PILOT SURVEY OF THE FRESHWATER PEARL MUSSEL POPULATIONS OF NORTHERN IRELAND (D.O.E. - CP1432/1).

D. ROBERTS, T.G, MACKIE

Division of Environmental and Evolutionary Biology, School of Biology and Biochemistry, The Queen's University of Belfast.

and H.G.C, ROSS

Department of Botany and Zoology, The Ulster Museum, Belfast.

FEBRUARY 1991.

CONTENTS.

1. INTRODUCTION

The freshwater pearl mussel Margaritifera margaritifera (Linnaeus 1758) is a palaeoheterodont bivalve mollusc of the order Unionoida; superfamily Unionacea; family Margaritiferidae, with world-wide distribution in the northern hemisphere. The life cycle of Margaritifera is illustrated in Fig. 1.

Margaritifera, in common with other members of the Unionoidea, has a parasitic larval stage , presumably to aid distribution against the unidirectional flow characteristic of its riverine habitat. The mature mussel (15-20 years of age)(Young and Willams, 1984.) produces fertilized eggs in the autumn which are retained in the marsupium (a modification of each demibranch of the gills). Some Irish mussels however have been found to be gravid at 7-8 years of age.(Ross,E. pers. comm., 1991.). In the marsupium the fertilized egg develops into a bivalved larval stage, the glochidium, which is capable of weak swimming movements.Glochidia are released between June and September in Irish waters. A suitable host fish for these glochidia must then be encountered. Due to an immune response in older fish, these must be young(less than 3 years of age) salmon, Salmo salar (L.1758), or brown trout, S.trutta (L.1758). The introduced and farmed rainbow trout (S.gairdneri) does not serve as a host (Bauer, 1988). Having been inhaled, glochidia attach themselves to the fish's gills, encysting in the soft tissue. Here they grow, undergoing the transformation to baby mussels, remaining encysted until late autumn or the following summer. Then in response to changing water temperature the juvenile mussels excyst by rupturing the gill tissue using movement of the foot and valves. (Ellis,1978).

They then drop to the river bed and burrow into the substratum, remaining buried for 5 - 10 years. Young mussels are generally not seen above the substratum before they are 50mm in length (5 years of age) and can grow to lengths of 150+ mm (up to 125 years of age) (Purser, 1985).

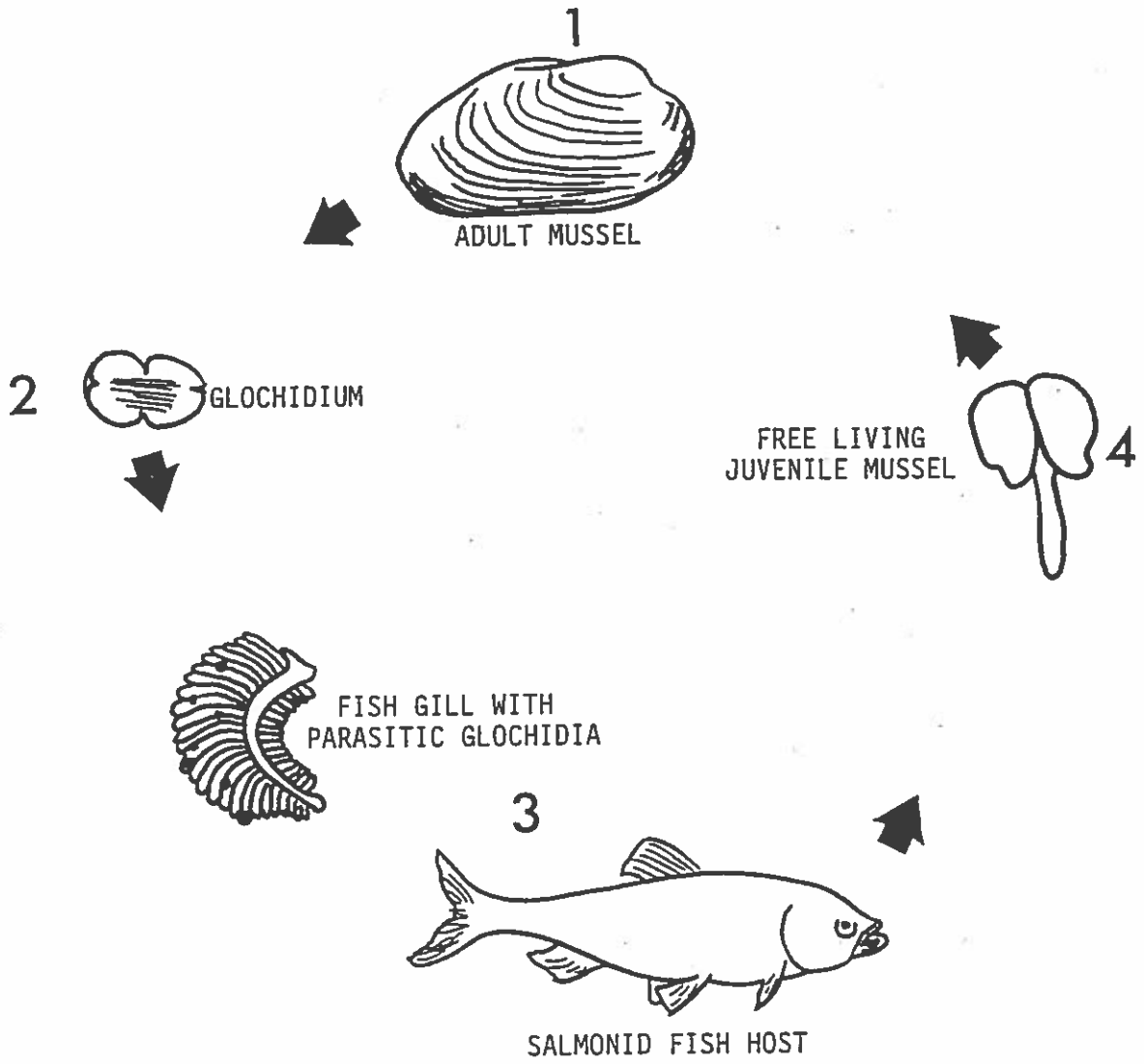


Figure 1. Life cycle of Margaritifera margaritifera (from various sources).

1. Adult reproductive stage: > 15 - 20 years of age, filter feeding in streams and rivers low in lime ($CaCO_3$) and nitrate (NO_3).

2. Glochidial stage: The free glochidium from time of release by the adult until inhaled and attached to the host's gill (4 - 6 weeks depending on water temperature).

3. Parasitic stage: Attached to the gills of fish < 3 years of age the glochidia metamorphose (this phase may be short-term i.e. until late autumn or long-term i.e. over winter).

4. Juvenile: The young mussel excysts and burrows deeply into a suitable substratum, emerging from the interstitial sediments at 5+ years of age.

Many different enviromental conditions affect the reproductive success and longevity of M margaritifera; most of these parameters have a more pronounced effect on the glochidial stages and juvenile mussels than on the adults.

Brooding is synchronised within a population (Bauer, 1987; Ross,H, in press) and a single female may produce 4.6×10^6 glochidia per year.

This leads to vulnerability from a single event for a year class.

The host specificity of M. margaritifera glochidia requires the presence of young salmonids. Host fish density therefore is a factor in recruitment, and environmental parameters not directly affecting glochidial viability may still decrease recruitment by decreasing fish stocks.

Pearl mussels are usually restricted to waters low in calcium and nutrients. However, M.m. var. durrovensis is typical of the calcareous waters of the Rivers Nore, Suir and Barrow (Republic of Ireland) (Phillips, 1928). Phosphate, calcium and conductivity (a reflection of overall pollution factors) have all been found to be important parameters for the survival of juvenile stages (Bauer, 1988).

After leaving the fish host, the juvenile mussels require a suitable substratum in which to grow to maturity. Young mussels can only develop in a sediment of low organic content. The causal mechanisms of juvenile death are not known, but possible explanations include shortages of oxygen, due to increased B.O.D., or an increase in predator density.

As growth is related to age, large mussels are generally older than small ones. However, this is not constant and is affected by both environmental factors and genotype. In M. margaritifera, generally considered to be a slow growing bivalve, the rate of growth is thought to be limited by the calcium carbonate levels in the waters in which it lives (Young and Williams, 1984). Juvenile mussels appear to direct their main metabolic effort to shell construction, until sexual maturity is reached. This can be seen in the broad growth increments (annuli) in the mussel shell. These annuli decrease in width as the animal ages. Further narrowing above the age of 50 years. (Young and Williams, 1983.)

Adult mussel mortality is closley related to nitrate (NO_3) concentrations. Bauer (1988) found that with increased nitrate levels most mussels died at an early age, producing an over-aged population, i.e. a population which lacked young mussels and had fewer long lived individuals.

Alteration of river courses and canalization have led to the drift of bottom sediments preventing adult mussels remaining established. Valovirta (1989) found the critical amount of drifting bottom material with adult mussels to be about 30 mg/l. This level can be exceeded by input from upstream gravel extraction, use of dredged river material for bank reinforcement and the alteration of river beds for salmonid spawning areas.

Adult mussels appear to have few natural enemies, although crows and otters are reported to have taken them. However, human activites such as direct removal of habitat and destructive pearl fishing may destroy large numbers of adult M. margaritifera.

Size, density and distribution estimates of pearl mussel populations are notoriously unreliable due to substrate variability, water flow and quality at the time of sampling as well as other physical characteristics of rivers. This is compounded by the potential for vertical migration of adults in the sediments and the fact that juvenile mussels are not seen at the surface of the substratum before they are 5 + years of age.

There has been a decline of more than 90% in the Central European populations of M.margaritifera. It is now listed in the I.U.C.N. Invertebrate Red Data Book, in which eutrophication is implicated as a major factor in this decline (Wells et al, 1983).

Increasing intensification of agriculture, land drainage and afforestation, and continuing pearl fishing in Northern Ireland pose major threats to this species.

2. AIMS AND OBJECTIVES (Contract Document :CP1432/1).

These were as follows :

2.1 To establish the distribution of freshwater mussel populations in the River Foyle system.

2.2 To determine the status and the viability of these mussel populations in the Foyle system.

2.3 To gather information on the potential threats (eg water quality) to existing mussel populations in the Foyle catchment.

2.4 To undertake a rapid survey to establish which other rivers in Northern Ireland have freshwater mussel populations.

3. METHODS

All data were noted on site record sheets (Appendix I).

3.1 The Survey.

Sample sites were chosen primarily by the ease of access to the river. Hence, most of the sites were quite near bridges. At each site, a 200 m stretch of suitable river bed (either upstream, downstream or both) was searched thoroughly. The search was not carried out over solid rock. The presence or absence of mussels at a given site was determined by visual inspection of the river bed using one of two methods:

1. wading, wearing a wetsuit or waders and looking through a perspex-bottomed box (30 cm x 40 cm and 30 cm deep).
2. snorkelling or using S.C.U.B.A. equipment in deeper water.

The first method was adequate for clear shallow water but in deeper stretches of river, or water with a lot of suspended particulate matter, the river bed became obscured. The second method had the advantage of allowing closer inspection of all substrata, making it easier to spot well buried mussels, but was limited by underwater visibility.

In all, about 23 Km of rivers were searched by snorkelling.

The invertebrate fauna at each survey site was investigated by kick sampling.

This involved selecting a patch of coarse gravel, where a standard 1 minute kick sample was taken from 3 areas at each site. The effort in each kick sample was roughly constant and the same net (21 cm x 21 cm with a mesh size of 144 holes / cm^2) was used in each case.The contents of the net were fixed in 4% formalin and returned to the laboratory where they were sorted, identified and transferred to 70% ethanol. Voucher material has been deposited with the Ulster Museum.

A presence / absence table of the species recorded at each site was then compiled and used in a detrended correspondence analysis (DECORANA) and a two way indicator species analysis (TWINSPAN) (Gauch, 1982) to determine invertebrates associated with M. margaritifera. The presence of these invertebrates was also used to calculate a Biological Monitoring Working Party (B.M.W.P.) score for each site. This is obtained by summing the specific B.M.W.P. values attributed to each invertebrate species recorded at each site.

3.2 Population Characteristics.

If M. margaritifera were found a sample of 50, (where available) were collected and measured to the nearest mm using calipers. Mussels were then returned to their original positions in the river. The total number of M. margaritifera present at the site was then estimated from mussel density and size of the mussel bed.

It is not possible to age M. margaritifera directly by visual inspection of the shell annuli due to their compact nature in older shells.

Sectioning the ligament of the valve hinge produces clear annuli, which can be used to determine the age of the mussels (Wellman, 1938; Hendleberg, 1961) and an attempt was made to use these in conjunction with shell size to determine age. However, due to the lack of mussels less than 60 mm, an initial growth rate calibration graph to account for the measureable growth lost from damage to the ligament could not be constructed. Consequently, the age of the mussels was estimated using a computer generated von Bertalanfly growth curve produced for mussels from the River Owenea, the nearest river system for which suitable data were available (Ross,H, 1988). (Appendix II).

4. RESULTS

4.1 AREA COVERED BY THE SURVEY

The sites surveyed (Fig.2) all fell within the Foyle catchment area with the exception of 4 which were also investigated because of reports of mussels. Detailed site information is given in Appendix III, which provides the name of the body of water, the abbreviated name used in the DECORANA and TWINSPAN analyses and the corresponding six figure O.S. grid references.

A total of 60 sites were surveyed, (Fig. 2, Appendix III) although only 58 of these provided kick samples. Kick samples were not available for two mussel sites on the River Mourne: the site under the mill buildings of Herdmans Mill, Sion Mills, and the site at Seein Bridge. This was due to these sites being surveyed using S.C.U.B.A. gear, making kick sampling impossible. These sample sites covered an estimated 190 Km (~ 70%) of the rivers in the Foyle system, with 23 Km of this total having been surveyed by swimming.(Table 1, Fig. 4).

TABLE 1. STRETCHES OF RIVER SURVEYED FOR *M. margaritifera*

BODY OF WATER	DISTANCE SPANNED BY SAMPLE SITES. Km.
QUIGGERY WATER	3
OWENREAGH RIVER	4
DRUMRAGH RIVER	7.5
CAMOWEN RIVER	27
CLOGHFIN RIVER	0
FAIRY WATER	11
CAPPAGH BURN	0
GLENELLY RIVER	29
OWENKILLEW RIVER	23
RIVER DERG	31
MOURNE BEG RIVER	6.5
RIVER MOURNE	13.5
GREVENUE BURN	0
BURN DENNET	8.5
FOYLE SYSTEM SUB TOTAL	189.5
OWENCARROW RIVER	0.5
BALLINDERRY RIVER	5
RIVER BLACKWATER	0.5
GRAND TOTAL	195.5

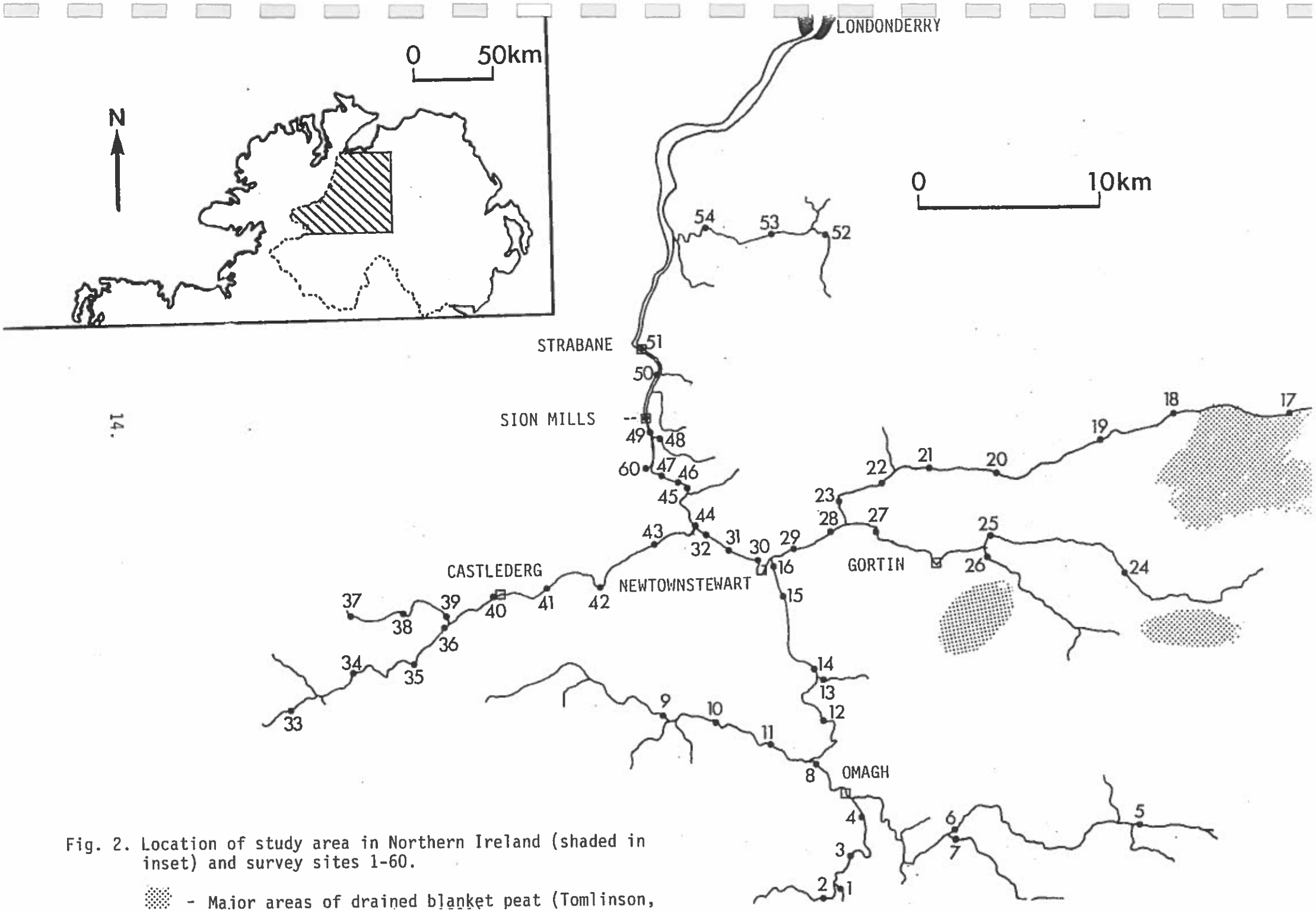


Fig. 2. Location of study area in Northern Ireland (shaded in inset) and survey sites 1-60.

▒ - Major areas of drained blanket peat (Tomlinson,

4.2 HISTORICAL DISTRIBUTION OF MARGARITIFERA:-

Records of the pearl mussel in the North of Ireland dates from as early 1094, when pearls from Tyrone were sent to the Archbishop of Canterbury. In the 17th century, the rivers of the Foyle catchment were said by Redding (1693) to be " heavily populated with pearl mussels".

The Ulster Museum has M. margaritifera specimens from counties Tyrone and Antrim, while the National Museum in Dublin has specimens from Fermanagh, Tyrone and Antrim. In both museums these mussels were collected before 1950 (Ross,H, 1988).

A comparison of records from 1925 (Jackson) and pre- and post-1950 (Kerney, 1976) are presented in Table 2. and Fig. 3a.

Data from the most recent M. margaritifera survey in Ireland (1988) are shown in Fig. 3b, which may be interpreted erroneously as representing an improvement over the situation in 1976.

