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INTERNATIONAL COUNCIL FOR
THE EXPLORATION OF THE SEA

FISH CAPTURE COMMITTEE
CM 1993/B:15 (REF. K)

THE EFFICIENCY OF SPRING-LOADED DREDGES USED IN THE WESTERN ENGLISH CHANNEL FISHERY FOR SCALLOPS, *PECTEN MAXIMUS* (L.)

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ABSTRACT

Three experiments were conducted to measure the overall efficiency of commercial dredges used to survey scallop stocks. Marked animals were laid on four plots located in the Cornish fishery on inshore and offshore grounds ranging from smooth, sandy or muddy gravels to rougher, stony substrates. Efficiency at catching each 5mm size (shell height) class of scallop was estimated by comparing mean numbers of releases and recaptures per 1000m^2 of seabed.

The gear was highly size-selective and of low efficiency overall with substrate-dependent variations. For these commercial dredges, with spring-loaded toothbars and 75mm belly and back meshes, mean efficiency at catching legally fishable (>90mm) scallops ranged from 6% (rough ground) to 41% (smooth muddy gravel). On the most widespread offshore ground type (sand and fine gravels) efficiency on two plots averaged 22%, but it fell rapidly with decreasing scallop size to 1.4% at 65mm and to only 0.2% at 45mm.

Dredge efficiency is the resultant not only of a two-stage selection and retention process (by toothbar and meshes) but of complex interactions between the gear, the seabed, hydrodynamic forces and the behaviour of scallops themselves. Overall, spring-loaded dredges retain rather few juvenile scallops and, although most effective on moderately soft grounds, their efficiency generally is low.

1. INTRODUCTION

Assessments of the abundance and population structure of scallops (*Pecten maximus*) and other deep-water molluscs, using dredges, are biased unless account is taken of gear efficiency and size selectivity. During 1983-85, a series of mark-recapture experiments was devised to assess the overall efficiency of commercial (standard) spring-loaded dredges used in the major fishery off south Cornwall in the western English Channel, and elsewhere in British waters. Comparative trials were conducted also with research (fine-mesh) dredges used to sample juvenile scallops (those results will be reported elsewhere). *P. maximus* typically lives recessed in saucer-shaped depressions which the scallops excavate in various sand, gravel and shell substrates. The flat, upper shell valve is aligned more or less in the plane of the sediment surface; the convex lower shell may, in larger animals, be buried 3-4 cm below the surface. Unlike *P. fumatus* and *Placopecten magellanicus*, the present species is not normally an active swimmer. Consequently, British and French dredges have been designed with toothbars so as to rake out scallops from the seabed. The length, thickness and spacing of teeth provide the primary size selection mechanism as dredges are towed over the bottom (Baird and Gibson, 1956; Baird, 1957). In theory, 'selected' scallops then enter the mesh bag where a proportion is retained (secondary selection), the remainder escaping through the meshes of the dredge belly and back. The overall efficiency (E) of the dredge is defined by Caddy (1971) as the ratio of the number of scallops caught to the number in the dredge path, and is the product of efficiency of capture and gear selectivity.

Overall efficiency estimates for various types of dredge used in the British and French fisheries for *P. maximus* were reported by Rolfe (1969), Chapman *et al.* (1977), Mason *et al.* (1979) and Dupouy (1982). More detailed work has been carried out with dredges for *P. fumatus* in Australia (McLoughlin *et al.*, 1991) and for *Placopecten magellanicus* in eastern Canada and USA (Dickie, 1955; Caddy, 1968 & 1971; Serchuk and Smolowitz, 1980; Worms and Lanteigne, 1986). Mesh selection has been measured directly only for Canadian dredges (Caddy, 1971), although indirect estimates based on alternate-haul comparisons of catches in unlined (commercial) and lined (fine-mesh research) dredges also have been obtained for the *P. magellanicus* fishery (Serchuk & Smolowitz, 1980; Worms & Lanteigne, 1986).

2. METHODS AND MATERIALS

This study was carried out on 4 rectangular plots of seabed, demarcated by Decca coordinates, and located over typical offshore and inshore dredging grounds off Falmouth and Dodman Point, Cornwall. Sites were chosen so as to represent a range of substrate types, from smooth and fairly soft to rough and stony, as indicated by echo-sounder, dredge sampling and (later) underwater television observations. Depths ranged between 25m and 75m. Plot sizes, and number of dredges deployed, depended upon size of chartered fishing vessel (Table 1).

Three experiments were conducted using marked scallops from two sources:

(a) collection from nearby grounds, using commercial dredges and marked by drilling a small hole through the hinge corner ('ear') of the flat shell valve - experiments 1 and 3 (Table 1); only larger scallops, mainly adults above minimum legal size (88mm shell height), were thus obtained.

(b) purchase of small (15-85mm) juveniles, of three successive year-classes, for experiment 2 from aquaculture systems in NW Scotland, via Sea Fish Industry Authority at Ardtoe; these 'seed' were derived from 'wild' spat caught on collectors and held in containers in sea-lochs where they acquired prominent fouling by barnacles and serpulid worms; such biological markers readily distinguished Scottish stocks from unfouled Cornish scallops, and obviated any need for tagging. An estimated 5,070 viable seed scallops were released, comprising 480 of 0-group, 2730 of I-group, and 1860 of II-group.

In each experiment, transit, dredging and handling mortalities of marked animals were estimated from sub-samples either before release (Scottish stocks) or upon recapture (Cornish stocks), so that the numbers of 'viable' scallops could be calculated. The plots were seeded by scattering scallops as evenly as possible, and during slack tidal periods, to minimise drift off the plot. Scallops were then allowed 2-3 days to settle and recess before the recapture phase started. This exercise comprised a series of parallel double-tows, each of 15-20 minutes duration, up and down the length of the plot until most or all the ground had been sampled. Dredges were towed at normal fishing speed, i.e. ~ 2.5 knots ground speed, in good or reasonable sea and tidal conditions, with windspeeds not above Beaufort forces 5 and 4 for larger and smaller vessels, respectively.

