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Habitat preferences of target species for application in PHABSIM testing

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SUMMARY

1. Habitat preference curves for 5 species of invertebrate and 7 species of fish are presented. The invertebrate data are derived from a large body of information held at the IFE River Laboratory. The fish curves are based on experience and local knowledge of UK conditions.

2. The results are discussed and some suggestions for future studies are proposed.

1. INTRODUCTION

1.1 The PHABSIM model simulates a relationship between stream flow and physical habitat for various life stages of a species of fish, benthic invertebrates or a recreational activity such as canoeing.

1.2 The model (which is still evolving) was developed in the USA and has been in use for about 10 years as a management tool.

1.3 Its applicability to British waters has not been tested and the objectives of this present study are listed below.

i) establish a methodology for providing habitat preference curves for target species from field work, literature, and local knowledge for UK conditions;

ii) apply this method to provide habitat preference curves in tabular form and in the form of the attached figure for each of three variables: depth, velocity, and substrate, for one or more species of fish and invertebrate, to be chosen by the FBA as being suitable for the following reaches selected for investigation: three reaches on the river Blithe, one upstream and two downstream of Blithfield reservoir (gauging station NGR SK 109192); two reaches on the river Gwash below Rutland water (NGR SK 951082); and two reaches on the river Derwent, one above and one below Ladybower reservoir (NGR SK 198851);

iii) plan and arrange invertebrate sampling in the study reaches selected for testing the PHABSIM model. The samples will be preserved and stored by the FBA to be processed when funds become available (Appendix 1).

2. METHODS

2.1 Invertebrates

2.1.1 The most accurate estimates of habitat preferences are derived from detailed analyses of distribution patterns of species with respect to specific variables measured at the point at which a faunal sample is taken. Such techniques are time-consuming and costly but are ultimately necessary for developing the model. In the absence of such data cruder estimates have to be used.

2.1.2 Large data bases which record both faunal occurrence and physical features at sites provide the raw material for preliminary assessments of habitat preference. The FBA River Communities Project (RCP) has, over the past 10 years, identified about 600 species of macroinvertebrates from more than 400 substantially unpolluted sites throughout Great Britain. Physical and chemical information has also been collected from these sites. These two blocks of data (distributional biology, and physical characteristics) have been used in this study to assess the habitat preferences of selected species.

2.1.3 The results below are based on the first phase of the project when 273 sites had been sampled. The remaining data are not currently in a form which is readily available for assessment of habitat preferences.

2.1.4 At a site benthic fauna is taken from all available habitats usually in proportion to their occurrence and a sample comprises all the material collected in a 3 minute period. This method therefore does not take account of distribution patterns within the site and the results express occurrence with respect to mean values of variables such as substratum, velocity, depth etc. This reduced precision is partly offset by the large number of records for the selected species.

2.1.5 The RCP data have been used to develop a model, RIVPACS, which uses environmental data to classify sites and predict the probability of capture of faunal taxa at unsampled sites. This model can also be used to determine habitat preferences mainly with respect to substratum. For example it is possible to predict the fauna of the site Hamstall Ridware on the Blithe using actual physical data and then enter simulated substratum values and observe the effect on the probability of a species occurring at the site. This method is explored briefly in this report.

2.1.6 In addition to the presence/absence data for species in the RIVPACS model information on the relative abundance of families is also available. This is important because changed physical habitat may affect both abundance and occurrence of benthic fauna.

2.1.7 Selection of taxa:- Many invertebrate species have a relatively wide distribution and can tolerate a range of environmental conditions, for example the mayfly Baetis rhodani is very widespread occurring in about 85% of the sites sampled for the RIVPACS model. For such a species environmental changes would have to be very severe to cause a significant decline in its probability of occurrence at a site. In making the selection for this attempt at determining habitat preferences, species with narrower ecological limits were used. They include two stoneflies Leuctra fusca and Isoperla grammatica, two caddis-flies Polycentropus flavomaculatus and Rhyacophila dorsalis, and the pea mussel Sphaerium corneum. All taxa occur in at least 42% of the total sites sampled.

2.2 Fish

2.2.1 In relation to fish stocks the predictive characteristics applied vary in their relevance to the species. In general, water velocity and depth are appropriate features to consider at all stages of a fishes life cycle.

2.2.2 Because no factor operates in isolation from others which are under consideration it is considered that to assign values of suitability as high as 1 (presumably 'perfection') would be inappropriate and thus the figures are usually truncated at an arbitrary value of about 0.8 to permit scope for modification as the models are refined. Substrate type (sediment particle size/detritus content) is so closely related to depth, and in particular to velocity, that the relationships to habitat suitability are likely to be very similar.

2.2.3 Cover descriptions appear to have been designed purely for salmonid fishes since they include predominantly overhanging banks and vegetation which are known to increase the holding capacities of running waters for brown trout and other territorial species inhabiting mainly smaller, narrow, fast-flowing watercourses in which the significance of the marginal overhangs and trailing vegetation is much greater than in wide, deep rivers.

2.2.4 The present analysis covers those species known to inhabit the streams/rivers effluent from the three reservoirs under consideration (Appendix 2). Because many of these species are not salmonids the presence of aquatic plants is likely to be of greater importance to them. This factor is of twofold significance. Firstly, it will behave in a similar manner to "instream cover" (rocks etc.) by sheltering fish from the direct effects of the flowing water, and secondly it will provide a substratum on which prey organisms may live or to which the eggs of the fish may be attached. In practice the successful spawning of many cyprinids, esocids and percids is almost totally dependent on the presence of aquatic vegetation or of structurally similar "cover" in the form of submerged tree roots, fallen tree branches, algae, bryophytes etc.

mosses

3. PRESENTATION OF RESULTS

3.1 Invertebrates

3.1.1 Tables 1-4 present data in tabular form which is repeated as curves for the selected species. Substrate data in the tables have been presented as phi values for increased accuracy and not as the code used in the PHABSIM model. Equivalent values have, however, been calculated for construction of the habitat preference curves. The highest weighted percentage value for each variable (Table 1), is considered as the most 'suitable', i.e. 1.0. Remaining 'suitability' values are calculated from the other percentages in relation to the highest value. Assessments based on existing knowledge of invertebrate distribution were used to suppy missing values.

3.2 Fish

3.2.1 Figures and tables are used to describe a set of appropriate parameters within which each major species present in the rivers under consideration can be considered to lie. The tables are constructed on the basis of the modal range of each factor. Other species such as gudgeon, minnow, bullhead, three-spined stickleback and loach which are likely to occur are not listed in table 5 and are of less direct relevance to water users and under the constraints of time imposed on the present study have not been considered. However, these species may be excellent indicators of changing conditions and should be taken into account in any complete model.

