Aspects of the washout of salmonid eggs.

6. Information on gravel composition, redd sites, the dimensions of redds and the depth of egg burial.

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SUMMARY

1. The present report is a brief and much simplified account of the results of a preliminary examination of data collected up to the end of 1984 on the dimensions of salmonid redds, the effects of salmonid spawning activity on gravel composition, and the depth of egg burial relative to female fish length, water velocity and gravel composition. Data were obtained from brown and sea trout (Salmo trutta), Atlantic salmon (S. salar) and rainbow trout (S. gairdneri) from sites in N.E. England, S.W. Wales and Dorset.

2. Initial analyses suggested that (with the possible exception of the Dorset data where surface gravels in redds were cleaner) working of the gravel by fish might slightly decrease the proportion of fines in the gravel. However, the observed changes were small and could not be shown to be significant.

3. The results suggest that the dimensions of the redd are positively correlated with one another and with the size of the female fish. Neither gravel composition nor water velocity had any major influence on these relationships.

4. No convincing linear relationships could be found between fish length and the water depth, the water velocity or the gravel composition at redd sites but data plots suggested that each of the latter two variables might have an upper limit which was a function of fish length. They also suggest that female salmonids generally avoid spawning at sites where water depth is less than their own body depth or water velocity is less than 20 cm s^{-1}.

5. Most eggs in the frozen cores were found to lie in a discrete horizontal band within the core and over 80% were within $\pm$ 2 cm of the mean egg burial depth. Mean egg burial depth in N.E. England and S.W. Wales could be related to female fish length and the calculated regression accounted for 60% of the variance of mean burial depth. The Dorset data appear to be anomalous but more data points are required from this study area.

6. The depth of the pot of the redd was not a useful predictor of egg burial depth.

7. Additional data, especially from Dorset, and more detailed data analysis are required.

INTRODUCTION

Knowledge of the physical characteristics of the spawning sites chosen by salmonid fishes, the dimensions and physical characteristics of the redds and the burial depth of the eggs has both fundamental and practical importance. Despite this there have been relatively few detailed studies of these topics and the available information is scattered through the literature and refers mainly to Pacific salmon species in North American rivers.

Ability to predict egg burial depth from the size of the female fish cutting the redd is an important first step in the prediction of vulnerability to washout, overcutting or exposure during low flows. It was the primary aim of the present study. During the course of the work, additional information on gravel composition, water depth, water velocity and redd dimensions have been collected and the results are described.

Most of the relevant literature on redds was summarized by Milner et al. (1981). Several authors have observed that the depth at which salmonids bury their eggs increases with the size of the female fish but, until recently, there has been little firm evidence for this. Greeley (1932), Belding (1934), White (1942), Jones & Ball (1954) and Hardy (1963) gave information on egg burial depth for four salmonid species. The female fish covered a size range of 28 to 58 cm and burial depths of 5 to 30 cm were observed. Milner et al. (1981) commented that much of the variation in egg burial depth may be a reflection of fish size rather than species.

More recently, Ottaway et al. (1981) reported pilot studies on redds of brown trout and sea trout (Salmo trutta L.) and Atlantic salmon (S. salar L.) in the tributaries of the Rivers Tees and Wear. They concluded that the surface dimensions of the redds and the depth of egg burial could be related to the size of the female fish, though few data on egg burial depth were obtained. In contrast, Elliott (1984) examined the egg depths of sea trout of 25-45 cm length in one stream and of brown trout of 17-30 cm length in another stream. Although the sea trout eggs were buried more deeply (modal depth 17 cm) than those of the brown trout (4 cm), the variation in burial depth within each stream was small relative to the variation in fish length. Van den Berghe & Gross (1984) showed a positive correlation ($r = 0.778$, $n = 42$) between the depth of the redd pot (the excavation at the upstream end of the redd) and the size of female coho salmon (Oncorhynchus nerka) in a Canadian stream with uniform gravel. In a multiple regression, 71% of the variance of pot depth was explained by fish length and a further 5% by gravel size. Their discussion implied that pot depth is an index of egg burial depth.

There have been suggestions that egg burial depth might depend upon gravel composition (Burner, 1981) and water velocity (Arnold, 1974; Fraser, 1975) as well as fish length and this seems likely. Although the lift force exerted on the streambed during redd cutting may be dependent upon the size of the female fish, the amount of bed material raised by that force is likely to depend upon gravel composition and the downstream movement of the disturbed material will be influenced by water velocity.

The present report describes work developed from the initial studies of Ottaway et al. (1981). The methodology has been improved and standardized and a larger number of data points has been obtained from a wider variety of locations.

METHODS

1. Terminology.

The terminology used in this report follows that of Ottaway et al. (1981) but the points at which some of the measurements were made are different.(Figure 1).

2. Redds and fish.

Redds for study were obtained by watching fish on the spawning beds. When a female was seen cutting, a careful watch was maintained until it was clear that spawning was in progress. This could be judged from the behaviour of the female fish and the attendant males and from observation of the quivering behaviour which accompanies the deposition of eggs. When spawning was considered to be almost complete, (judged from the behaviour of the fish, the emaciated appearance of the female and the size of the redd) the female was captured by stealthy electro-fishing. It was usually possible to stun the female fish on the redd. However, on some occasions, she moved away and was pursued into nearby pools or cover and sometimes more than one female was captured. The relevant female could generally be identified from characteristics (size, wounds, fungus patches) noted during the period of observation. Where there was any doubt on this score, the redd was rejected.

