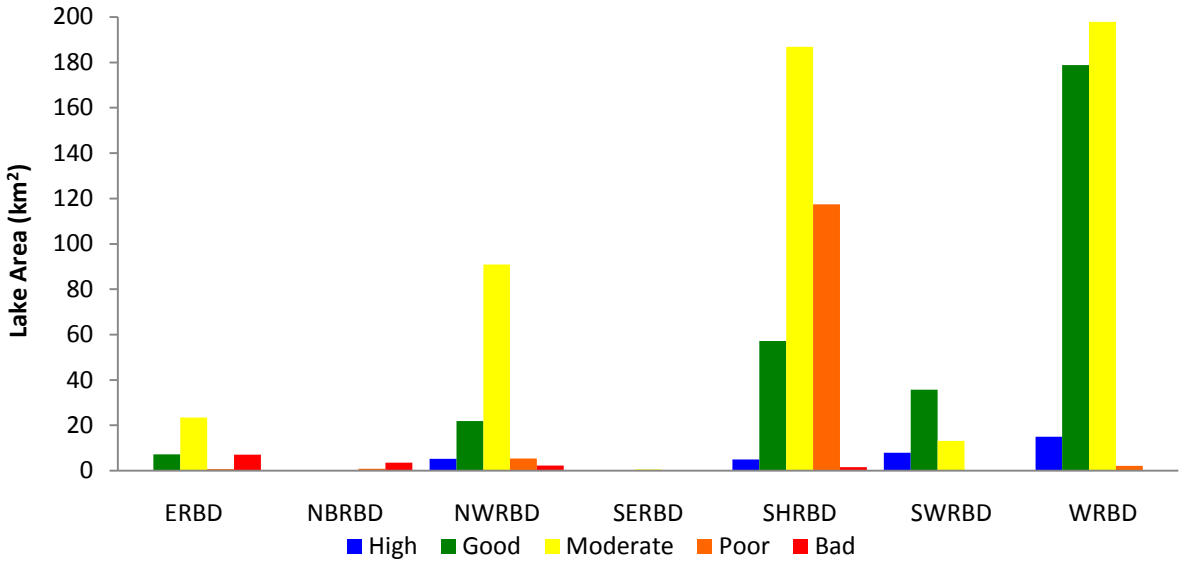


Figure 4.13. WFD Biological Status: The lake area (km^2) assigned to each biological status class for each River Basin District.