3.2.2 The current PHABSIM model (as given) appears to have no provision for cover in the form of algae, bryophytes (↳ mosses) or angiosperms (↳ flowering macrophytes) within the river. As mentioned above such plants are often critical to the spawning and/or feeding of coarse fishes so, in the absence of a definite directive, a ??? is used to indicate that this factor should be considered in future models.

4. RESULTS

4.1 **Invertebrates**:- The following data are presented in figures and tables.

4.1.1 Habitat preferences of the five invertebrate species based on frequency of occurrence data. Additional curves are presented for Isoperla grammatica which are based on relative abundance in the data set (Figs 1-5).

4.1.2 Substrate preferences of the families represented by the species Isoperla grammatica (= Perlodidae), Leuctra fusca (Leuctridae), Polycentropus flavomaculatus (Polycentropodidae), Rhyacophila dorsalis (Rhyacophilidae) and Sphaerium corneum (Sphaeriidae) based on predictions with the RIVPACS model applied to two sites, one on the R. Gwash, the other on the Blithe. Data are presented on both predicted occurrence (Table 6) and relative abundance (Table 7).

4.1.3 Substrate preferences of three species L. fusca, I. grammatica and Sphaerium corneum based on predictions with the RIVPACS model as in 2 above (Table 8).

4.2 Fish

4.2.1 In general each of the fish species listed is likely to have specific requirements at each stage of its life. Thus, while adult dace spawn in fast flowing, shallow water over gravel substrata (the eggs adhere to the hard bottom and are susceptible to damage by deposition of finer sediments) the fry stages are restricted to slow flowing, shallow, marginal areas in which the substratum may range from fine sand to silt or fragmented organic detritus. It will certainly be possible, with a greater input of research time, to prepare detailed information sheets for these and other species even though the limitations outlined above still apply.

5. DISCUSSION

5.1 Invertebrates

5.1.1 Most of the taxa tested were found over a wide range of conditions but were common only over a narrow range. To a degree the wide spread of occurrences reflects the composite nature of the samples but at the same time emphasises that species can be found in small areas of a site which otherwise may be totally unsuitable. This suggests that occurrence data are not suitable for defining habitat preferences. However, the results from the one case where relative abundance for a single species, Isoperla grammatica, were analysed indicate good agreement between occurrence and abundance data at a site.

5.1.2 Relative abundance data are readily available at the family level. Predictions of family response to substrate change also show good agreement between abundance and occurrence data despite the fact that the families contain more than one species. In a previous study specific variation has been examined and the response curves for occurrence are presented here for information (Fig. 39). It can be concluded that although there is good agreement in general between abundance and occurrence at family level individual species may show a wide range of responses. The family curve will be defined by the most common species within that family.

5.1.3 The data from predictions at the two sites for which environmental features were readily available showed an interesting phenomenon. Some species/families appeared to have a greater tolerance to changing conditions in the Blithe (as indicated by their wider habitat preferences) than in the Gwash. This was particularly marked in those taxa which prefer coarser substrates. There was insufficient time available to study this further but if the indications are true then it suggests something that might have been expected, that is that the fauna of some rivers will react less to environmental change than will that of more 'susceptible' streams.

5.1.4 The invertebrate community at a site is a dynamic complex of interactions and in consequence attempts to attribute change to three or four variables are not likely to be totally successful. A feature of major importance to benthos is the distribution and settlement of fine particulate material. This material which is partly biological in origin can determine the nature and abundance of invertebrates in rivers. It is important that attempts are made to establish the relationship between flow characteristics and channel morphometry and the dynamics of fines. The situation is complicated by the fact that managed flow changes may not be sufficiently great to alter the basic substratum type but would allow the deposition of a thin layer of the fines. This would result in faunal change.

5.1.5 Accurate assessments of habitat preferences require detailed analysis of microdistribution patterns in relation to flow velocity and substrate. Data used in this study provide a gross assessment of preference and indicate the relative susceptibility of species to environmnental change. It should be stressed however that most regulatory schemes in Great Britain do not have a gross effect on the physical characteristics and faunal changes are frequently rather subtle involving shifts in dominance of species and increases or decreases in overall abundance. In order to predict these changes with accuracy in relation to physical habitat changes more basic work is needed on the factors controlling the distribution of individual species.

5.2 Fish

In many cases the application of the assigned habitat characteristics may vary with the time of day and the behaviour or physiological conditions of the species concerned. For example, the brown trout will, if disturbed, normally seek overhead cover and an adequate area of overhanging banks, trees etc. may be essential for a stream to support substantial populations of this species. Undisturbed fish which are feeding will require territories in which they are visually separated from their neighbours. The separation distances required may decrease in faster flowing water or in the presence of increased prey densities. In addition to these aspects it is probable that the majority of feeding activity takes place in the hours of darkness when the fish may move into shallower, faster flowing regions in order to take advantage of enhanced invertebrate drift rates at such times. In practice it can be seen that the optimal habitat for the adults of this species may not lie at a simple optimum for each habitat characteristic but could depend rather on the presence of a wide range of different conditions being present within the normal swimming range of the species and may vary in relation to the state of other factors. It follows that the values incorporated in the present report are simply one possible set and that a substantial amount of research will be required before it is possible to assign values with confidence for rivers having different characteristics (e.g. chalk streams and upland streams).

6. FUTURE WORK

6.1 Invertebrates

6.1.1 The data presented in this report are based on the RCP data base. Further studies of habitat preferences could include the collation of information from exhaustive literature searches. However it is clear that the most accurate information will come from detailed analyses of microdistribution patterns of selected species at different life-history stages in a range of river types.

6.1.2 It is worth considering the relative importance of each variable. Are they all given equal weighting in the model? Experience in the field has indicated that, for example, substratum and velocity are more important determinands of an invertebrate's distribution than depth.

6.1.3 The concept of cover requires investigation and its importance would seem to depend largely on the behaviour of the individual species and the niche-type that species occupies on the stream bottom.

6.1.4 An opportunity to compare predicted habitat preferences with observed preferences should be provided to determine the extent of agreement between the two methods. Such a study will help define more accurately the future needs in the calculation of habitat preferences.

6.2 Fish

The present attempt to provide data appropriate to PHABSIM suggests that, in future, the following approaches should be adopted.

6.2.1 An exhaustive search of all the relevant literature for detailed information on the habitat requirements of both the larger species of fish and those lesser forms which, although of no interest to anglers, may be excellent indicators of changing conditions.

6.2.2 The variables used in the construction of the PHABSIM model must be defined more clearly. In particular, cover must be defined with respect to the many functions of water plants and other characteristics relevant to British fishes.

6.2.3 Findings should be tested with surveys of selected running waters covering the main stream and river types in this country. It is quite clear that much more information on the detailed habitat choices of fish is required.

6.2.4 Application of habitat variables is, at present, too rigid and provision must be made for diurnal and other shifts in choice of factors by fish of a given species and group in relation to interactions with other parameters.