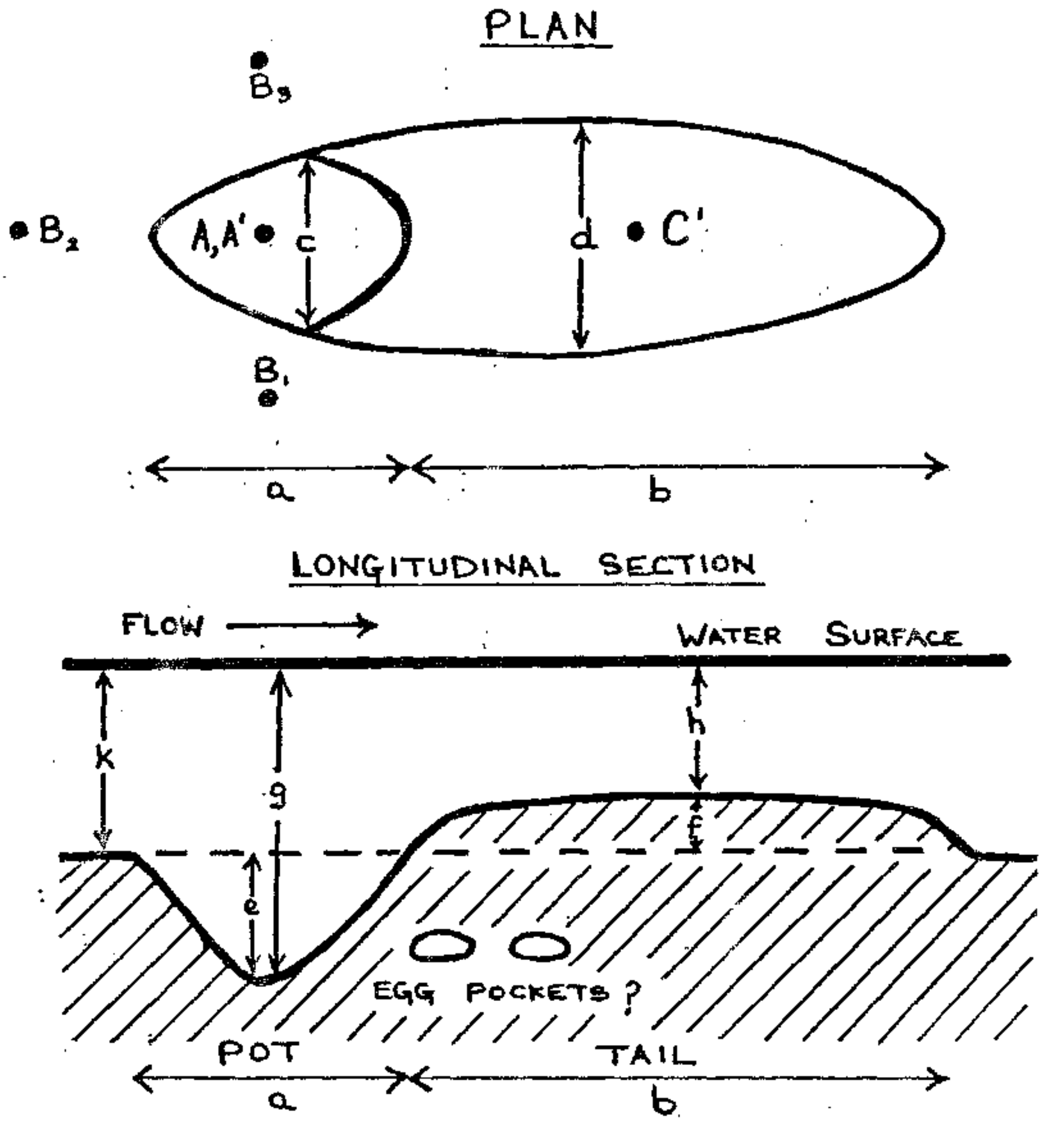

Fig. 1. Diagrammatic representations of a redd to show the dimensions measured and the points at which water velocity was measured. B_1, B_2 and B_3 points for measurement of water velocity at 0·6 of depth around pot. $\bar{B} = B_1 + B_2 + B_3/3$. A velocity at 0·6 of depth at deepest point in pot. A' and C' velocities close to the bed in middle of pot and over centre of tail respectively. Water depths around the redd were taken at points B_1, B_2 and B_3 and averaged to give k. Depths were also measured at the deepest part of the pot (g) and over the middle of the tail (h). Pot depth (e) = g − k and tail height (f) = k − h. The lengths of pot and tail were a and b respectively and the corresponding widths were c and d.

The fork length of the female fish was measured to the nearest 0.1 cm and the species identified. A sample of scales was taken and used to confirm the field identification and the opportunity was taken to assess if the female was spent, part-spent, or still contained most of her eggs. The fish was then released.

3. Measurement of redd dimensions and water velocity.

The lengths of redd pot and tail and the corresponding widths (a, b, c & d, respectively, on Figure 1) were measured to $\pm$ 5 cm. Water depth over the tail of the redd (h), at the deepest point in the pot (g) and at three points on undisturbed gravel around the pot were measured to $\pm$ 1 cm. The latter measurements were averaged to give an estimate of the water depth around the redd (k).

Water velocities were measured with an Ott meter. Velocities at 0.6 of depth were determined at three points around the pot (B_1, B_2, B_3) and were averaged ($\bar{B}$) to give an estimate of the depth-integrated water velocity around the redd. Water velocity was also measured at 0.6 of depth in the deepest part of the pot (A) and on some occasions also at 2.5 cm above the gravel surface in the deepest part of the pot (A') and over the tail (C').

The redd position was then marked by steel pegs driven into the stream bed at the upstream end of the pot, the junction of pot and tail and the downstream end of the tail.

4. Freeze-coring.

After marking and measurement of the redd a freeze-core method (Carling & Reader, 1981) was used to obtain undisturbed gravel samples from the individual redds and from uncut gravels close to the redds.

The method retains the fine sediment fraction which is commonly lost in flowing water when sampling using other techniques. It also facilitates the recording of sediment structure and of the location of fish eggs. Generally several cores were taken, about 10 cm apart, along the longitudinal axis of the upstream third of the redd tail. Previous work on egg burial depth has depended in whole or in part upon manual excavation, and this is liable to give rather imprecise results.

In the laboratory, cores were dissected as they thawed and the number of fish eggs at given depths in the core were recorded. When a distinct concentration of eggs occurred at a particular depth, core sediments were split into two fractions; that sediment above the egg pocket and the sediment below the pocket. Otherwise cores were split into distinct stratigraphic units where these were evident, or retained as bulk samples.

Air-dried samples were sieved mechanically at 1 phi intervals ($-\log_2$ diameter) over the range -6 phi to 4 phi (68 mm to 63 µm). Larger particles were measured using calipers and assigned to a phi class interval on the basis of the intermediate axis measure. The phi-scale of particle size and its derivation is given by Sumner (1978) amongst others. Grain-size nomenclature used is that of Wentworth-Lane (Pettijohn, 1975). The median, arithmetic and geometric mean grain-size were recorded as were the standard deviation, skewness and kurtosis values for each distribution. Large well-shaped samples also were used to estimate the porosity of the deposits.

5. Data processing.

Data collected up to the end of the 1984-85 spawning season have been placed on computer file and a preliminary analysis only has been made. The remainder of this report is a much simplified and purely interim account of the main findings.

The collection of data was an extremely laborious process and relatively few data points were obtained. It has, therefore, been necessary to combine data from different salmonid species on the simplifying assumption that for present purposes the size of a female fish is more important than her species.