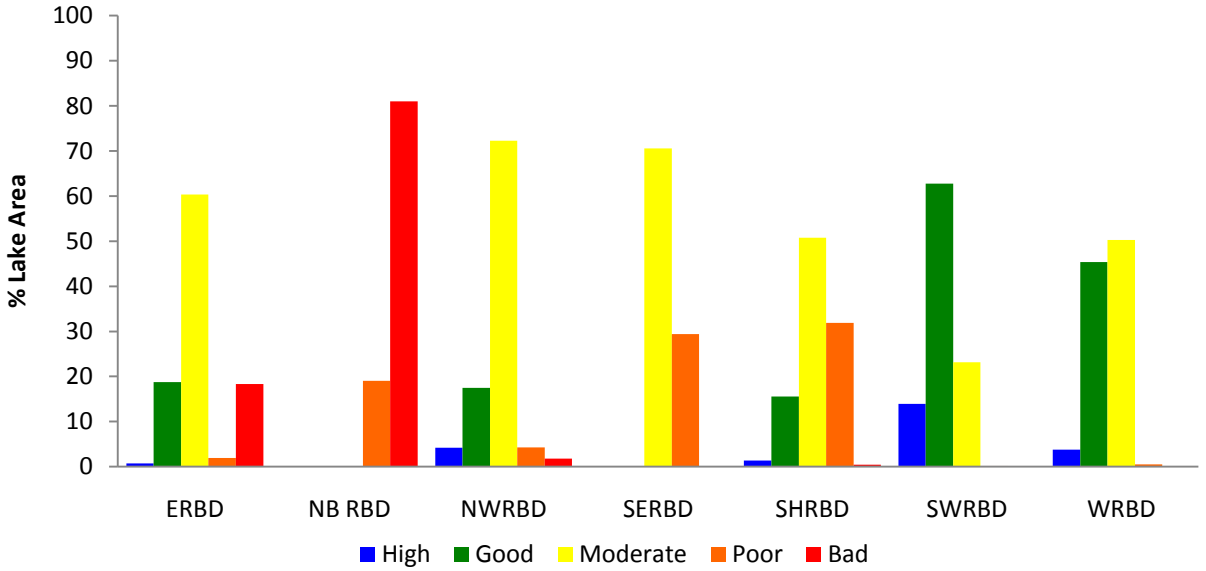


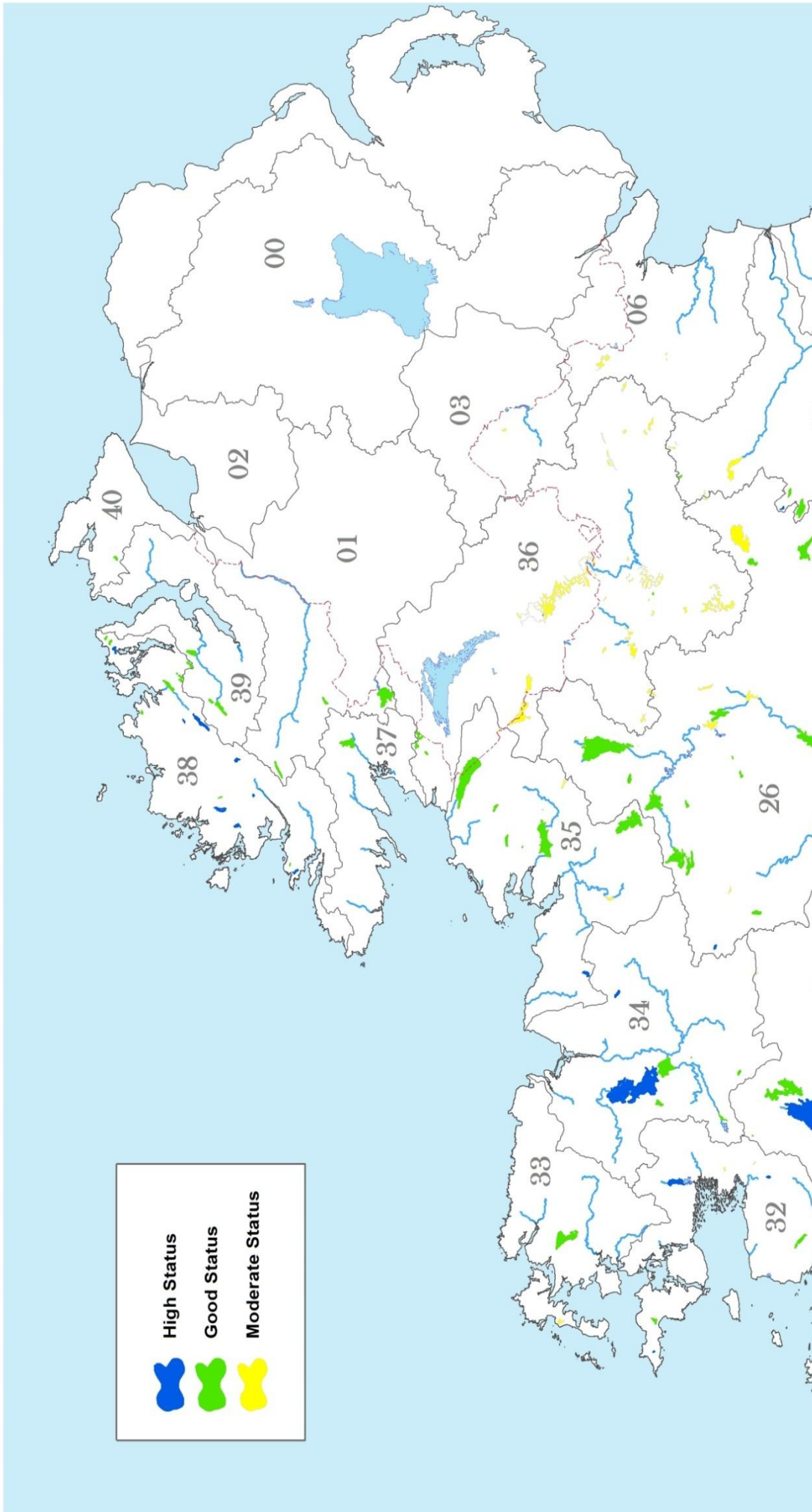
Figure 4.14. WFD Biological Status: The percentage lake area assigned to each biological status class for each River Basin District.

GENERAL PHYSICO-CHEMICAL STATUS

This section gives a breakdown of physico-chemical status, nationally and at RBD level which when combined with biological status above yields final WFD Ecological Status on a one-out-all-out basis.

National: The national geographical distribution of lakes in each of the three physico-chemical quality element status classes is mapped in Figure 4.15. Of the lakes monitored, 140 (63%) were in high or good physico-chemical quality element status (Figure 4.16). These were predominantly in the WRBD (Figure 4.15). Only 20 per cent of monitored lakes were in high physico-chemical status. The remaining 82 lakes (37%) were in moderate physico-chemical status and with over 50 per cent predominantly located in the NWRBD and SHRBD (Figure 4.15, Figure 4.17).

In terms of lake area, 851 km^2 (86%) of the total lake area monitored was in high or good physico-chemical status. Within this category good status lakes represented 57 per cent of monitored lake area. The remaining 14 per cent or 138 km^2 of monitored lake area was assigned moderate status and was predominantly located in the NWRBD and SHRBD.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Good Status
Moderate Status