All recaptured scallops were measured and retained; unmarked scallops from the plots were also recorded. Overall efficiency (E) was calculated from the relative numbers of marked scallops recaptured, to those released, per unit area of dredge path.

Gear

The commercial dredge (Fig 1) consists of a triangular frame with a mouth opening 75cm wide and ~ 14cm high, a spring-loaded toothbar with 9 teeth, an 88cm long bag with steel belly rings (8mm thick, 75mm internal diameter, 95-100mm space between rings), and a netting back of 75mm mesh. The teeth are 80mm long (new) with 70mm spacing. The toothbar's effectiveness, especially on rougher ground, depends upon the compression in the springs; this was regularly checked and 'fine-tuned' during dredging.

3. RESULTS

3.1 Dredge Efficiency: fishable-size (adult) scallops

Details of tagging and of recapture efforts for the three offshore plots (I-III) are given in Table 2, and for the inshore plot (IV) in Table 6. From 89% to 96% of the areas of plots I to III were sampled for recaptures, and 44% of plot IV.

The size compositions of tagged scallops released on each plot are compared with those of recaptures in Figures 2 and 3. The overall range was typical of most commercial catches observed in this area, with ~85% of scallops exceeding the minimum legal size (MLS) of 88mm height (100mm length). Kolmogorov-Smirnov tests showed no significant differences ($P > 0.05$) between the size distributions of released and recaptured animals, although there was a tendency for the three largest size-classes to be under-represented in the recaptures on plots I-III.

Estimates of the size-specific efficiency of the gear are calculated for each plot, and for successive 5mm size-classes of scallop, in Tables 3-6. For scallops larger than MLS (here taken as 90mm height) the observed differences between 5mm classes were not significant on any plot; data are therefore aggregated.

Overall efficiency differed markedly between plots and substrate types. It was greatest (40.6%) on the softest ground of muddy shell gravel (plot IV) and lowest (6.2%) on the hard stony ground (plot III). On the two plots of intermediate substrates (sand and fine gravel) - and which are more typical of the main scallop grounds 10-30 km offshore - efficiencies of 24.6% and 19.4% (average 22.0%) were obtained. Values estimated for pre-recruit (80-89mm) scallops were significantly different (lower) only on the softest ground (26.9%, Table 6), whilst ranging between 16.3% and 24.1% at the other three sites.

3.2 Dredge Efficiency: juvenile scallops

Release and recapture data for the Scottish seed scallops relaid onto plot I are given in Table 7, together with the size ranges of the three age-classes (see also Fig 3). The entire plot area was sampled for recaptures. To check for lateral drift of scallops during relaying, four tows were made in the zone up to 25-50 m outside the plot's periphery. Only two Scottish scallops (I and II-group) were taken in 33,600m^2 sampled, a recapture density of 0.06 per 1000m^2 or about one-fifth of that within the plot (see below). Using these recapture indices, and allowing for the disparate sizes of plot (200,000m^2) and outside zone (100,000m^2), it is estimated that at least 92% of scallops landed on the plot. This error may result in a small under-estimation of dredge efficiency.

A total of 108 (2.1%) live scallops was recaptured at a mean rate of 0.27 ± 0.13 per 1000m^2 swept, compared with a release density of 25.4 scallops per 1000m^2 (Table 7). Figure 4 shows the recapture size distribution to be skewed significantly towards larger sizes, within the I and II-groups, compared to the original size composition of all scallops released (Kolmogorov-Smirnov test, 2-sided, calculated D = 0.447, P<0.01). None of the 0-group was caught, alive or dead.

Size-specific efficiency (E) estimates are given in Table 7 and plotted linearly in Fig 5. Over the range 40-89 mm (I and II-groups) the data are fitted by the log-linear regression:

$$\log_{10} y = 0.0473\ x - 4.9333\ (r = 0.9826, P<0.01, 6df).$$

where x = shell height (mm), y = efficiency (logit). Percent values of efficiency were transformed to

$$\text{logit} \frac{E}{(100-E)}$$

Estimated efficiencies thus obtained increased from only 0.16% for 45 mm scallops to 10.9% for 85 mm pre-recruits and ~25% at MLS, i e. similar to that found here in Experiment I (Table 3). The latter experiment's results are also shown in Fig 5 where a curve has been fitted (by eye) to both sets of data.

If the 0-group (20-29mm) zero recapture values are included (after transforming by addition of a constant 0.01% to all percent value of E) the regression becomes:

$$\log_{10} y = 0.0515\ x - 5.2248\ (r = 0.9925, P<0.01, 8df)$$

This provides an estimated E = 0.01% at 25 mm rising to ~20% at MLS. The smallest scallop ever caught by us in commercial dredges on these fishing grounds measured 19mm, and was retained only because the meshes had become blocked with coarse gravel and stones.

4. DISCUSSION

4.1 Efficiency Estimates From Other Studies

Estimated values of E for scallop dredges used in other fisheries are tabulated and compared with the present results for commercial gear, in Table 8. All gears employed belly ring meshes in the range 70-83mm internal diameter. It will be noted that, irrespective of gear design, their efficiencies when taking legal-sized scallops (usually > 90 or 100 mm) typically varied between 5-35%, and more usually 10-25%, depending largely on substrate features.

The Cornish estimates from a typical range of fishing ground types thus are in general agreement. The very low (6%) efficiency on the rough ground (Plot III) matched that of Canadian dredges working similar bottoms. At the other extreme, the highest Cornish value (41%) on the soft, smooth Plot IV approximated the 30-35% of French dredges working smooth sandy areas.