STUDY AREAS

Data were collected from tributaries of the Rivers Wear and Tees (Co. Durham) in the autumns of 1980, 1981, 1982, 1983 and 1984, from the River Piddle system and a tributary of the River Frome (Dorset) in 1982 and from the Rivers EasternCleddau, Taf and Syfonwy and their tributaries (Dyffed) in 1983 and 1984. Details are given in Table 1.

RESULTS

1. General information.

The outcome of the sampling programme is summarized in Table 2. A total of 51 redds was examined and eggs were found by freeze coring in 29 (57%) of them. In almost half of the redds examined (49%) more than 5 eggs were obtained in the freeze cores. A total of 1,544 eggs was obtained in freeze cores (average 30 per redd examined).

TABLE 1. Names of rivers and tributaries from which data were collected. National Grid References are also given as an approximate guide to the general areas from which data were collected.

LOCALITY	RIVER(TRIBUTARY)	NAT. GRID REFS.
Dorset	Piddle	SY/889886 to SY/791943
	Piddle (Bere Stream)	SY/856928 to SY/857927
	Frome (Tadnoll Brook)	c.SY/774871
S.W. Wales	Syfonwy	SN/038242 to SN/047222
	Taf	SN/164224 to SN/214328
	Eastern Cleddau (Llandeilo Brook)	c. SN/114252
N.E. England	Tees (Great Eggleshope Beck)	NY/980295 to NY/977302
	Wear (Bollihope Burn)	NZ/038366 to NZ/034362
	Wear (Brotherlee Runner)	NY/923378 to NY/924379
	Wear (Stanhope Burn)	NY/985418 to NY/987409

TABLE 2. Summary of the numbers of redds examined by species and region, together with information on the success of freeze coring for eggs.

LOCALITY	SPECIES	No. of REDDS	NO. WITH EGGS	NO. WITH ≥ 5 EGGS	TOTAL EGGS
Dorset	*Salmo trutta* (brown trout)	-	-	-	-
	Salmo trutta (sea trout)	12	4	3	193
	Salmo gairdneri (rainbow)	1	0	0	0
	Salmo salmo (salmon)	-	-	-	-
S.W. Wales	*Salmo trutta* (brown trout)	1	0	0	0
	Salmo trutta (sea trout)	10	8	8	261
	Salmo salmo (salmon)	2	1	1	19
N.E. England	*Salmo trutta* (brown trout)	9	5	5	480
	Salmo trutta (sea trout)	13	10	7	549
	Salmo salmo (salmon)	3	1	1	42
Combined	*Salmo trutta* (brown trout)	10	5	5	480
	Salmo trutta (sea trout)	35	22	18	1003
	Salmo gairdneri (rainbow)	1	0	0	0
	Salmo salmo (salmon)	5	2	2	61
TOTALS		51	29	25	1544

Failure to find eggs in a redd may arise because no eggs are present or because eggs are present but cannot be located by the coring process. The overall success rate was high, in the circumstances, though the results from Dorset were poor compared to those from the other regions. In several instances, in Dorset, almost completely spent females were taken from large redds and yet no eggs could be found by coring.

2. Fish behaviour during spawning.

The present study was not intended as a study of the behaviour patterns of spawning salmonids. Nevertheless, during the course of the fieldwork a relatively large number of spawning salmonids has been watched. As the behaviour of the fish was an important element in judging the stage of development of each redd, a brief summary of our observations is included.

It is generally agreed that a female salmonid may deposit one or more egg pockets in a redd and that, in any given spawning season, she may construct one or more redds. Our observations support these conclusions, but suggest that one redd per female is the most usual.

Redd construction is preceded by a site search by the female, usually with a male in attendance. Once an apparently suitable site is located the female begins to cut systematically by repeated flexures of her body. During this preparatory cutting there are usually one or more males at or close to the redd site. As the time for egg deposition approaches, the dominant male and any others in the vicinity become increasingly active and aggressive. The dominant male pays close attention to the female and swims over her back from time to time. Subsidiary males attempt to enter the redd and are chased away by the dominant male. This aggression between males may be prolonged and can considerably delay the spawning process. The female fish generally remains in or very close to the redd throughout and the frequency of cutting increases as spawning becomes imminent. At the time of egg deposition the female and male lie close together in the pot of the redd and the emission of the ova and milt is accompanied by characteristic quivering of both fish. At the same time, both fish gape and the white insides of their mouths often can be clearly seen. After egg deposition the female cuts rapidly to cover the eggs. This sequence of egg deposition and covering may be repeated several times on one redd. After the last pocket of eggs has been deposited and covered, the female continues to cut but the subsidiary males often begin to disperse and, on some occasions, the dominant male also moves away from the immediate vicinity of the redd.

During this period, cutting frequency decreases, the movements of the female become languid and the sites of individual cutting episodes appear to be rather randomly distributed at and around the upstream edge of the pot.

Not all redds are successfully completed. Although it is generally agreed (White, 1942; Stuart 1953a, b, 1954) that redd site selection is a response to physical cues, it is clear that the selection is not always precise (Hobbs, 1937; White, 1942). In some streams in Teesdale parts of the streambed consist of clay covered by a few cm depth of fine, clean gravel. At these places it is common for females to cut until they strike the clay and then abandon the site. In other places salmonids have been seen to cut substantial redds and then abandon them without depositing any eggs. These observations suggest that, as the construction of a redd proceeds, the physical cues required for continuation of the spawning process become increasingly rigorous.

The foregoing general description of the process is applicable to most of the examples observed during our study. However, exceptions to the expected behaviour patterns have been observed and the main examples are:

a. Although it is normal for a male to be present at the initiation of cutting, one female sea trout in Weardale was seen to cut alone for several hours and a male finally appeared shortly before egg deposition began.

b. Once the cutting routine is established, the female generally remains on or close to the redd throughout the period of redd construction, unless disturbed. At one redd, however, a female salmon left the redd for no obvious reason, and spent 5-10 minutes in a pool about 10 m downstream of the redd before returning and resuming cutting. The male remained on the redd during the absence of the female.

c. McCart (1969) described cutting by male coho salmon (<u>Oncorhynchus nerka</u>) and referred to observations of cutting by males of other salmonid species (Kendall & Dence, 1929; White, 1930; Wickett, 1959). During our observations only one clear example of male cutting (by an Atlantic salmon) has been observed.

d. On many occasions the dominant male was collected from a redd as well as the female and could be positively identified as such. The pair of fish generally belonged to the same species. The one observed exception was a redd in Dorset occupied by a female sea trout and a male Atlantic salmon.

