IRISH FISHERIES INVESTIGATIONS

SERIES A (Freshwater)

No. 15 (1975)

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CHRISTOPHER MORIARTY

STUDIES OF THE EEL *ANGUILLA ANGUILLA* IN IRELAND.
4. IN THE MUNSTER BLACKWATER.

Studies of the eel *Anguilla anguilla* in Ireland.

4. In the Munster Blackwater River.

by

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(Received November 25, 1974).

ABSTRACT

Yellow eels from estuarine and freshwater populations were sampled by fyke netting: in 1965 and 1966 2,221 specimens from the estuary and in 1972 and 1973 826 specimens from freshwater. It was the first extensive study of eels in an Irish river and the population was found to be more dense than that recorded in lakes.

Growth in the estuary was relatively fast and spawning migration began at 9 years while in the freshwater growth was slower and migration began about four years later. One specimen of 36 years old was found and more than 17% of the freshwater sample were over 19 years. Eels of less than 40 cm fed largely on invertebrates whereas eels of 50 cm and over fed mainly on fish, cyprinids being taken to a much greater degree than salmonids. It was calculated that fyke netting of the unexploited fishery could yield a catch of 21 tonne of eels of over 50 cm length in the lowland freshwater portion of the river.

1. INTRODUCTION

This paper describes the first study of a river population of eels to have been undertaken in Ireland. It took place in two parts, the first in the estuary of the Blackwater at Villierstown in 1965 and 1966, the second in the freshwater portion near Fermoy and Banteer in 1972 and 1973. The work was instigated at the request of local fishery owners for information on the possibility of establishing commercial eel fisheries.

The Blackwater has been described in some detail by Toner and O'Connell (1971) who made an intensive water quality investigation there from 1966 to 1969. The greater part of the river, 90 km of the total of 142 km, runs due east over a bed of rock of Carboniferous Limestone to Old Red Sandstone age. The estuary, 24 km, runs due south to enter the sea at Youghal. The alkalinity at Ballyduff in April 1969 was 64 m eq/l and above Mallow was 31 m eq/l. Full tide salinity at Villierstown in August 1968 was approximately $5^0/_{00}$.

The eel sampling stations are shown in Fig. 1. The map also shows the positions where the contours at 30.5, 61 and 91.5 m (100, 200 and 300 ft) cross the main river. The river flows through a plain and there are no obstructions to the migration of eels. At Banteer and the Island the flow was rapid in places and the bottom deposits were moss-covered boulders. At Castlehyde and Careysville the rate of flow was slower and mud predominated. The estuary at Villierstown had a thick deposit of mud.