Likewise, all published results, excepting one from Canada (Caddy, 1971), confirm that commercial gears are extremely inefficient at catching small scallops, even those only 2 cm below minimum legal size. From both industry and fisheries management viewpoints, it seems clear that the spring-loaded dredges employed in British fisheries have been evolved to a design that now provides an acceptable compromise between overall efficiency and optimal size selection, whilst minimising retention of debris and enabling the gear to be operated on a wide range of grounds.

4.2 Operational Aspects of Dredges

In practice, overall dredge efficiency is the resultant not only of a two-stage (toothbar and mesh) selection process but also of the complex, and continuously changing, interplay of ~20 mechanical, environmental and behavioural factors (Table 9). Diver and television observations of dredges in action (e.g. Caddy 1968; Chapman *et al.*, 1977) reveal four conditions that reduce dredge efficiency, depending on seabed type and other operational circumstances:-

(i) 'bulldozing' - a mound of stones, epifaunal 'trash' and scallops is pushed ahead of the dredge and prevents or delays the entry of scallops, especially the larger animals, into the bag;

(ii) bouncing - the gear loses contact with the bottom, particularly on rougher grounds, and the scallops escape beneath the dredge;

(iii) blockage - the dredge mouth is blocked by large stones (additional to (i)).

(iv) clogging - meshes become blocked by stones and 'trash' which progressively reduce the passage of small scallops through the belly and back meshes until eventually a 'back pressure' or reverse flow prevents further entry of scallops. Both clogging and bulldozing are exacerbated as tow length increases, by worn teeth and incorrect toothbar tensions, as well as by any reduction in mesh size or tooth spacing.

Active gear avoidance which may occur with mobile species such as *P. fumatus* and *P. magellanicus* (McLoughlin *et al.*, 1991; Caddy, 1968) is not a problem with the more sluggish *P. maximus*.

4.3 Form of the Efficiency Curve

Both theoretically, and from dredging experience and underwater television observations, the size-specific efficiency of scallop dredges might be expected to approximate a logistic curve; with E rising from zero at smallest sizes to finally level off where dredge-substrate interactions begin to prevent entry of large scallops otherwise retainable by the meshes. Such a levelling-off was indicated on plots II, III and IV (Tables 4, 5, and 6) but not on plot I (Table 3) where a reverse trend (i.e. declining efficiency) was suggested for the biggest scallop size-classes although this cannot be confirmed in the absence of error estimates.

Similar problems with interpreting the upper end of efficiency curves were reported from Scottish experiments (Chapman *et al.*, 1977; Mason *et al.*, 1979). A re-analysis those data (Dare, unpublished) indicates that logistic curves can be fitted to two of three Scottish data sets; namely, for spring-loaded and standard fixed toothbar dredges towed on relatively smooth gravel ground. No such fit is obtainable, however, for spring-loaded dredges working a rough, stony bottom where efficiency declined rapidly against largest scallops, after peaking at ~ 90 mm shell height. This unexpected result was attributed by the authors to 'bulldozing' effects. Our Cornish data for plot I (Fig 5) follow a similar pattern.

Mesh selectivity studies with N. American scallop dredges have produced similar anomalous effects at largest *Placopecten* sizes (Worms & Lanteigne, 1986; Serchuk & Smolowitz, 1980). Reverse (downward) trends in many selectivity ogives were ascribed to an assumed combination of hydrodynamic, substrate and behavioural factors. These workers concluded that the problem of evaluating scallop dredge selectivity is far more complex than testing the retention ratio of conventional trawl meshes; a view confirmed by the present study.

Our Cornish experiments also suggest that scallop dredge efficiency is best regarded as a continuously changing variable such that estimates are only guides to performance.

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Table 1. **Summary of field experiments to measure overall efficiency of spring-loaded dredges in the Western Channel fishery for scallops, 1983-88**

Experiment No.	Date	Experimental Plots No.	Depth (m)	Area (m^2)	Viable Scallops Released No.	Height (mm)	Dredge Number	Fishing Vessel (length, m)
1	1983 (June)	I, II, III	55-75	200,000	3,664	70-120	16	Pescado (21m)
2	1985 (May)	I	60-65	200,000	5,070	18-85	13	Harm Johannes (22m)
3	1985 (July)	IV	27	73,500	1,088	60-110	3	Rockhopper (9m)

Table 2. **Experiment 1. Physical features of the 3 plots with total numbers of marked scallops released and recaptured.**

Plot	Depth (m)	Substrates	Marked scallops released: Mortality (%)	Total viable	Density (no./1000m^2)	Recaptures: No. (alive)	Total Area sampled (m^2)	Density (no./1000m^2)	Unmarked scallops
I	60-65	sand + gravel; coarser than II	4.1	1,423	7.12	324	187,500	1.73	1,129
II	55-60	sand + fine gravels smooth; finer than I	6.7	1,134	5.67	202	189,000	1.07	2,008
III	70-75	hard, stony, level	3.3	1,107	5.53	68	192,000	0.35	1,749
				3,664		594			4,886

Table 3. Experiment 1. Dredge efficiency estimates on Plot I for 5mm size groups of scallops.

	SCALLOPS TAGGED & RELEASED				SCALLOPS RECAPTURED*		EFFICIENCY		
Size Group (height, mm)	Sample No.	(%)	Estim. Total No	Density (no./1000m²) d_1	Total No.	Density (no./1000m²) d_2	$E = d_2/d_1$		
65-69	4	(1.3)	19	0.095	0	(0)	-		
70-74	0	(0)	0	0	1	0.005	-		
75-79	4	(1.3)	19	0.095	3	0.016	(0.168)		
80-84	13	(4.3)	61	0.305	8	0.043	0.141)	0.163	
85-89	41	(13.6)	194	0.970	31	0.165	0.170)		
90-94	68	(22.6)	322	1.610	93	0.496	0.308)	0.311)	
95-99	77	(25.6)	364	1.820	107	0.571	0.314)		) 0.246
100-104	65	(21.6)	307	1.535	64	0.341	0.222)	0.198)	
105-109	26	(8.6)	123	0.615	16	0.085	0.138)	)	
110-114	3	(1.0)	14	0.070	1	0.005	(0.071)		
	301		1,423	7.115	324	1.728			

* from first 8 tows covering 187,500m² swept area (93% of plot).

note: variances of efficiency estimates not available (see text).

values in parentheses relate to very small samples and are not used further.