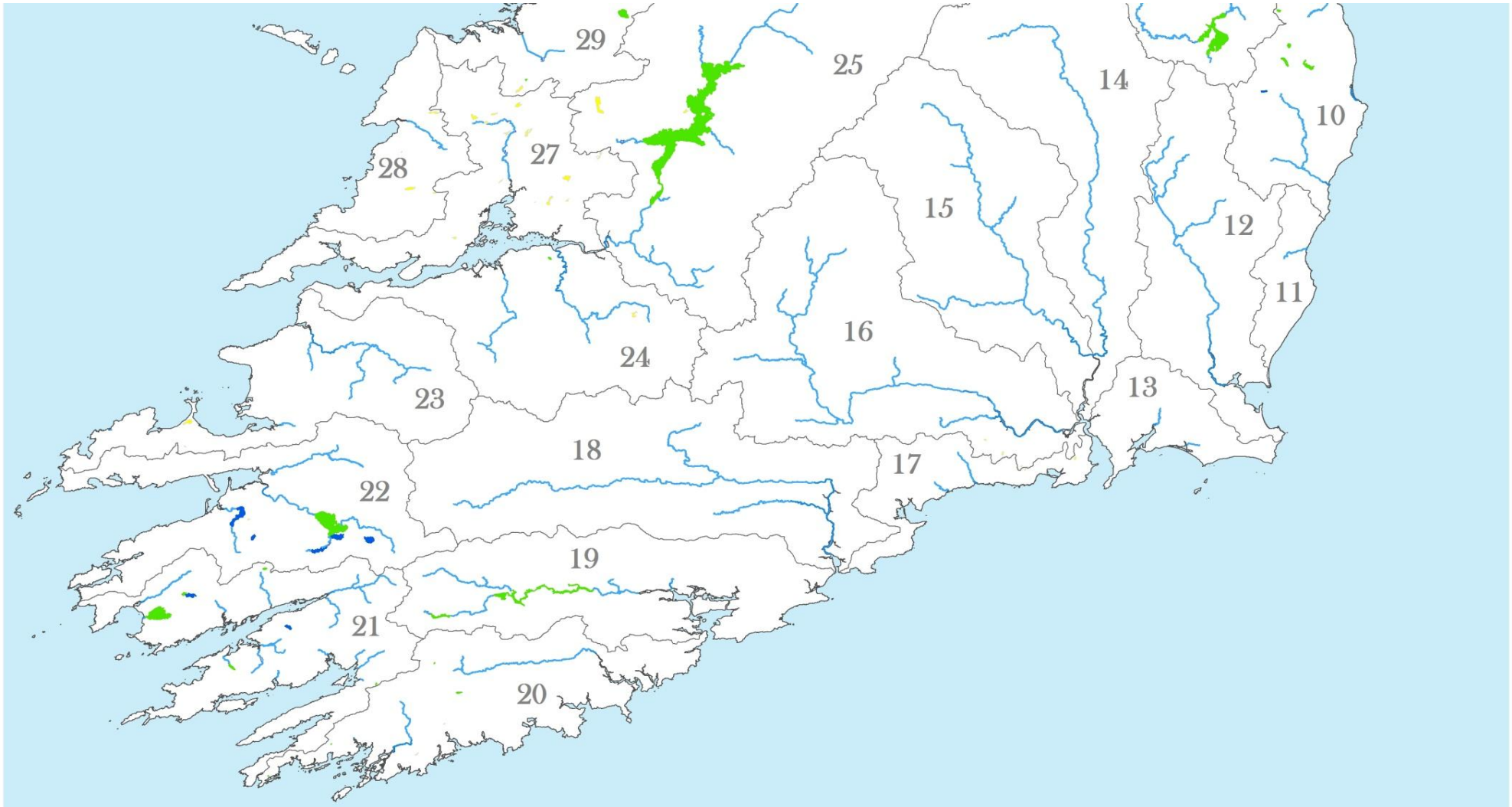

Figure 4.15. WFD Physico-chemical Status: The national geographical distribution of lakes in three physico-chemical quality element status classes.

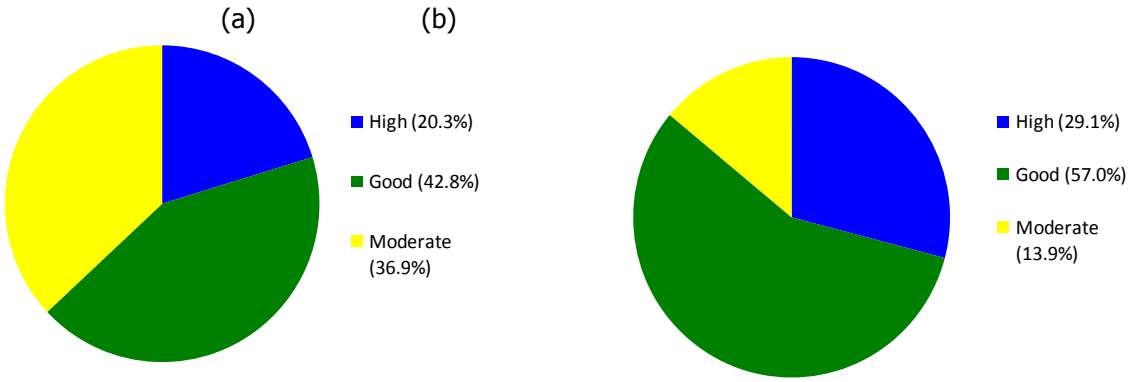

Figure 4.16. WFD Physico-chemical Status: (a) The percentage number of lakes and (b) the percentage of monitored lake area, assigned to the three physico-chemical quality element status classes.