3. The composition of undisturbed gravels.

The bed materials used by spawning salmonids included gravel, sand and silt-size particles. Although in all three study areas the geometric mean grain size of the deposits generally fell in the pebble range, redds occasionally were observed cut in cobble or coarse sand beds. Gravels were usually coarser and more poorly sorted at sites in N.E. England than at sites in S.W. Wales. The finest gravels were found in Dorset. Field observations indicated that this difference reflected geological control of sediment size rather than preferential selection of spawning sites by the fish.

Grain size distributions were usually unimodal and positively skewed at sites in N.E. England and S.W. Wales, although bimodal and polymodal deposits did occur. In Dorset, however, almost all samples were bimodal with a primary mode in the gravel size-range and a secondary mode in the sand size-range.

In the N.E. of England the percentage of fine sediments (< 1 mm) was typically 10% and rarely exceeded 20%, although there was considerable variability dependent, in part, on the mean grain-size of the deposit (Carling & Reader, 1982). Similar variability was seen in the S.W. Wales gravels, although these had a slightly higher mean content of fines present (c. 19%), this in part reflects the smaller mean grain size (Table 3).

Porosity is a measure of the amount of open space in the gravel beds. In a detailed study Carling & Reader (1982) showed that porosity varied as a negative function of both the grain-size and the degree of sorting. For the geometric mean grain-size of the N.E. England deposits (i.e. 33.83 mm) the average porosity is 0.16. Only eight determinations of porosity have been made for the S.W. Wales gravels but these yield a mean value of 0.22. The geometric mean of the sediments is 12.43 mm and from the curve relating the median grain size to the porosity (Carling & Reader, 1982) an average porosity of 0.21 would be predicted. The results would appear to be consistent. The biomodal Dorset sediments were considered in detail by Carling(1983) and seven samples gave an average porosity of 0.35. The percentage of the void space in the framework gravels filled by sands was low and consequently a higher porosity might be expected than would be predicted from Carling & Reader's relationships. Komura's (1961) curve relating the median grain-size and porosity seems more appropriate for Dorset gravel and yields a porosity of 0.30.

4. The effect of redd construction on gravel composition.

It might be supposed that cutting by spawning fish would change the composition of the gravels in the area of the redd. As finer particles are most easily disturbed and washed downstream this would lead to a coarsening of the gravel composition, a change in the sorting of the deposit, a change in the skewness value and a reduction in the percentage of fines.

Changes in gravel composition were assessed in three ways: 1) the statistical characteristics of the gravels composing the spawning beds were compared with those gravels in the tails of redds. 2) in the tail of redds, surface gravels were compared with gravels at depth. (Cores were separated vertically, based on stratigraphy or the presence of an egg pocket). 3) the percentage of fines (<2 mm) in the various gravels was considered. In each instance a paired T-test was used to test for discrete populations after visual inspection of scatter plots.

Using approach (1) and considering either subsets or the bulk data set there was no indication that the grain-size distributions were significantly different. Marginally significant results could be obtained by excluding a small number of outliers and this result indicated a possible coarsening of the gravels. Using approach (2) for the subset for N.E. England there was no significant difference in populations, but for the S.W. Wales data there was evidence that surface gravels were slightly coarser and more poorly sorted than basal gravels.

The percentage of fines in the gravels could vary considerably, even having more fines in the surface layers than at depth. When comparing fines content in the surface and basal layers and in the spawning riffles generally, results for N.E. England and S.W. Wales were inconclusive although where very low percentage fine values were encountered they tended to occur in the surface layers. The few data for Dorset were analysed by Carling (1983). Results were more conclusive, surface gravels being cleaner (13% fines) than the basal gravels (25% fines).

The results of the various analyses indicate that (with the possible exception of Dorset), no significant change in gravel composition was observed, although changes in composition were in the direction anticipated.

5. Dimensions of the redd, relative to one another, to the size of the female fish, and to gravel composition and water velocity.

Interrelationships between redd dimensions were examined by comparison of calculated regressions. Redd tail length (= b, cm) could be related to pot length (a, cm) and tail width (d, cm) by linear relationships which fit the data from all three study areas. They are: $b = 1.82a$ and $b = 1.71d$. These simple equations allow prediction of three major horizontal dimensions of the redd from one another. However, the relationships of tail width and pot length to pot width could be best described by power law relationships which differed significantly between sites. No significant correlations between vertical dimensions (pot depth and tail height) could be demonstrated. The preliminary analysis did not indicate any significant effect of water velocity upon the interrelationships of redd dimensions.

All of the measured redd dimensions were positively and significantly correlated with the length of the female fish (x, cm). For pot depth (e, cm) and tail height (f, cm) the proportional relationships $e = 0.14x$ and $f = 0.15x$ fit the data from all three study areas, whereas the power law relationship $b = 1.10x^{1.28}$ fits the data for tail length (b, cm). For pot length, pot width and tail width, proportional relationships are appropriate but the proportionality is specific to each study area. The analyses indicated that neither water velocity nor gravel composition were major factors in influencing redd dimensions.

6. Water depth, velocity and gravel composition relative to fish size.

Plots of water depth upon fish length (Fig. 2) show considerable scatter of data points. A simple linear regression can be fitted to the data but accounts for only 21% of the variance of observed depth. As there is no logical reason why salmonids of any size should not spawn satisfactorily in water depths which are large relative to their own size, there is no reason to expect any upper limit on the scatter of points, apart from that imposed by the limited availability of greater water depths. However, it is unlikely that salmonids will, of choice, spawn in water much shallower than their own body depth. Therefore body depth may approximate to a lower depth limit. A regression relating body depth (at the deepest point) (=y) to fish length (=x) for 61 ripe female brown trout, sea trout and salmon from N.E. England and S.W. Wales had the equation $y = 0.176x + 0.76$ ($r^2 = 0.9187$, $P<0.001$) and is shown in Fig. 2. It is clear that most spawners spawned in water deeper than their own body depth, though occasional exceptions were observed.

The plot of mean water velocity against fish length (Fig. 3) could be interpreted as having a lower limit of c. 20 cm s^{-1}, below which velocity salmonids of all sizes prefer not to spawn. The absence of data points in the upper left hand corner of the figure suggests that there may also be an upper velocity limit which is related to fish size.