Precise locality data for historical site records of M. margaritifera are not readily available. Such data were only available for 8 sites in the Foyle system (Appendix IV); these are illustrated in Fig. 4. No corresponding data for population densities were available for these sites.

However, detailed site information and crude population estimates for one stretch of the River Strule were available in a letter from a local pearl fisherman to H.R. and dated 1981. This letter gave details of all the places on the Strule between the Derg confluence and Sion Mills known by him to have pearl mussel populations. This pearl fisherman, whose family had been fishing for generations, had at that time been fishing the river for 30 years.

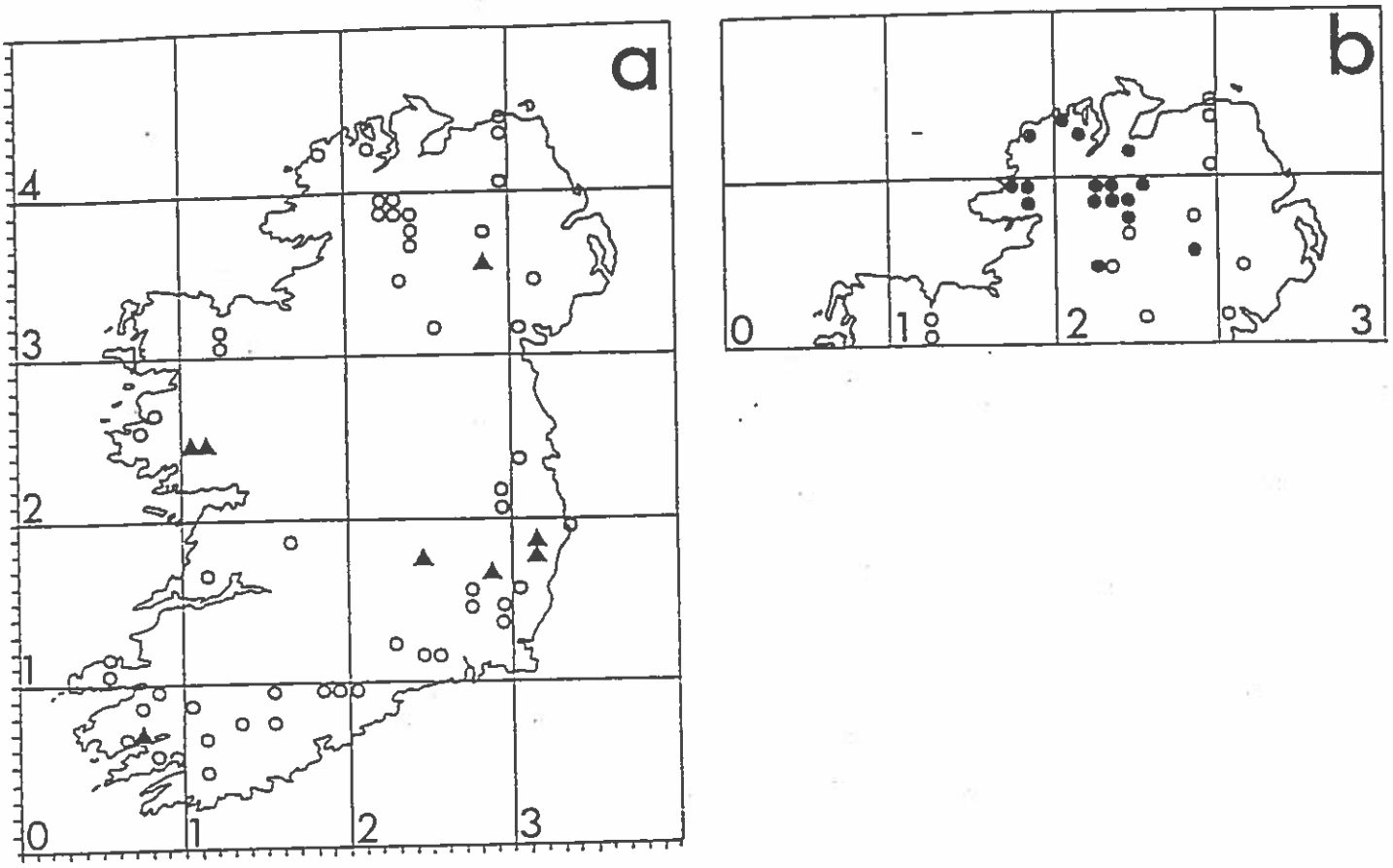


Fig. 3. Historical distribution records of M. margaritifera in Ireland on a 10km grid.

a) data compiled before 1976 as represented in the Atlas of the non-marine Mollusca of the British Isles (Kearney, 1976).

b) data for the north of Ireland compiled in 1989 (unpublished report, Royal Irish Academy; Ross, H. 1989).

o - pre 1950 records of live Margaritifera

▲ - records of live Margaritifera between 1950 and 1976

● - records of live Margaritifera in 1989 survey

He described seven main stretches with large numbers of "shells", (live M. margaritifera) only three of which had mussels present during this survey, and not in the numbers he described in 1981. A site 200 m downstream of the Derg confluence to "Muluin Bie", described as "the best place for large numbers of shells", revealed only 17 mussels, (site 44 in the present survey). The sites Victoria Bridge 1 and 2 (sites 46 and 45) were described as "my own happy hunting ground where I have been finding fairly good pearls for the last 30 years." This single bed now has an estimated population of 300 mussels, in two distinct sites separated by a 200 m stretch of river. At Seein Bridge (site 60), a population estimated at 300 mussels was discovered. This site was not mentioned in the 1981 letter, but was also known to the pearl fisherman.

TABLE 2. Vice county distribution records of M. margaritifera in N. Ireland.

Vice county No.	Vice county	Jackson (1925)	Kerney - 1976 Pre '50	Post '50
H 33	Fermanagh	+	+	-
H 36	Tyrone	+	+	-
H 37	Armagh	+	+	+
H 38	Down	+	+	-
H 39	Antrim	+	+	-
H 40	Londonderry	+	+	-

4.3 PRESENT DISTRIBUTION, DENSITIES AND POPULATION CHARACTERISTICS OF MARGARITIFERA IN THE FOYLE CATCHMENT.

4.3.1 Distribution and Densities.

During the present detailed survey of the Foyle system, M. margaritifera was found at only 8 out of 58 sites visited (Fig. 4). All these sites fell within the northern sector of the survey (Fig. 4a). This is in a section of the river historically noted for pearl mussels and close to some of the larger centres of human population (Figs. 2,4a). Estimates of total numbers at these sites ranged between 20 and > 200 (Table, 3). This gives an estimated grand total of < 1000 mussels at all sites in our survey. If we assume 50% sampling efficiency and that approximately 70% of the river system was surveyed in detail, there may be as few as 3000 pearl mussels left in the Foyle. This compares with an estimated 200,000 mussels in the River Owenea, Donegal (Ross,H, 1988), which is only about 1/10th the length of the Foyle system.

Table, 3. Estimated total numbers of M. margaritifera at mussel sites in the Foyle survey (1990).

Site No.	Location	No. measured	Estimated total
28	Owenkillew	36	40
31	Strule - Fish farm	27	>50
32	Above Derg/Strule conf.	11	20
44	Derg / Strule confluence	17	30
45	Victoria Bridge 2	33	50
46	Victoria Bridge 1	50	200
--	Herdman's Mill	--	200
60	Seein Bridge	50	250
	Grand Total =		840

Fig. 4. Estimated densities of Margaritifera populations at each site surveyed and compared with historical records for the Foyle catchment.
a) Northern sector; b) Eastern sector; c) Southern sector.

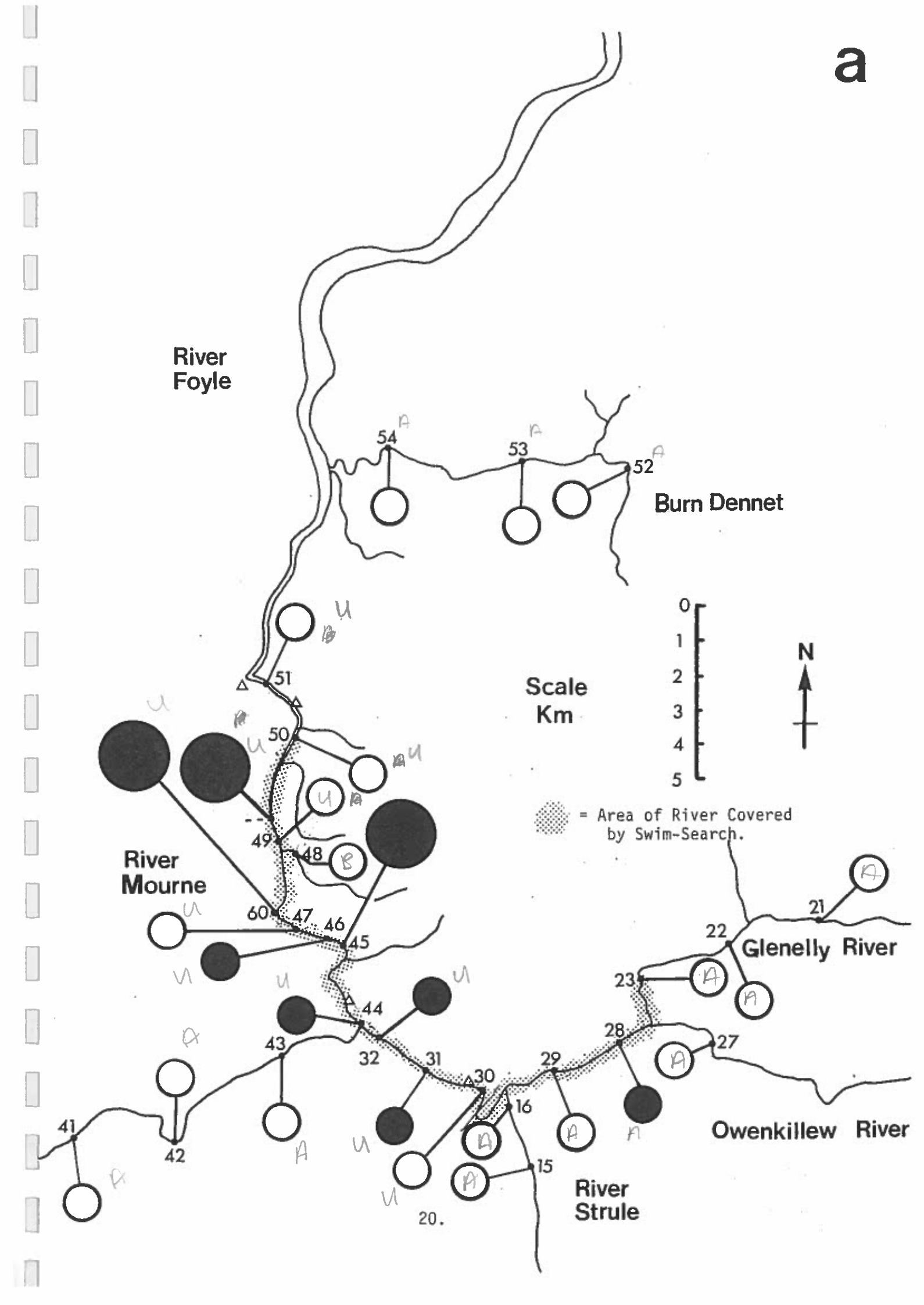
△ - historical records of live Margaritifera pre-1925 (APPENDIX IV)

▲ - historical records of live Margaritifera 1969

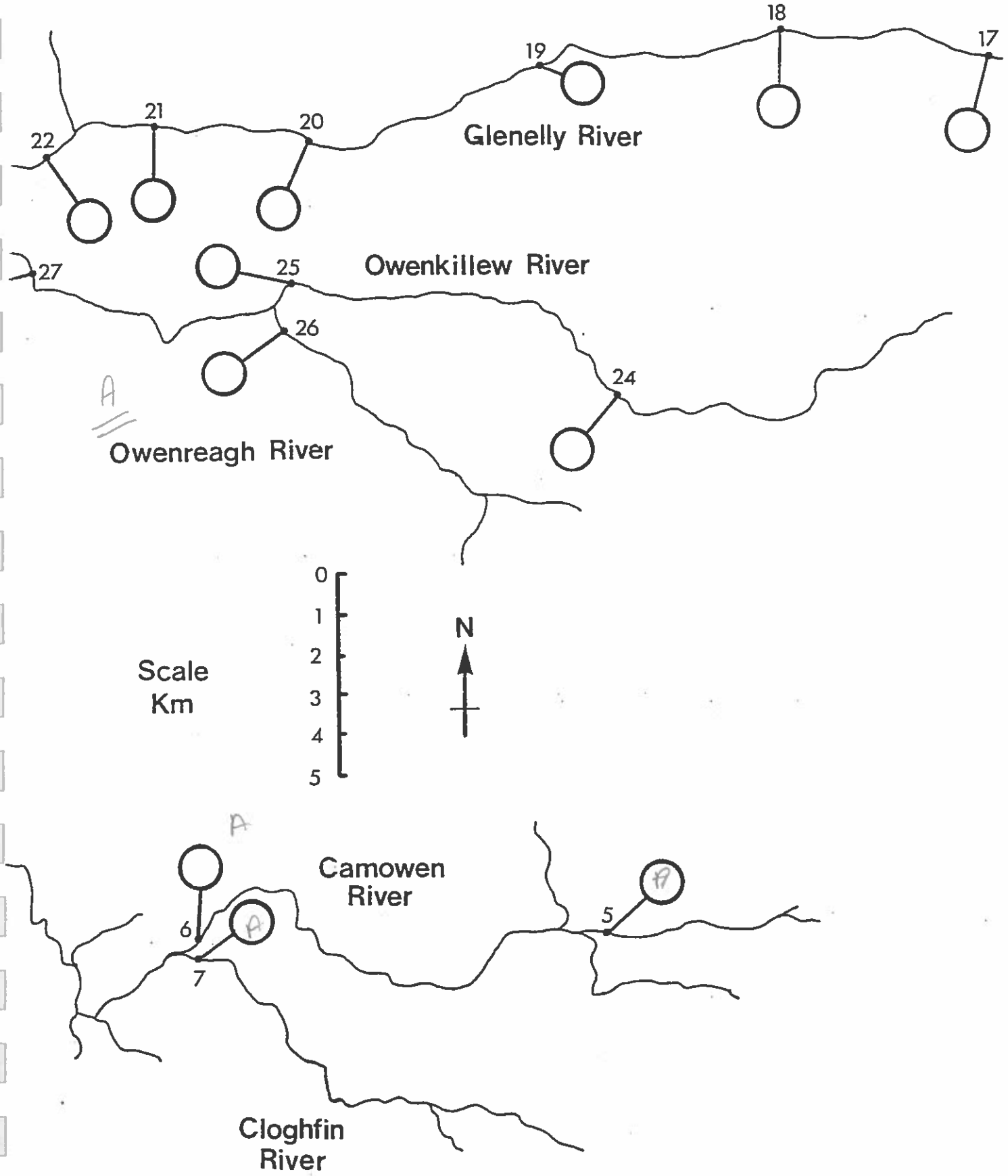
○ - no live mussels, present survey

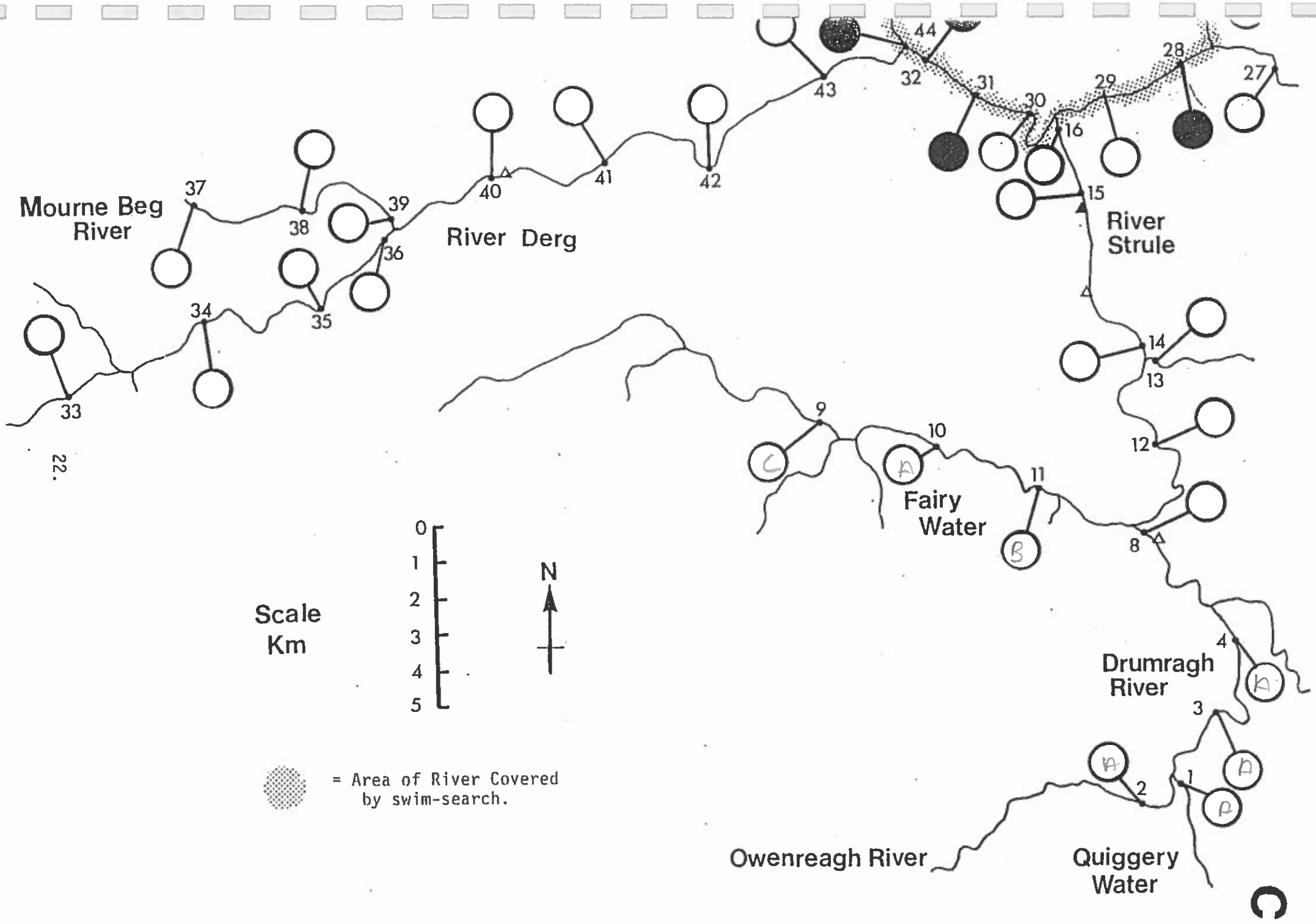
● - 10-99 live mussels, present survey

● - 100-300 live mussels, present survey


a
River Foyle
Burn Dennet
River Mourne
Glenelly River
Owenkillew River
River Strule
Scale Km
0
1
2
3
4
5
N
= Area of River Covered by Swim-Search.
54
53
52
51
50
49
48
60
47
46
45
44
43
32
31
30
29
28
27
22
21
23
16
15
41
42

b


18
17
19
21
20
22
Glenelly River
27
25
Owenkillew River
26
24
A
Owenreagh River
0
1
2
3
4
5
Scale
Km
N
A
Camowen
River
6
A
5
A
7
Cloghfin
River


Mourne Beg River
River Derg
River Strule
Fairy Water
Drumragh River
Owenreagh River
Quiggery Water
Scale Km
0
1
2
3
4
5
N
= Area of River Covered by swim-search.