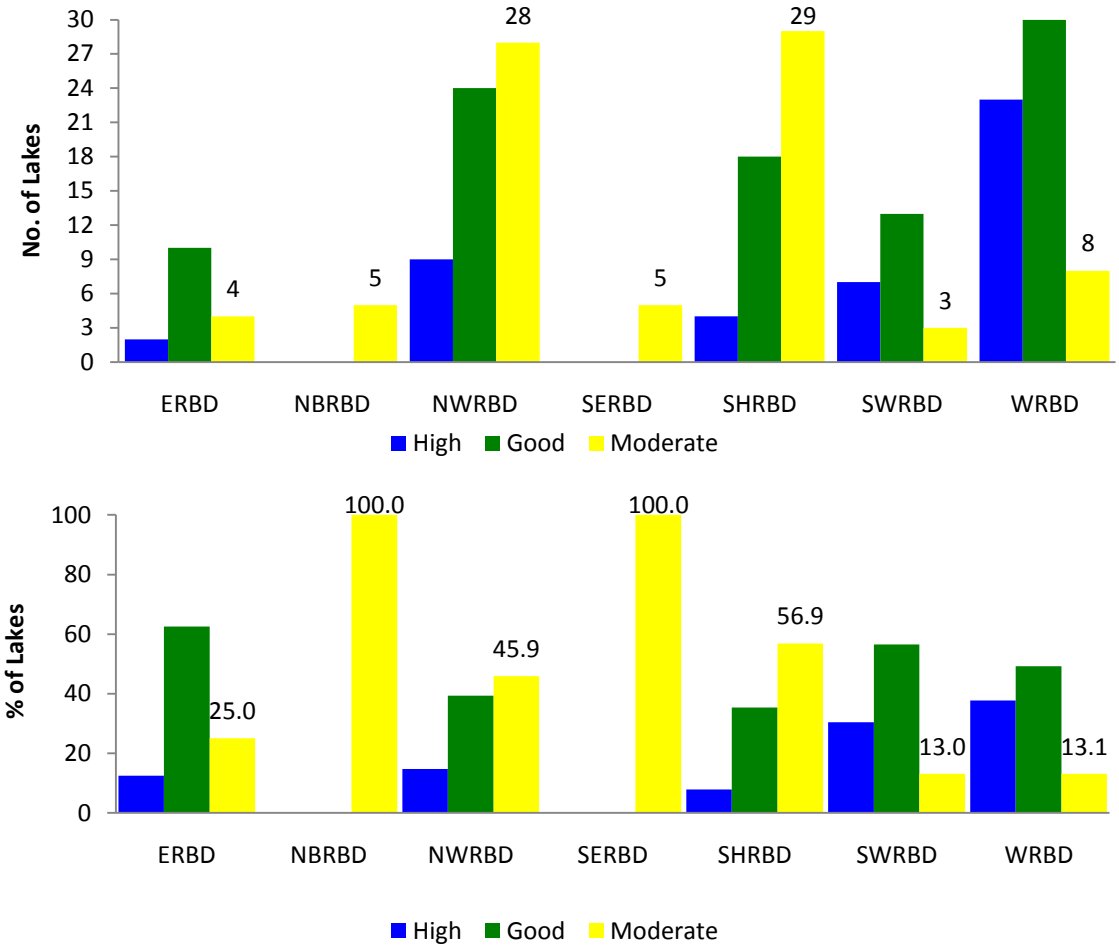

Figure 4.17. WFD Physico-chemical Status: Number (top) and percentage (bottom) of lakes assigned to the three physico-chemical quality element status classes in each RBD.

WRBD: In the WRBD high or good physico-chemical status was assigned to 53 lakes (87%) (Figure 4.17) representing 389 km^2 or almost 99 per cent of monitored lake area in the district (Figure 4.18). Moderate status was assigned to 13 per cent of lakes representing 1.3 per cent of monitored lake area in the WRBD.

SWRBD: In the SWRBD 20 lakes (87%) achieved high or good physico-chemical status, representing over 99 per cent of the 57 km^2 lake area monitored. Three lakes were

assigned moderate status representing 0.6 per cent of lake area surveyed.

NWRBD: In the NWRBD high or good physico-chemical status was assigned to 33 lakes (54%), representing 42 per cent of monitored lake area in the district. The remaining 28 lakes (73 km^2) were assigned moderate physico-chemical status.

ERBD: Of the lakes monitored in the ERBD, 12 lakes (75%) were assigned high or good physico-chemical status, accounting for 78 per cent of the 39 km^2 of monitored lake area in the ERBD. Four lakes were assigned moderate physico-chemical status.

SHRBD: In SHRBD, 22 (43%) lakes representing 88% per cent of the 368 km^2 monitored lake area there were assigned high or good physico-chemical status. Moderate physico-chemical status was assigned to 29 lakes (57%) based on their physico-chemical quality elements, representing 12 per cent of lake area in the district.

NBRBD: All five lakes in the NBRBD were of moderate physico-chemical status (Figure 4.17 and 4.18).

SERBD: The five lakes monitored in the SERBD were of moderate physico-chemical status (Figure 4.17 and 4.18).

Driving Physico-chemical Parameters

Of the 222 lakes monitored nationally, 45 lakes were assigned high physico-chemical quality element status and 95 lakes were assigned good physico-chemical status. Of these, 63 lakes were assigned good physico-chemical status based on total phosphorus (TP). Good physico-chemical status was assigned to 32 lakes based on both total ammonia and TP levels with over 50 per cent of these (20 lakes) located in the NWRBD. Only two lakes were assigned good physico-chemical status based on total ammonia alone.

Of the 82 lakes classified as being of moderate physico-chemical status, Lough Gur failed to meet the required oxygenation conditions, had an elevated pH (>9), an average TP value exceeding the interim EQS and an average ammonia exceeding the EQS for the good/moderate boundary. One lake, Summerhill, which is small and shallow, failed to meet required oxygenation conditions. Lough Cam in Kerry failed the EQS on low pH. This lake has a heavily afforested catchment and has been included on the acid lake subnet for the 2010-2015 lake monitoring programme.

The following lakes: Corcaghan, MacNean Upper and Lower, Monalty, Naglack, Upper Lough Skeagh and White Lough (Monaghan), failed to meet required oxygenation and nutrient conditions to achieve good status. Poor oxygen conditions and elevated pH levels are secondary effects of eutrophication. The remaining 72 lakes fail because of elevated nutrient conditions alone.

For the 80 lakes that failed nutrient conditions 33 failed both the interim TP and ammonia EQS values for the good/moderate boundary. These lakes were predominantly located in Leitrim, Monaghan, Cavan and Clare (NWRBD and SHRBD). Thirty-eight lakes failed to meet the interim TP EQS value for the good/moderate boundary. Over half of these lakes were located in Cavan in the NWRBD. A further nine lakes failed the ammonia EQS value for the good/moderate boundary, seven of which were located in Clare in the SHRBD.