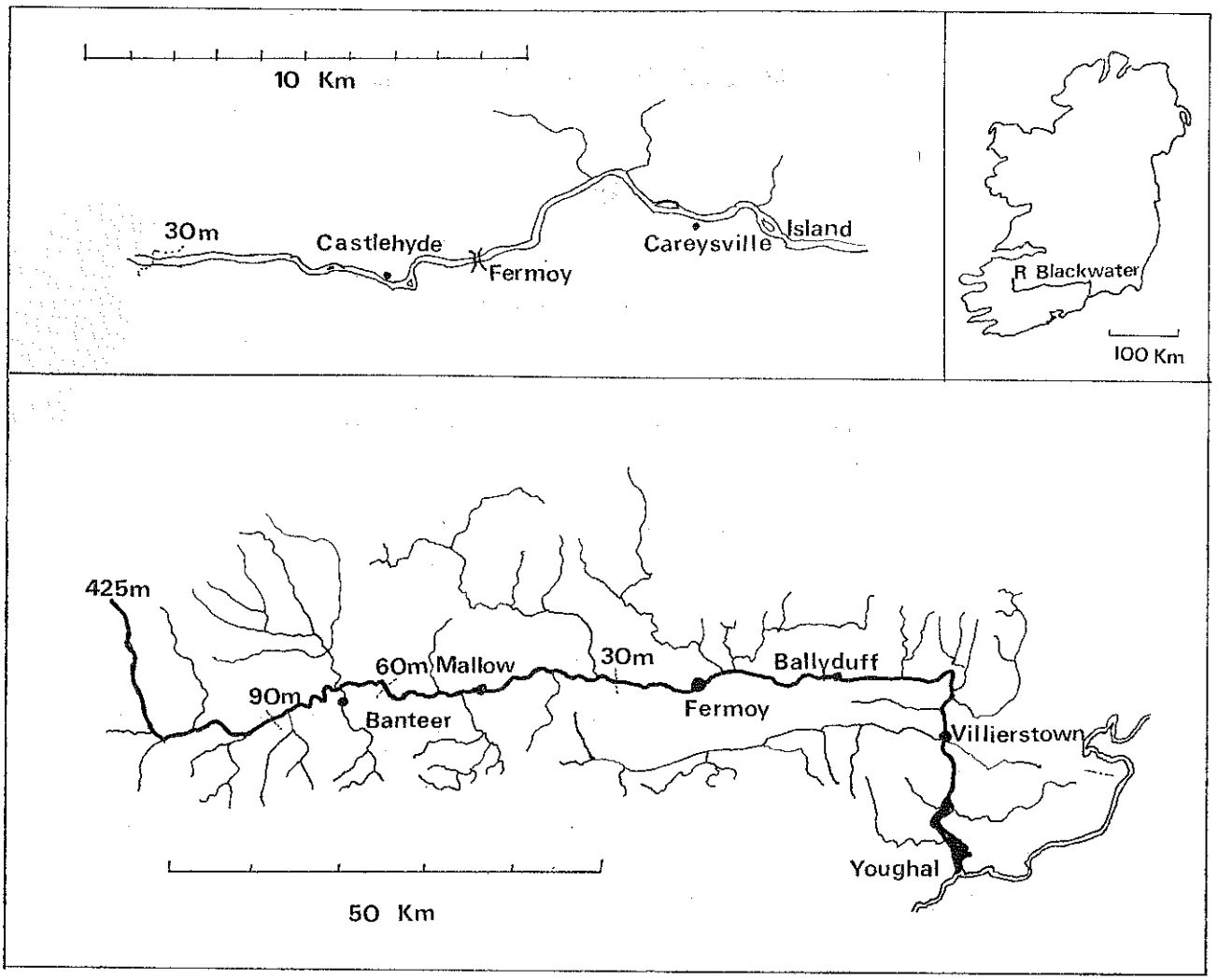

Figure 1. The River Blackwater showing sampling stations and land elevations (metres). Based on the Ordnance Survey by Permission of the Government (Permit No. 1833).

The methods used have been described in detail by Moriarty (1972). The gear was a train of small fyke nets (maximum hoop diameter 50 cm), each consisting of a pair of traps joined mouth to mouth by a leader. The usual method of sampling was to fish the nets (unbaited) daily and set them shortly after fishing. Specimens were anaesthetised in Chlorbutol, weighed and measured, otoliths extracted and stomach contents preserved in alcohol. When the numbers in the sample were too large to allow detailed examination of all specimens sub-samples consisting of the entire catch of a number of nets were used. Eels from the remaining nets were counted and released. Ages were determined by examining burned otoliths (Moriarty 1973).

2. RESULTS

Catch and effort

In 1965 three trains of three nets were used, two of the trains being fished in different positions daily except at weekends. The third was set in one position just to the north of the ferry quay on the west bank, and fished daily from June 25 to July 19, August 8 to 14 and 23 to 28. All nets were attached to stakes set in the mud. At first, attempts were made to set them across the river but it was found simpler and equally effective to set them with the current. The cod end mesh size was 20 mm and the leader length 9 m.

The following year nets with a leader of 6.5 m were used. These were attached by anchors and marked with buoys. Trains of ten nets were used on the first three days but these caught too many eels for examination. The daily effort was therefore reduced to five nets.

In 1972 and 1973 trains of eight or nine nets were set, attached to anchors. On August 15, 1973 and August 10, 1973 strong currents and shallow water in parts prevented some of the nets from fishing effectively. The cod end mesh of these nets was 20 mm and the leader length 4.7 or 3.3 m.

Figures for the catch per unit of effort are given in Table 1. The unit is one net consisting of two traps joined to a leader fished for one night. The effect of different lengths of leader has been discussed (Moriarty 1972 and in press). In still water the leader length of 6.5 m was found to have about double the catching power of the 9 m leader and four times the power of the 3.3 and 4.7m which were equal to each other. Comparative experiments in running water have not been made between all four nets used in this survey. It is therefore impossible to use the figures provided to compare the density of eel populations between successive seasons in the estuary and between the estuary and the river. In spite of these reservations it does seem that there were many more eels of the sizes sampled in the river than in the estuary.