Table 4. Experiment 1. Dredge efficiency estimates on Plot II for 5mm size groups of scallops.

	SCALLOPS TAGGED & RELEASED				SCALLOPS RECAPTURED*		EFFICIENCY	
Size Group (height, mm)	Sample No.	(%)	Estim. Total No.	Density (no./1000m²) d_1	Total No.	Density ± sd (no./1000m²) d_2	$E = d_2/d_1 \pm sd$	
70-74	2	(0.7)	8	0.040	0	(0)	-	
75-79	3	(1.0)	11	0.055	2	(0.011)	-	
80-84	13	(4.3)	49	0.245	3	(0.016)	-	
85-89	21	(7.0)	79	0.395	18	0.095 ± 0.077	0.241 ± 0.196	
90-94	64	(21.3)	242	1.210	40	0.212 ± 0.088	0.175 ± 0.073)	
95-99	99	(33.0)	374	1.870	71	0.376 ± 0.121	0.201 ± 0.065	) 0.194 ± 0.045
100-104	63	(21.0)	238	1.190	47	0.249 ± 0.110	0.209 ± 0.092)	
105-109	28	(9.3)	106	0.530	18	0.095 ± 0.063	0.179 ± 0.118)	
110-114	6	(2.0)	23	0.115	3	(0.016)	-	
115-119	1	(0.3)	4	0.020	0	(0)	-	
	300		1,134	5.670	202	1.069		

* from first 8 tows covering 189,000m² swept area (89% of plot)

Values in parentheses relate to very small samples and are not used further

Between-size group differences in E are not significant.

Table 5. Experiment 1. Dredge efficiency estimates on Plot III for 5mm size groups of scallops.

	SCALLOPS TAGGED & RELEASED				SCALLOPS RECAPTURED*		EFFICIENCY	
Size Group (height, mm)	Sample No.	(%)	Estim. Total No.	Density (no./1000m²) d_1	Total No.	Density ± sd (no./1000m²) d_2	$E = d_2/d_1 \pm sd$	
70-74	4	(1.2)	14	0.070	0	(0)	-	
75-79	8	(2.4)	27	0.135	1	(0.005) -		
80-84	15	(4.6)	50	0.250	1	(0.005) -		
85-89	21	(6.4)	71	0.353	12	0.063 ± 0.071	0.178 ± 0.201	
90-94	48	(14.6)	162	0.808	10	0.052 ± 0.053	0.064 ± 0.066)	
95-99	108	(32.8)	363	1.817	24	0.125 ± 0.086	0.069 ± 0.048	) 0.062 ± 0.029
100-104	82	(24.9)	276	1.379	15	0.078 ± 0.052	0.057 ± 0.038)	
105-109	37	(11.3)	125	0.623	5	0.026 ± 0.030	0.042 ± 0.050)	
110-114	6	(1.8)	21	0.105	0	(0) -		
	329		1,107	5.540	68	0.354		

* from first 8 tows covering 192,000m² swept area (96% of plot)

values in parentheses relate to very small samples and are not used further

Between-size group differences are not significant.

Table 6. **Experiment 3. Dredge efficiency estimates on Veryan Bay plot IV for 5mm size groups of scallops.**

SIZE GROUP (height, mm)	SCALLOPS TAGGED & RELEASED (viable) Sample	(%)	Estim. Total No.	Density (no./1000m^2) d_1	SCALLOPS RECAPTURED Total No.	Density ± sd (no./1000m^2) d_2	EFFICIENCY $E = d_2/d_1 \pm sd$	
60-64	1	(0.3)	4	0.054	0	(0)	-	
65-69	3	(1.0)	11	0.150	0	(0)	-	
70-74	11	(3.7)	40	0.544	0	(0)	-	
75-79	32	(10.7)	116	1.578	12	0.374 ± 0.449	0.237 ± 0.285	
80-84	24	(8.0)	87	1.184	11	0.342 ± 0.792	0.289 ± 0.669)	0.269 ± 0.339
85-89	49	(16.3)	177	2.408	20	0.623 ± 0.681	0.259 ± 0.283)	
90-94	69	(22.9)	249	3.388	51	1.587 ± 0.771	0.468 ± 0.228)	
95-99	74	(24.6)	267	3.633	42	1.307 ± 0.818	0.360 ± 0.225)	
100-104	33	(11.0)	119	1.619	19	0.560 ± 0.661	0.346 ± 0.408)	0.406 ± 0.192
105-109	5	(1.7)	18	0.245	5	(0.156 ± 0.311)	(0.637 ± 1.269)	
	301		1088	14.803	160	4.949		

Table 7. **Experiment 2. Dredge efficiency estimates on Plot II for 5mm size groups of juvenile scallops.**

Size Group (height, mm)		SCALLOPS RELEASED (viable) Estimated Total No.	Density (no./1000m^2) d_1	SCALLOPS RECAPTURED Total No.	Density (no./1000m^2) d_2	EFFICIENCY $E = d_2/d_1$	
15-19	)	10	0.050	0	0	(0)	
20-24	) 0-group	173	0.865	0	0	0	) 0
25-29	)	268	1.340	0	0	0	)
30-34	)	29	0.145	0	0	(0)	
			2.400				
40-44	)	55	0.280	0	0	(0)	) 0.002
45-49	)	723	3.615	3	0.007	0.002	)
50-54	) I)	894	4.470	6	0.015	0.003	) 0.006
55-59	))	1233	6.165	21	0.052	0.008	)
60-64	))	810	4.050	11	0.027	0.007	) 0.010
65-69	) II	190	0.950	10	0.025	0.026	)
70-74	)	266	1.330	14	0.035	0.026	)0.037
75-79	)	303	1.515	28	0.069	0.046	)
80-84	)	76	0.380	14	0.035	0.092	) 0.067
85-89	)	37	0.185	1	0.003	(0.016)	)
			23.020				
		5070	25.420	108	0.266 ± 0.132 (sd)		

Mean sizes of the 3 year-classes were:
I 25 ± 2.5mm (range: 18-30mm)
II 53 ± 5mm (range: 43-62mm)
III 66 ± 8mm (range: 52-85mm)

Values in parentheses, referring to very small sample sizes, are excluded from further analyses.
Total sampling area = 405,500m^2.