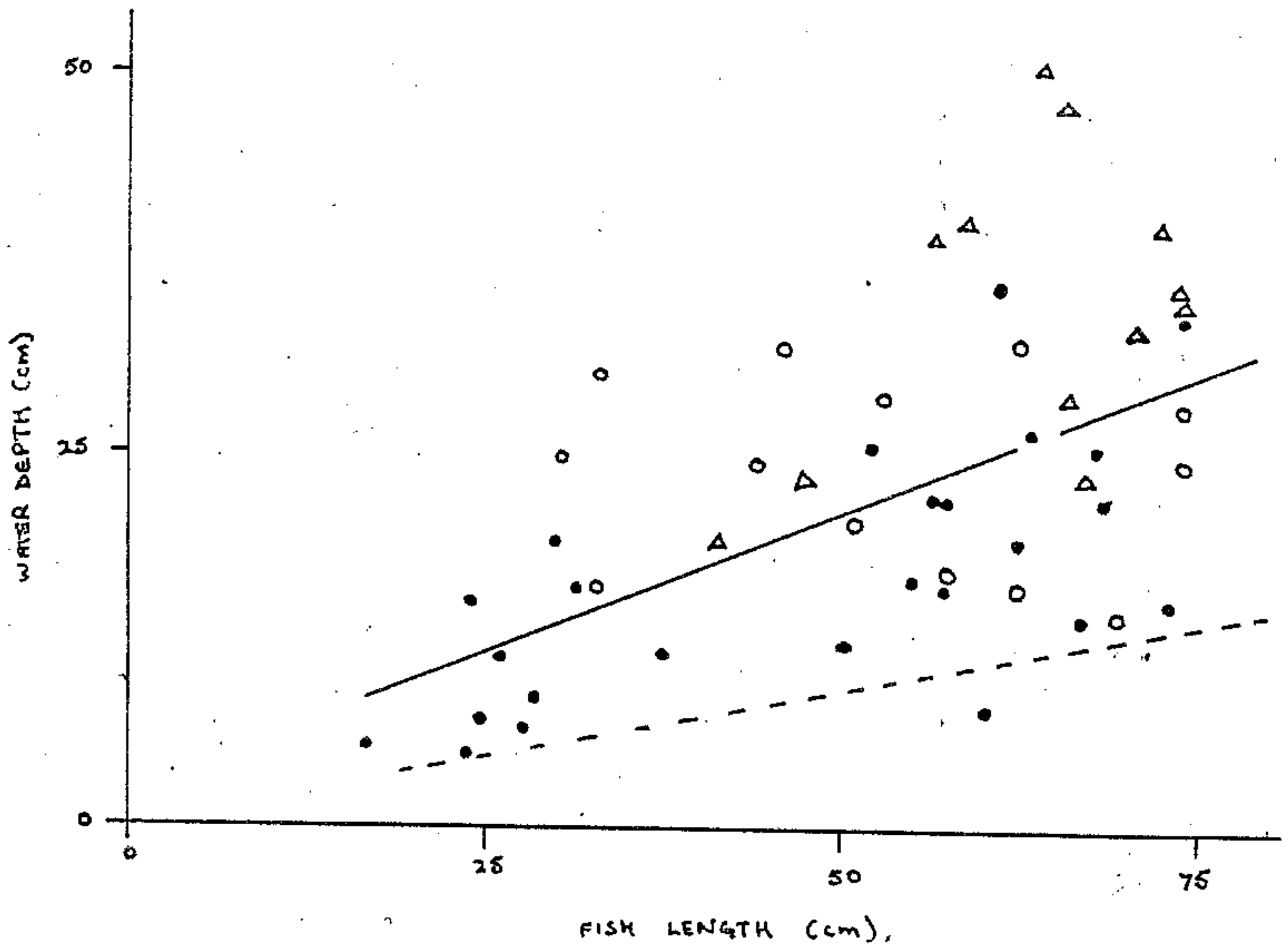

Fig 2. Plot of water depth against fish body length. ● = N.E. England, O = S.W. Wales, Δ = Dorset. The solid line is a calculated regression of water depth upon fish length and the broken line is a calculated regression relating fish body depth to fish length.