The catches in the estuary in 1965 showed a steady increase from month to month. This may reflect an immigration of eels to the area but it is possible that, with increasing experience in using the nets, there was a tendency to select the more productive positions as the season advanced.

The catches made at the Island, at Careysville and Castlehyde at over seven eels per net were substantially greater than those in any freshwater area in Ireland studied to date. The best catch of all on the Blackwater was at Castlehyde, where the water is relatively deep and slow-flowing, its level maintained by the weir at Fermoy. The current at Careysville was faster and at the Island there were rapids in places, suggesting that the eels preferred the more placid waters.

At the Island in 1972 nets were set in approximately the same position on four successive nights. The catch showed the expected fall over the first three nights but appeared to level out on the fourth. This result contrasted sharply with that in the estuary in 1965 when nets were set in the same position over a prolonged period. The figures for the estuary are shown graphically in Fig. 2. In the first four nights, the highest catch took place on night 2 and the next on night 4. From June 25 to July 19 the highest catch of all was made on night 8 and over the whole period the peak was reached on August 8, 45 days after the experiment began. This experiment indicated that in the estuary the eels ranged over a wide area in search of food. When fishing depleted the population in one position more eels would appear in as little as two days.

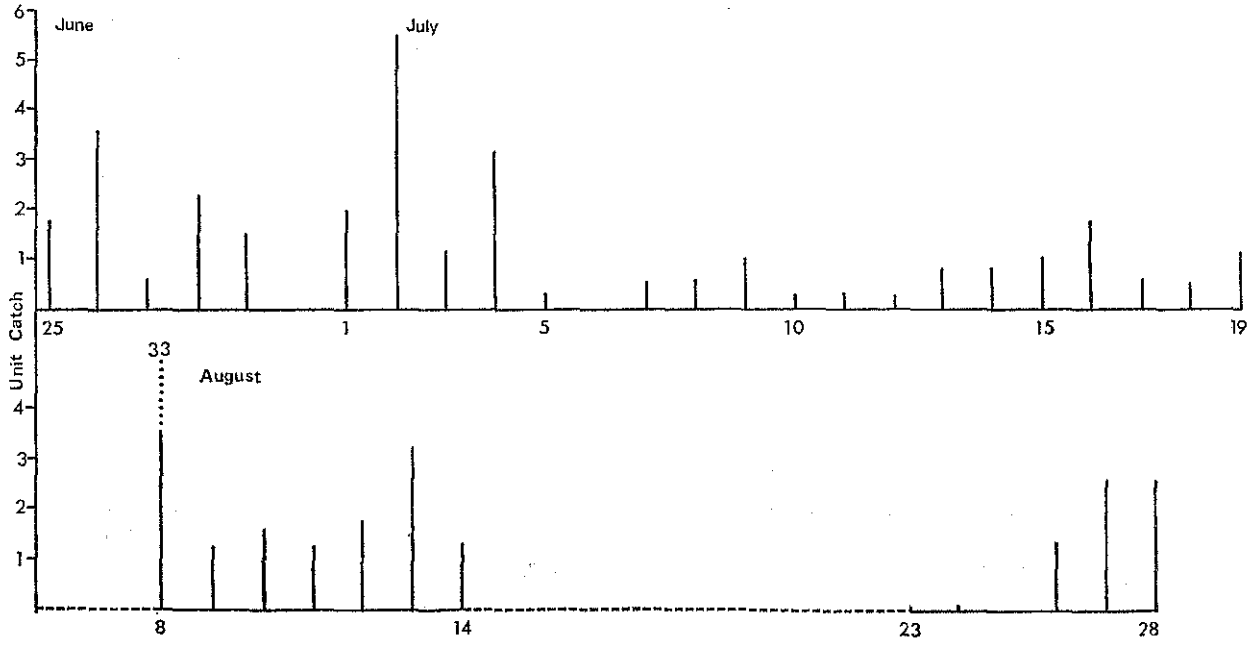

Figure 2. Catches in net set in fixed position at Villierstown Ferry in 1965.