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Table 8. EFFICIENCIES OF SCALLOP DREDGES USED IN FISHERIES FOR PECTEN MAXIMUS, P. FUMATUS AND PLACOPECTEN MAGELLANICUS

SPECIES	FISHERY		EFFICIENCY (%) BY 1 CM SIZE-CLASSES (SHELL HEIGHT)												COMMERCIAL GEAR SPECIFICATION					REFERENCE
	Region	Ground type	4	5	6	7	8	9	10	11	12	13	14	ALL	Type	Tooth spacing	Mesh size (int. diam. mm) belly	back	pressure plate	
Pecten maximus	UK	smooth-medium	<	2.0		>	<			16.2			>	13.4	Spring-loaded	80-97	83	80	-	)Chapman et al. (1977)
		" "	<	3.3		>	<			23.3			>	18.3	'standard'	77-94	83	80	-	)
P. maximus	UK	muddy gravel					26.9	<40.6	>						Spring-loaded	70	75	75	-	This study
	(English	sand + fine gravel					16.3	<24.6	>						" "	70	75	75	-	" "
	Channel, W)	" "	0.2	0.6	1.0	3.7	6.7	<19.4	>						" "	70	75	75	-	" "
		rough						< 6.2	>						" "	70	75	75	-	" "
P. maximus	UK						<			33.2	>			33.2	Baird	76	76	63	+	Rolfe, 1969
	(English						<			24.3	>			24.3						
	Channel, W)																			
P. maximus	France	smooth, sand,			8.6	14.8	24.9	<	35		>				French	100	72	35	+	Dupouy, 1982
	(St Brieuc Bay)	shells			8.6	7.9	16.4	<	30		>				French	100	72	35	-	"
Pecten fumatus	Australia	smooth		<	4	<	13.0							11.6	Mud	60	70 x 45	70 x 45	+	McLoughlin et al. 1991
	(Bass Strait)																			
Placopecten	Canada	rough				0.4	5.0	4.6	4.5	4.8	4.7	6.1	[illegible].9	4.9 (>90)	Digby	0	76	76	-	Dickie, 1955
magellanicus	(Bay of Fundy)	smoother			1.0	2.1	8.8	10.5	13.2	16.6	13	9.7	11.2	12.2 (>90)	"					
"	(St Lawrence)	smooth	0.7	<	1.4	><		8.3						2.1	offshore	0	76	76	+	Caddy, 196[illegible]
"	(Georges Bank)	gravel	9.6	<		20.3		>	<	16.9			>	15.4	"	0	76	76	+	Caddy, 1971

Table 9. Factors affecting the overall efficiency of spring-loaded scallop dredges when fishing *Pecten maximus*

Factor		Importance Ranking	Reference
Gear design:	teeth - length, thickness, spacing, attack angle	***	Baird (1957); Baird & Gibson (1956); industry
	toothbar - tension	***	Industry
	- ground clearance	*	Chapman *et al.* (1977)
	mesh size - belly rings	**	Drinkwater (1974); MAFF
	- back netting	**	Baird (1957); MAFF
	weight (incl. towing beam)	*	Industry
Vessel operation:	size and power		
	tow speed, length and duration	**	Shaffee (1979); Industry
	tow pattern - tidal direction, repetition	*	Industry
	warp length - speed relation	**	Baird (1957)
	operator - experience		
Environmental:	seabed - substrate type	***	Industry; all literature; MAFF
	sea state - swell/wave height	**	Industry, MAFF
	tide - velocity	*	Industry, MAFF
Biological:	shell size/gross weight	***	All studies
	recession - depth	*	Chapman *et al*, (1977)
	active avoidance - swimming		Chapman *et al*, (1977)