4.3.2 Population Characteristics.

Size frequency data for mussel populations at each of the seven Foyle sites where they were found are shown in Fig. 5. At sites where total numbers exceeded 40, size frequency histograms were typically unimodal (Fig. 5a, b, e, f, g). The small populations recorded at other sites bear little comment (Fig. 5c, d). The two populations sampled from the Ballinderry River showed similar size frequency characteristics to larger populations from the Foyle (Fig. 6).

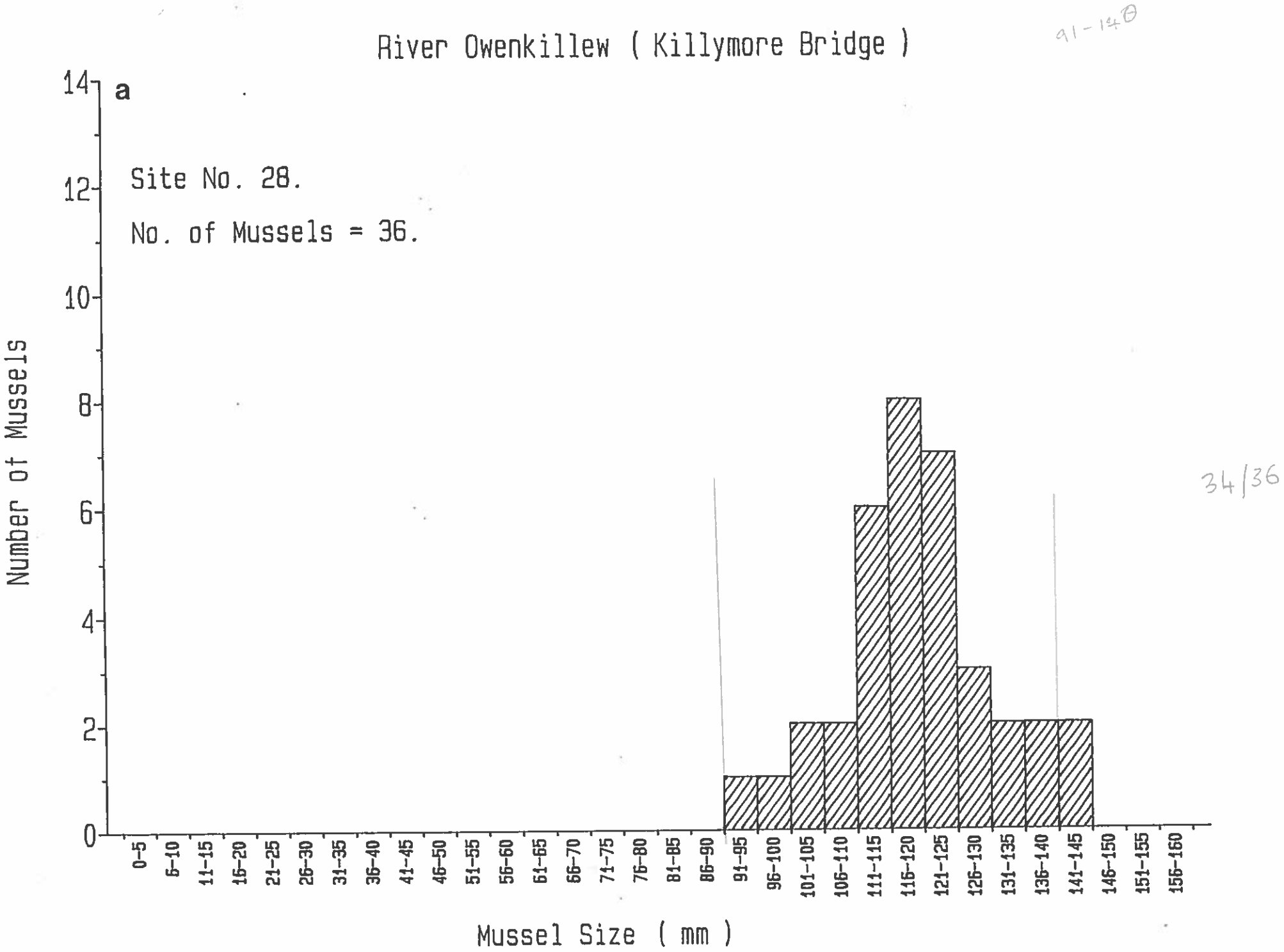
No mussels < 59 mm were found in either visual searches or in the kick samples, both of which uncovered pea mussels of only 8 mm. Sorted kick samples revealed pea mussels and ostracods as small as 1 mm. The absence of juvenile mussels appears to be real, and not a function of sampling technique, since kick samples from the Stack Burn in Scotland revealed mussels as small as 3 mm (Woodward pers. comm. 1990).

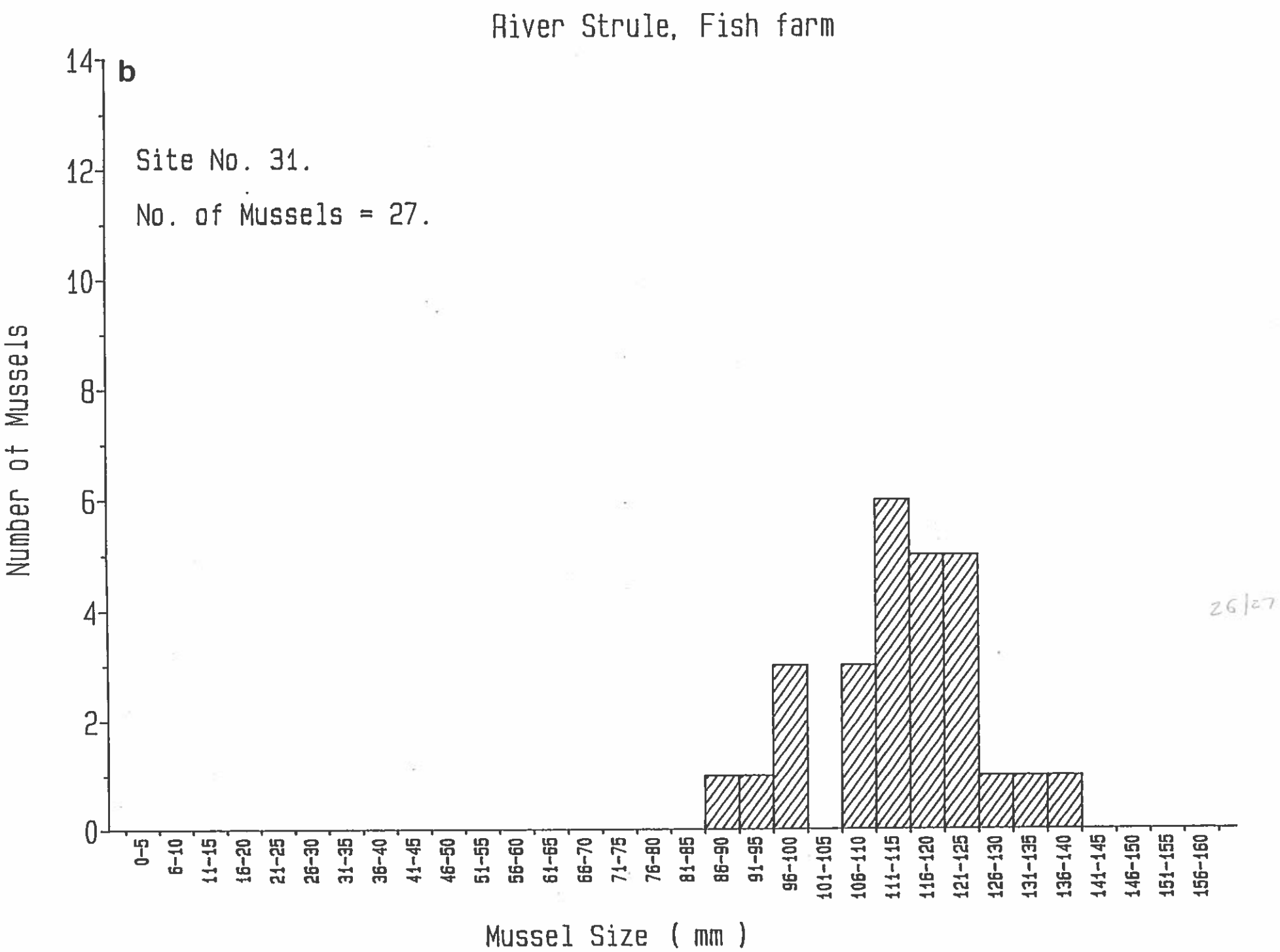
The age of all the individuals from the Foyle measured during the survey was estimated from length by means of a von - Bertalanfly growth curve computed for mussels from another river system (see methods and Appendix II). This was the best compromise which could be achieved in view of limitations imposed by the material available. The youngest mussels were between 9 and 10 years old and the oldest mussel was > 100 years old (Fig. 7 C).

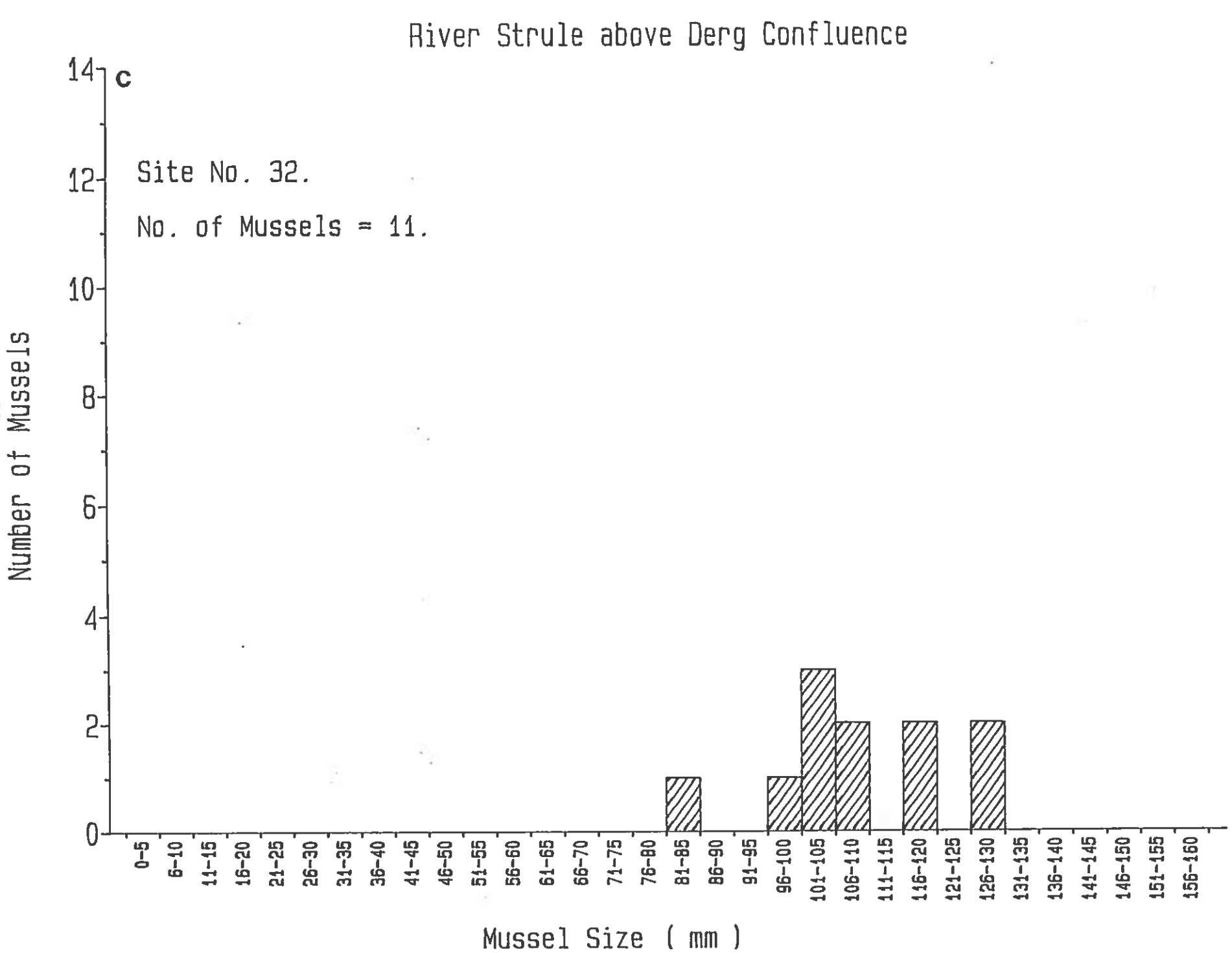
Mean age was 32 years. Age / frequency data appear polymodal, with peaks at 15 - 16 years, 19 - 20 years, 31 -32 years, 43 - 44 years, 55 - 56 years and 67 - 68 years before present (1990) suggesting these as periods of enhanced recruitment. A number of these peaks co-incide with years of below average annual rainfall and above average annual temperatures (Fig. 7). The apparent absence of mussels < 9 years of age, suggests that there has been no recruitment of M. margaritifera in the Foyle catchment since 1981.

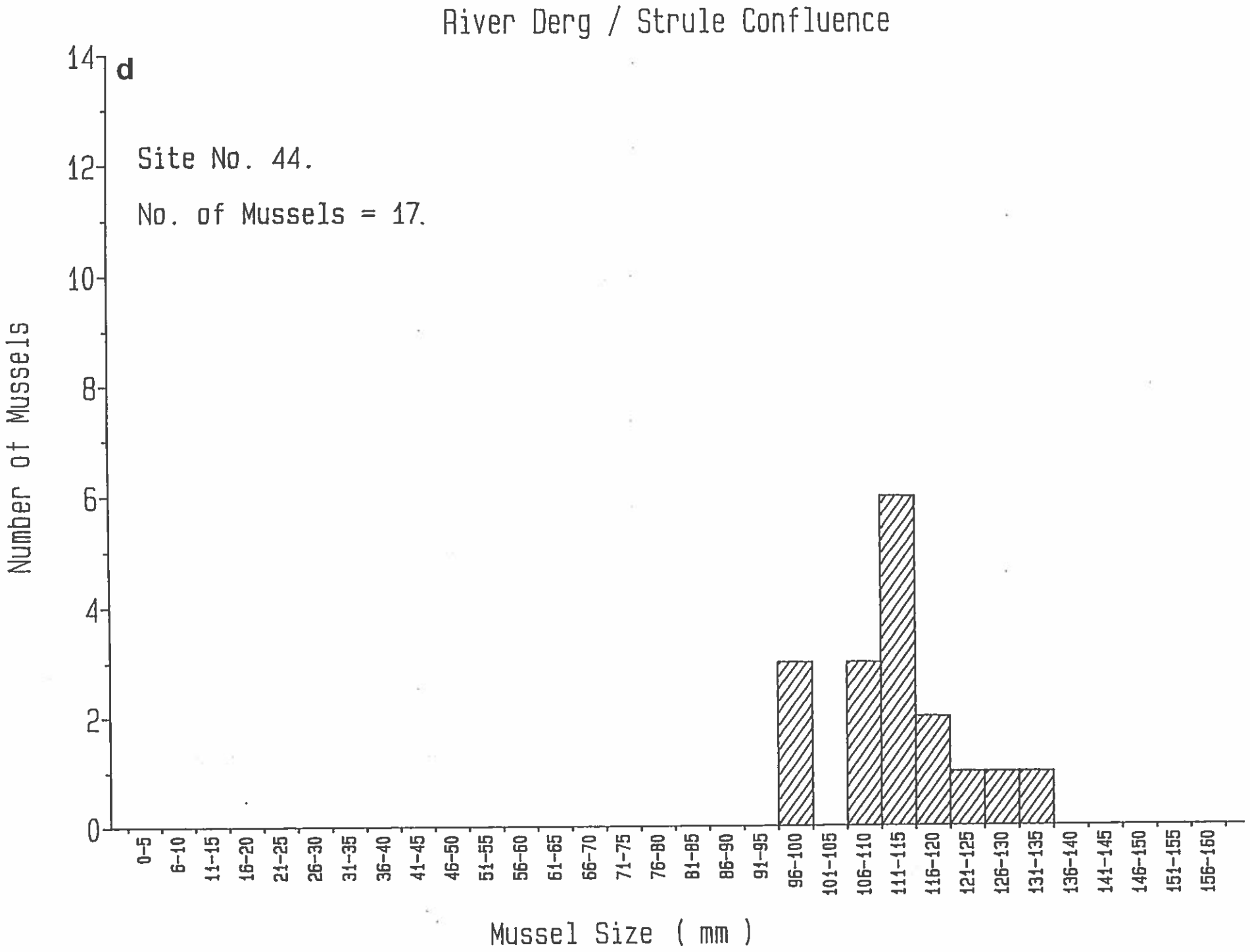
Fig. 5. Length-frequency characteristics of all mussel populations located in the Foyle catchment during summer and autumn 1990.