The catch figures showed that there were considerable variations in the population density at different points in the estuary. Table 2 gives details of the catch per unit of effort at the nine positions where four or more nightly samples were taken. The positions are shown on the map in Figure 3. The catches are arranged in Table 2 in order of width of the river at high tide compared with the width at low. It can be seen clearly that the most dense populations were found where the river flowed between steep banks and the extent of tidal mud was lowest. When the catch per unit of effort was plotted against the percentage width of river bed containing water at low tide a high co-efficient of correlation of 0.76 was obtained ($p > 0.98$).

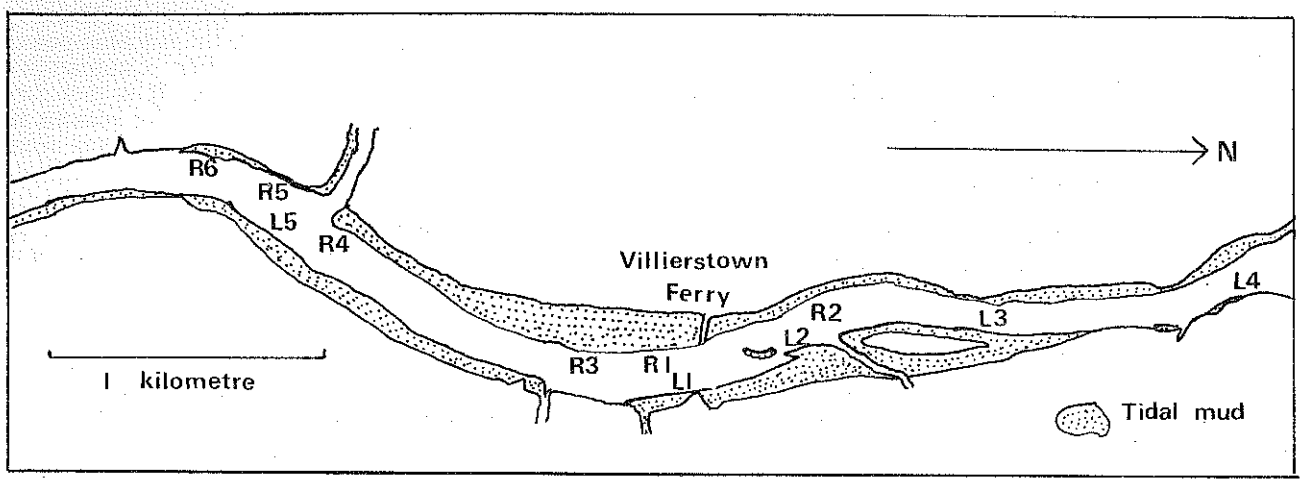

Figure 3. Sampling stations in Blackwater Estuary 1965 and 1966. L 1-5 left bank stations, R 1-6 right bank. Based on the Ordnance Survey by permission of the Government (Permit No. 1833).

Length, weight, age and sex

The length distribution of the estuary eel sample in 1965 was bimodal (Table 3). No significant difference was found between the July and August/September samples and therefore all readings for the season have been shown together. The two peaks were at length groups 30-34 cm and 40-44 cm. The pattern in 1966 when sampling took place at the end of May and beginning of June was quite different. Seventy five per cent of the eels were less than 40 cm long, the most frequent lengths were from 30 to 34 cm (40%) and the mode at 40-44 cm was not apparent.

No significant differences were observed between the mean lengths of the river populations sampled in 1972 but the Island population contained a significantly greater proportion of eels of less than 40 cm ($p < 0.05$). Possibly the presence of rapids at the Island made it a less suitable region for large eels. In 1973, when the populations at Careysville and Banteer (48 km upstream) were compared, eels of less than 45 cm were found to be much scarcer at Banteer ($p < 0.01$), suggesting a very slow migration upstream.

When nets were set in the same position on successive nights the proportion of large eels fell sharply after one night's fishing. In 1972, 62% of the first night's catch were larger than 65 cm compared with only 17% of the second. Slightly higher proportions of longer eels were caught on the third and fourth nights. In 1973, 53% of the first night's catch were longer than 65 cm and 26% of the second.