Rankings: *** = high; ** = medium; * = lesser importance

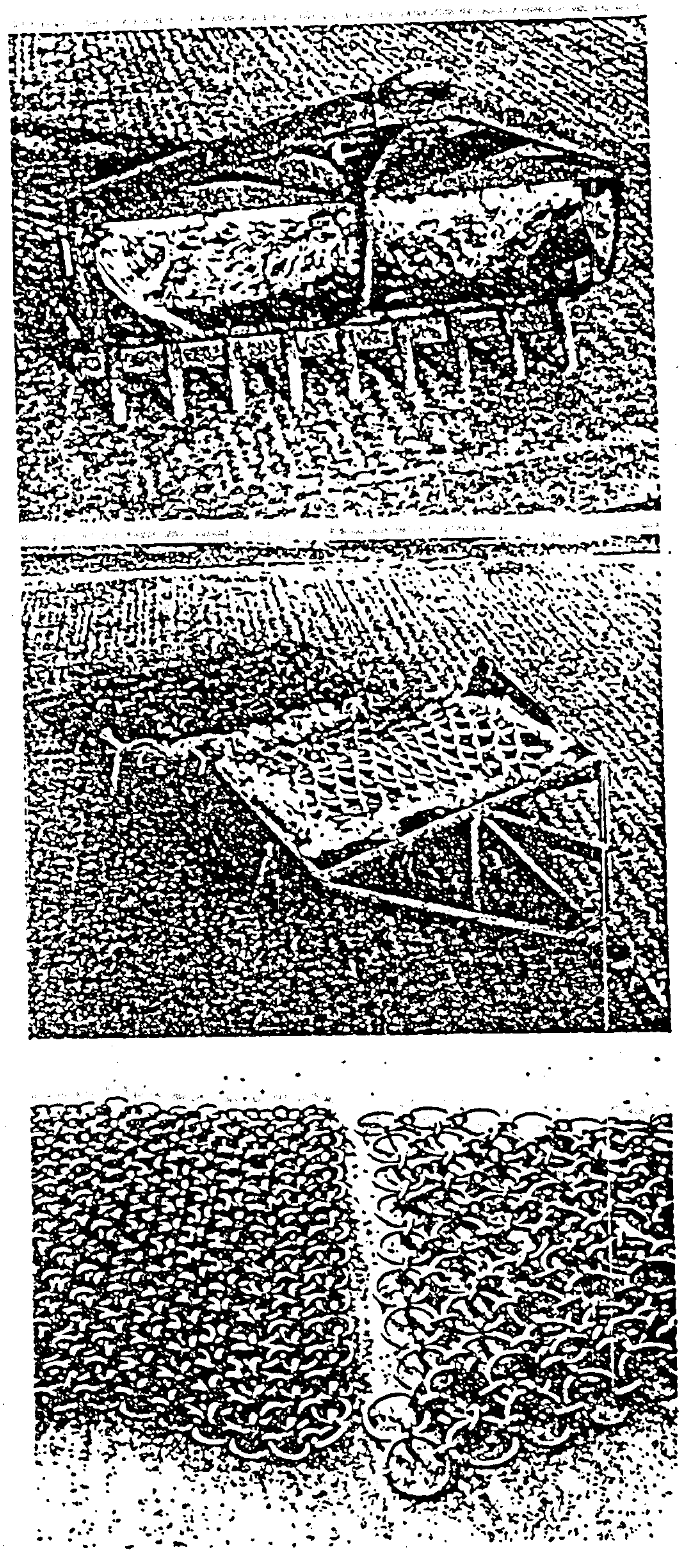

Figure 1. A typical spring-loaded scallop dredge as used in the experiments and in the western English Channel fishery.
Top - front view of commercial dredge showing toothbar.
Centre - the same, to show back meshes and toothbar spring.
Bottom - commercial (75 mm) chain meshes on right, research fine meshes (40 mm) on left.

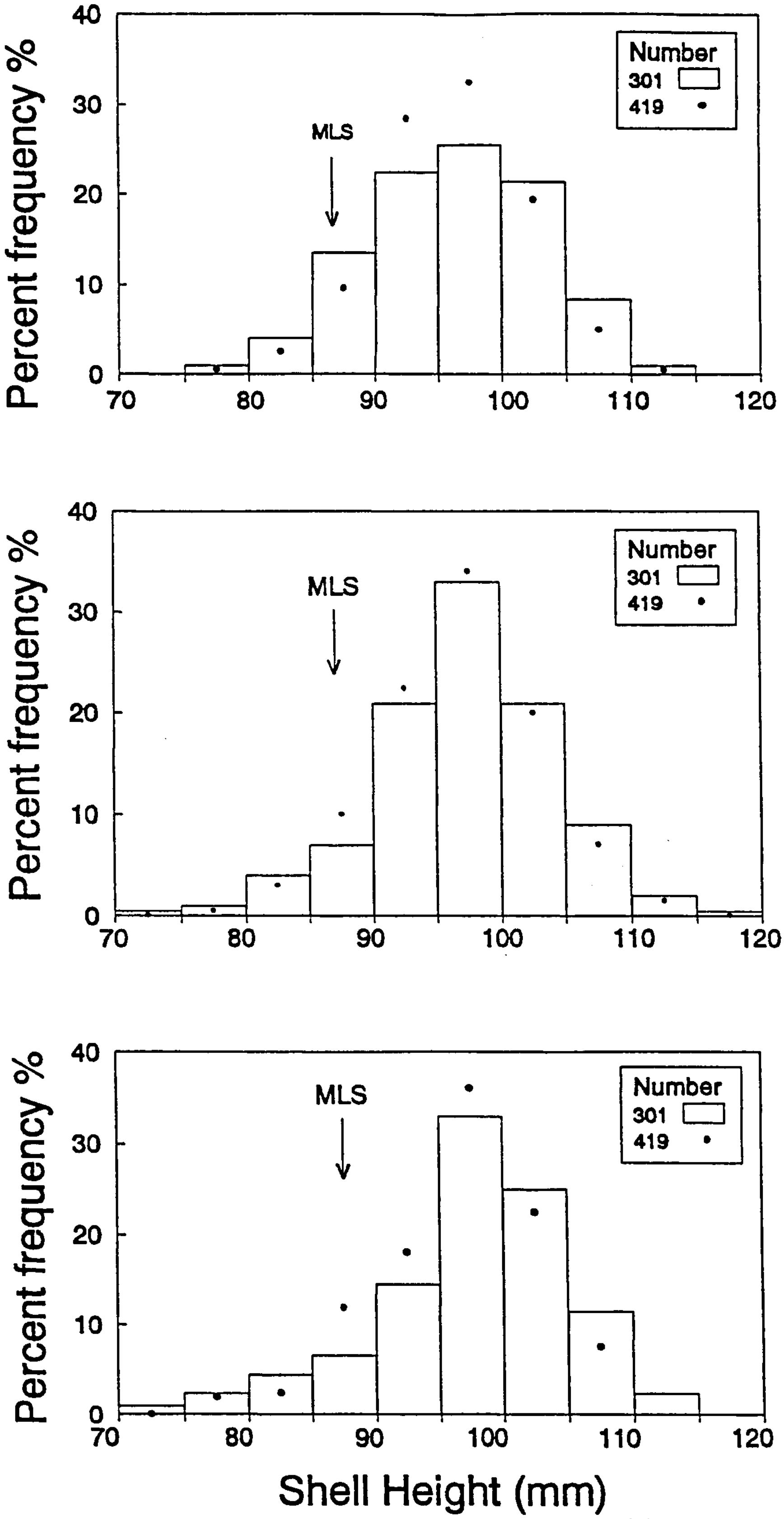

Figure 2. Size composition of tagged scallops released (•) and of those recaptured (o) by commercial dredges on three plots, Experiment I. (arrows denote minimum legal size, MLS)