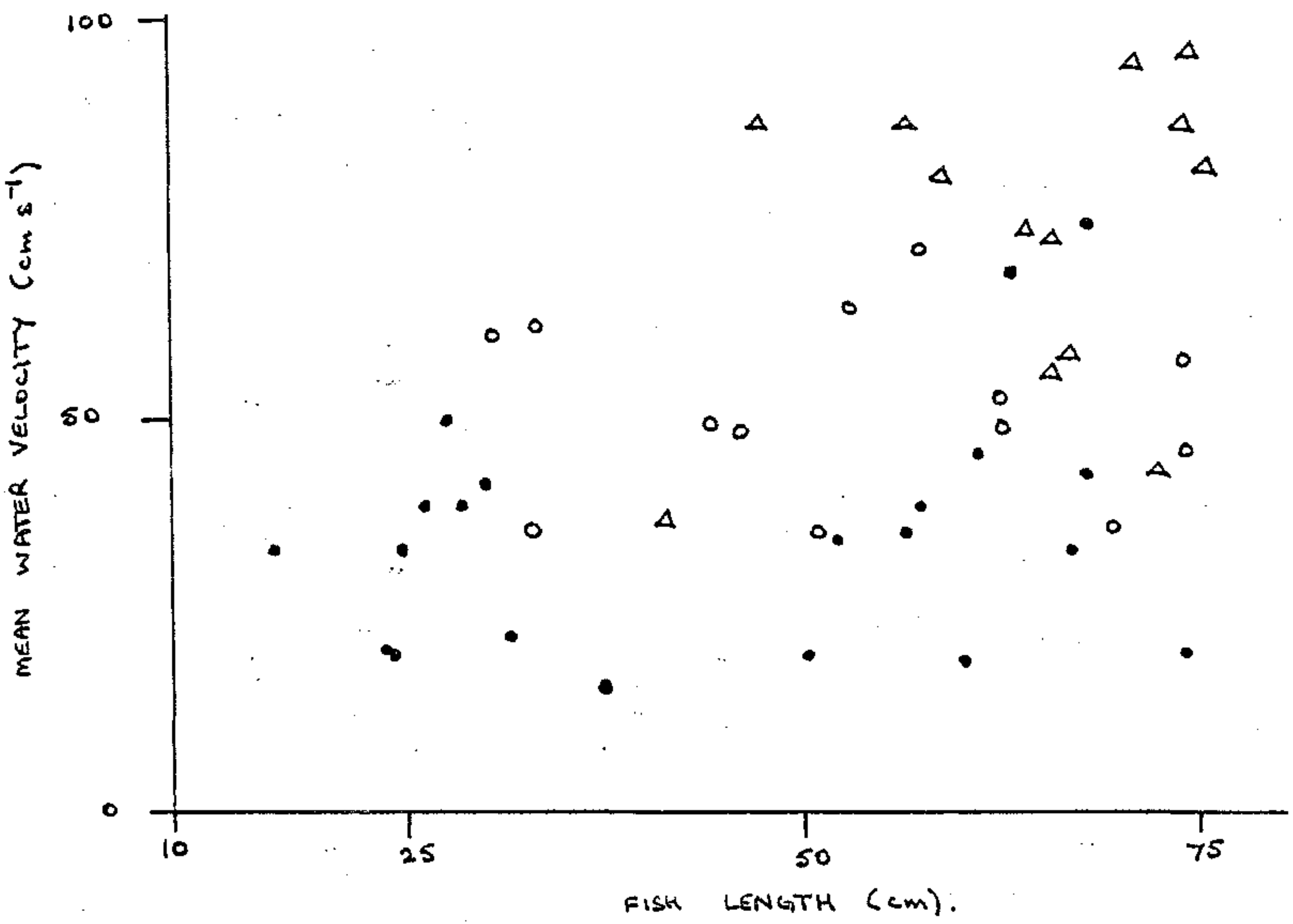

Fig 3. Plot of mean water velocity against fish length. Symbols as in Fig. 2.

Preliminary analyses suggest that there is no relationship between the geometric mean gravel size and fish length, though the data plot (Fig. 4) could imply an upper limit related to fish length.

Future analysis will require the fitting of more appropriate models, as linear regressions are not adequate for the purpose. However, the use of linear regressions, as an interim measure, shows significant correlations between water velocity and fish length, water depth and fish length and also between water velocity and water depth. More detailed analysis is needed to assess these interrelationships.

7. Egg burial depth relative to fish length, water velocity and gravel composition.

A plot of mean egg burial depth in each redd against female fish length for all redds from which five or more eggs were obtained is shown in Fig. 5. Only three data points were obtained from Dorset and these did not accord well with the trend suggested by the data from N.E. England and S.W. Wales. Egg burial depths have been regressed upon fish length, water velocity and various statistics of gravel composition in simple and multiple regressions, both with and without logarithmic transformation. The present account refers mainly to simple linear regressions but also briefly summarizes the interim conclusions derived from the more elaborate approaches.

When the Dorset data are included, then mean burial depth (y) can be related to fish length (x) by the equation $y = 0.202x + 4.38$ ($n = 24$, $P<0.01$ and $r^2 = 0.33$). If the Dorset data are excluded, the appropriate equation is $y = 0.262x + 2.42$ ($n = 21$, $P<0.001$ and $r^2 = 0.60$). The fit of these relationships is not improved by logarithmic transformation.

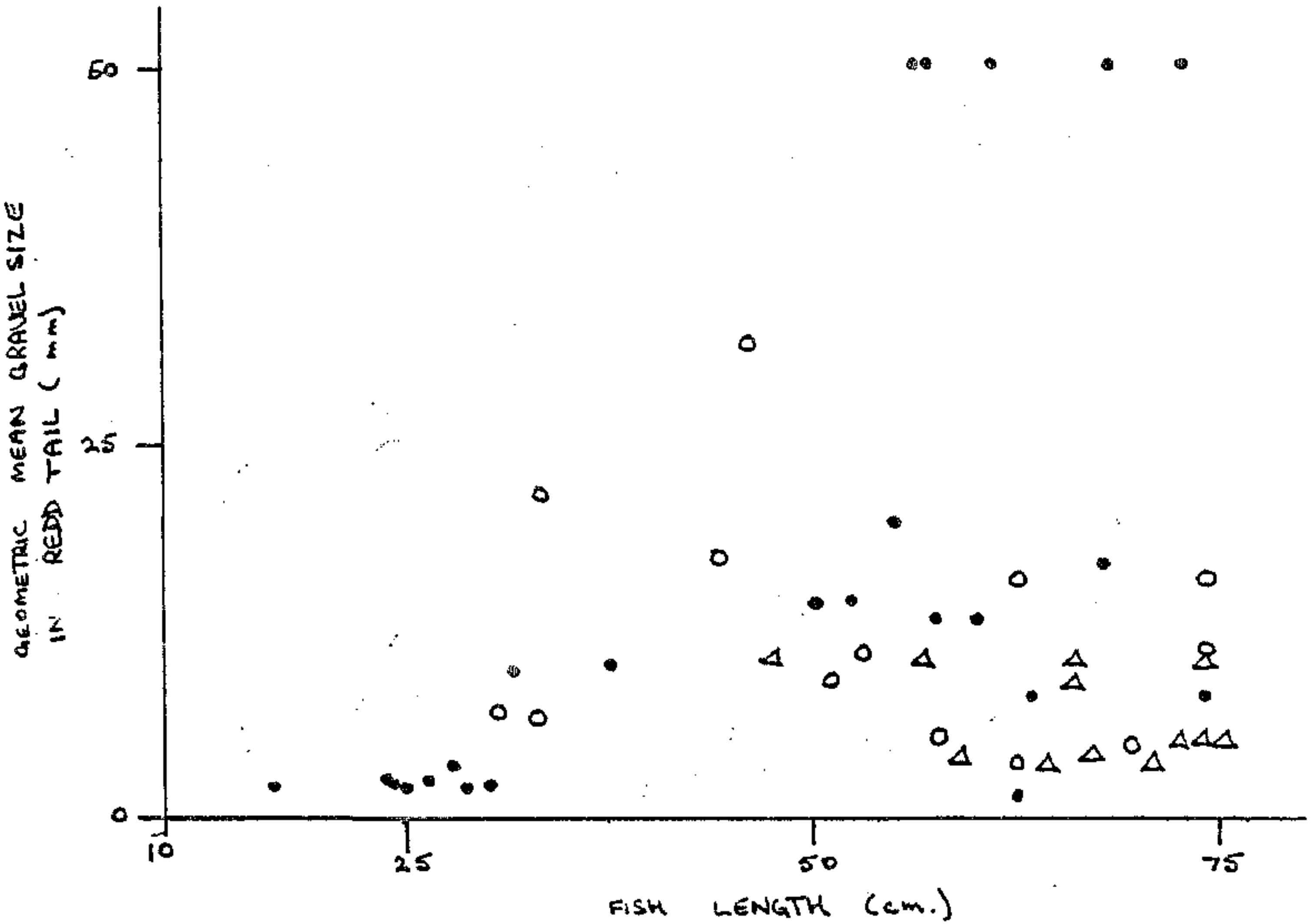

Fig 4. Plot of geometric mean gravel size against fish length. Symbols as in Fig. 2.