The physico-chemical EQS standards are aimed at detecting pollution that may impact on the biological quality elements and affect overall ecological status. Elevated levels of nutrients, ammonia and phosphates are generally indicative of diffuse pollution (e.g., agriculture, forestry, septic tanks) and point source pollution (e.g., municipal or industrial wastewater treatment plants). These sources can result in depleted or elevated levels of oxygen in the water as a result of plant or phytoplankton growth and increased pH levels (>pH 9).

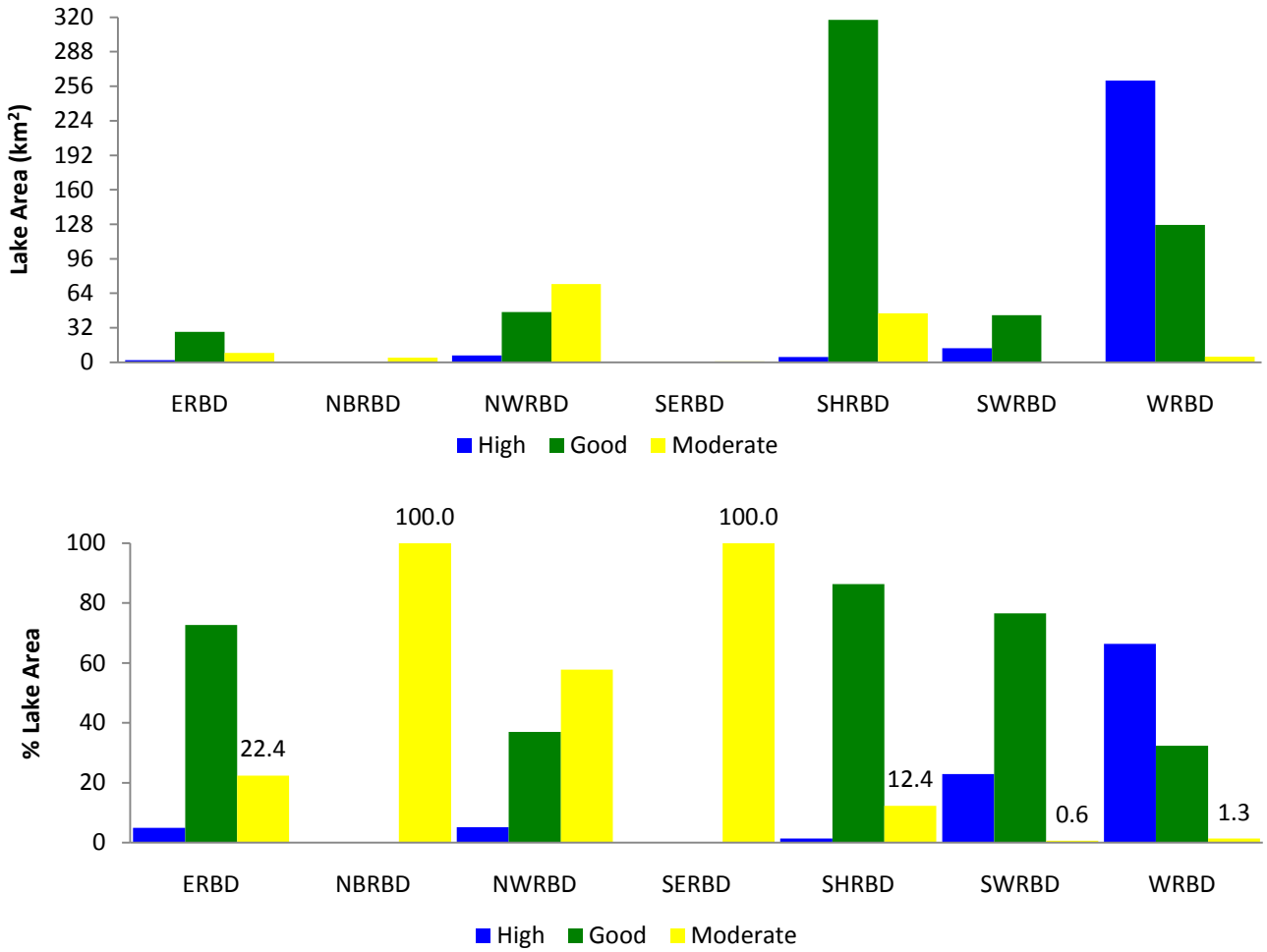

Figure 4.18. WFD Physico-chemical Status: The area (top) and percentage area of lake (bottom) examined assigned to each physico-chemical status category in each RBD.

Nitrates in Lakes

The concentration of nitrates in lakes is a key quality indicator because of its enriching effect as a nutrient and because of the potential health implication of high nitrate concentration in lake waters abstracted for potable supplies.

The EU Nitrates Directive (91/676/EEC)* requires member states to take specific measures to protect surface waters and groundwater from nitrate contamination arising from agricultural activities. The Irish Regulations implementing the Directive, and incorporating the action plan, were enacted and published as the European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2006 (S.I. No. 378 of 2006).** In addition direct waste discharges, such as sewage, may also contribute to such contamination and the EU Directive on urban wastewater treatment (91/271/EEC) provides for the removal of nitrogen from such waste in certain circumstances.