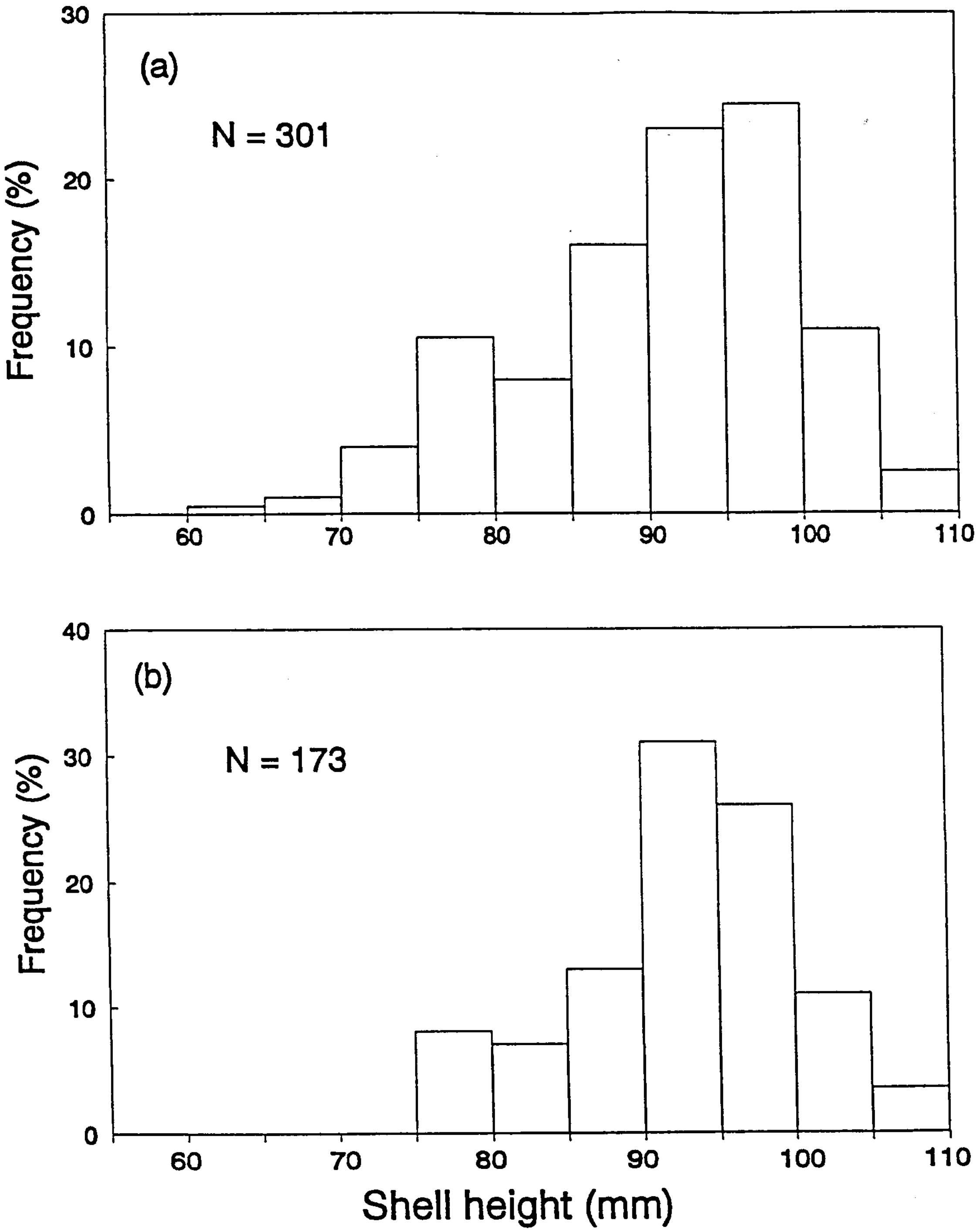

Figure 3. Size compositions of (A) tagged scallops released on plot IV, and (B) recaptures by commercial dredges, Experiment III. (arrows denote minimum legal size).