6.2.5 Abundance data for certain fish in rivers is already available but a standard methodology should be implemented if PHABSIM is to be developed.

RIVPACS has been developed jointly by J.F. Wright, P.D. Armitage, M.T. Furse and D. Moss.

Table 1. Frequency of occurrence of selected species in a data set of 273 sites representing source to near mouth locations on a wide range of rivers in Great Britain. Occurrence (O) and weighted % (W%) in classes of surface velocity, depth and mean substratum particle size (MSUBST) are presented for Leuctra fusca, Isoperla grammatica, Rhyacophila dorsalis, Polycentropus flavomaculatus and Sphaerium corneum.

Parameter classes	Total sites	L. fusca O	L. fusca W%	I. grammatica O	I. grammatica W%	R. dorsalis O	R. dorsalis W%	P. flavomaculatus O	P. flavomaculatus W%	S. corneum O	S. corneum W%
Velocity											
<10 cm s^{-1}	18	1	2	0	0	0	0	3	7	10	25
10-25	29	13	18	13	20	12	17	14	18	15	22
25-50	84	47	22	31	17	49	24	49	22	39	20
50-100	113	69	24	71	29	78	28	78	26	39	15
>100	29	25	34	22	34	22	31	20	26	13	18
Depth											
0-25 cm	117	74	32	67	30	82	36	70	21	37	12
25-50	97	61	32	51	27	56	29	60	22	47	18
50-100	36	14	20	15	22	21	30	24	24	18	19
100-200	19	6	16	3	8	2	5	8	15	11	22
200-300	4	0	0	1	13	0	0	2	18	3	29
MSUBST											
-8 -6 (phi)	64	55	26	54	30	57	27	52	19	11	4
-6 -4	60	45	23	41	24	54	27	39	16	15	6
-4 -2	56	28	15	22	14	26	14	32	14	33	14
-2 0	33	7	7	7	7	14	13	17	12	21	15
0 +2	18	8	14	6	12	7	12	6	8	9	12
+2 +4	15	2	4	3	7	2	4	7	11	11	18
+4 +6	11	4	11	2	6	1	3	6	13	7	15
+6 +8	14	0	0	0	0	0	0	0	0	9	15

Phi values used as PHABSIM code equivalents
(2 - 6 = 3; 2 - 0 = 4; 0 - -4 = 5; -4 - -6 = 6; -6 - -8 = 7)

Table 4. Predictions of probability of occurrence of three species at Hunstall Ridware on the Blithe and downstream of A.606 road bridge on the Gwash below Rutland Water following simulated substratum change. (MSUBST = mean substratum particle size - phi values; O = probability of occurrence as %).

MSUBST	*Leuctra fusca*	*Isoperla grammatica*	*Sphaerium corneum*
a) River Gwash			
-8	70.8	48.5	55.2
-6	43.7	28.9	69.9
-4	20.5	12.2	80.9
-2	11.4	5.8	84.5
0	7.9	3.6	85.5
2	5.5	2.6	86.2
4	4.9	3.2	86.3
6	8.2	4.4	84.4
8	12.3	3.7	83.0
b) River Blithe			
-8	82.8	66.5	59.1
-6	77.9	61.2	64.7
-4	68.0	51.5	71.1
-2	51.6	37.0	77.3
0	32.2	21.0	83.5
2	18.2	8.3	89.8
4	13.4	2.4	92.9
6	13.5	1.2	91.8
8	0	0	86.9

Table 2. Abundance of Isoperla grammatica in classes of surface velocity, depth and mean substratum particle size based on actual numbers recorded in spring, summer and autumn samples at 273 sites.

	Total sites	Total individuals	Mean no. per site
Velocity			
<10 cm s^{-1}	18	0	0
>10-25	29	290	10
>25-50	84	203	8
>50-100	113	2713	24
>100	29	550	19
Depth			
0-25	117	1987	17
25-50	97	1217	13
50-100	36	1004	28
100-200	19	38	2
200-300	4	4	1
MSUBST			
-8 -6	64	1999	31
-6 -4	60	1171	20
-4 -2	56	797	14
-2 0	33	161	5
0 +2	18	67	4
2 4	15	46	3
4 6	11	15	1

Table 3. Predictions of probability of occurrence (O) and relative abundance (A) of five families of invertebrates where a simulated substratum change is entered into the RIVPACS model. (See text for details.) (MSUBST = mean substratum particle size in phi units.)

MSUBST	Perlodidae		Leuctridae		Polycentropodidae		Rhyacophilidae		Sphaeriidae	
	O	A	O	A	O	A	O	A	O	A
a) R. Gwash downstream of A606 road bridge										
-8	48.7	0.96	74.1	2.23	75.8	2.05	81.3	3.70	98.1	4.11
-6	29.0	0.56	48.4	1.33	67.8	2.01	65.0	2.64	98.5	5.16
-4	12.2	0.22	26.3	0.61	61.1	1.99	51.0	1.79	98.5	5.96
-2	5.8	0.09	17.4	0.34	58.2	1.97	44.3	1.45	98.0	6.17
0	3.6	0.05	13.4	0.25	56.9	1.95	38.7	1.22	97.4	6.17
2	2.6	0.03	9.6	0.17	56.1	1.93	29.9	0.89	96.5	6.14
4	3.2	0.03	6.8	0.11	51.3	1.72	20.0	0.46	95.4	6.03
6	4.4	0.04	8.6	0.10	35.7	1.04	19.4	0.25	95.0	5.48
8	3.7	0.04	12.3	0.13	22.8	0.47	25.1	0.26	96.2	4.86
b) R. Blithe at Hamstall Ridware										
-8	67.5	1.48	88.9	2.53	83.3	2.09	87.2	4.09	91.8	3.86
-6	61.8	1.33	84.3	2.28	82.2	2.11	83.6	3.77	93.7	4.19
-4	51.8	1.09	74.6	1.90	80.1	2.19	77.5	3.30	95.9	4.71
-2	37.1	0.75	58.1	1.38	77.3	2.35	68.0	2.70	97.7	5.39
0	21.0	0.40	38.3	0.86	76.3	2.55	53.1	1.98	98.8	6.05
2	8.3	0.15	22.3	0.51	77.7	2.63	30.9	1.07	99.3	6.47
4	2.4	0.04	15.0	0.37	75.9	2.48	14.7	0.39	99.2	6.49
6	1.2	0.01	13.9	0.31	61.8	1.89	14.0	0.19	98.8	6.01
8	1.1	0.01	15.0	0.23	38.3	1.00	22.8	0.23	98.8	5.18

Table 5. Estimated physical habitat preferences of 18 species of fish.