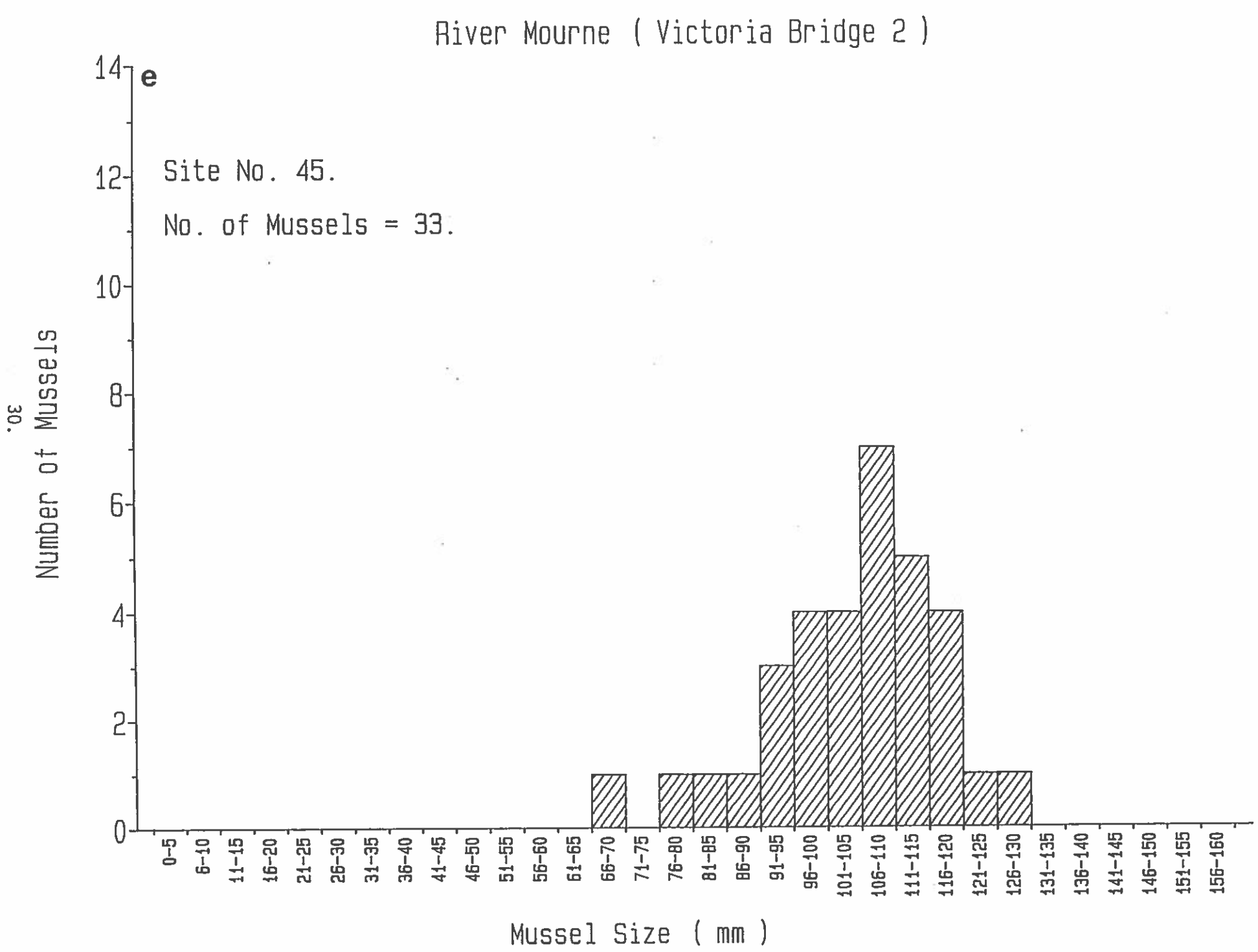
a) River Owenkillew (Killymore Bridge)
b) River Strule (Fish Farm)
c) River Strule above Derg Confluence
d) Derg-Strule Confluence
e) River Mourne (Victoria Bridge 2)
f) River Mourne (Victoria Bridge 1)
g) River Mourne (Seein Bridge)
h) Pooled data for all sites

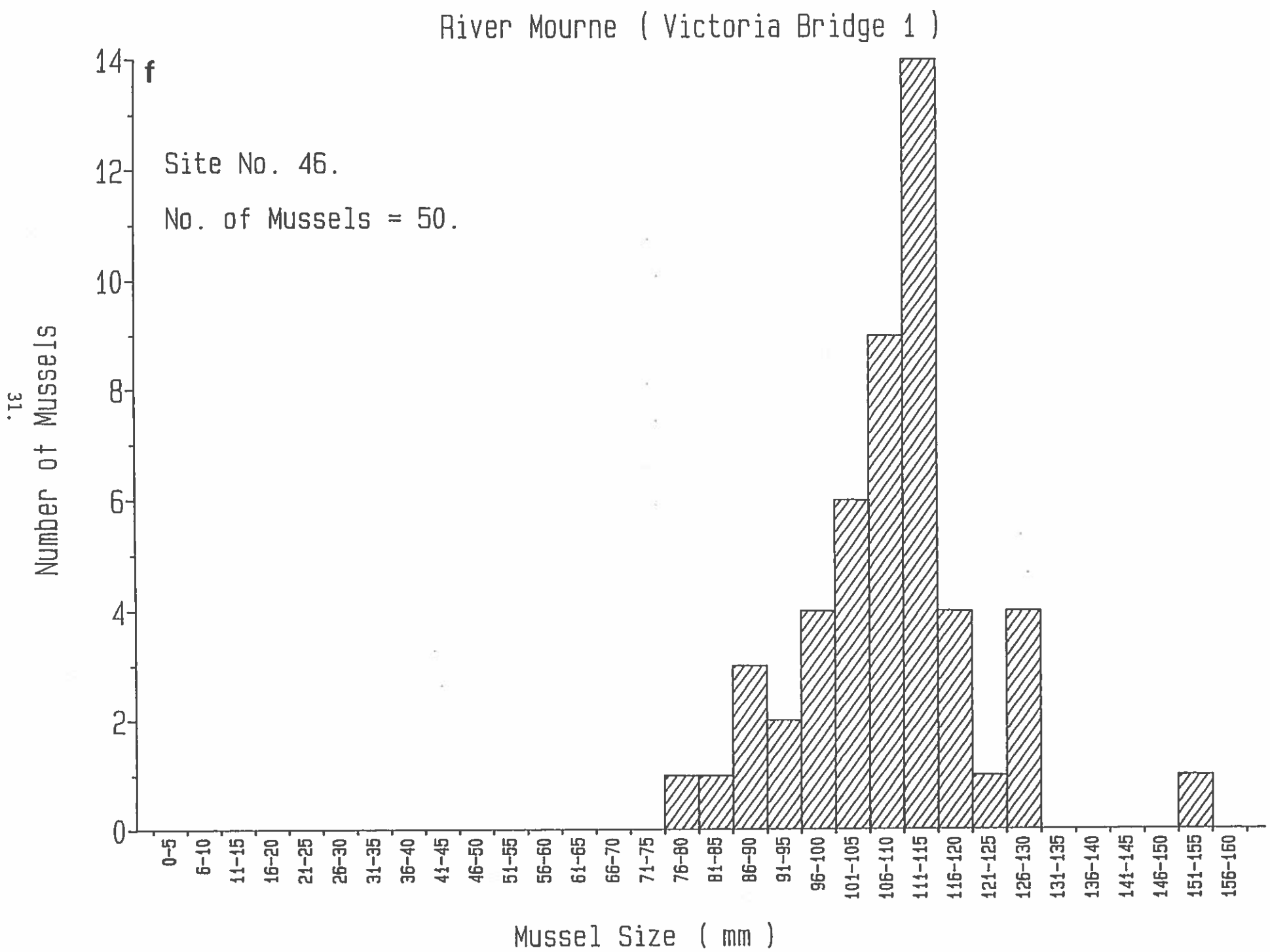

River Owenkillew (Killymore Bridge)
91-140
a
Site No. 28.
No. of Mussels = 36.
34/36
Number of Mussels
0
2
4
6
8
10
12
14
0-5
6-10
11-15
16-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95
96-100
101-105
106-110
111-115
116-120
121-125
126-130
131-135
136-140
141-145
146-150
151-155
156-160
Mussel Size (mm)

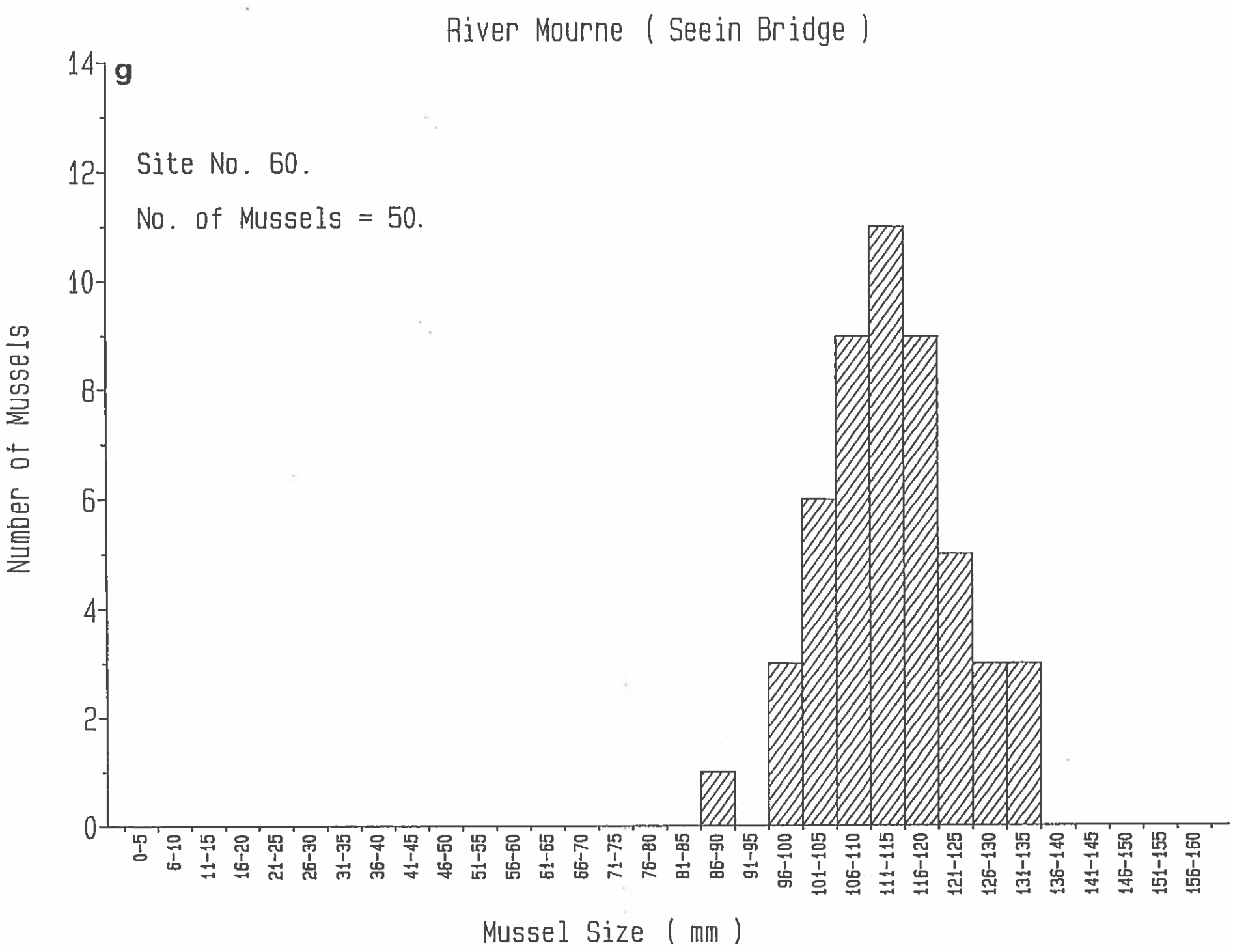

River Strule, Fish farm
b
Site No. 31.
No. of Mussels = 27.
Number of Mussels
0
2
4
6
8
10
12
14
0-5
6-10
11-15
16-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95
96-100
101-105
106-110
111-115
116-120
121-125
126-130
131-135
136-140
141-145
146-150
151-155
156-160
Mussel Size (mm)


River Strule above Derg Confluence
c
Site No. 32.
No. of Mussels = 11.
Number of Mussels
0
2
4
6
8
10
12
14
0-5
6-10
11-15
16-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95
96-100
101-105
106-110
111-115
116-120
121-125
126-130
131-135
136-140
141-145
146-150
151-155
156-160
Mussel Size (mm)


River Derg / Strule Confluence
d
Site No. 44.
No. of Mussels = 17.
Number of Mussels
0
2
4
6
8
10
12
14
0-5
6-10
11-15
16-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95
96-100
101-105
106-110
111-115
116-120
121-125
126-130
131-135
136-140
141-145
146-150
151-155
156-160
Mussel Size (mm)


River Mourne (Victoria Bridge 2)
e
Site No. 45.
No. of Mussels = 33.
Number of Mussels
Mussel Size (mm)
0
2
4
6
8
10
12
14
0-5
6-10
11-15
16-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95
96-100
101-105
106-110
111-115
116-120
121-125
126-130
131-135
136-140
141-145
146-150
151-155
156-160


River Mourne (Victoria Bridge 1)
f
Site No. 46.
No. of Mussels = 50.
Number of Mussels
Mussel Size (mm)
0
2
4
6
8
10
12
14
0-5
6-10
11-15
16-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95
96-100
101-105
106-110
111-115
116-120
121-125
126-130
131-135
136-140
141-145
146-150
151-155
156-160


River Mourne (Seein Bridge)
g
Site No. 60.
No. of Mussels = 50.
Number of Mussels
Mussel Size (mm)
0
2
4
6
8
10
12
14
0-5
6-10
11-15
16-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95
96-100
101-105
106-110
111-115
116-120
121-125
126-130
131-135
136-140
141-145
146-150
151-155
156-160

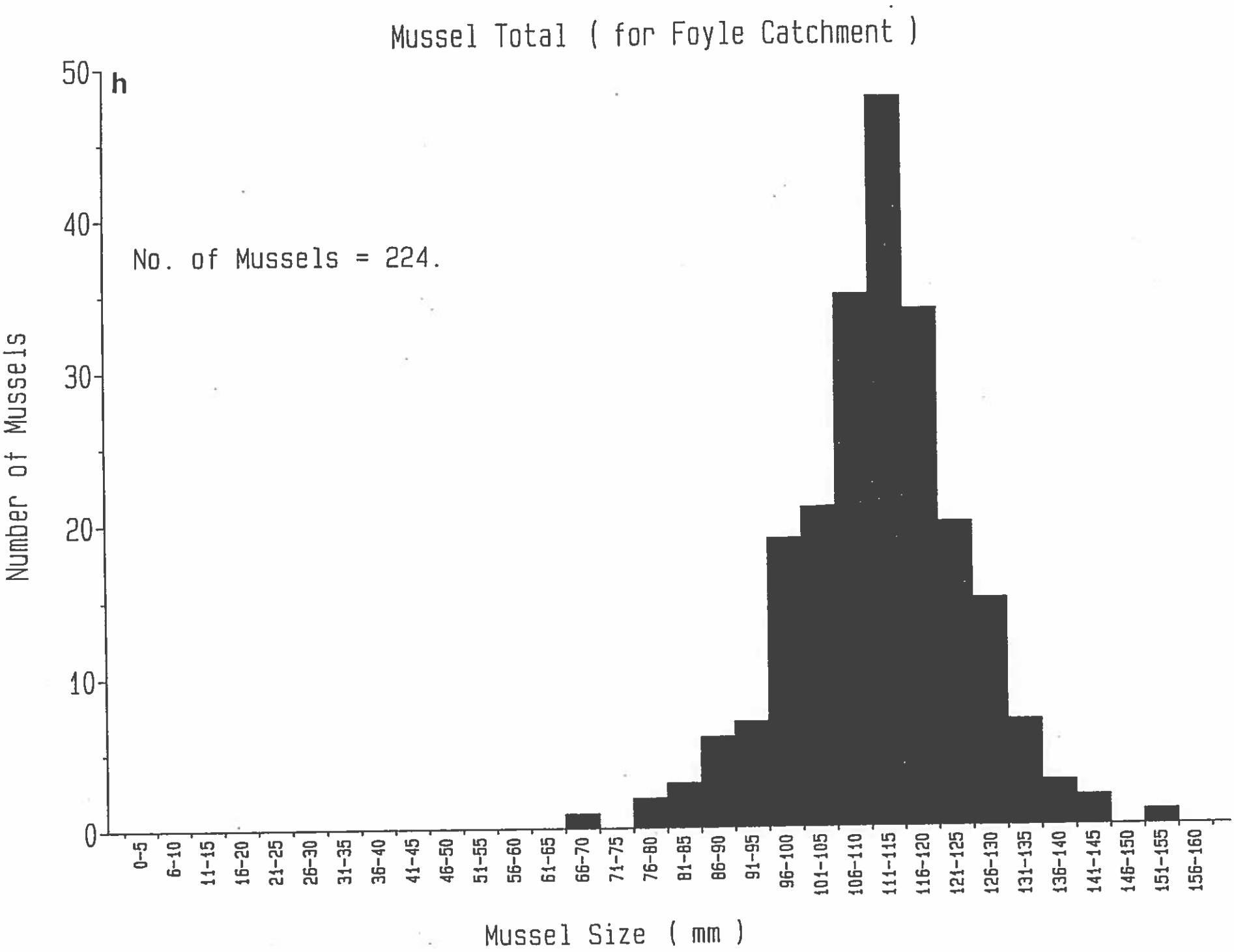
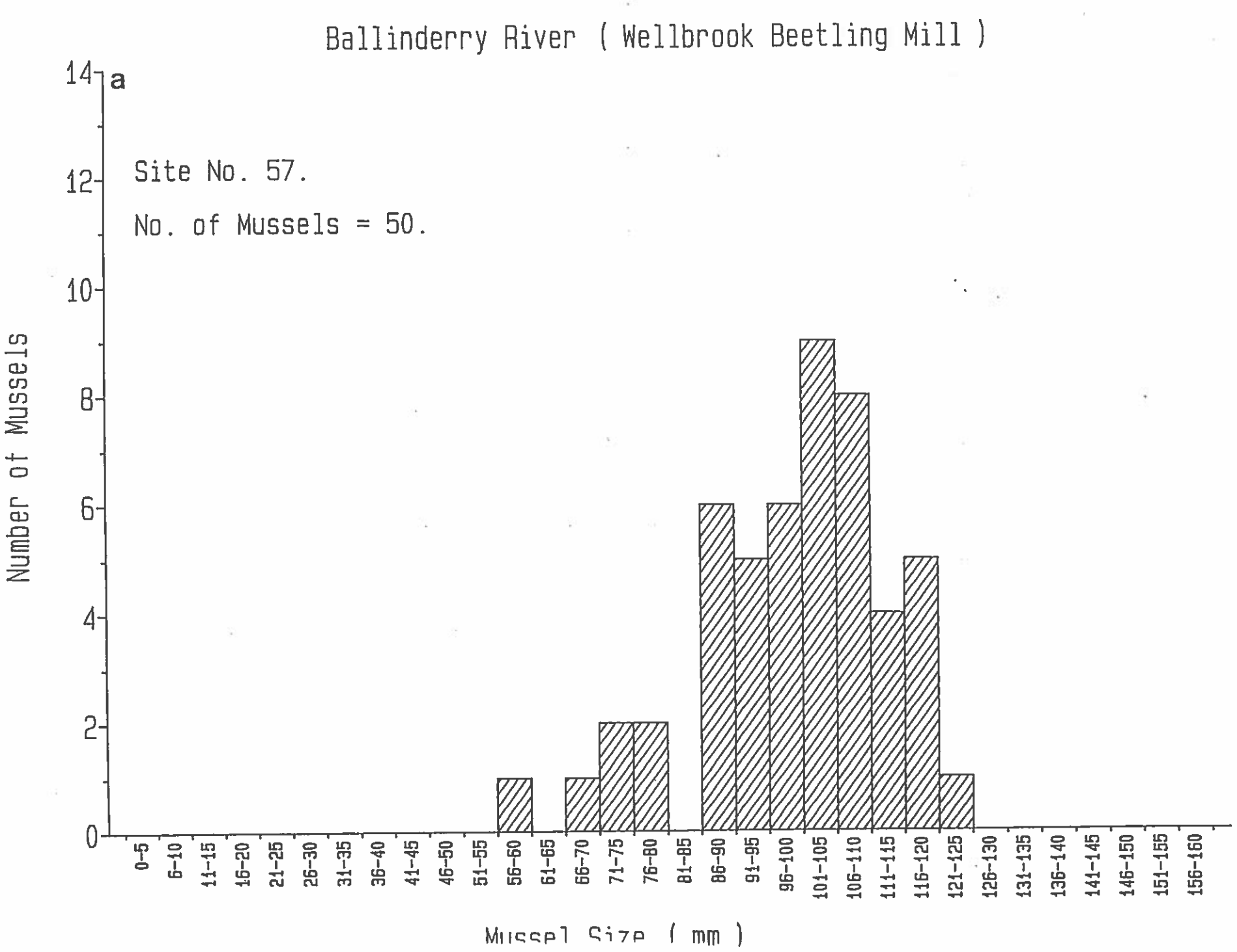

Mussel Total (for Foyle Catchment)
h
No. of Mussels = 224.
Number of Mussels
Mussel Size (mm)
0
10
20
30
40
50
0-5
6-10
11-15
16-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95
96-100
101-105
106-110
111-115
116-120
121-125
126-130
131-135
136-140
141-145
146-150
151-155
156-160

Fig. 6. Length-frequency characteristics of mussel populations located outside the Foyle catchment during summer and autumn 1990.
a) Ballinderry River (Wellbrook Beetling Mill)
b) Ballinderry River (Auglish)