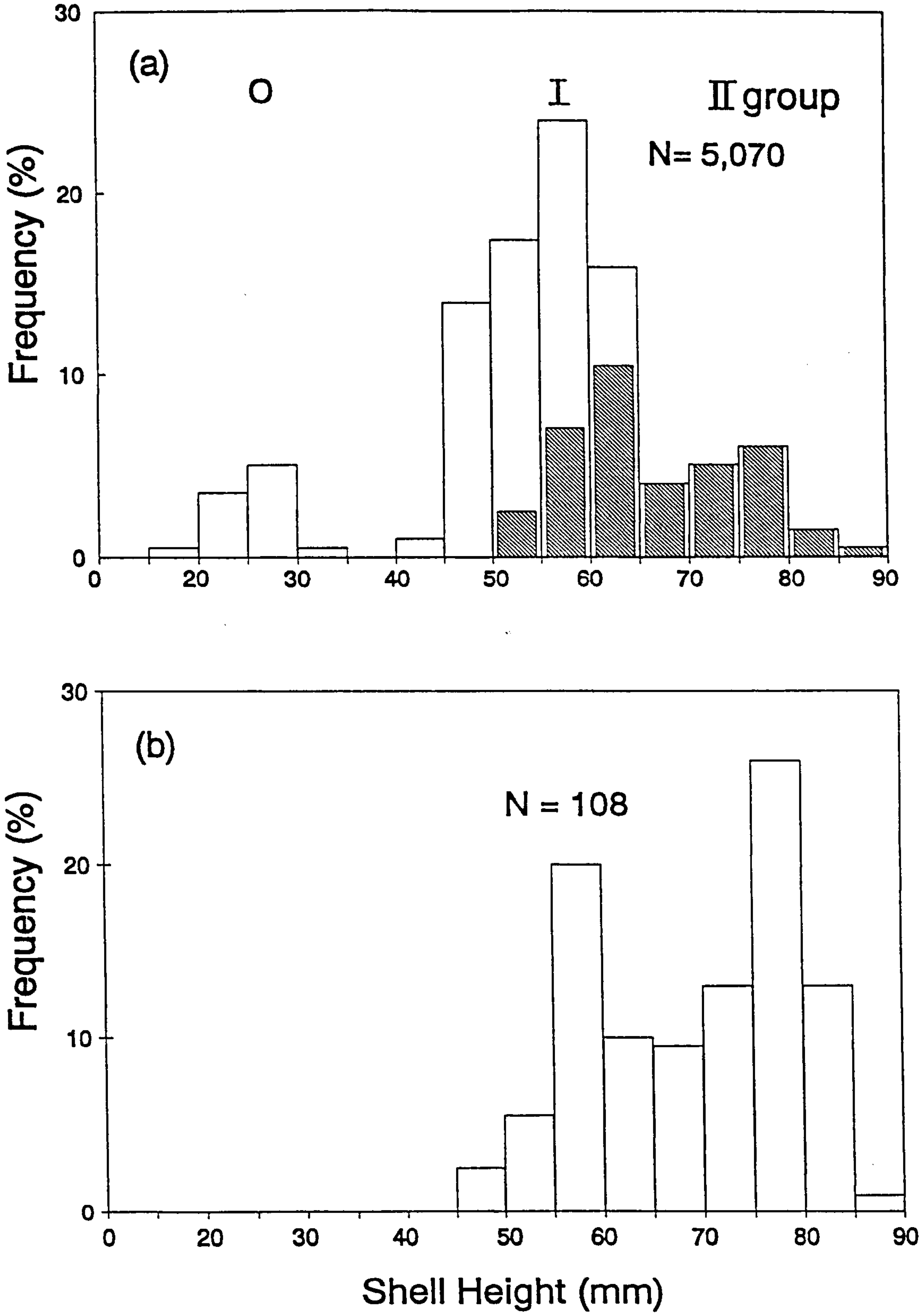

Figure 4. Size compositions of juvenile Scottish scallops of three year-classes (0,I & II group): (A) relaid onto plot I, and (B) subsequently recaptured by commercial dredges, Experiment II.

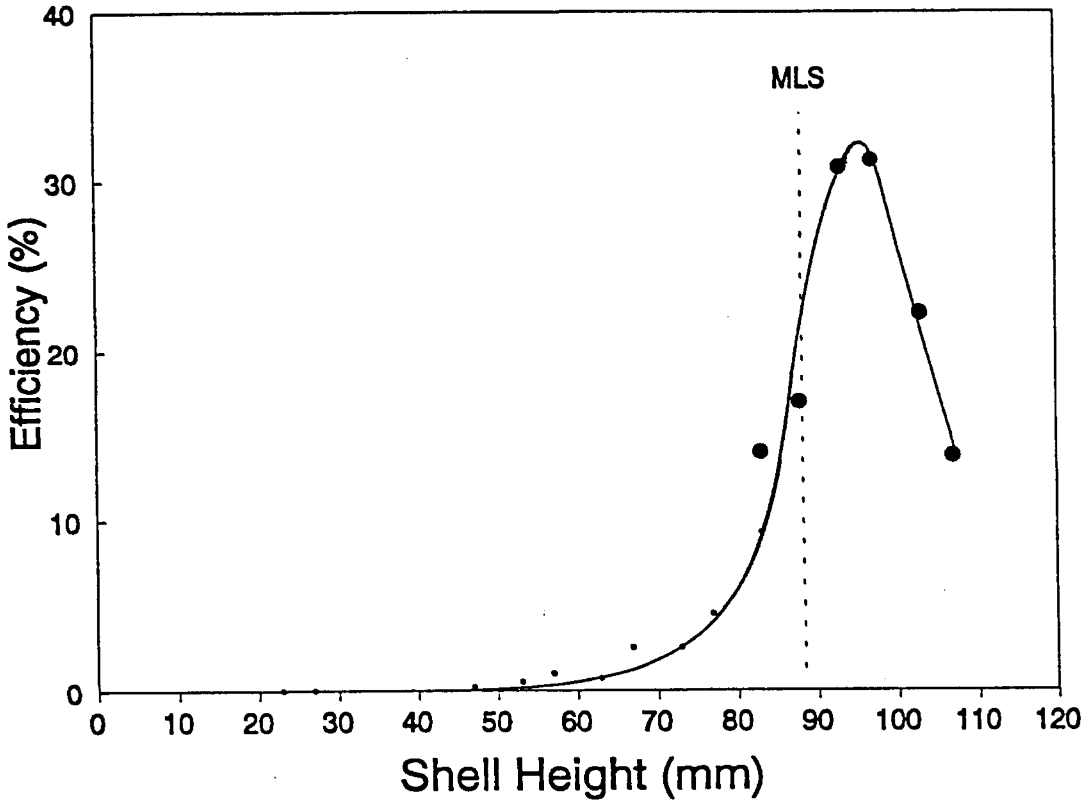

Figure 5. Relationships between dredge efficiency (E) and scallop size for commercial dredges fishing on plot I for: juvenile Scottish scallops (•) relaid for Experiment 2, and adult local scallops (o) relaid for Experiment 1. Curve fitted by eye. MLS = minimum legal size.