Modal value	Velocity (cm/s)	Depth (cm)	Substrate (code)	Cover (code)
Species				
Brook trout				
Spawning	40-80	25-100	4-5	?
Fry	10-30	10-30	3.4	?
Juveniles	20-60	25-80	3-5	High
Adults	40-80	50-150	5.5-6.5	High
Grayling				
Spawning	20-60	40-120	3-4	0
Fry	10-20	10-30	1-3	?
Juveniles	20-60	50-200	3-5	?
Adults	20-60	50-300	3-5	?
Dace				
Spwaning	55-100	20-80	4.5-5.5	?
Fry	5-25	10-30	0.2-1.7	?
Juveniles	15-35	30-70	2-4	?
Adults	20-70	50-100	3-5	?
Chub				
Spawning	25-90	40-170	3.5-5.5	?
Fry	5-30	50-90	1-3	?
Juveniles	30-70	50-160	3.5-6	High
Adults	30-70	50-160	3.5-6	High
Roach				
Spawning	40-80	30-300	1-2 5-8	?
Fry	0-20	25	1-2	?
Juveniles	0-40	100-300	1-2	?
Adults	0-40	100-300	1-2	?
Bream				
Spawning	0-10	50-100	1-2	?
Fry	0-5	5-50	1-2	?
Juveniles	0-10	50-300	1-2	?
Adults	0-10	170-300	1-2	?
Pike				
Spawning	0-10	20-80	1	?
Fry	0-10	20-90	1	?
Juveniles	0-20	10-70	1-2	High
Adults	0-20	40-290	1-2	High
Perch				
Spawning	0-30	30-150	1-8	High
Fry	0-10	10-50	1-3	?
Juveniles	0-30	20-80	1-4	High
Adults	0-40	30-250	1-4	High

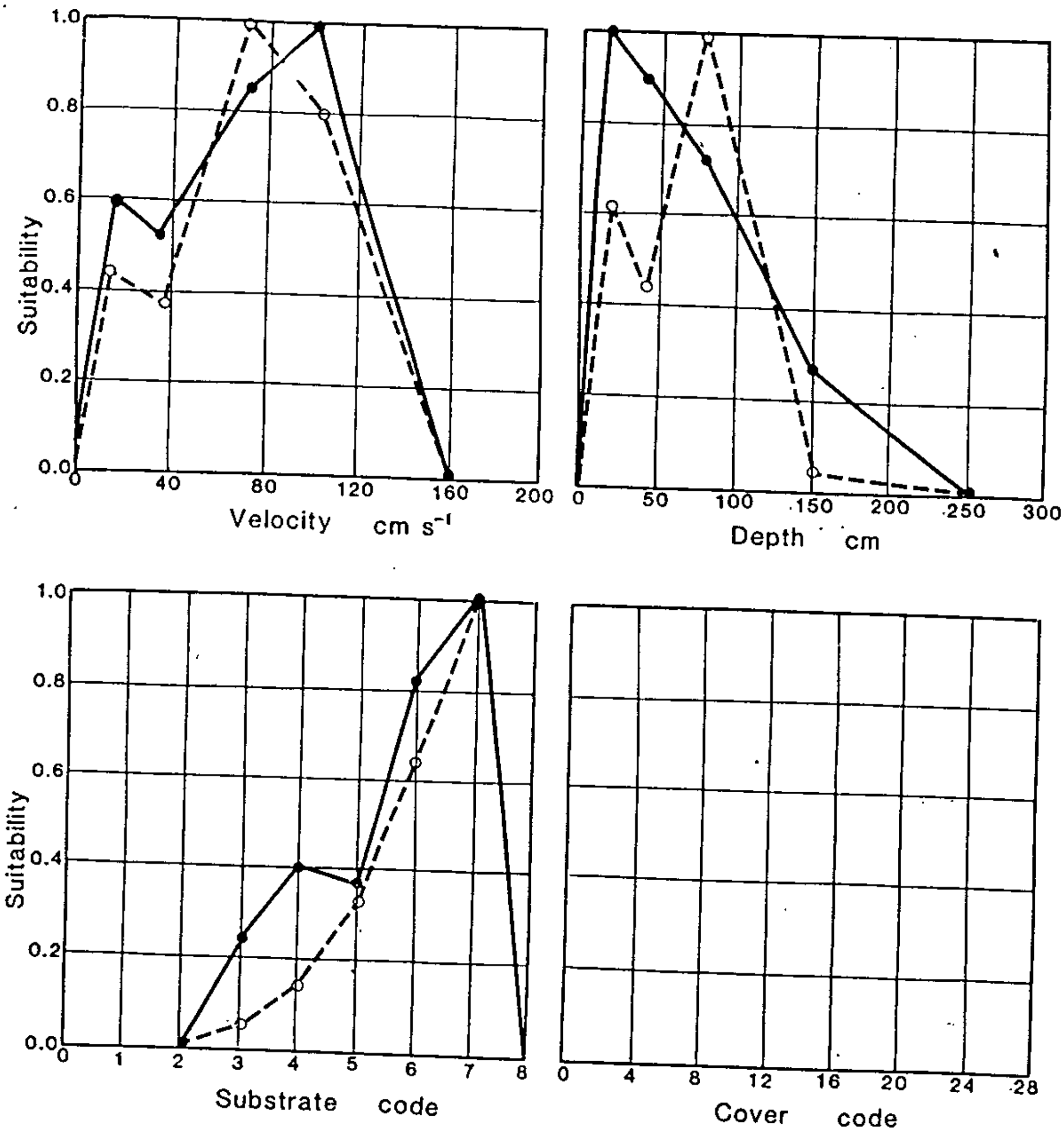


Fig. 1 Habitat suitability curves for <u>Isoperla grammatica</u> based on observed occurrence (———) and relative abundance (------).