Under Regulations (S.I. No. 272 of 2009), which give effect to the measures needed to achieve the environmental objectives established by the Water Framework Directive (2000/60/EC), no criteria have, as yet, been

* The Nitrates Directive (91/676/EEC) – Council Directive of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources – was adopted in 1991 and has the objective of reducing water pollution caused or induced by nitrates from agricultural sources.

** These Regulations revoke, and re-enact with amendments, the European Communities (Good Agricultural Practice for Protection of Waters) Regulations, 2005 (S.I. No. 788 of 2005). However, the European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2009 revises and replaces the previous Regulations made in 2006 and 2007.

established for nitrates in lakes or rivers. However, for reporting purposes, under the Nitrates Directive, six quality classes are included ranging from 0->50 mg NO_3/l. Nitrate, often reported as total oxidised nitrogen (TON), given very low nitrite, is measured in the lake monitoring programme and Figure 4.19 shows for 2007 to 2009 most lakes were below 2 mg/l NO_3.

Trends in Total Phosphorus

Currently, there is no formal Ecological Quality Standard (EQS) for total phosphorus. However, as it is the main nutrient driving enrichment, it is important that phosphorus is included in any assessment of lake quality.

Under the Phosphorus Regulations, the annual mean target value for TP was set at 20 µg/l. For the period 2007-2009 just over 58 per cent of lakes with monitoring data had average TP values less than 20 µg/l. Therefore, almost 42 per cent of lakes would not be compliant with the Phosphorus Regulations. Of these lakes, 34 per cent or 31 lakes had average TP values in excess of 50 µg/l (Figure 4.20). As most of the failures under the physico-chemical status assessments were due to nutrient levels this is in line with expectations. A formal EQS for phosphorus in lakes will be set in the next phase of standard setting for the WFD. It is proposed that these will take into account the sensitivity of individual lakes to phosphorus loading as well as in-lake concentration.

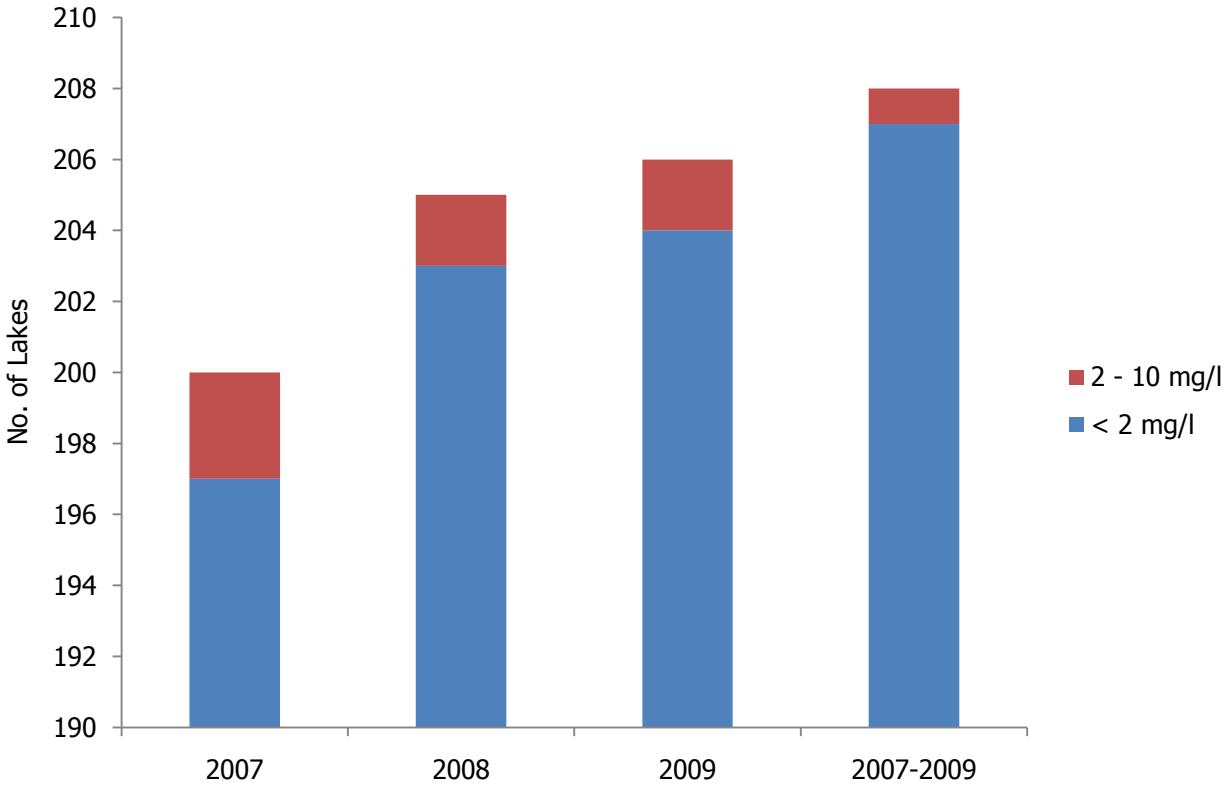

Figure 4.19. The number of lakes in each category of average total oxidised nitrogen – only one lake exceeded 2 mg/l when averaged over the 3-year period 2007-2009.