The use of multiple regressions gave no indication of any effect of water velocity upon egg burial depth and the preliminary analysis for effects of gravel composition was inconclusive.

The results, therefore, indicate a clear effect of fish length upon egg burial depth for N.E. England and S.W. Wales but the three data points from Dorset appear to be anomalous. This may simply reflect the small number of Dorset data or it may reflect some peculiarity of the chalk stream environment. More data are needed to clarify this point.

8. Scatter of egg burial depths.

Within individual freeze cores, some eggs occurred up to 10 cm above or below the mean depth of eggs within the core. These large deviations from the mean may be partly, at least, explained by natural displaeement during oviposition and by displacement during the freeze coring process. However, eggs were generally found in a discrete layer within the core and this is demonstrated in Fig. 6. For each core, the depth of each egg was expressed in terms of its distance (within 1 cm bands) above or below the mean depth of eggs in that core. The data from all cores were then combined to give the percentage frequency distribution shown in the figure. The values were reasonably evenly distributed about the mean. About 70% of eggs occurred within ±1 cm of the mean and over 80% within ±2 cm of the mean.

9. Pot depth as a predictor of egg burial depth.

A regression of mean egg burial depth upon fish length accounted for 58% of the variance of mean burial depth but a regression of pot depth upon fish length accounted for only29% of the variance of pot depth. A regression of

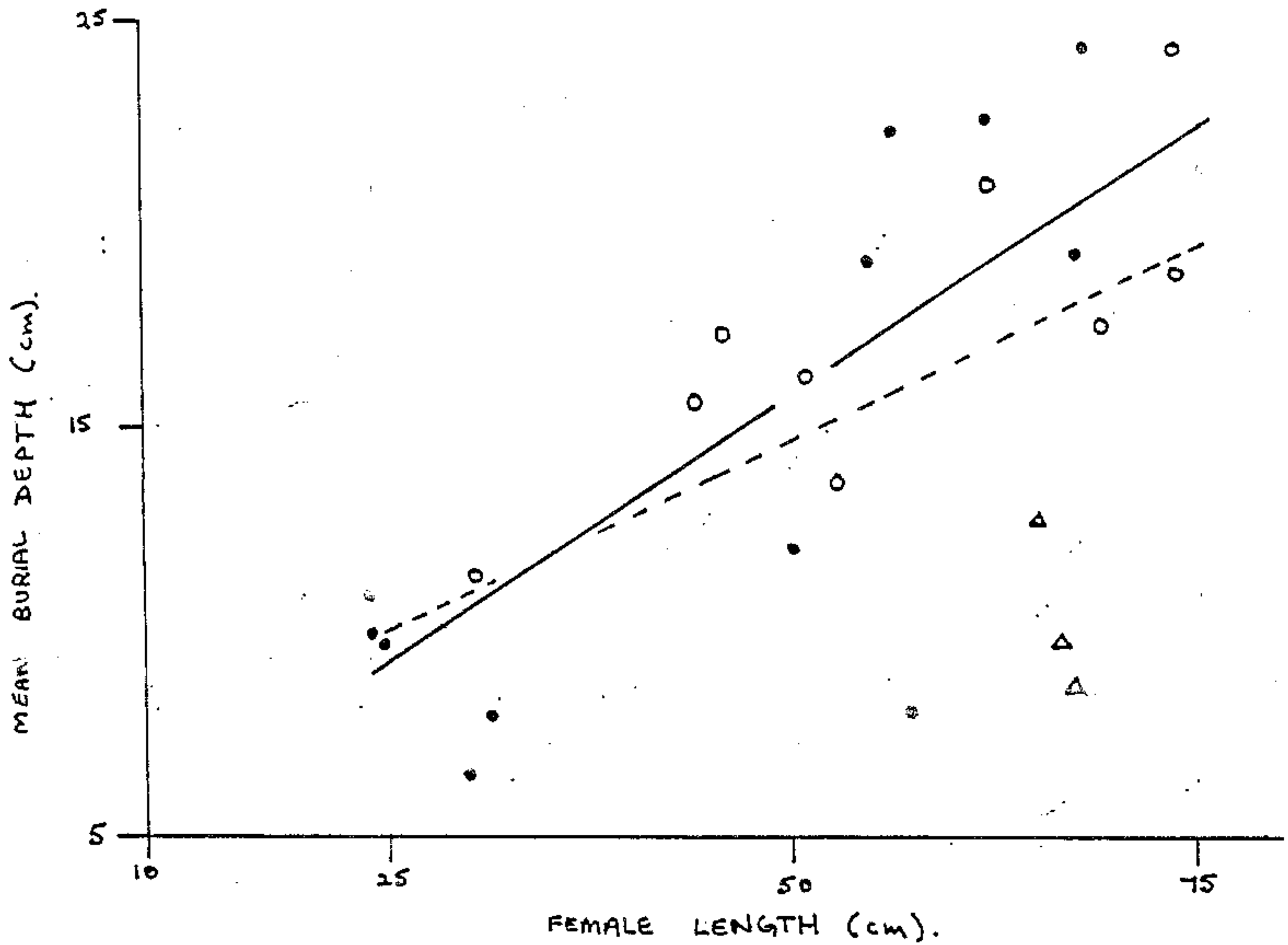

Fig 5. Plot of mean egg burial depth against fish length. Symbols as in Fig. 2. Solid line is the calculated regression which excludes Dorset data, broken line is the regression which includes Dorset data.