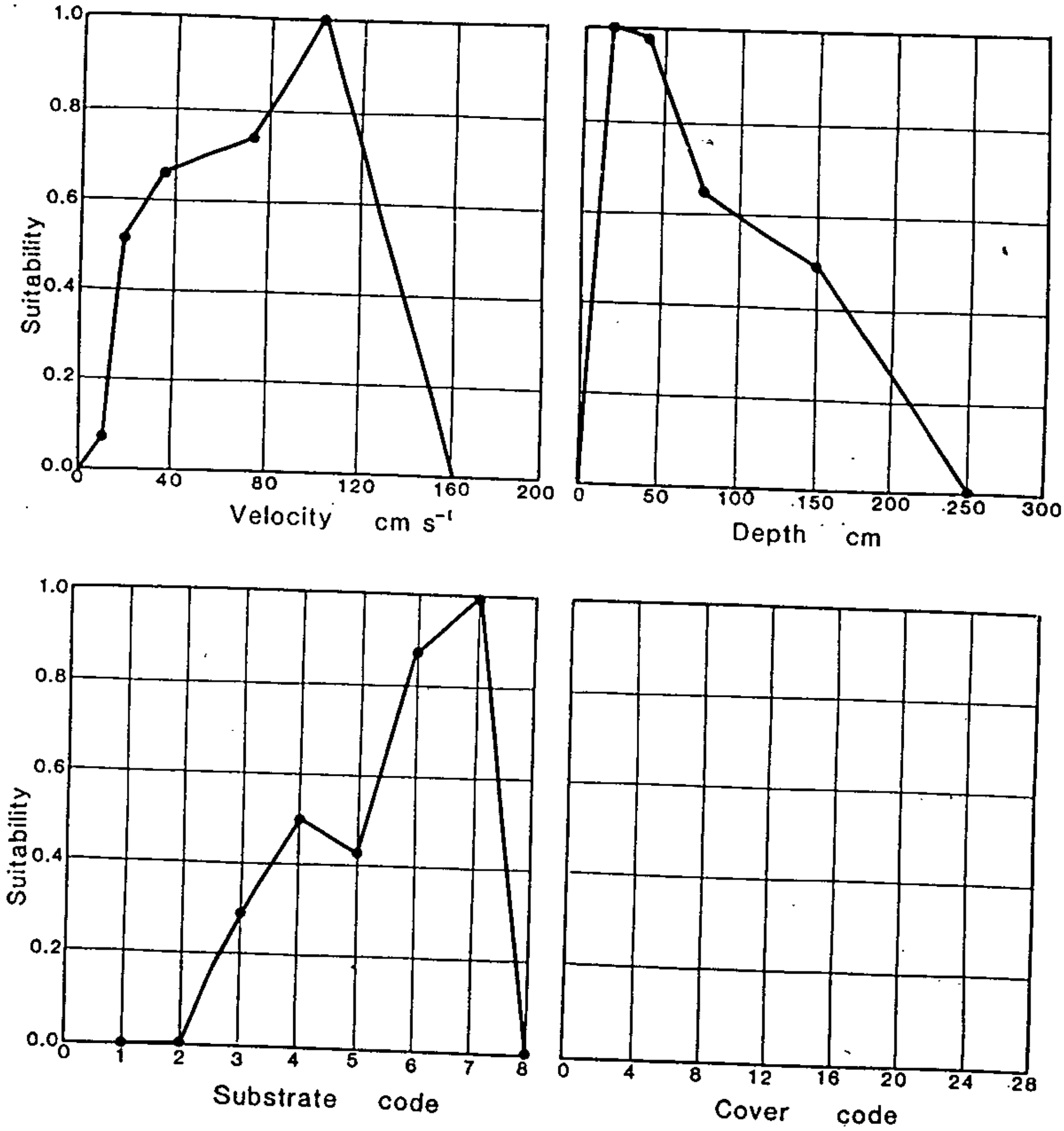


Fig. 2 Habitat suitability curves for Leuctra fusca based on observed occurrence.

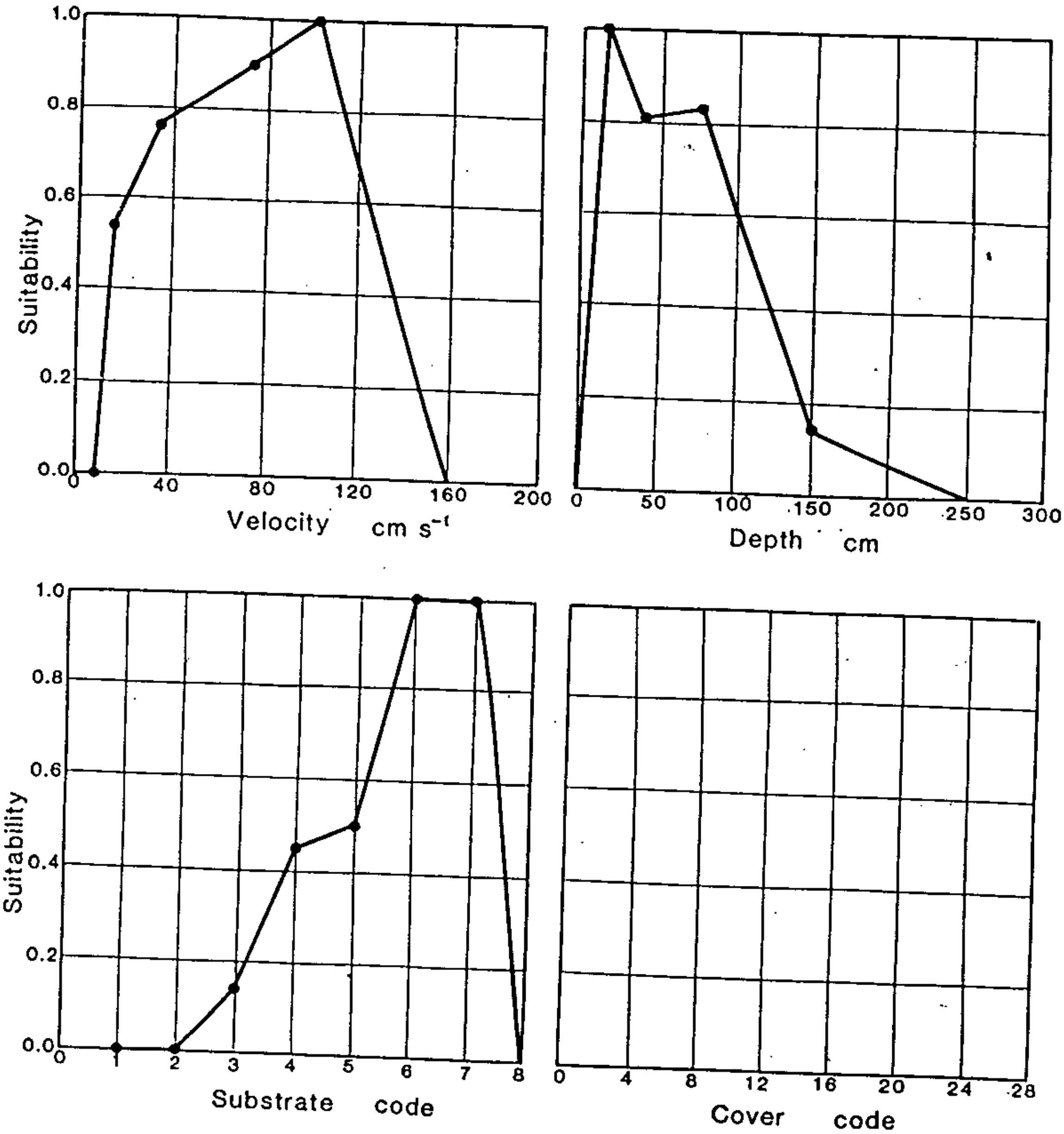


Fig. 3 Habitat suitability curves for <u>Rhyacophila dorsalis</u> based on observed occurrence.