The variations of weight for a given length were so great that the samples in general were too small to allow firm conclusions to be drawn. For example, the weight range of nineteen 45 cm eels in July 1965 was 120 to 171, mean 145, standard deviation 16.5. In spite of this reservation some interesting observations were made. Mean weights per cm length group are shown in Table 4. The table also gives values for a and b in the length/weight regression: $W = al^b$. The regression line was computed by the least squares method for centimetre length groups against mean weight for eels of 40 cm and over.

An increase in weight for length is clearly shown from July to September 1965 in the estuary. The mean weight for all lengths from 40 to 50 cm was significantly higher in the August/September period than in July and higher mean weights were shown by most of the eels from 50 to 70 cm for the same periods. The weights for the smaller samples taken in the estuary in May/June 1966 and in the river in August 1972 and 1973 both appeared to be marginally higher than those for the estuary in 1965 and the values of the condition factor *b* were also higher.

Data from the age determinations are set out in Table 5. The 102 eels in the estuary sample, none of which were older than 18 years, showed a relatively high rate of growth with a mean annual increment of 3.5 cm. Eels from the river of under 19 years increased in length by 2.0 cm a year while the 39 specimens of 19 years and over showed an even slower increase of 1.6 cm a year.

In the estuary more than half of the eels in the May/June sample were eight years old or less. In the river only 2% of specimens were less than 8 years while 40% at Fermoy and 56% at Banteer were older than 15. Although eels down to eight years were found at Banteer, specimens of less than ten were relatively scarce there.

Of the eels of less than 45 cm long, 28% in the river and 45% in the estuary were either male or of indeterminate sex. The growth rate of the males in the river appeared to be slower than that of the females. The biggest and oldest male found was 19 years and measured 38 cm. The majority were aged 9/10 with a length of 33.9 cm.

Food

The stomachs of two thirds of the eels in the estuary sample contained food. All sizes appeared to feed at the same rate as judged by the proportion of stomachs containing food. In the river a higher proportion of stomachs containing food was found amongst smaller eels: 79% of those under 40 cm as against 67% of larger individuals. Eight per cent of the small eels had completely empty digestive tracts, indicating a fasting period of two or three days while 16% of larger eels had similarly fasted. Figures are given in Table 6.

The stomach contents of the estuarine eels were not analysed in detail. Mysids and a species of *Gammarus* were the dominant invertebrates and were plentiful in eels of less than 50 cm. A change with increase in length to a largely piscivorous diet was shown: only 6% of eels of less than 40 cm contained fish, as did 42% of those in the 40-49 cm length group and all three of the longer specimens. Flounder *Platichthys flesus* was the most frequently identified prey species.

In the river, Ephemeroptera were the principal diet of eels of less than 40 cm (Tables 7 and 8); present in 70% of the stomachs which contained food and the dominant organism in 14 of the 21 full stomachs.

Trichoptera, usually *Athripsodes bilineatus* were frequently eaten in the lower reaches, though not recorded from the Banteer sample. Simuliids appeared in some numbers at Careysville and Chironomids at the Island. *Asellus* and two leeches were recorded occasionally and the full stomach of one large eel (78 cm) contained five specimens of *Erpobdella octoculata* and 61 *Asellus aquaticus* amongst other invertebrates. Fish were present in eels of all size groups, increasing in importance from 8% of all eels less than 40 cm to 73% of those over 50 cm.

Details of the genera and species of food organisms identified are given in Table 9. *Ephemerella ignita* was the principal Ephemeropteran nymph but *Baetis rhodani* was important in the Banteer stretch. Five other species were recorded. Amongst the five Trichopterans *Athripsodes bilineatus*, a small species which lives in a secreted case, was the only important form. Chironomid larvae of three genera and seven species of Simuliid larvae were recorded. Thirty specimens of *Simulium salopiense* were found in one stomach.

Remains of 68 fish were found of which two were Salmonids: one a brown trout and one not identified. Five eels were found as prey. The dominant fish were cyprinids. Roach *Rutilus rutilus* were identified twice at Banteer but other specimens were recognised by their scales only which precluded determination of the species. Undoubtedly many were roach but dace *L. leuciscus* may also have been eaten. No other cyprinids with large scales are known in the area.