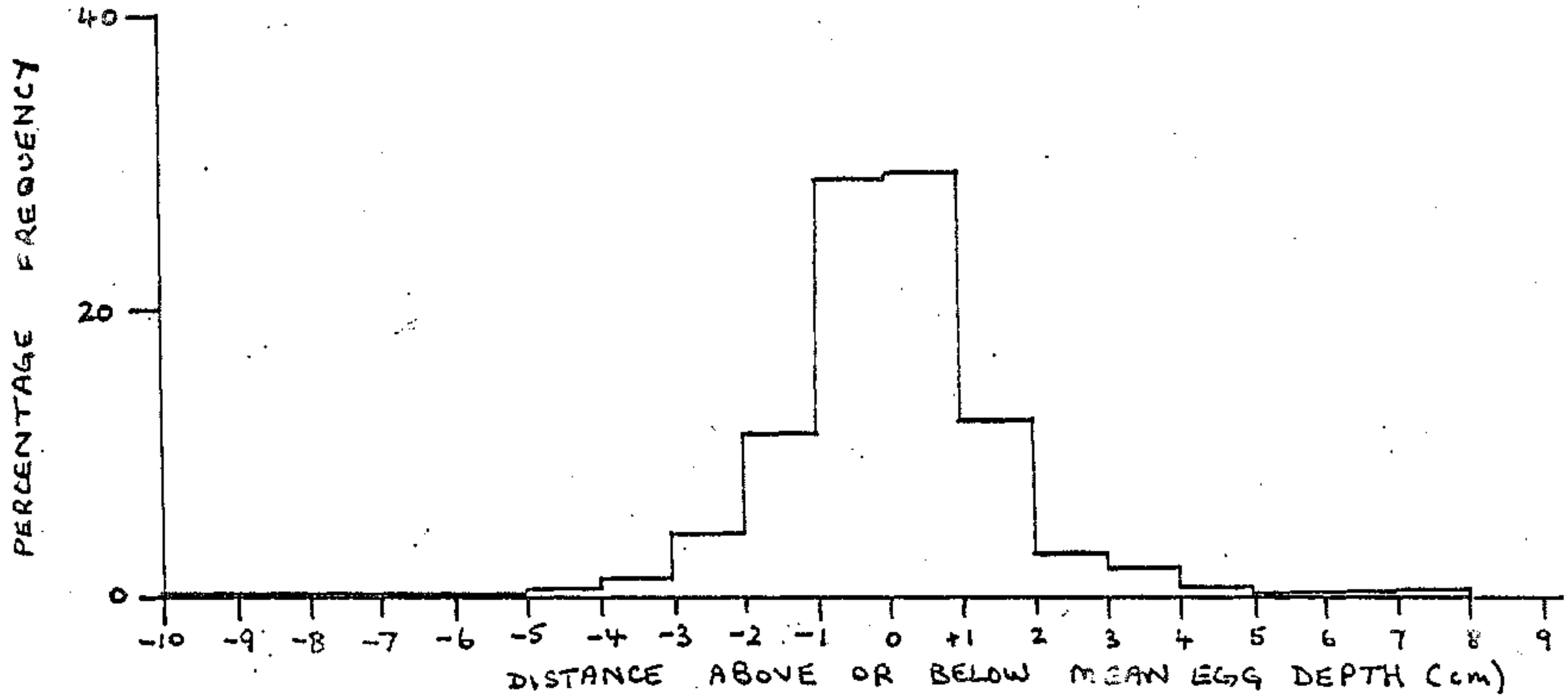

Fig 6. Percentage frequency of occurrence of eggs within 1cm depth ranges about mean egg depth. Combined data from all cores for a total of 1537 eggs.

mean egg burial depth upon pot depth accounted for only 9.6% of the variance of burial depth and was not significant ($P>0.05$).

It can be concluded that pot depth is not a useful predictor of egg burial depth and field observation suggests that this may reflect changes in the relative dimensions of the redd pot, particularly in the relationship between its depth and its width, during the course of redd construction and possibly also during individual cycles of oviposition and egg covering behaviour.

The pots of Dorset redds appear to be of similar depth, relative to fish length, to those in the other study areas. In view of the generally shallower than expected egg burial depths observed in Dorset redds, this point requires further examination.

DISCUSSION

The present report is a brief and much simplified account of the results of preliminary data analyses. These preliminary analyses clearly indicate a need for more data points, especially from Dorset. The present report is intended primarily as an interim version for the Department of the Environment, whose contract ends on 30 September 1985. Support from the other customers continues until 31 March 1986 and will be used to obtain more data points from Dorset and to make more thorough analyses of the data. The aim is preparation of a more detailed report to all customers in March 1986.

A number of investigations have reported that spawning activity of salmonid fish leads to a significant reduction in the fines content of surface gravels in redds. The preliminary analysis of spawning gravels in this report was inconclusive in this respect.

It should be borne in mind, however, that surface gravels may be low in fines for a number of reasons other than the winnowing action of fish. Surface gravels may be hydraulically winnowed and fines tend to settle and fill well-sorted framework gravels from the base upward (Beschta & Jackson, 1979; Carling, 1984). Fines content in surface gravels may also be reduced by the process of kinematic sieving (Middlton, 1970); as the gravels are disturbed during the cutting process, fines settle deeper into the deposit.

The significance of a slight reduction in fines content is small, as laboratory and field investigations suggest that resilting of redds will be rapid, even in low flows bearing small suspended sediment concentrations (Carling, 1984; Carling & McCahon, in prep.).

The results indicate that the major horizontal dimensions of the redd can, within limits, be predicted from the size of the female fish and that gravel composition and water velocity have little, if any, influence on either the size of the redd or on its relative proportions. This opens up the possibility of predicting the size of the female fish which made a given redd from regressions of fish length upon an appropriate redd dimension.

The depth of egg burial can be related to the length of the female fish and, provided that questions about the apparently anomalous data points from Dorset can be resolved, the appropriate regression line(s) will be of value as a component in the prediction of egg mortality through washout, overcutting and exposure above the water surface.

Field observation suggests that the depth of the redd pot may vary during the course of redd construction. First, there may be variation between different phases of the cycle of excavation, oviposition and egg covering which is associated with the deposition of each batch of eggs within the redd. Second, some infilling of the pot is likely when the female cuts around the upstream edges of the pot after completion of oviposition within the redd. In the present study the process of redd construction was interrupted before completion. Although the interruption was always made as late as possible during the process, it is likely that this led to some variation in measured pot depth, relative to female length, between redds made by females of similar length. This is a possible contributor to the fact that pot depth was not a useful predictor of egg burial depth and to the observation that, in general, the average pot depth for a fish of any given size was appreciably less than the corresponding mean burial depth. Van den Berghe & Gross (1984) found a significant correlation between pot depth (9 to 25 cm) and female length (45 to 75 cm) for coho salmon, but their measurements were made on fully completed redds. The present data cast some doubts on the validity of the assumption made by these authors that pot depth is a useful estimator of egg burial depth.

One of the major problems in interpretation of the results is that they refer to only three study areas and for one of them (Dorset) there are only three good data points on egg burial depth. Assuming that the latter problem can be overcome during 1985-86 then, given adequate funding, future work should be aimed at extending these studies to one or more additional areas (one of which should be North Wales) and possibly to the acquisition of further data from N.E. England.

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