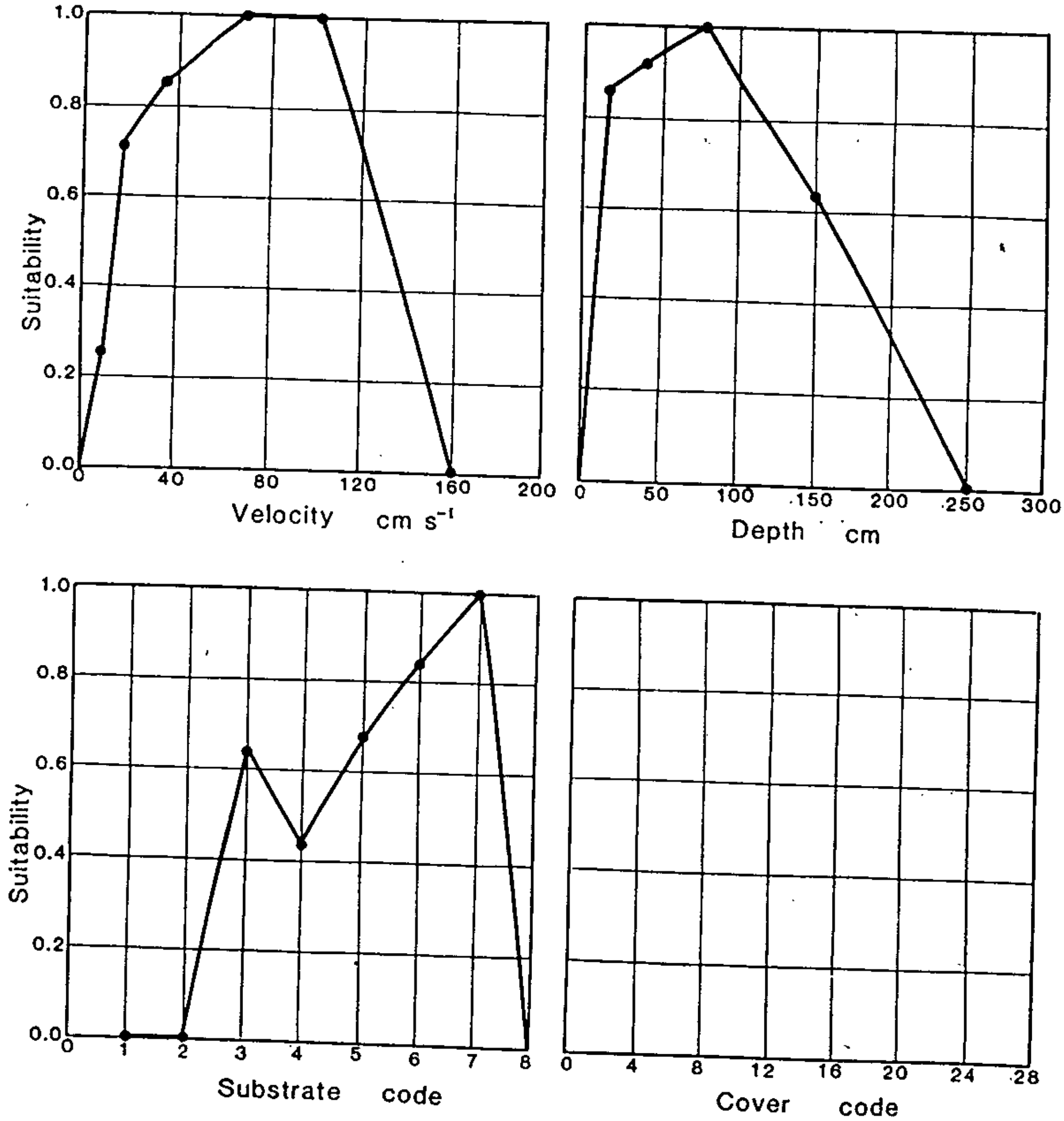


Fig. 4 Habitat suitability curves for Polycentropus flavomaculatus based on observed occurrence.