Ballinderry River (Wellbrook Beetling Mill)
a
Site No. 57.
No. of Mussels = 50.
Number of Mussels
0
2
4
6
8
10
12
14
0-5
6-10
11-15
16-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95
96-100
101-105
106-110
111-115
116-120
121-125
126-130
131-135
136-140
141-145
146-150
151-155
156-160
Mussel Size (mm)

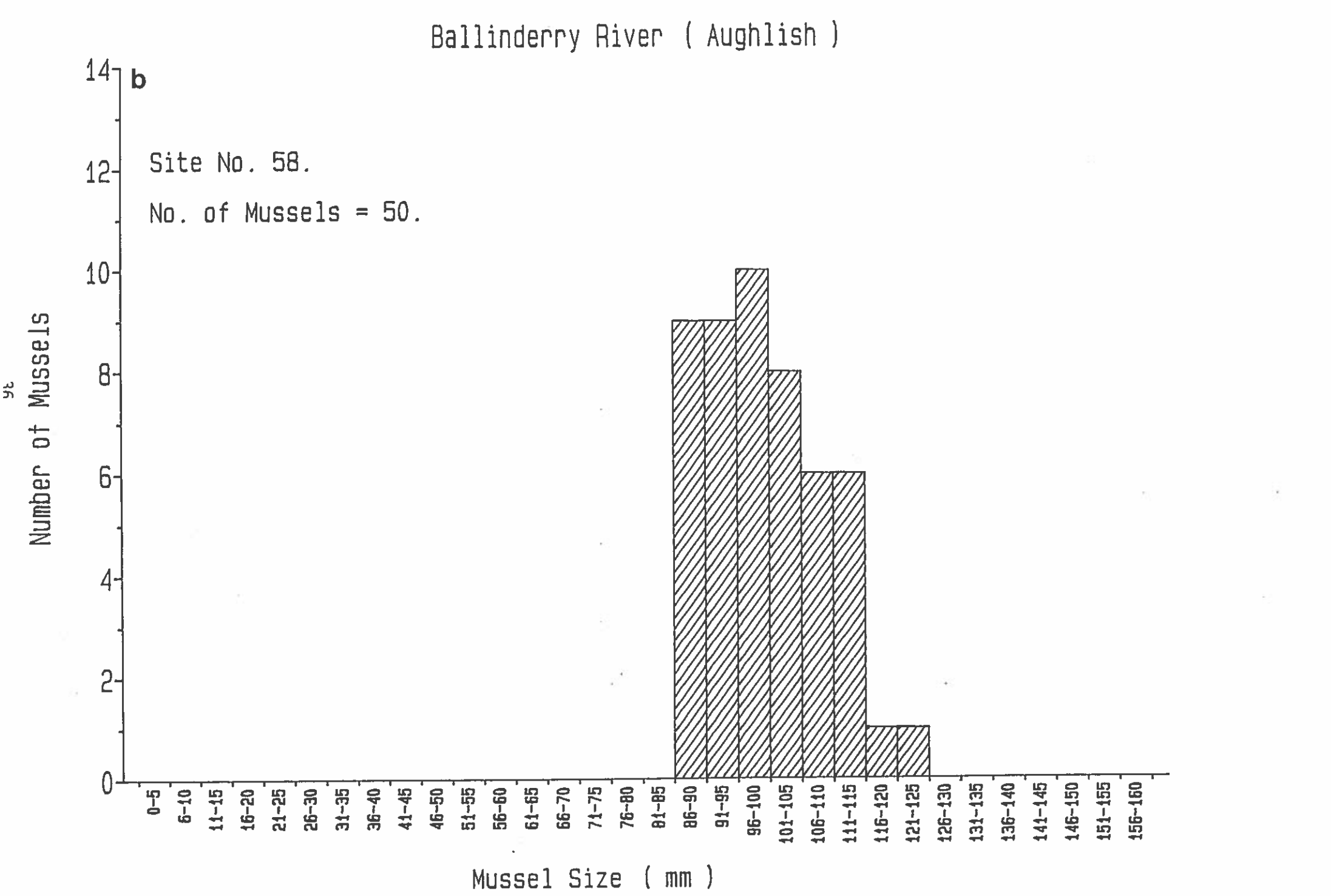
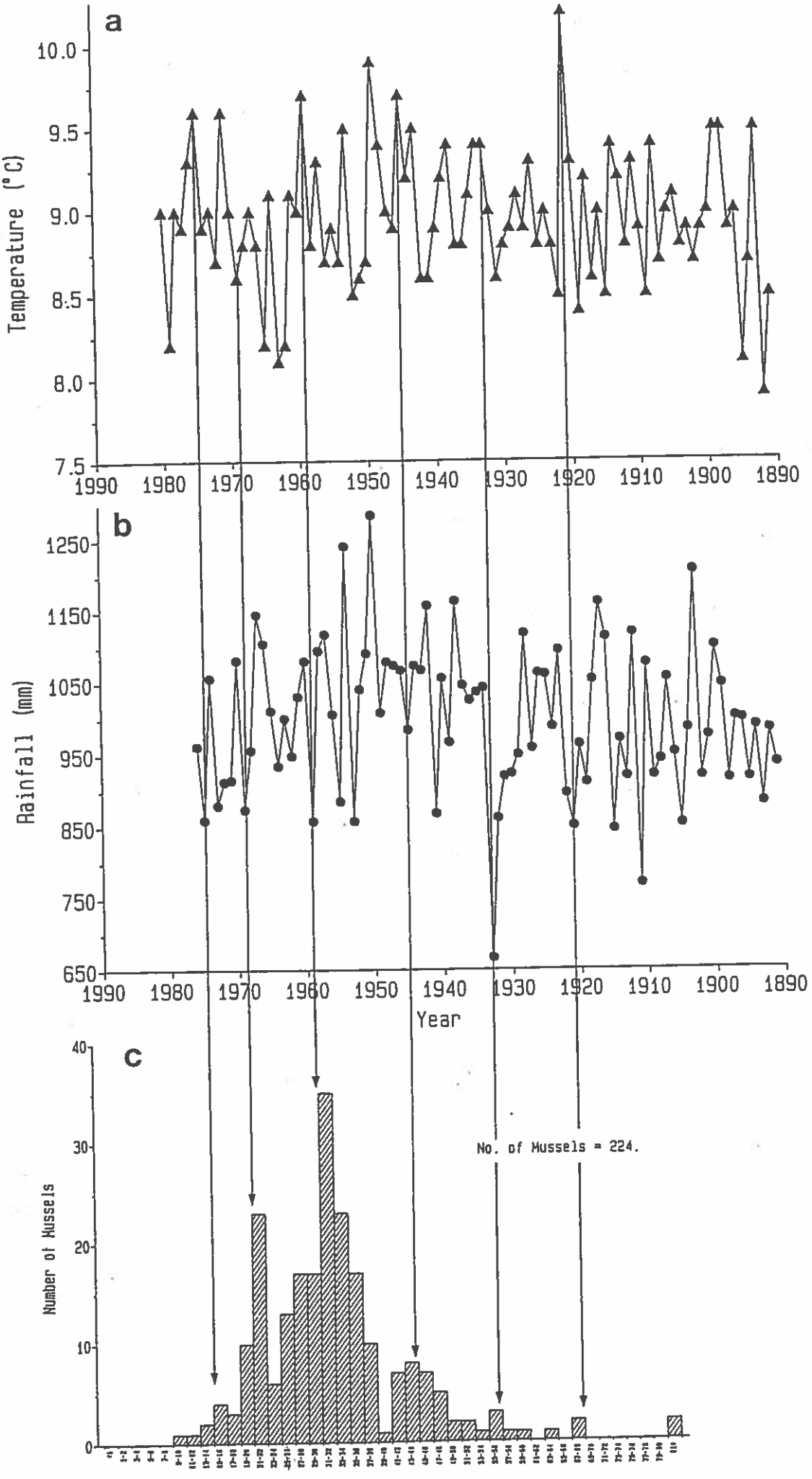

Ballinderry River (Aughlish)
b
Site No. 58.
No. of Mussels = 50.
Number of Mussels
Mussel Size (mm)
0
2
4
6
8
10
12
14
0-5
6-10
11-15
16-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95
96-100
101-105
106-110
111-115
116-120
121-125
126-130
131-135
136-140
141-145
146-150
151-155
156-160

Fig. 7. Historical climatic data for Northern Ireland and age characteristics of mussels:
a) Mean annual air temperature for Belfast (1890-1981)
b) Mean annual rainfall for Londonderry (1890-1977)
c) Age frequency of all mussels sampled in the Foyle catchment during summer and autumn 1990.


a
Temperature (°C)
10.0
9.5
9.0
8.5
8.0
7.5
1990 1980 1970 1960 1950 1940 1930 1920 1910 1900 1890
b
Rainfall (mm)
1250
1150
1050
950
850
750
650
1990 1980 1970 1960 1950 1940 1930 1920 1910 1900 1890
Year
c
Number of Mussels
40
30
20
10
0
No. of Mussels = 224.

4.4 BIOLOGICAL CHARACTERISTICS OF THE SURVEY SITES.

4.4.1 The Fauna

A total of 69 species were recorded (Table 4). Species richness (S.R.) ranged from 3 (Site 30) to 23 (Sites 3, 11, 64) [Appendix V]. Examination of the relative importance of the different taxa in terms of S.R. shows that insects predominate, comprising > 70% of the total fauna. The molluscs represented 13%, annelids ~5% whilst other arthropods and other taxa both contributed ~ 4% to faunal richness.

4.4.2 Multivariate Analysis.

Detrended correspondance analysis (DECORANA) and two way indicator species analysis (TWINSPAN) were used to examine species and site groupings. There were no obvious groupings of invertebrate taxa on the DECORANA plot, but most species formed a central band along axis 1 (Fig. 8). Although gradients represented by axes 1 and 2 are not known, species with higher B.M.W.P. values predominated towards the left of axis 1 which may therefore represent a gradient of decreasing water quality. (Some species with high B.M.W.P. values occur on the extremes of axis 2 but these species were only recorded once during the survey, and their position is a product of their rarity) (Fig. 8, Appendix V). These trends are more apparent in the TWINSPAN species analysis in which a clear grouping of taxa with predominantly high individual B.M.W.P. values was produced (Fig. 9). *M. margaritifera* occurs within this grouping (Fig 9).

Over 50% of the sites were concentrated in one central grouping with the remaining sites spreading outwards from this (Fig. 10). Categorization of these sites according to species grouping produced from TWINSPAN analysis of species and B.M.W.P. site scores shows a distinct site grouping according to the former (Figs. 10 B, 11).

Over 70% of sites in the a - b grouping, which includes all the Margaritifera sites in the Foyle system, have B.M.W.P. scores > 60 (Fig. 10 B, C). This suggests that many of these sites may be suitable for mussels. The only Margaritifera site outside the a - b groupings is an outlier on the Ballinderry River (site 58, Fig. 10 A).

Table 4. Invertebrate Taxa Recorded During The Present Survey.

INSECTA			
EPHEMEROPTERA -			
1	MAYFLY NYMPHS	F.Heptageniidae	Sp.1
2			Sp.2
3		F.Baetidae	Baetis Sp.
4		F.Baetidae	
5		F.Caenidae	Caenis Sp.
6		F.Ephemerellidae	Ephemerella Sp.
68		F.Ephemeridae	Ephemera Sp.
69		F.Leptophlebiidae	Paraleptophlebia Sp.
PLECOPTERA -			
7	STONEFLY NYMPHS	F.Chloroperlidae	Chloroperla Sp.
8		F.Leuctridae	Leuctra hippopus
9		F.Perlidae	Dinocras cephalotes
10		F.Leuctridae	Leuctra moselyi
11		F.Perlidae	Isoperla Sp.
12		F.Nemouridae	Protonemura Sp.
13		"	Nemoura Sp.
14		F.Nemouridae	Protonemura meyeri
15		F.Chloroperlidae	Chloroperla tripunctata
TRICHOPERA -			
16	CADDISFLY LARVAE	F.Hydropsychidae	Hydropsyche Sp.
17		F.Polycentropidae	Plectrocnemia Sp.
18		F.Rhyacophilidae	Rhyacophila Sp.
19		F.Psychomyiidae	
20		F.Leptoceridae	Setodes Sp.
21		F.Sericostomatidae	
22		F.Philopotamidae	
65		F.Rhyacophilidae	Agapetus Sp.
ODONATA -			
23	DAMSELFLY NYMPH	F.Odontocerida	
MEGALOPTERA -			
24	ALDERFLY NYMPH	F.Sialidae	Sialis Sp.
DIPTERA -			
25	SIMULIUM	F.Simuliidae	Simulium Sp.
26	MIDGE LARVAE	F.Chironomidae	
27		F.Ceratropognidae	
28		F.Dixidae	
29	FLY LARVAE	F.Ephydridae	Ephydra Sp.
30		F.Empididae	Hemerodroma Sp.
31		F.Muscidae	
67		F.Sciomyzidae	
32	CRANEFLY LARVAE	F.Tipulidae	Sp.1 (Big)
33		"	Sp.2 (Small)
34		F.Tipulidae	Dicranota Sp.

HEMIPTERA -			
35	WATER BUGS	F.Mesoveliidae	Mesovelia furcata
36		F.Corixidae	Sigara falleni
66		F.Veliidae	Microvelia Sp.
COLEOPTERA -			
37	WATER BEETLES	F.Dytiscidae	Oreodytes sanmarki
38		"	Stictotarsus duodecimpustulatus
39		F.Dytiscidae	O.septentrionalis
40		"	Potamonectes depressus depressus
41		F.Haliplidae	Brychius elevatus
42		F.Gyrinidae	Gyrinus Sp.
43		F.Elmidae	Oulimnius tuberculatus
44		F.Elmidae	Elmis aenea
45		"	Limnius volckmari
MOLLUSCA -			
46	F/W LIMPET	F.Ancylidae	Ancylus fluviatilus
47	SNAILS	F.Physidae	Physa fontinalis
48		F.Limnaeidae	Limnaea pereger
			" stagnalis
49		F.Hydrobiidae	Hydrobia jenkinsi
50		F.Valvatidae	Valvata piscinalis
51		F.Planorbidae	Planorbis carinatus
			Anisus leucostoma
52		F.Hydrobiidae	Bithynia tentaculata
BIVALVIA -			
53	PEA MUSSEL	F.Sphaeriidae	Pisidium pulchellum
			" casertanum
			Pisidium amnicum
			" milium
			Sphaerium Sp.
54	PEARL MUSSEL	F.Margaritiferidae	Margaritifera margaritifera
MALACOSTRACA -			
55	F/W SHRIMP	F.Gammaridae	Gammarus duebeni
56	F/W HOGLOUSE	F.Asellidae	Asellus Sp.
ARACHNIDA -			
57	WATER MITE	F.Hydrachnellae	
HIRUDINEA -			
58	LEECH	F.Glossiphoniidae	

OLIGOCHAETA -			
59	WORMS	F.Lumbricidae	Sp.1
60		"	Sp.2
61		F.Lumbricidae	Sp.3
NEMATODA			
62	NEMATODE		
COELENTERATA -			
63	HYDRA		Hydra Sp.
OSTRACODA -			
64	OSTRACOD		

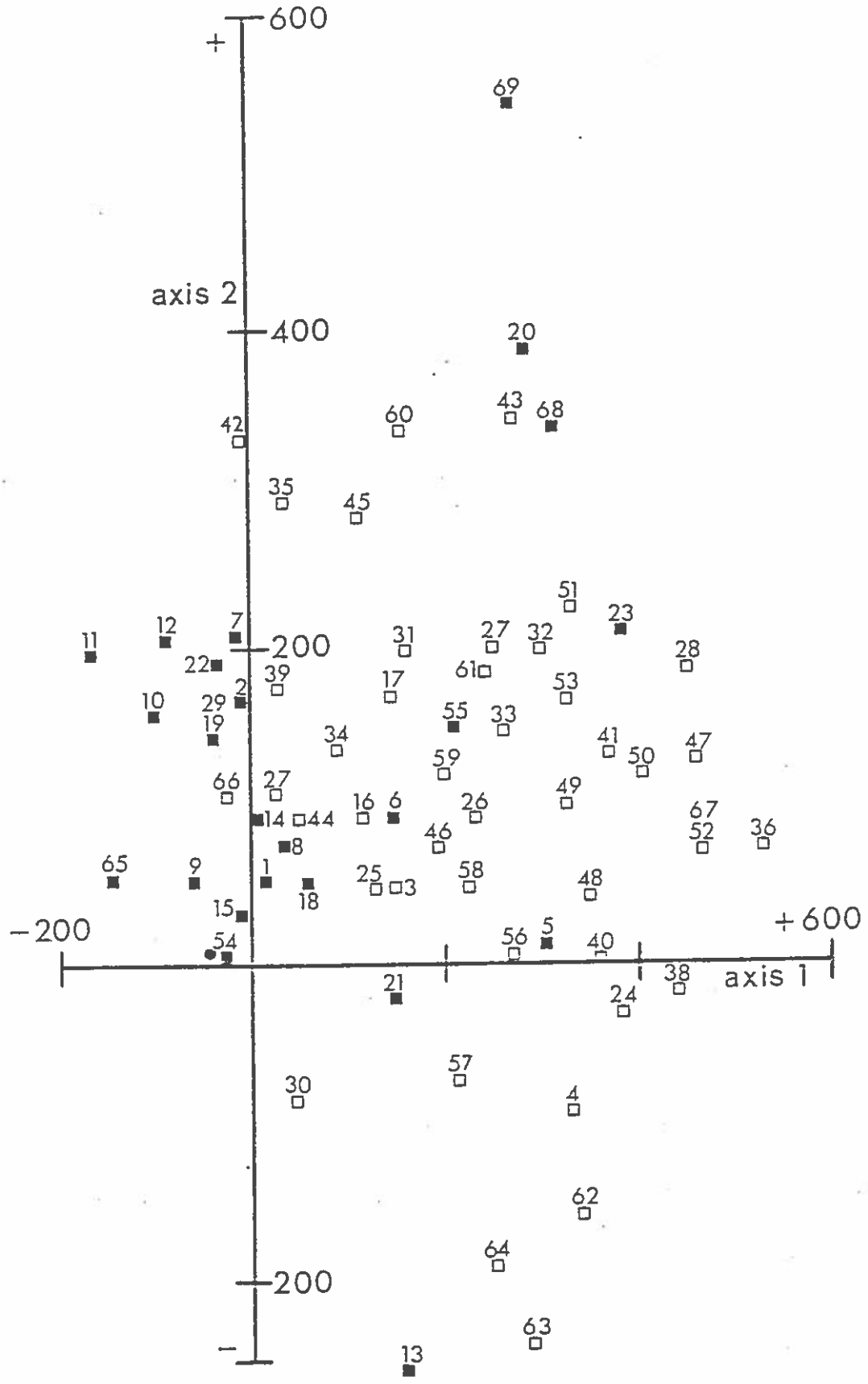


Fig. 8. Ordination of species found during survey (for species reference nos. see Table 4) showing those species with individual BMWP values 6-10 (solid squares) and those with BMWP values 1-5 (open squares).