3. DISCUSSION

The figures for catch per unit of effort showed that the density of population of eels in the River Blackwater was considerably greater than in any of the lakes studied in this investigation. The south basin of Lough Corrib, for example, yielded 4.4 eels per unit while the catch on the Careysville stretch was 7.5 per unit. The high density of population can be explained by the absence of serious obstructions to the passage of elvers in the Blackwater and by the fact that the area of suitable habitat for eels in a river such as the Blackwater is very much smaller than in a lake. The lowland part of the Blackwater has an area of water of the order of 500 ha while the area of Lough Corrib is 166,000 ha. A similar supply of elvers to each water could be expected to give rise to a much higher density of eels in the river.

Examination of the catch figures and of the length distributions allowed some conclusions to be drawn concerning local movements of the eels. In the estuary, the length distribution in May and June was quite different from that found from July to September. In the early summer period 64% of the sample were less than 35 cm in length while in late summer this proportion had fallen to 25%. The lengths in early summer showed a strong negative skew with a single mode at 30-34.9 cm while in late summer there were two modes: at 30-34.9 and 40-44.9. As the numbers caught per unit of effort were about the same for each period it appears that small eels left the area and larger ones came in as the summer advanced.

Setting of nets in the same position on successive nights indicated that there was a far greater degree of local movement in the estuary than in the freshwater. The catches were always highest on the first night in freshwater but fluctuated on the estuary. The capture of more large eels on the first night in freshwater than later suggested that the large eels range more widely in search of food in the course of a night than the small ones do.

The increase in mean weight for each length group shown by the estuary population had not been observed previously. On account of the wide variation in weight per length large samples would be required to show it and the Blackwater population is the only one to have yielded enough specimens. It would appear that increase in length of the eels ceases in July and from then on the food is used for building up reserves rather than for growth.

Age determinations in the estuary were confined to the 1966 sample with its high proportion of small eels and no individuals of more than 18 years were found. In the freshwater portion a high proportion of eels of 19 and over were present, accounting for 17% of the Fermoy sample and 22% at Banteer. The oldest specimen was 36 years. Eels of as little as 37 cm length were aged up to 19 years and it appears that the absence of old eels in the estuary sample did indicate early migration. The growth rate of 3.5 cm per year in the estuary was considerably higher than in the river. The rate of growth amongst the older eels in the river was rather lower than in the younger. The annual increment was 2.0 cm for specimens of less than 18 years and 1.6 cm for those of 19 and over. Taking the modal age as an indication of the beginning of maturity, estuary eels began to migrate at 9 years while the river population took about four years longer.

In feeding, a gradual change from an invertebrate to a fish diet was apparent in estuary and freshwater. Eels of less than 40 cm seldom contained fish, those of over 50 cm seldom held invertebrates but even some of the biggest eels contained large numbers of invertebrates. Cyprinids were the principal fish eaten, salmonids were identified in only two of 31 cases where the type of fish could be recognised. Eels were identified in five stomachs. Ephemeroptera and Trichoptera were the most frequent prey invertebrates. The principal ephemeropteran, *Ephemerella ignita* was considered by Rogers (1964) in the Cottage River to be actively selected there. In the River Dwyfach in Wales, Sinha and Jones (1967) found *Ephemerella* an important prey and Ephemeroptera were also the principal food of small American eels *A. rostrata* in New Jersey streams (Ogden 1970).

The survey gave a fair indication of the possible return of eels if a fishery were to be established using the summer fyke nets. In the estuary the daily yield of eels of over 50 cm length was 422 g per net. In the river the yield at Careysville was 1,666 g per net. Assuming an uniform population of eels in the 90 km of lowland river a catch of 21 tons of eels of over 50 cm might be made. This would not, of course, be an annual yield. An approximate calculation of the annual production of the river gave a figure of between five and ten tonne. It seems unlikely that an efficient trap for migrating eels could be built at a low enough cost to make such a fishery profitable. Casual fishing on the other hand based either on netting the entire river every four or five years or netting a portion of it annually could be profitable, the present value of eels being of the order of £1,000 per ton.

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Table 1. Catch per unit of effort, River Blackwater, based on results of single night's fishing.