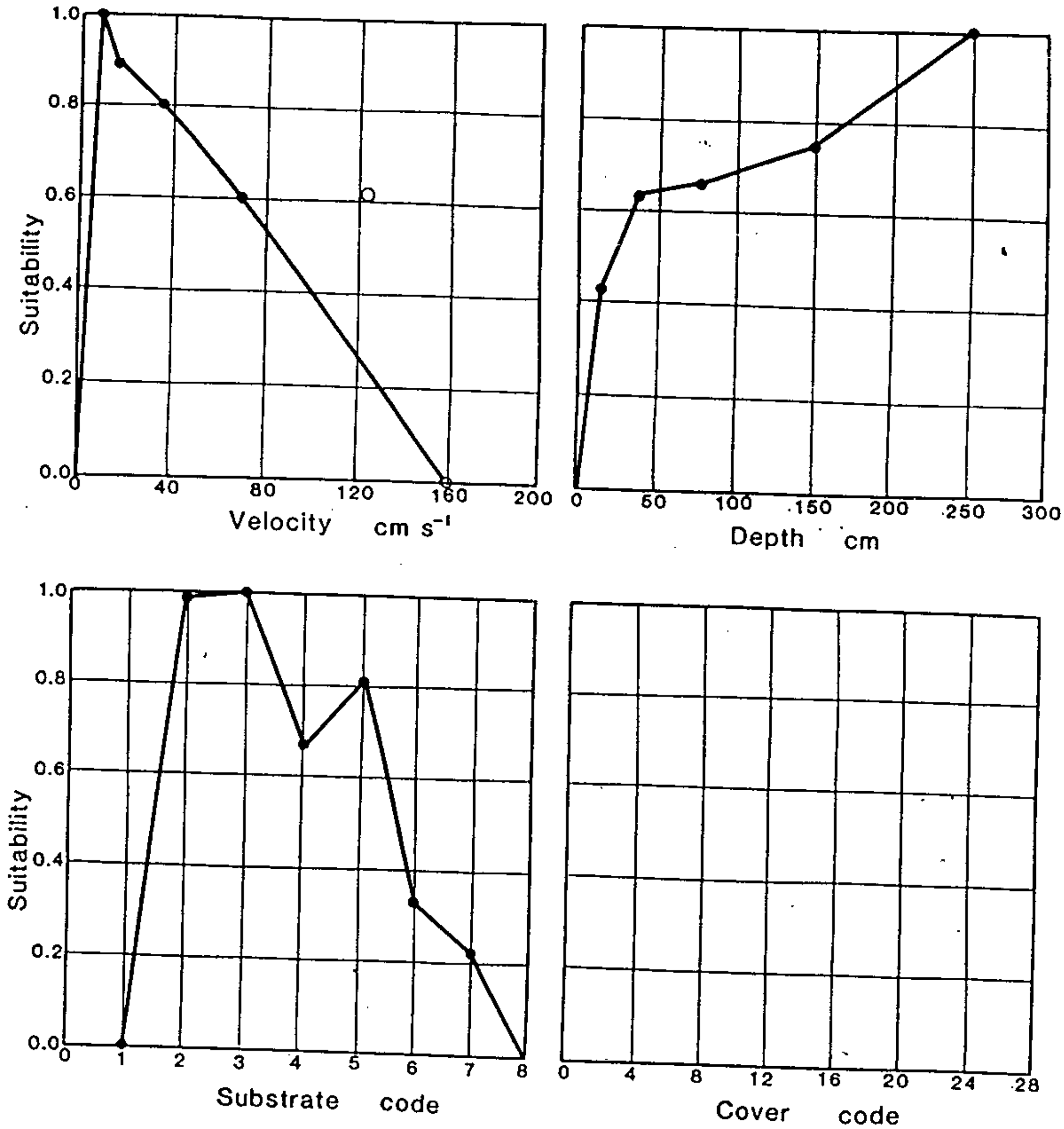


Fig. 5 Habitat suitability curves for Sphaerium corneum based on observed occurrence.

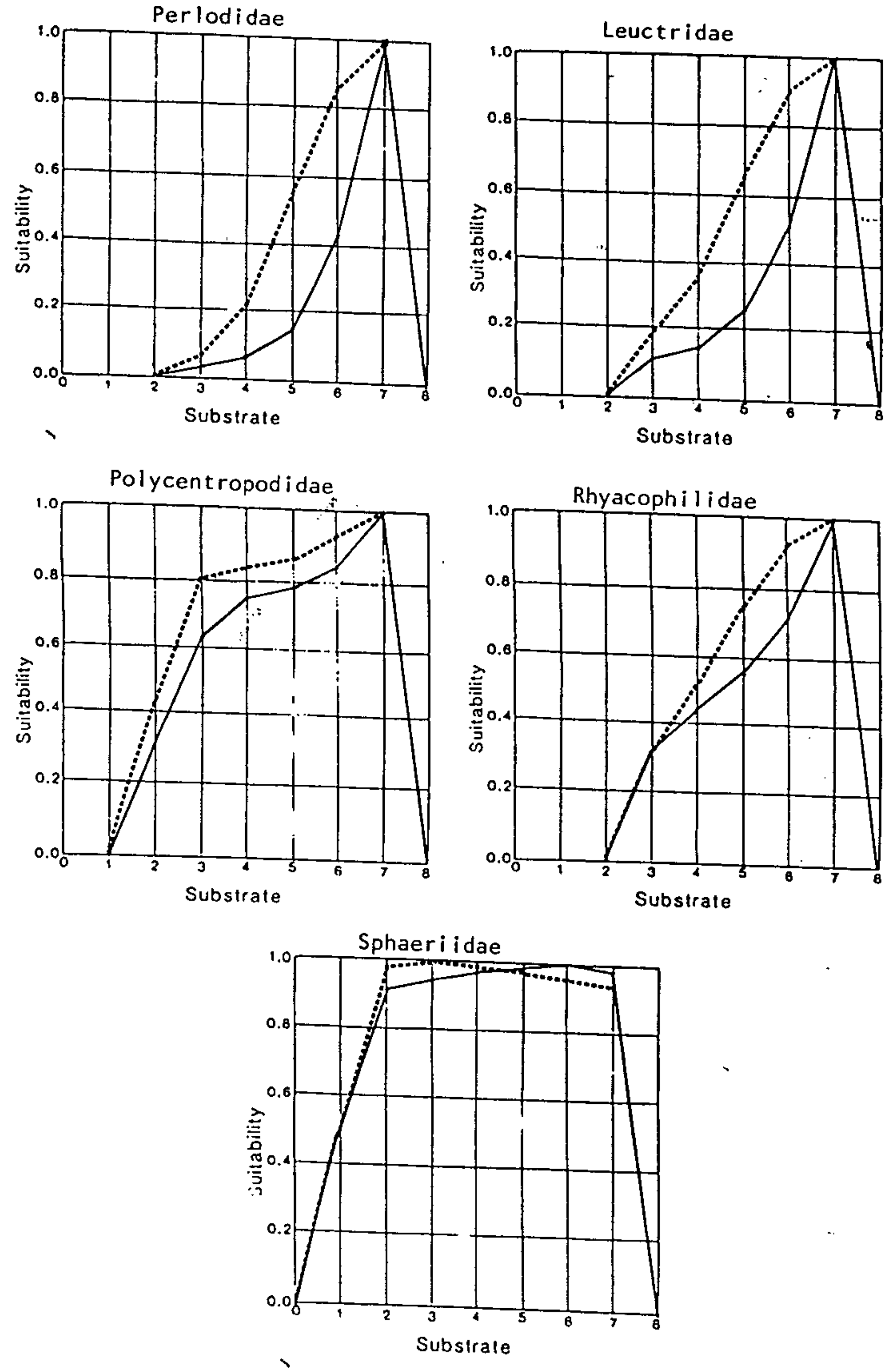


Fig. 6 Habitat suitability curves based on predictions of the probability of occurrence of selected families at two sites (——— Gwash, ------ Blithe) where a simulated substratum change is entered into the RIVPACS model. (See text for details.)