• - Margaritifera

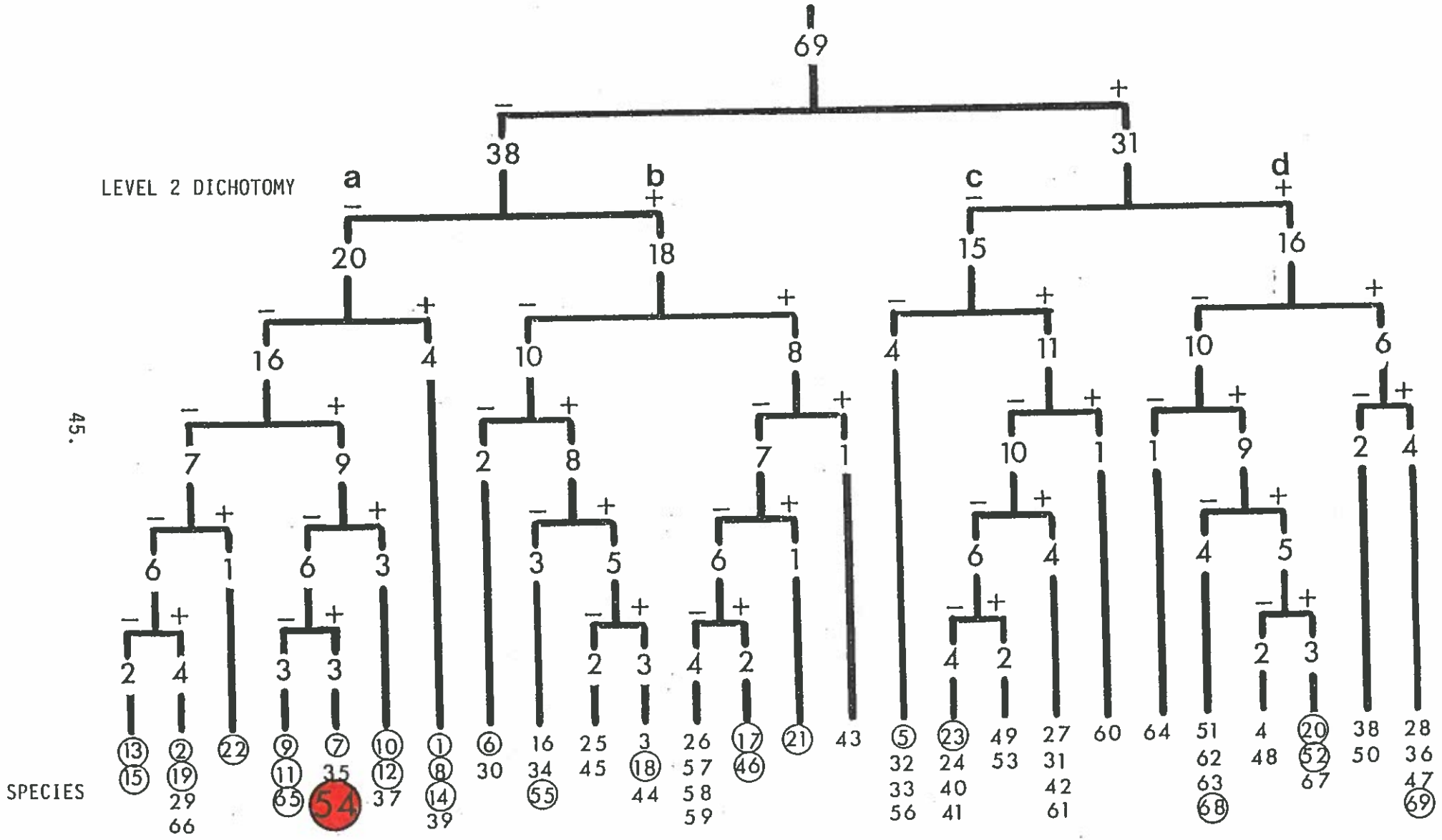


Fig. 9. Species grouping as demonstrated by TWINSPAN analysis. Margaritifera in red. Species with individual BMWP scores > 5 encircled.

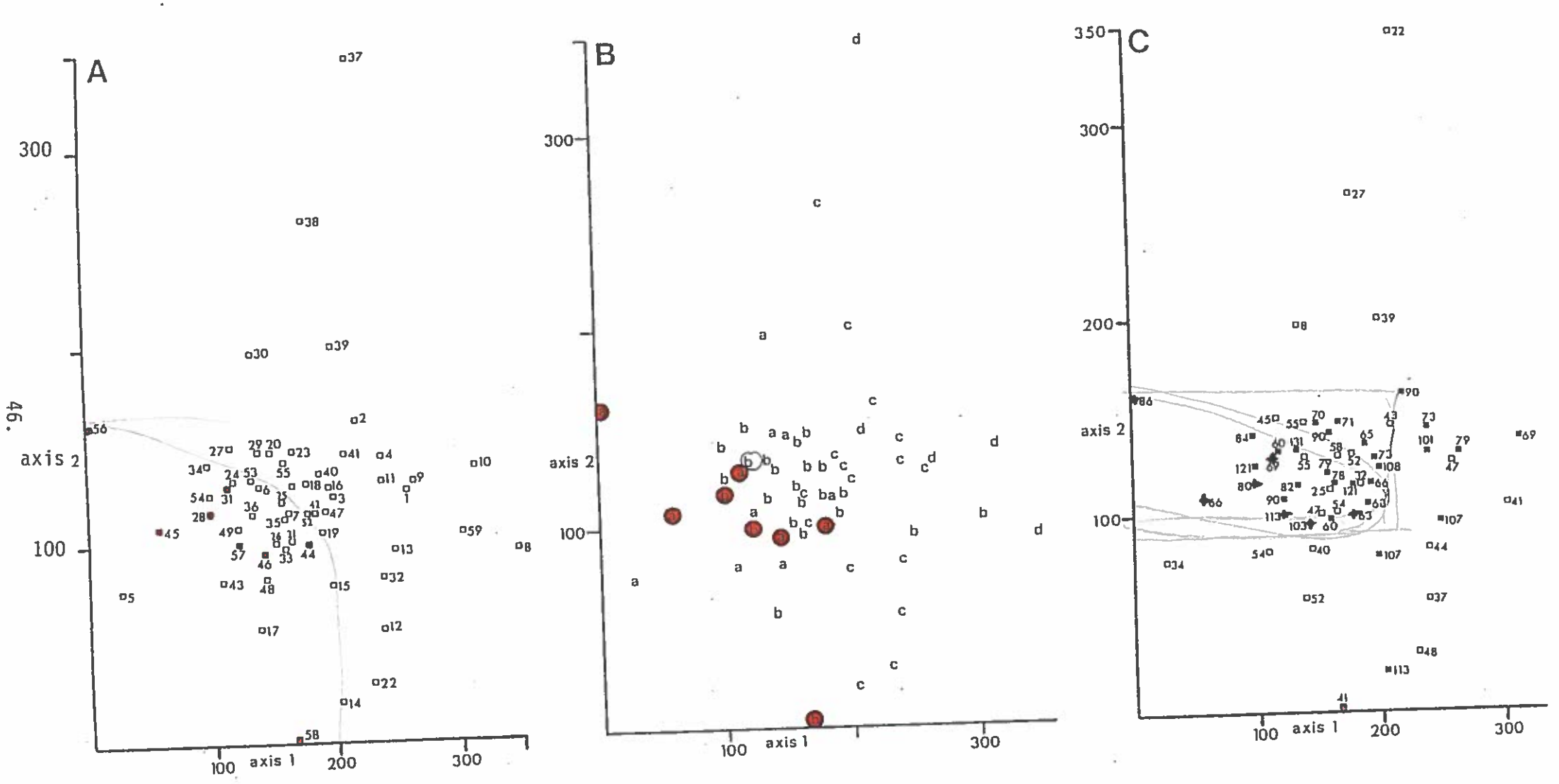


Fig. 10. Ordination of sampling sites showing: A) Site numbers (APPENDIX I); B) with groups a-d produced from TWINSPAN analysis species dichotomy at level 2 (Fig.9) superimposed on each site and C) with BMWP scores superimposed on each site. N.B. All Margaritifera sites fall within a distinct group and have BMWP scores >60 with the exception of site 58 which is an outlier from the Ballinderry River. (Margaritifera sites in red)

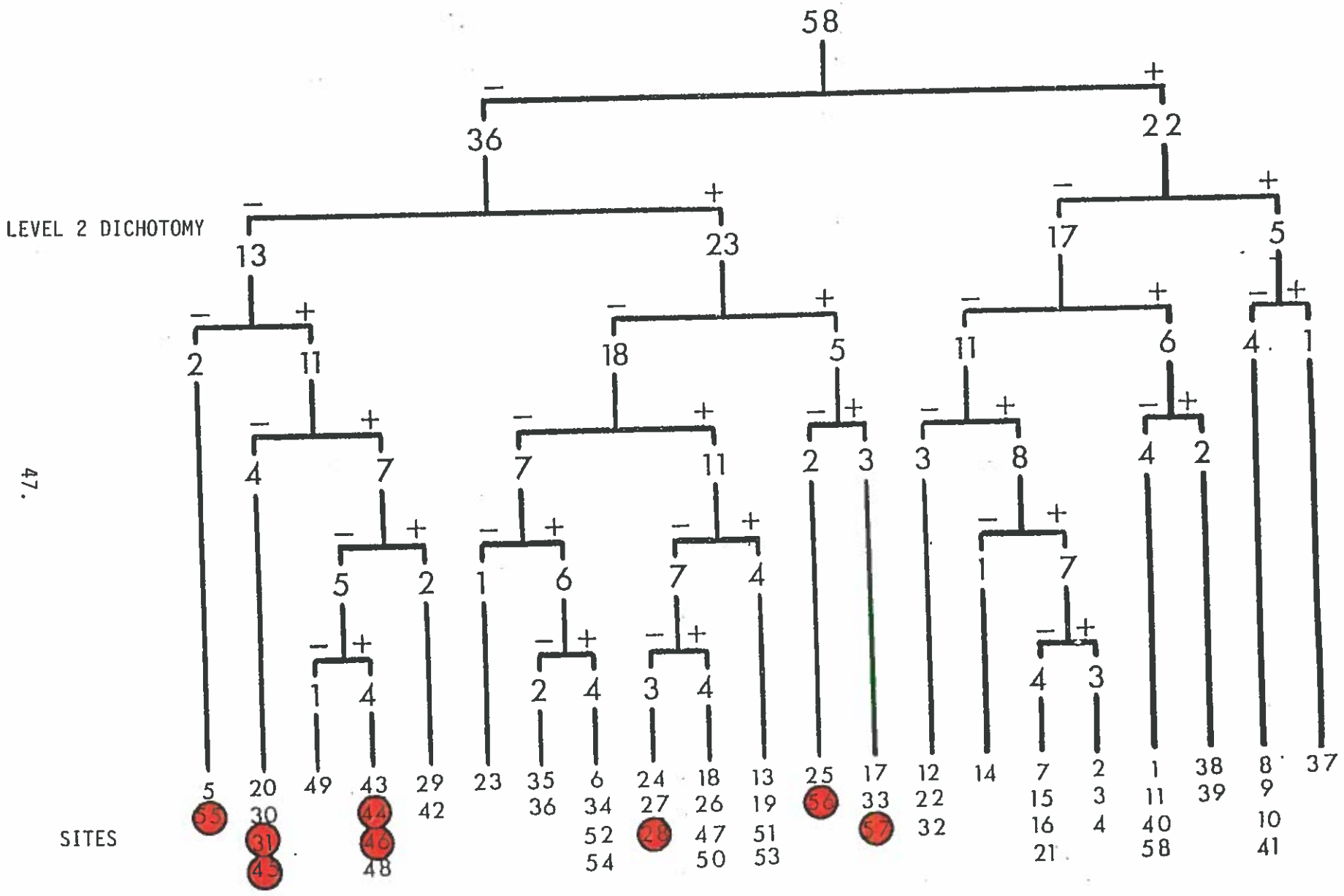


Fig. 11. Site grouping as demonstrated by Twinspan analysis of invertebrate taxa. (Margaritifera sites in red).

4.5 Water Quality.

Fieldwork was carried out during summer and autumn 1990 under varying rainfall conditions. It was considered therefore, that physical and chemical data collected on a one-off basis from our sampling sites would be of little value and not strictly comparable. However, we had access to water quality data covering a 17 year period for sites on the Foyle (courtesy of the D.O.E. Water Quality Branch), and had biotic indicator data (B.M.W.P. scores) from site kick samples. These were considered more relevant to the study than single estimates of water quality parameters.

From 18 measures of water quality available (D.O.E.), variation since 1973 in seven of these was examined in relation to B.M.W.P. site scores for 1990 (Table 5). With the exception of suspended solids, all these values had increased since 1973 indicating declining water quality throughout the period. Factors contributing to the decline in suspended solids, which could be interpreted as reflecting improving water quality, are likely to be many and varied. They may reflect however, a general increase in management of flow.

M. margaritifera numbers were slightly correlated with B.M.W.P. site scores (Fig. 12). Since mussels occurred at only one of the sites for which there was long-term physico-chemical information, no direct comparisons of the effects of changing water quality on M. margaritifera populations were possible.

Table 5. Percentage change in selected measures of water quality at 15 sites on the Foyle system since 1973.

Site No.	cond	BOD	Cl.	S.S	P.tot	NO_2-N	T-hard	BMWP
1.	+11	+35	+22	-62	+16	+47	+8	47
2.	+12	+23	+20	-12	+22	+53	+7	90
3.	+7	+39	+12	-56	+12	+25	+9	108
5.	+9	+9	+20	-166	+28	+35	+8	34
8.	+8	+22	+17	-30	+30	+39	+9	45
12.	+12	+11	+12	-33	+10	+18	+7	37
16.	+8	+18	+19	-46	+11	+16	+10	73
23.	+12	+28	+3	-217	+2	+47	+12	71
28.	+15	+33	+5	-83	+19	+52	+9	80
30.	+18	+12	+9	-70	+4	-10	+19	8
* 34.	+5	+24	-19	+27	+7	+50	+4	84
* 38.	-23	+18	-34	-3	-12	+52	+18	27
43.	+14	+27	+16	+7	+30	+15	+9	54
51.	+23	+50	+16	-82	+33	+33	+25	58
55.	+12	+19	+15	-73	-45	+44	+5	90

For site positions see Fig. 2. Values (except BMWP scores) are expressed as percentage change of the total sample mean from the 1973 mean values, except those marked " * " where sampling only started in 1983. (Based on data provided by D.O.E., Water quality Branch).

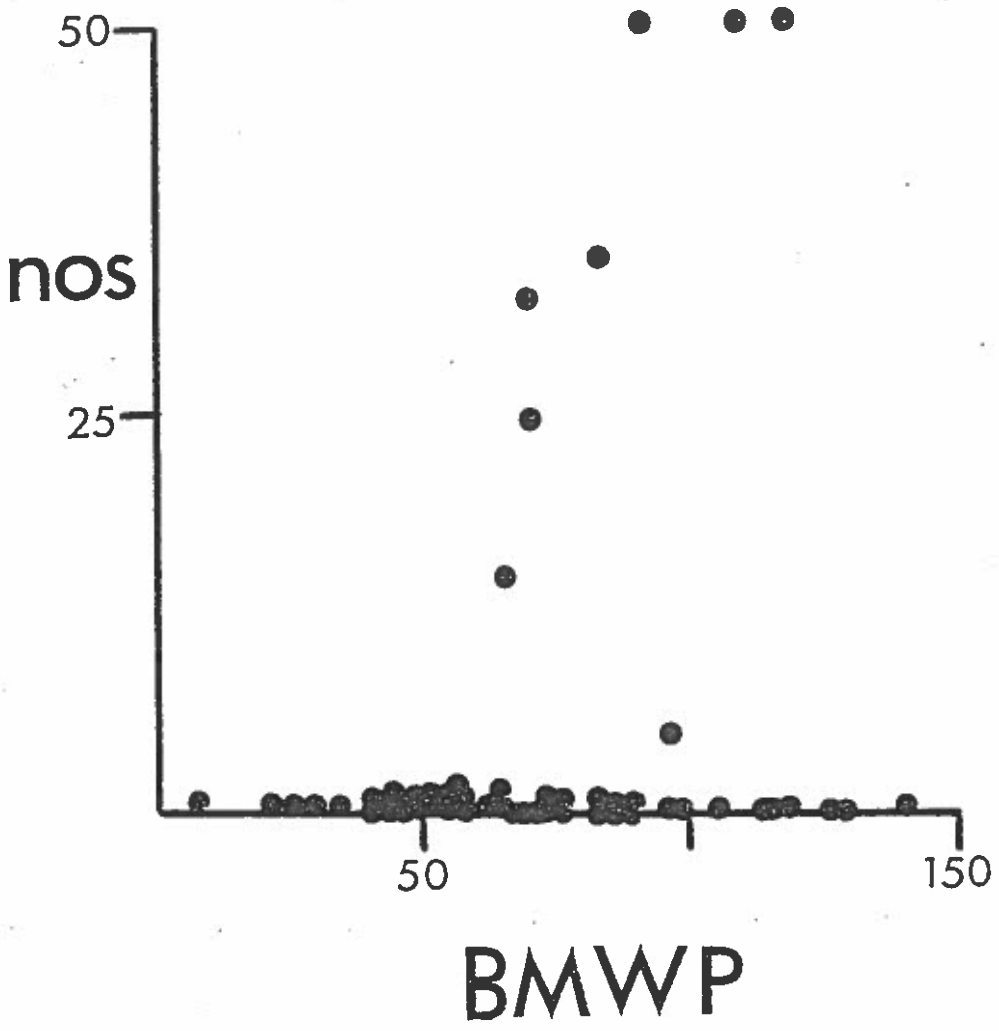


Fig. 12. Correlation between total numbers of Margaritifera and BMWP for all sites (N=57, r=0.261, P<0.1)

B.M.W.P. site scores unexpectedly revealed slight positive correlation with the percentage change in B.O.D.$_5$ and NO_2 - N over the last seventeen years (Fig. 13). However, low levels of enrichment may cause increased biological diversity in certain situations (Tilman, 1982). The occurrence of M. margaritifera at one of the sites which demonstrate a decline, since 1973, in water quality in terms of B.O.D.$_5$ and NO_2 - N suggests tolerance to a certain degree of eutrophication. Nitrate levels were only available for 1990 (D.O.E. - W.Q.B.). Average NO_3 - N levels were lowest at site 28 (Killymore Bridge, River Owenkillew) and highest at site 30 (Abercorn Bridge, Newtownstewart) (Table 6). The only one of these four sites where mussels were found during the present survey was at Killymore Bridge.

Table 6. NO_3 - N levels at selected sites on the Foyle system (these are D.O.E. - W.Q.B. sites which co-incided with sites in the present survey).