Position	Date	Effort (nights x nets)	Catch per unit	Total
Estuary	1965			
	July 1—31	204	3.6	734
	August 1—31	156	4.2	655
	September 1—19	84	6.0	504
	Whole season	444	4.3	1,893
Estuary	1966			
	May 24—June 8	45	4.4	328
River Island	1972			
	August 15	13	7.6	99
	„ 16	18	4.2	75
	„ 17	24	2.8	68
	„ 18	24	3.0	71
Castlehyde	„ 17	18	9.5	171
Careysville	„ 18	18	7.8	141
	1973			
Careysville	August 9	16	7.3	116
	„ 11	24	1.5	35
Banteer	„ 10	11	4.5	50

Table 2. Catch per unit of effort, Blackwater Estuary, based on results of single night's fishing at positions where four or more samples were taken.

Position	River width at low tide as % of total	Total width of river (m)	Catch per unit effort	Number of samples
R5	96	224	6.5	12
L5	92	168	6.4	27
R2	89	160	3.7	11
L1	87	184	3.7	8
L4	83	131	2.3	4
L3	59	128	2.4	5
R1	57	162	3.6	9
L2	49	133	1.9	6
R4	48	83	1.7	7

Table 3. Length distribution of Blackwater eels, in cm to nearest whole number downwards (percentage of *n*).

	25—29	30—34	35—39	40—44	45—49	50—59	60—69	70—90	*n*	x	SE
1965 Estuary July—September	3	22	17	23	14	14	6	1	1,809	42.5	0.29
1966 Estuary May—June	24	40	11	8	7	6	3	1	311	35.9	0.55
1972 Island August 15		17	10	11	10	27	19	6	99	49.9	1.3
16	1	41	31	8	2	5	6	4	75	39.7	1.3
17	2	50	26	2	6	6	4	4	68	39.0	1.4
18		38	28	10	4	8	6	6	71	41.0	1.4
Castlehyde August 16	1	26	17	12	10	13	15	6	168	46.1	1.0
Careysville August 17	1	17	26	10	5	14	17	10	141	47.7	1.2
1973 Careysville August 9		18	21	8	9	17	15	12	116	49.7	1.4
11		37	34	3	3	11	6	6	35	41.2	2.0
Banteer August 10		10	6	4	20	33	16	12	50	52.4	1.7

Table 4. Mean weights per length group and values in length/weight regression.

Length (cm)	Mean Weight (g)			
	1965		1966	1972/73
	July Estuary	August/September Estuary	May/June Estuary	August River
40	107	111	123	109
41	115	119	121	113
42	126	130	127	131
43	130	145	151	166
44	142	148	176	177
45	145	165	173	165
46	156	181	188	166
47	164	196	216	188
48	172	214	250	193
49	200	242	234	218
50	223	245	—	241
51—52	250	242	275	256
53—54	267	285	254	307
55—56	304	314	300	332
57—61	377	380	381	409
62—66	487	464	551	554
67—71	577	591	753	638

Length/weight regression $w = al^b$

	n	*a*	*b*	r
1965 July	425	0.00087	3.17	0.98
August/September	652	0.00121	3.10	0.99
1966 May/June	82	0.00086	3.21	0.99
1972/1973 August	103	0.00080	3.22	0.98

Table 5. Length and age data.

Estuary	Age Percentage of n (n = 102)	Length (cm) Minimum	Maximum	Mean	SE
3—4	2	24	26	25.0	0.80
5—6	11	25	30	28.8	0.67
7—8	43	24	44	32.1	0.67
9—10	22	24	65	39.3	1.97
11—12	10	34	61	46.5	2.44
13—14	5	44	63	52.5	3.94
15—16	4	52	71	61.4	5.40
17—18	3	68	82	76.0	4.16

River	Fermoy	Banteer				
n	171	47				
7—8	2	4	31	47	36.5	2.95
9—10	19	4	30	51	37.4	0.91
11—12	18	19	31	56	41.7	1.33
13—14	22	17	33	80	47.5	1.71
15—16	13	21	30	81	50.7	1.98
17—18	9	13	32	77	55.4	2.84
19—22	10	13	37	78	60.8	2.32
23—28	4	9	51	83	65.5	2.49
29—36	3		38	91	78.8	3.92

Values in length/age regression $y = cx + d$

	Age	Numbers	c	d	r	length range
Estuary	3—18	102	3.5	8.4	0.97	24—82
River	7—18	178	2.0	19.8	0.98	30—81
	19—36	40	1.6	26.5	0.97	37—91
	7—36	218	1.76	22.6	0.99	30—91

Table 6. Fullness of stomachs (% of *n*).