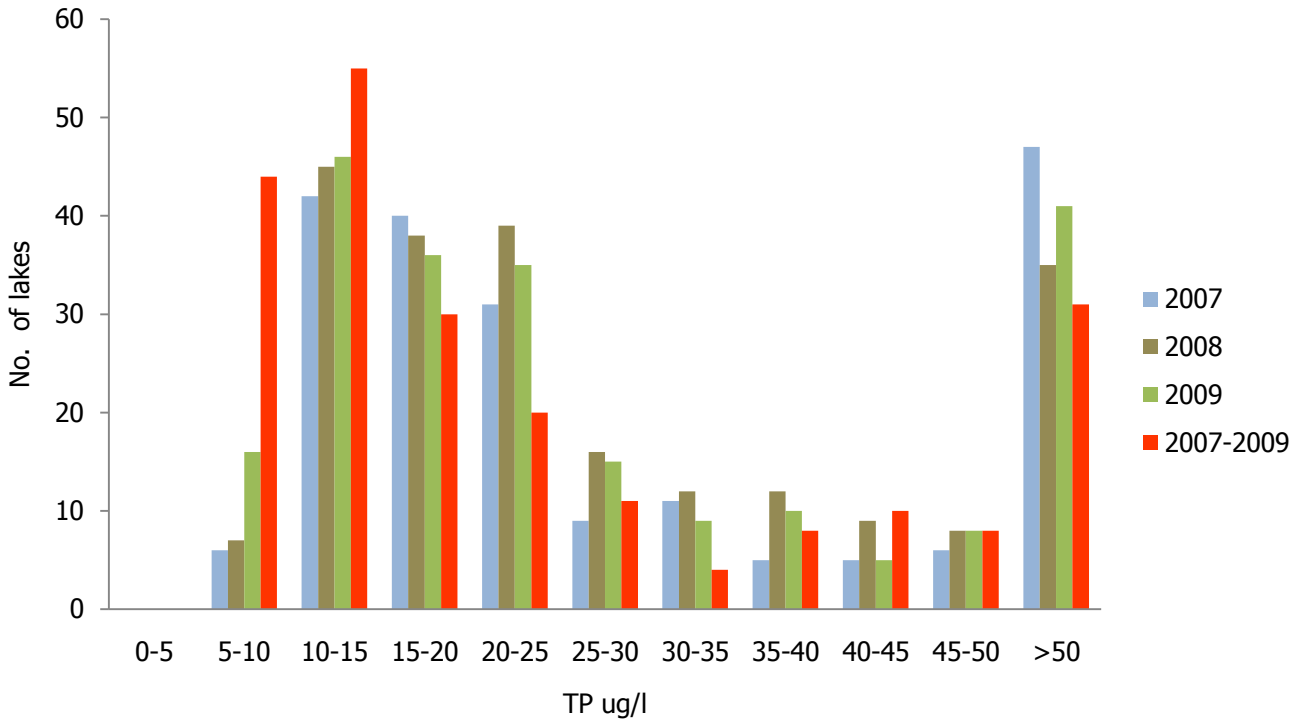

Figure 4.20. The number of lakes in each category of average total phosphorous (TP) µg/l in 2007-2009.

Acid Sensitive Waters

The principal areas in Ireland with acid sensitive water bodies are located along the western seaboard and in Co. Wicklow on the east coast. The geology in these areas is characterised by base-poor rocks such as granites and schists. Waters in these areas have a poor buffering capacity typified by their low alkalinities and are in consequence sensitive to acid inputs.

Three lakes, in Connemara, Donegal and Wicklow were selected to be the subject of a detailed investigation examining the impact of acid precipitation, in the period 1987-89 (Bowman, 1991). This investigation in the late 1980s showed that Irish waters were generally free of the impacts of anthropogenic or artificial acidification. Subsequently a longer-term monitoring programme has been carried out annually in December and April of the chemical and biological characteristics of three lakes and their inflowing streams: Loughs Veagh (Donegal), Maumwee (Galway) and Glendalough Lake Upper (Wicklow). These are regarded as representative of the larger acid-sensitive areas and this programme will continue into the 2010-2012 monitoring cycle.

The levels of acidity in the three lakes and their feeder streams were described by reference to the Raddum Index (N.I.V.A., 1987); see Table 4.10. This index is based on the sensitivity of the macroinvertebrate fauna to reduced pH and is widely used to describe the acid status of surface waters. Species are assigned an acidification score or index, in accordance with their sensitivity or tolerance to acidity. The Raddum Index scores for the three lakes systems examined in the period 2007–2009 are set out in Table 4.11. The faunal composition of the Lough Maumwee and Lough Veagh systems continue to be characterised by the presence of acid-sensitive forms, with the exception of the lake shore sampling point of the former lake.

The intermittent presence of acid-sensitive organisms at the sampling station on the Lugduff River tributary of Glendalough Lake Upper and in the littoral fauna of the lake suggest a reduction in the level of impact by artificial acidity in these waters which were regarded as severely degraded by acidity in the past.

Water samples for physico-chemical analysis were taken in conjunction with the biological

examinations on all occasions. The results of these analyses are summarised in Table 4.12. Alkalinity values were very low (<10 mg/l $CaCO_3$) at all sampling points indicating very poor buffering capacity and thus a high degree of sensitivity to acid inputs.

Little change in the acid status of these waters has been noted, however, since investigations began in 1984.

The pH values recorded at Lough Maumwee and Lough Veagh showed no evidence of inputs of artificial acidity to these systems. This assessment is supported by the relatively low concentrations of non-marine sulphate and oxidised nitrogen recorded in these systems.

Table 4.10. Raddum Index with invertebrate categories, associated acidification scores, minimum pH tolerance and inferred impact.

Category	Min. pH tolerated	Score	Inferred Acidification Impact by Presence
A	5.5-6.0	1.0	None
B	5.0-5.5	0.5	Moderate
C	4.7-5.0	0.25	Serious
D	<4.7	0	Severe

Table 4.11. The Raddum Index acidification score for Lough Maumwee, Glendalough Lake Upper and Lough Veagh and their inflowing streams during the period 2007-2009.