Site No.	River	Location	NO_3 - N (mg / l) Min.	Av.	Max.	No. of Samples
4	Strule	Abbey Br. Omagh	0.20	2.198	4.9	17
28	Owenkillew	Killymore Br.	0.12	1.243	1.9	9
30	Strule	Abercorn Br.	1.30	2.350	3.4	2
51	Mourne	Strabane	0.37	1.932	3.7	17

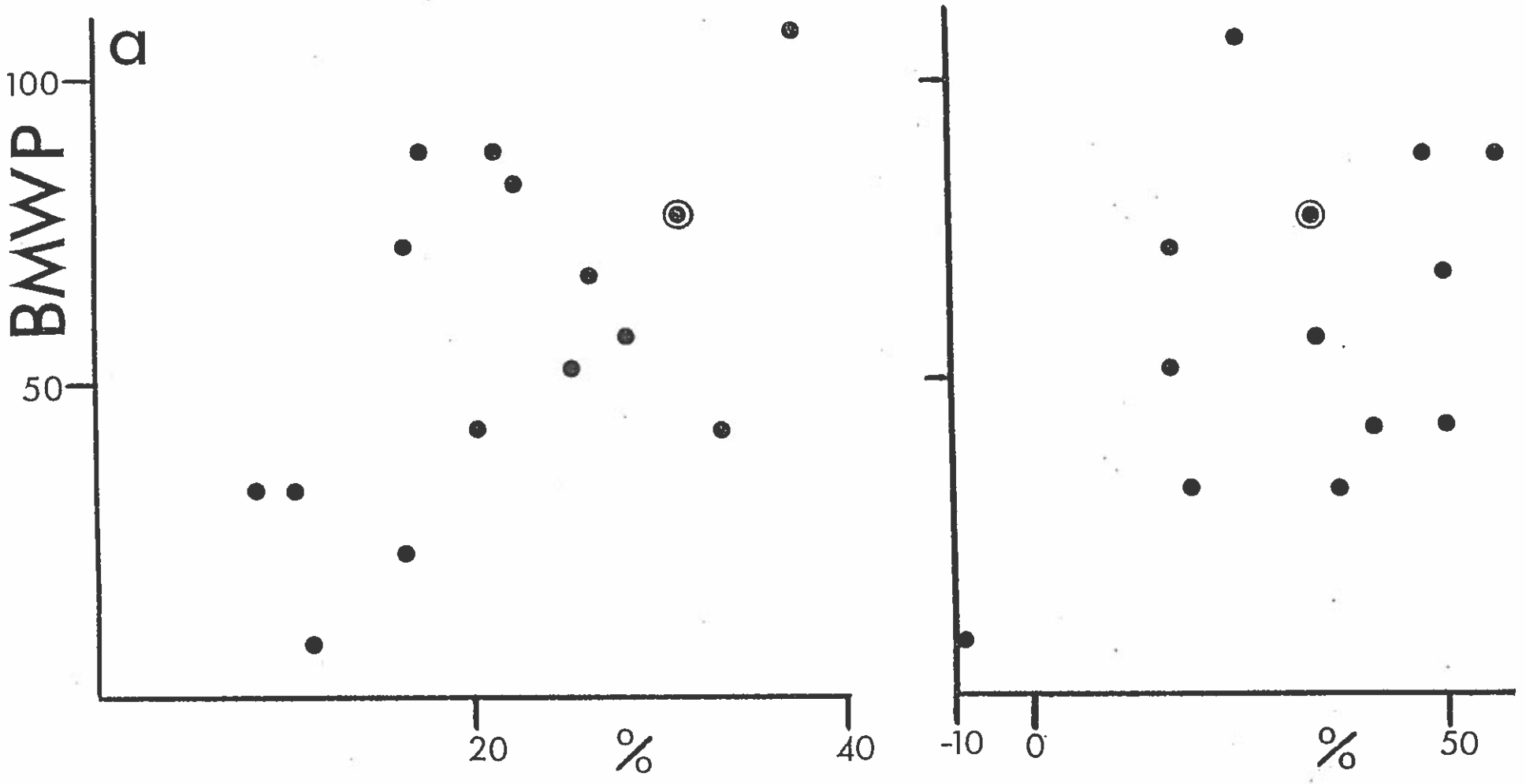


Fig. 13. Correlations between BMWP and deteriorating water quality as indicated by a) percentage change in BOD over the last 17 years (N=13, r=0.591, P<0.05) and b) percentage change in NO_2-N over the last 17 years (N=13, r=0.497, P<0.1) in the study catchment.

4.6 Drainage.

Evidence of drainage is limited to data on drained blanket peat (courtesy of Dr. R. Tomlinson, Q.U.B.) and seems to be greatest in the eastern sector of our survey, on the Glenelly and Owenkillew rivers (Fig. 3). Field observations support this view.

4.7 Pearl Fishing.

From conversation with local pearl fishermen, it would appear that, although they do still take "shells" from the Foyle system, they do not take as many as they once did for the simple reason that mussels are not present in the numbers that they once were. In an average day on the Strule, where once thousands of Margaritifera could have been taken, 25 - 100 mussels could now be expected. As a result several fishermen have turned their attention to the rivers of the Republic of Ireland, especially those of Donegal.

The lifting of pearl mussels is prohibited in the Republic of Ireland, yet it is known that even Scottish pearl fishermen regularly travel to fish the rivers of the West coast. Here, up to 6,000 Margaritifera may be destroyed in a day as the shells are simply levered open using a knife, to save the time involved in using the less destructive tongs. Despite the large numbers of mussels they remove, the fishermen are still under the impression that the drastic decline in Margaritifera they have seen in recent years is due to a deterioration in water quality.

The weir at Sion Mills, to provide water for Herdmans Mill, produces a deep pool which in the past was fished by boat using a glass-bottomed bucket and a split hazel rod.

Several hundred dead shells, almost certainly fished, were found in the mill race. However once the race enters the mill yard, access to pearl fishermen is prevented. The race travels for about 50 m under the mill buildings, before going to the tubines. Here a population of ~ 150 mussels were found in total darkness. This may seem to be an ideal refuge, but the mill buildings above are supported on piles painted with red lead, and while repainted only once every five years, provide the workmen with easy pickings as the race is drained to a depth of only 10 cm.

No mussels were found in any of the streams flowing into the Strule during the survey, including those streams which were formerly known to support Margaritifera.

Another destructive influence on some populations is fishing by school children. At the Wellbrook mussel site, children lie on the banks and rocks to reach the "oysters" and smash them open to find the pearls, not realising the damage they are doing.

5 CONCLUSIONS.

This first part of the discussion is speculative since hard baseline data on historic mussel populations in the Foyle system are not available. There is however, strong anecdotal evidence that M. margaritifera was formerly common in the Foyle catchment. A pearl necklace (Fig. 14) from rivers in Tyrone (presumably largely from the Foyle system) contains 80 gem quality pearls. This collection of freshwater pearls would probably have necessitated the destruction of between 40,000 and 80,000 Margaritifera. The contemporary photo - caption suggests that the supply of mussels was virtually limitless at that time and we can only guess at their numbers, conceivably over a million. Our census suggests that there may be as few as 3,000 mussels left in the Foyle system. Judging by a report from a local fisherman, this may represent less than half the number present as recently as 1981. That there appears to have been no recruitment since this date suggests that, if nothing is done Margaritifera may effectively be extinct in the Foyle catchment.

In the absence of baseline data it is difficult to identify the major contributory factor or factors resulting in this decline. According to Bauer (1988) while mortality af adult mussels is possitively correlated with the concentration of nitrate (NO_3), decreasing survival and recruitment of juveniles is correlated with PO_4, Ca and $B.O.D._5$ levels. Thus the increase in PO_4, Ca and $B.O.D._5$ recorded over the last 17 years may account for the decline and failure of recruitment over this period.

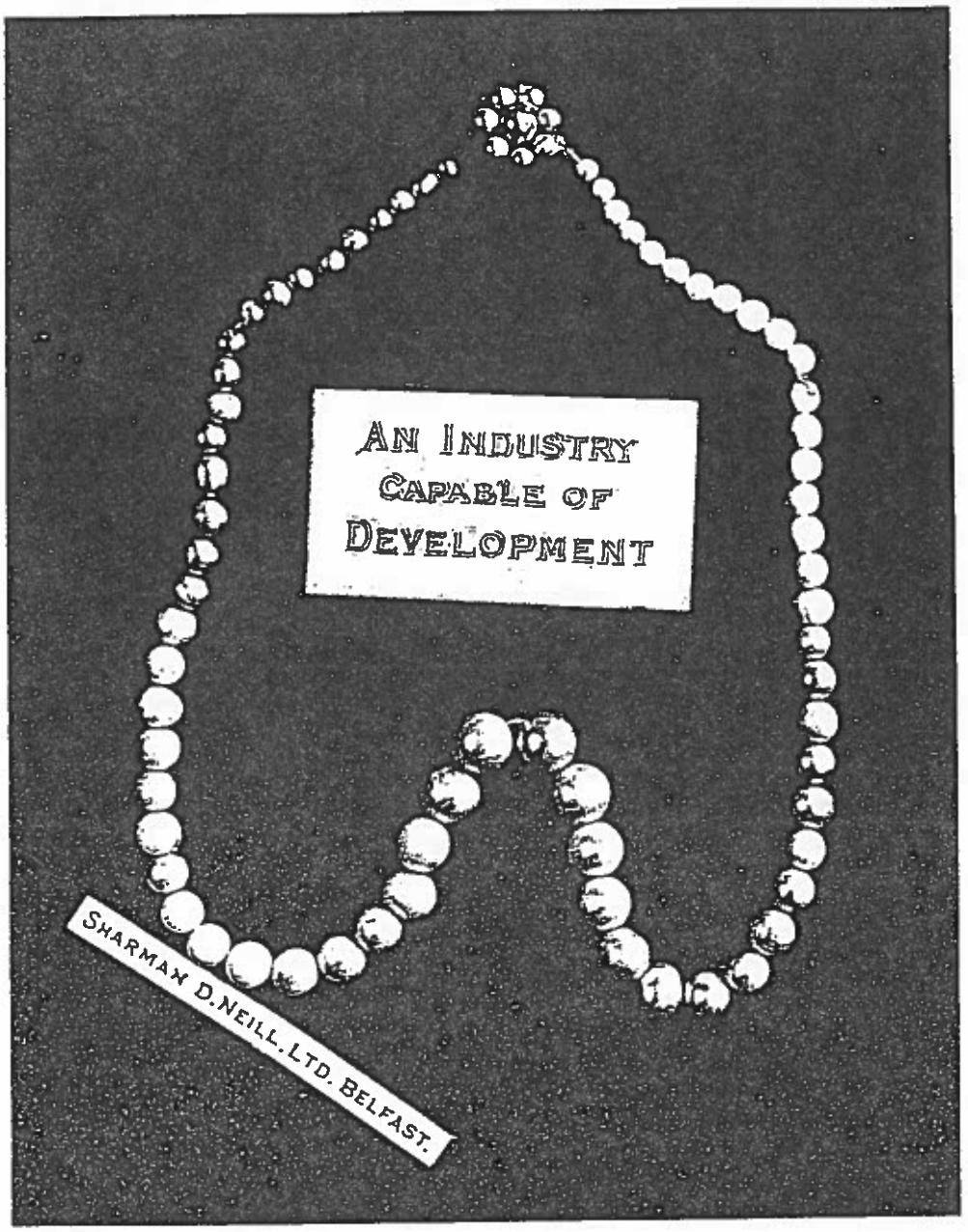


Fig. 14. Necklace of freshwater pearls from Tyrone (c.1990) (photo - Welch collection, Ulster Museum).

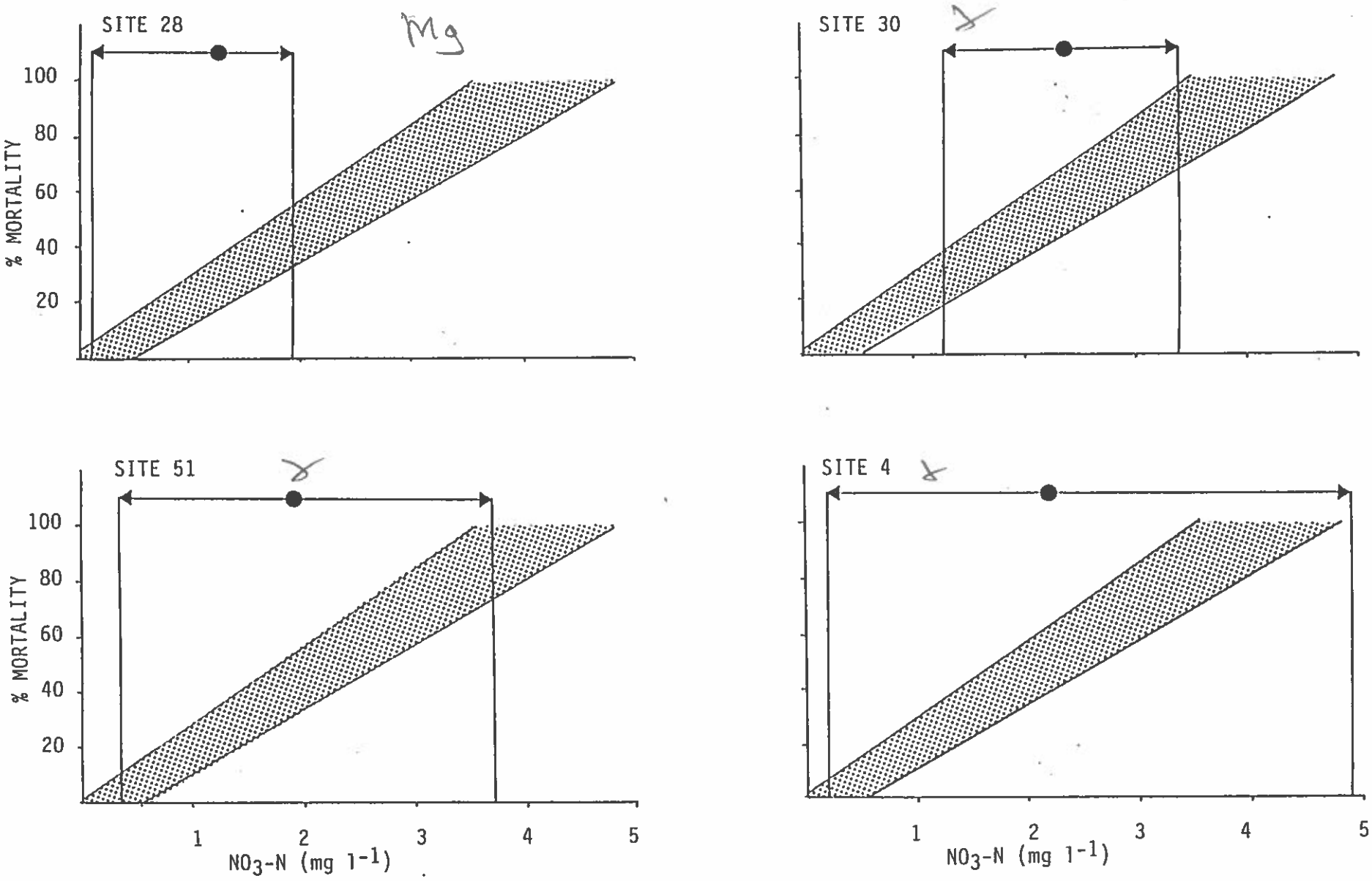


Fig. 15. Range (arrows) and average (●) NO_3-N concentrations at four sites in the Foyle system compared with experimental mortality data (shaded) for adult Margaritifera exposed to increasing concentrations of nitrate (after Bauer, 1988).

Recruitment is also dependent on host fish populations and is probably affected by climatic factors such as temperature and rainfall.

Nitrate levels at 4 of our survey sites are compared with Bauer's 1988 experimental toxicology data for adult Margaritifera (Fig.15). This suggests that adult Margaritifera would not survive at three of these sites which include one site (30) known to have formerly supported healthy mussel populations (Hood, Pers. comm. 1990). However, the presence of Margaritifera at one site where $B.O.D._{5}$ and NO_{3} - N have increased since 1973 suggests that adult mussels may tolerate some deterioration of water quality. Indeed, field observations at this site (28) suggest that individual large mussels are healthy and viable. In addition, multivariate analysis of the invertebrate communities at sites where Margaritifera is present differ little from many where it is absent (our a - b sites, Fig. 10 B) suggesting that these sites would be capable of supporting adult Margaritifera.

Thus, although fairly complex, the causal factors for the slump in Margaritifera populations in the Foyle can be identified under three headings : 1) overfishing

2) deteriorating water quality affecting recruitment and juvenile survival,

3) elevated nitrate concentrations which may increase adult mortality.

The problem of overfishing is recognised nationally, and U.K. legislation is currently underway to add Margaritifera to Schedule 5 of the Wildlife and Countryside Act 1981. This will make it illegal to kill or injure freshwater mussels. Experience in the United States, where freshwater pearl mussel poaching continued after protection (Fitter, 1986), suggests that legislation alone is unlikely to be effective.

Due to current practices in land and river management and agriculture, water quality is difficult to control. Despite European guidelines water quality is likely to deteriorate before it improves.

The glochidial host was not studied during this survey but its status is highly relevant to mussel recruitment.

This survey demonstrates the extremely serious situation facing Margaritifera populations in the Foyle catchment and points to a number of gaps in our knowledge. On the positive side, Margaritifera is a long lived species and the youngest individuals in the Foyle system may survive for another 50 years or more. This period of grace should not be wasted.

6. RECOMMENDATIONS.

These fall into two categories:

1) Practicable recommendations to delay the likely extinction of pearl mussels in the Foyle River system.

2) Recommended future research to facilitate the re-establishment of the species in the Foyle on a viable basis.

6.1 Practicable Measures.

6.1.1 To avoid poaching, local pearl fishermen should be paid an annual retainer (£100 - £200 p.a.) to monitor rivers and inform the Department of the status of mussel populations (cost £ 1,000 p.a.).

6.1.2 When river dredging and local drainage schemes and outfalls are planned for areas close to known mussel beds, mussels should be removed to safety and restocked if possible. The personnel suggested above could be involved at moderate additional occasional costs.

6.1.3 To avoid reducing genetic diversity, no re-stocking (other than 6.1.2 above) should be allowed.
(No cost).

6.1.4 A public awareness campaign to advertise the new legislation should be mounted.
(Cost ~ £ 1,000).

6.1.5 Water quality should continue to be monitored and efforts made to improve this where feasible. The latter is recognised as a complex and intractable problem with potentially high costs.

6.2 Recommended Future Research.

6.2.1 Current survey methods should be extended to other river systems in Northern Ireland which are likely to support Margaritifera.

6.2.2 Densities of young salmonids (potential glochidial hosts) and infection levels should be investigated with a view to artificially infecting hosts to increase mussel recruitment.

6.2.3 Suitable stretches of river which could support viable mussel beds should be identified with a view to their conservation.

7. ACKNOWLEDGEMENTS.

We would like to express our gratitude to the Royal Irish Academy (Praeger Fund) for the initial support to H.R. which prompted this survey and to the Directors and Trustees of the Ulster Museum for access to historical information about freshwater pearls and pearl mussels. Our grateful thanks are extended to Phil Jones, U.E.A. Climatic Research Unit and John Spain, Q.U.B. Division of Palaeoecology for access to long-term climatic data. We are also endebted to the D.O.E.(N.I.) (Environmental Protection Branch) for access to data on water quality, and to Paul Raven and Richard Weyl (D.O.E. C. and W. Branch) for useful early discussion on our findings. Statistical analysis was provided by Dr. I. Montgomery (Q.U.B.). Fieldwork would not have been possible without the information and assistance of John McGrath and the stalwart support of Gerry Armstrong and Biddi MacSweeny.

8. REFERENCES.

Bauer, G. 1986 "The status of the freshwater pearl mussel Margaritifera margaritifera L. in the south of its European range." Biol. Conserv. 38: 1 - 9.

Bauer, G. 1987 "Reproductive strategy of the freshwater pearl mussel Margaritifera margaritifera." J. anim. Ecol. 56:691 -704.

Bauer, G. 1988 "Threats to the freshwater pearl mussel Margaritifera margaritifera L. in central Europe." Biol. conserv. 45: 239 - 253.

Croft, P.S. 1986 "A key to the major groups of British freshwater invertebrates." F.S.C. publication 181.

Ellis, A.E. 1978 "British freshwater Bivalve mollusca." Synopses of the British fauna. New series No. 11: 1 - 93.