	Empty		With food			
	Hind-gut void	Hind-gut full	Partly filled	Full	*n*
Estuary 1965					
July—September	32		68		51
Estuary 1966					
May	32		68		121
River 1972-73					
August					
30—39 cm	8	12	46	33	81
40—90 cm	16	16	41	26	143

Table 7. Occurrences of major food items (% of *n* where *n* = number of stomachs containing food).

	Mysidacea	*Asellus*	*Gammarus*	Ephemeroptera	Trichoptera	Chironomidae	Simuliidae	Gastropoda	Fish	*n*
Estuary										
1965	31		37						62	16
1966										
20—39 cm	17		62	6	17	2		12	6	64
40—49	21		64			7			42	14
50—85									100	3
River										
Island										
30—39 cm		17	26	73	17	52		4	17	23
40—49		12	23	6	6	6			64	17
50—83		3		3	3				80	31
Careysville										
30—39 cm				64	44	9	26	6	3	34
40—49				42	25	8	8		50	12
50—91				14	14		29		71	14
Banteer										
30—39 cm			29	100				29		7
40—49			14	29				14	57	7
50—84			6	11					67	18

Table 8. Dominant food in full stomachs, all river stations.

Length	*Ephemerella ignita*	Fish	Others		Number of stomachs wth food
30—39 cm	14	4	*Athripsodes bilineatus*	1	74
			E. ignita & *A. bilineatus*	1	
			E. ignita & *Simulium* sp.	1	
40—49	2	14			37
50—89		21	*Asellus* & *Erpobdella*	1	60

Table 9. Food organisms. Insects are larvae except where indicated.

	Numbers of stomachs			Individuals per stomach	
	Island	Careysville	Banteer	Range	Mean
Erpobdella octoculata	1			1	1.0
Helobdella stagnalis	1			2	2.0
Asellus aquaticus	4		1	1—61	15.3
Gammarus duebeni	8		4	1—10	2.7
Leuctra inernis	1			1	1.0
Caenis horaria	1			1	1.0
C. moesta	1			1	1.0
Ephemerella ignita	15	26	8	1—95	20.4
Ecdyonurus insignis	2			1— 2	1.5
E. venosus	4		4	1— 9	3.0
Ecdyonurus sp.	1	1	1	1	1.0
Heptagenia sulphurea	2	1		1	1.0
Baetis rhodani		2	6	1—39	9.6
Ephemeroptera inid.	9	2	1	1—47	7.2
Coleoptera ad.		1		1	1.0
Hydroptila sp.	3			1—13	8.3
Polycentropus flavomaculatus	3			1— 4	2.3
Hydropsyche	3	2		1—13	4.3
Athripsodes bilineatus	17			1—22	7.5
Leptoceridae	1	1		1— 3	2.0
Molanna sp.		1		4	4.0
Trichoptera	1	3	1	1— 2	1.7
Trichoptera pupae		7		1— 4	1.7
Procladius sp.		1		2	2.0
Tanytarsus sp.		1		2	2.0
Pentaneurini		2		1— 5	3.0
Total Chironomidae	12	4		1— 9	3.1
Chironomidae pupae	3	1		1	1.0
Prosimulium inflatum		1		3	3.0
Simulium brevicaule ad.		1		22	22.0
S. zetlandense	1			2	2.0
S. salopiense		2		8—30	19.0
S. reptans	3			1	1.0
S. erythrocephalum	1			1	1.0
S. aureum	1			1	1.0
Total Simuliidae	10	13		1—99	8.2
Culicini pupae		1		1	1.0
Diptera pupae	3			1	1.0
Winged insects	2			1— 2	1.5
Ancylastrum fluviatile	2	2	2	1	1.0
Potamopyrgus jenkinsi			1	1	1.0
Bithynia tentaculata	1			1	1.0
Lymnaea peregra			1	1	1.0
Trout			1	1	1.0
Salmonidae			1	1	1.0
Eel	3	1	1	1	1.0
Roach			2	1	1.0
Cyprinidae	8	7	7	1— 2	1.1
Cyprinidae egg mass	4			1	1.0
Fish inid.	28	5	4	1	1.0
Total food items	29	22	16		
Total stomachs with food	73	61	32		

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