	2007		2008		2009	
Lough Maumwee	May	Nov	May	Dec	June	Dec
Lake shore	ns	ns	0.5	0	0.5	0
Inflow No.1	ns	1	1	1	1	1
Inflow No.2	ns	1	1	1	0.5	1
Glendalough lake Upper	May	Dec	May	Nov	May	Nov
Lake shore	0	0	1	1	0.5	1
Glenealo River	1	1	1	1	1	1
Lugduff River	0.5	1	1	0	0	1
Lough Veagh	May	Nov	May	Dec	June	Dec
Lake shore	1	ns	ns	1	ns	1
Sruthnacoille	1	ns	ns	1	1	1
Derrybeg River	1	ns	ns	1	ns	ns
Owenveagh River	1	ns	ns	1	1	1
Glenlackburn	1	ns	ns	1	1	1
ns: not sampled						

Table 4.12. The minimum (Min) and median (Med) pH values and the median concentration of alkalinity (Alk), total aluminium (Tot. Al), non-marine sulphate (N-M SO4) and oxidised nitrogen (Ox-N) in Loughs Maumwee, Glendalough Upper and Veagh and their inflowing streams during the period 2007- 2009.

Location	pH Min	pH Med	Alk $CaCO_3$ mg/l	Tot. Al µg/l	N-M SO_4 mg/l	Ox-N µg/l N
Lough Maumwee						
Lake Surface	5.7	6.5	7.6	25	0.28	40
Inflow No. 1	6.0	6.3	7.0	25	0.22	100
Inflow No. 2	6.2	6.3	6.0	25	-	30
Glendalough Lake Upper						
Lake Surface	5.6	6.9	5.2	127	2.04	115
Glenealo River	5.9	6.2	4.5	112	2.92	100
Inflow No. 2	5.9	6.4	7.0	39	4.52	545
Lugduff River	5.2	5.7	2.5	217	2.20	200
Lough Veagh						
Lake Surface	5.9	6.5	6.0	77	0.27	50
Sruthnacoille River	5.7	6.1	4.5	106	-	40
Derrybeg River	5.3	6.3	2.5	93	0.28	50
Owenveagh River	6.1	6.4	7.0	68	0.37	45
Glenlackburn River	6.3	6.6	8.0	59	0.20	150
Inflow No. 5	5.6	6.3	7.0	88	-	100

BATHING WATER QUALITY IN LAKES

The EU Directive concerning the quality of bathing waters specifies mandatory and guide standards for the protection of public health and the environment (CEC, 1976). The number of designated inland bathing areas has remained at nine since 1994. Freshwater bathing areas failed to achieve 100 per cent compliance with the EU mandatory standards for the years 2008 and 2009 (EPA, 2010). This is in contrast to the previous period (2004-2006) for which 100 per cent compliance with the EU mandatory standards was achieved. The failures were at Ballyallia Lake (Ennis), Keeldra (Leitrim) and at Lilliput (Lough Ennell). Two of the three lakes recovered in 2009, the exception was Lough Ennell. Compliance of the freshwater bathing areas with the more stringent EU guide values has declined from 67 per cent in 2007 to 44 per cent in 2008 but improved again in 2009 (Figure 4.21). Ballyallia Lake, Keeldra and Lilliput consistently failed during the assessment period.

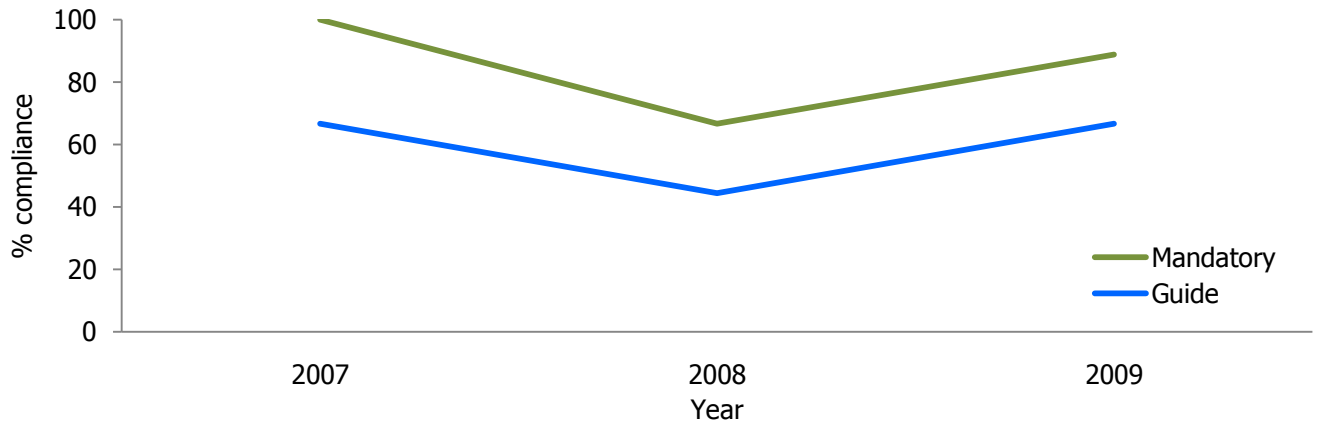

Figure 4.21. Compliance of Freshwater Bathing Areas with EU Mandatory and Guide Standards 2007 – 2009 (Source: EPA, 2008, 2009, 2010)

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