Fitter, R. 1986 "Wildlife for man. How and why we should conserve our species." Collins, London.

Friday, L.E. 1988 "A key to the adults of British Water Beetles." F.S.C. publication 189.

Gauch, H.G. 1982 "Multivariate Analysis in Community Ecology." Cambridge University Press.

Hynes, H.B.N. 1977 "A key to the adults and nymphs of the British Stoneflies." Freshwater Biological Association Scientific publication No. 17.

Hendelberg, J. 1961 "The freshwater pearl mussel Margaritifera margaritifera. On the localisation, life and growth of the individual and on the composition of the population according to an investigation in Parlalven in Artic Sweden." Rep. Inst. Freshwat. Res. Drottningholm 41: 149 - 171.

Jackson, J.W. 1925 "The distribution of Margaritifera margaritifera in the British Isles. Part I Journal of Conchology 17: 195 - 211.

Jackson, J.W. 1925 "The distribution of Margaritifera margaritifera in the British Isles. Part II Journal of Conchology 17: 270 - 278.

Kerney, M.P. 1976 "Atlas of non-marine Mollusca of the British Isles." Institute of Terrestrial Ecology, Cambridge.

Macan,T.T. 1972 "A guide to the freshwater invertebrate animals." Longman. Lond.

Macan, T.T. 1976 "A revised key to the British Water Bugs." Freshwater Biological Association Scientific publication No. 16.

Phillips, R.A. 1928 "On Margaritifera durrovensis, a new species of pearl mussel from Ireland. Proc. malac. Soc. Lond. 18: 69 -74.

Purser, G.J. 1985 "Factors affecting the distribution of the freshwater pearl mussel Margaritifera margaritifera (L.) in Britian." Unpub. PhD thesis. Univ. of Aberdeen.

Redding, Sir R. 1693 "A letter from Sir R.Redding late fellow of the R.S. concerning pearl fishing in the North of Ireland." Phil. Trans. Roy. Soc. 17: 659 - 664.

Ross, H.C.G. 1988 "Aspects of the ecology of the freshwater pearl mussel Margaritifera margaritifera (L.) in N.W. Ireland, with special reference to life history stratergy." Unpub. MSc. thesis. Queen's Univ. Belfast.

Ross, H.C.G. 1990 Unpub. report to the Royal Irish Academy.

Tilman, D. 1982 "Resource Competition and Community Structure." Princeton University Press, Princeton.

Valovirta, J. 1989 "Conservation of Margaritifera margaritifera in Finland." T. PVS 34: 59 - 62 second Rev.

Wellman, G. 1936 "Untersuchungen über die Flussperlmuschel (Margaritifera margaritifera L.) und ihren Lebensraum in der Lüneburger Heide. Z. Fische 36: 489 - 603.

Wells, S.M., Pyle, R.M. and Collins, N.M. 1983 "Invertebrate Red Data Book." Gland, Switzerland.

Young and Williams 1983 "The status and conservation of the freshwater pearl mussel (Margaritifera margaritifera) in Great Britian." Biol. Cons. 25; 35 - 52.

Young and Williams 1984 "The reproductive biology of the freshwater pearl mussel in Scotland." I. Field Studies Arch. Hydrobiol. 99; 405 - 422.

9. SUMMARY.

1. 58 sites on the Foyle system and 4 outside this catchment were surveyed for *Margaritifera* and associated macroinvertebrates between July and November 1990.

2. *Margaritifera* were found in comparatively low numbers at only 8 of these sites.

3. Our census suggests that there only about 3,000 pearl mussels left in the Foyle system.

4. Historical anecdotal information points to enormous populations (c. 1 million) of *Margaritifera* in the Foyle system at the turn of the century.

5. Age frequency analysis of *Margaritifera* samples suggests that there has been no mussel recruitment in the Foyle system since 1981 and that the species may now be effectively extinct in this river system.

6. Recruitment of *Margaritifera* is dependent on water quality, host fish populations and climate.

7. Multivariate analysis of invertebrate communities at sites where mussels are present differ little from many where they are absent which suggests that these sites could support adult *Margaritifera*.

8. Water quality at many sites in the Foyle system has deteriorated over the last 17 years, and this deterioration is reflected in changes in biotic communities.

9. Practicable recommendations which might delay the likely extinction of pearl mussels in the Foyle system are proposed.

10. APPENDICES I - V.

APPENDIX I Site Record Sheet - Field Survey of Margaritifera margaritifera.

Name of water body _____
Location/Nearest town or village _____
Species (if known) _____
Length of shell. Largest _____ Smallest _____
Colour _____
Other features ie. shell thickness/erosion etc.
Habitat (please tick)

river	☐ fast flowing	☐ sand	☐
stream	☐ slow moving	☐ mud	☐
canal	☐ still water	☐ shingle	☐
loch	☐ trees overhanging	☐ boulders	☐
pond	☐ aquatic plants present near bank		

Photographs enclosed of shell ☐
habitat ☐
pearl fishing evidence ☐

(Please use space overleaf for any additional notes)

EVIDENCE OF POLLUTION :- _____

O.S. Map Ref. ☐☐ ☐☐☐☐☐☐
Appox. no. of shells ☐
Estimate no'.s: Living ☐
Dead//Empty ☐

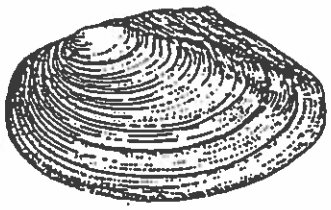
Evidence of Pearl Fishing? _____
_____
(continue overleaf if necessary)
Fish known?:
Trout ☐ Minnow ☐
Stickleback ☐ Others _____
Date ☐☐ ☐☐ ☐☐
Name and Address Recorder
_____
_____
_____

SIZE
1_____
2_____
3_____
4_____
5_____
6_____
7_____
8_____
9_____
10_____
11_____
12_____
13_____
14_____
15_____
16_____
17_____
18_____
19_____
20_____
21_____
22_____
23_____
24_____
25_____
26_____
27_____
28_____
29_____
30_____
31_____
32_____
33_____
34_____
35_____
36_____
37_____
38_____
39_____
40_____
41_____
42_____
43_____
44_____
45_____
46_____
47_____
48_____
49_____
50_____

WATER QUALITY
Palintest Results
Permanganate test. _____
BOD _____ pH_____
COD _____
TOC _____ Relative stability
Methylene Blue Test_____%_____
Turbidity test_____BOD check_____
Invertebrate Indices_____

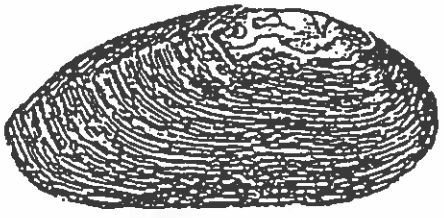
DENSITY
(please tick)
0 _
5-20 _
20-100 _
100-1000 _
>1000 _
per 100m stretch
of river.

DUCK MUSSEL
Anodonta anatina (L.)
Prefers hard, flowing water, although some-s found in ponds or lakes. Shell olive -wn with darker rays, and thicker near front edge. This can be seen when held up to light. Length up to 4 inches.



SWAN MUSSEL
Anodonta cygnaea (L.)
Prefers hard water. Found on muddy bottoms of slow rivers, canals, lakes and ponds. Shell usually yellowish green without darker rays. Shell of uniform thickness. Length up to 8 inches.

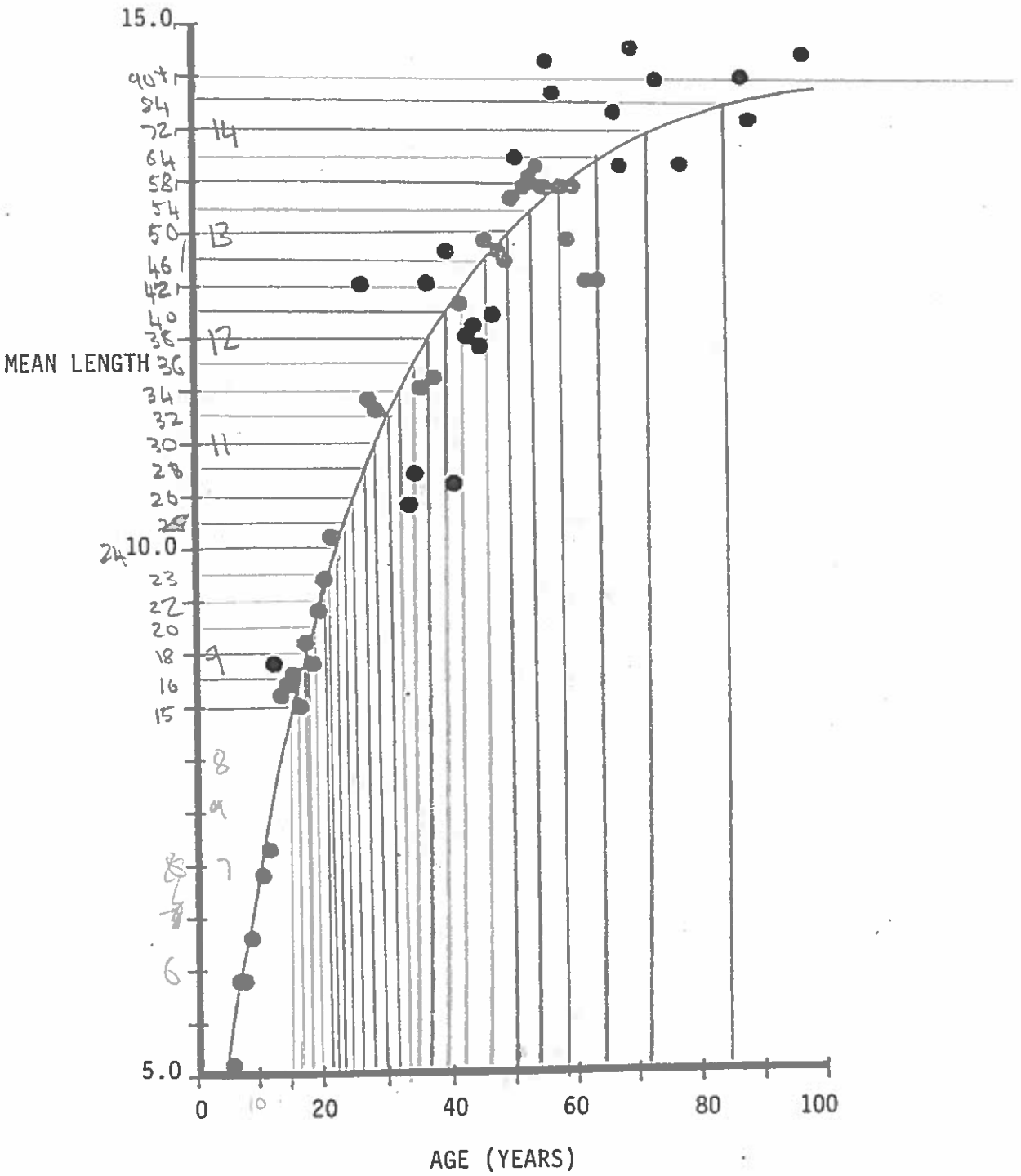
PEARL MUSSEL
Margaritifera margaritifera (L.)
Prefers soft water. Usually found in clean, fast flowing rivers and streams. Shell blackish on outside, often eroded near hinge. Teeth present inside hinge. Length up to 6 inches.



APPENDIX II. Growth curve for M. margaritifera from the River Owenea, Co. Donegal. Curve fitted by von Bertalanffy growth equation:

$$L_t = L_\infty [1 - e^{-k(t-t_o)}]$$

where $L_\infty = 14.482$, $k = -0.041$, $t_o = 5.917$



APPENDIX III - Site Details.

Site No.	DECORANA / TWINSPAN Name	Body of water	Site Name	O.S. Grid Reference
1.	QUIGGERY	Quiggery Water	Blackfort Br.	18.454656
2.	O'REAGH	Owenreagh River	Blacksessagh Br.	18.422679
3.	D'RAGHDH	Drumragh River	Drumragh Br.	18.457698
4.	D'RAGHLN	Drumragh River	Lissan Br.	13.462707
5.	C'OWENNE	Camowen River	Nine Mile Br.	13.625709
6.	C'OWENDY	Camowen River	Deverney Br.	13.510708
7.	C'FINCON	Cloghfin River	Ab.Camowen con.	13.509706
8.	S.R. POE	Strule River	Poe Br.	12.433749
9.	F.W.MONA	Fairy Water	Monaghan's Br.	12.345776
10.	F.W.PRIE	Fairy Water	Priest's Br.	12.366773
11.	F.W.DUDG	Fairy Water	Dudgeon Br.	12.407759
12.	S.R.STON	Strule River	Stone Br.	12.437776
13.	CAP.BTAT	Cappagh Burn	Tattynure Br.	12.437795
14.	S.R.TATT	Strule River	Tattynure Br.	12.435796
15.	S.R.BLAK	Strule River	Blackrock Br.	12.418833
16.	S.R.MOYL	Strule River	Moyle Br.	12.411859
17.	G.R.GOLE	Glenelly River	Goles Br.	13.672947
18.	G.R.SPER	Glenelly River	Sperrin Br.	13.634940
19.	G.R.OUGH	Glenelly River	Oughtboy Br.	13.593026
20.	G.R.CLOG	Glenelly River	Clogherny Br.	13.563913
21.	G.R.DRUM	Glenelly River	Drumnaspar Br.	13.522915
22.	G.R.PLUM	Glenelly River	Plumbridge	13.482913
23.	G.R.LISL	Glenelly River	Lislea Br.	13.457900
24.	O'K.GREE	Owenkillew River	Greenan Br.	13.589868
25.	O'K.GARV	Owenkillew River	Garvagh Br.	13.533872
26.	O'R.DRUM	Owenreagh River	Drumlea Br.	13.535859
27.	O'K.TRIN	Owenkillew River	Trinamadan Br.	13.494867
28.	O'K.KILL	Owenkillew River	Killymore Br.	12.438873
29.	O'K.CROS	Owenkillew River	Crosh	12.417866
30.	S.R.ABER	Strule River	Abercorn Br.	12.404862
31.	S.R.FISH	Strule River	Fishfarm	12.386867

Continued over leaf

Site No.	DECORANA / TWINSPAN	Body of water	Site Name	O.S. Grid Reference
32.	S.R.CONF	Strule River	Ab. Derg con.	12.369878
33.	R.D.LEGV	River Derg	Legvin Br.	12.125777
34.	R.D.AGHY	River Derg	Aghyaran Br.	12.191805
35.	R.D.KILL	River Derg	Killeter Br.	12.208807
36.	R.D.GLAS	River Derg	Glashagh Br.	12.228826
37.	MBR.FORD	Mourne Beg River	Ford	12.176834
38.	MBR.MOUR	Mourne Beg River	Mourne Br.	12.207838
39.	MBR.M.BE	Mourne Beg River	Mourne Beg Br.	12.228829
40.	R.D.CAST	River Derg	Castlederg Br.	12.263844
41.	R.D.OAKD	River Derg	Oakdene Weir	12.288847
42.	R.D.CREW	River Derg	Crewbridge	12.316845
43.	R.D.ARDS	River derg	Ardstrsw Br.	12.349874
44.	R.M.D.CF	Mourne/Derg con.	Mourne/Derg con.	12.368879
45.	R.M.VIC2	River Mourne	Victoria Br.2	12.363904
46.	R.M.VIC1	River Mourne	Victoria Br.1	12.357905
47.	R.M.VICT	River Mourne	Victoria Br.	12.352907
48.	GR.BGREV	Grevenue Burn	Grevenue burn	12.349928
49.	R.M.SION	River Mourne	Sion Mills Weir	12.346933
--	--------	River Mourne	Herdmans Mill	12.344934
50.	R.M.M'TN	River Mourne	Milltown Br.	12.348963
51.	RM.MMOUR	River Mourne	Mourne Br.	12.339980
52.	B.D.SLIV	Burn Dennet	Silverbrook Br.	7.447004
53.	B.D.GLEN	Burn Dennet	Glencrush Br.	7.415045
54.	B.D.BURN	Burn Dennet	Burn Dennet Br.	7.375048
55.	R'O'CO'C	River Owencarrow	Owencarrow Br.	C.063257
56.	B.R.WELL	Ballinderry River	Wellbrook Mill	13.748792
57.	B.R.AUGH	Ballinderry River	Aughlish Br.	13.788782
58.	R.BWBWTN	River Blackwater	Nr. B'water Tn.	19.837512
60.	--------	River Mourne	Seein Br.	12.344912

APPENDIX IV. Historical site records of M. margaritifera on the Foyle system pre-1900 to 1969 (courtesy of the Ulster Museum).

Ireland.
Grid Ref: 23/2--/8--
Location: River Derg.
Ref: Welch collection, Belfast Museum; Dr. Kearney's records.
Before 1990
J. Wright.

Ireland.
Grid Ref: 23/2--/9--
Location: River Finn, near Strabane.
Ref: J. W. Jackson (1925) J. Conch 17: 209.
Before 1900
R. J. Welch.

Ireland.
Grid Ref: 23/3--/8--
Location: River Mourne near Strabane.
Ref: Belfast Museum; Dr. Kearney's records.
Circa 1900
R. J. Welch.
VC: H - 36.

Ireland.
Grid Ref: 32/3--/8--
Location: River Mourne.
Ref: Belfast Museum; Dr. Kearney's records.
1905
J. N. Milne.
VC: H - 36.

Ireland.
1905
Location: Mourne pearl fishery, close to Newtownstewart.
Ref: Census molluscs, Y96: Dr. Kearney's records.

Ireland.
Before 1905.
Location: River Mourne.
J. N. Milne.
Ref: Census molluscs, Y96: Dr. Kearney's records.

Ireland.
Grid Ref: 23/4--/6--
Location: River Camowen ~ 3 miles above Omagh.
Ref: Census molluscs, Y96: Dr. Kearney's records.
1909
Irish Fisheries Board.

Ireland.
1909
Location: River Strule, 4 miles below Omagh.
Irish Fisheries Board.
Ref: Census molluscs, Y96: Dr. Kearney's records.

Ireland.
Grid Ref: 23/4--/7--
Location: Omagh.
Ref: Census molluscs, Y96: Dr. Kearney's records.

1909
P. H. Grierson.
VC H - 36.

Ireland.
Grid Ref: 32/3--/8--
Location: River Mourne, near Newtownstewart.
Ref: Census molluscs, Y96: Dr. Kearney's records.

Before 1911
J. N. Milne.
VC H - 36.

Ireland.

Location: Omagh.
Ref: Census molluscs, Y96: Dr. Kearney's records.

Before 1911
VC H - 47.

Ireland.

Location: Co. Tyrone.
Ref: Census molluscs, Y96: Dr. Kearney's records.

Before 1911
J. W. Jackson.

Ireland.

Location: River Mourne, near Newtownstewart.
Ref: Dublin Museum, Census molluscs, Y96: Dr. Kearney's records.

Before 1911

Ireland.
Grid Ref: 23/4--/8--
Location: Newtownstewart (near station)
Garrickmore Abbey.
Ref: Field obs. Stelfox : J. Conch? 3: 7-8, Dr. Kearney's records.

A.W.S.
VC - H 36.

Ireland.

Location: River Strule, 7 miles below Omagh,
1 mile above Newtownstewart.
Ref: Census molluscs, Y96: Dr. Kearney's records.

1969
Irish Fisheries
Board.

APPENDIX V. Site/Species records showing individual species BMWP values and Species Richness (SR) scores for each site.