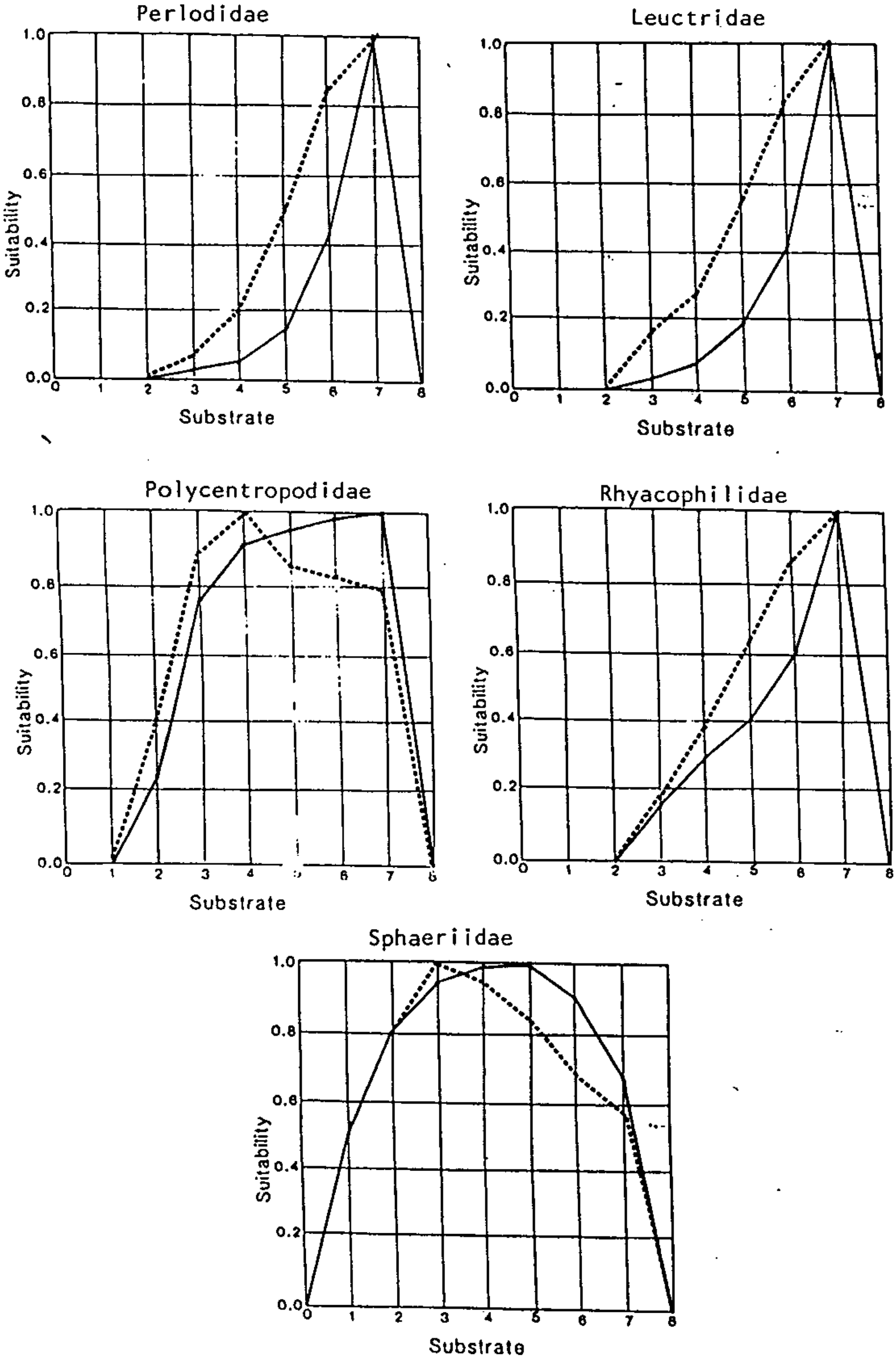


Fig. 7 Habitat suitability curves based on predictions of relative abundance of selected families at two sites (——— Gwash, ------ Blithe) where a simulated substratum change is entered into the RIVPACS model.

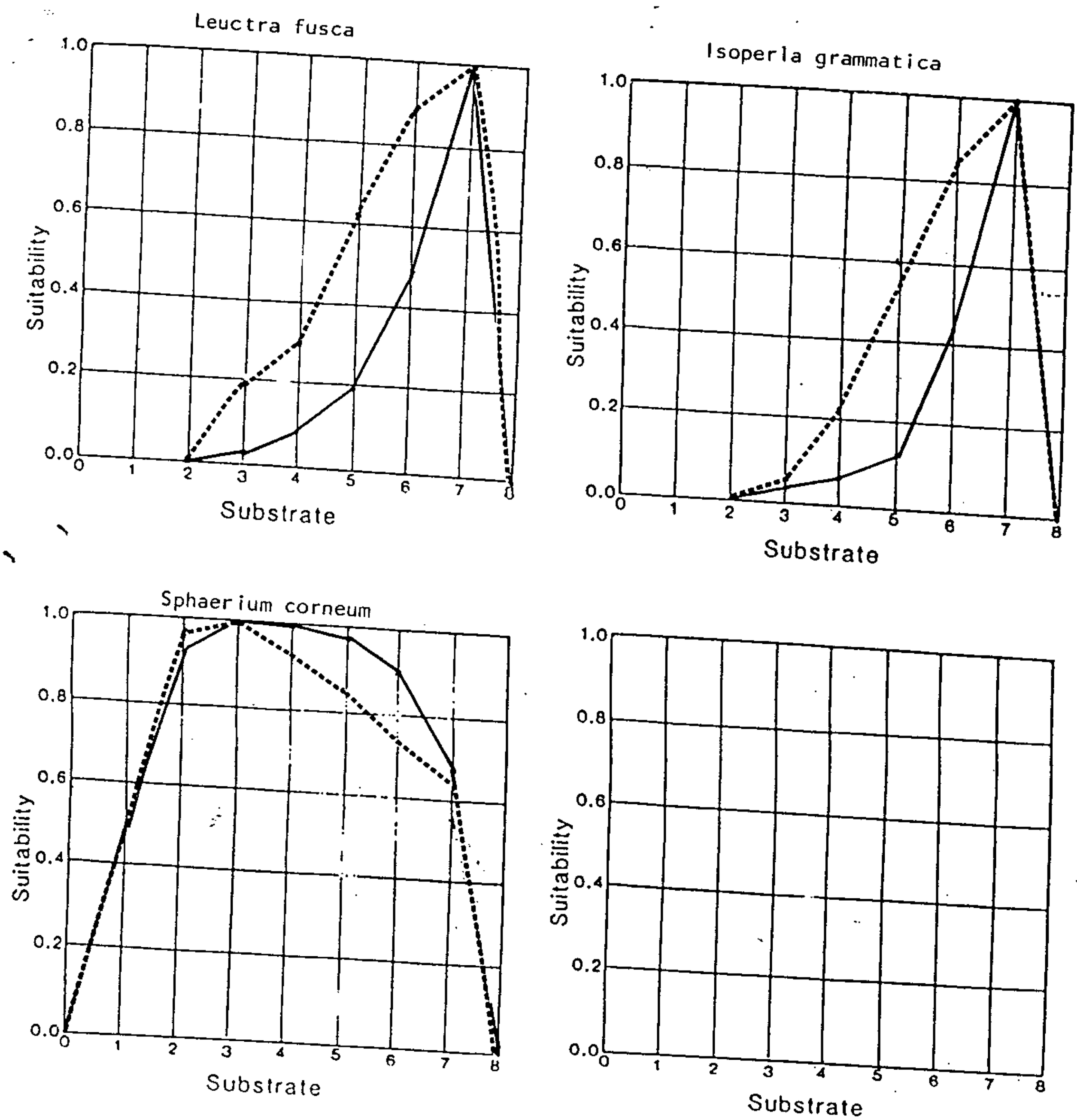


Fig. 8 Habitat suitability curves based on predictions of the probability of occurrence of 3 species of invertebrate at 2 sites (——— Gwash, ------ Blithe) where a simulated substratum change is entered into the RIVPACS model. (See text for details.)

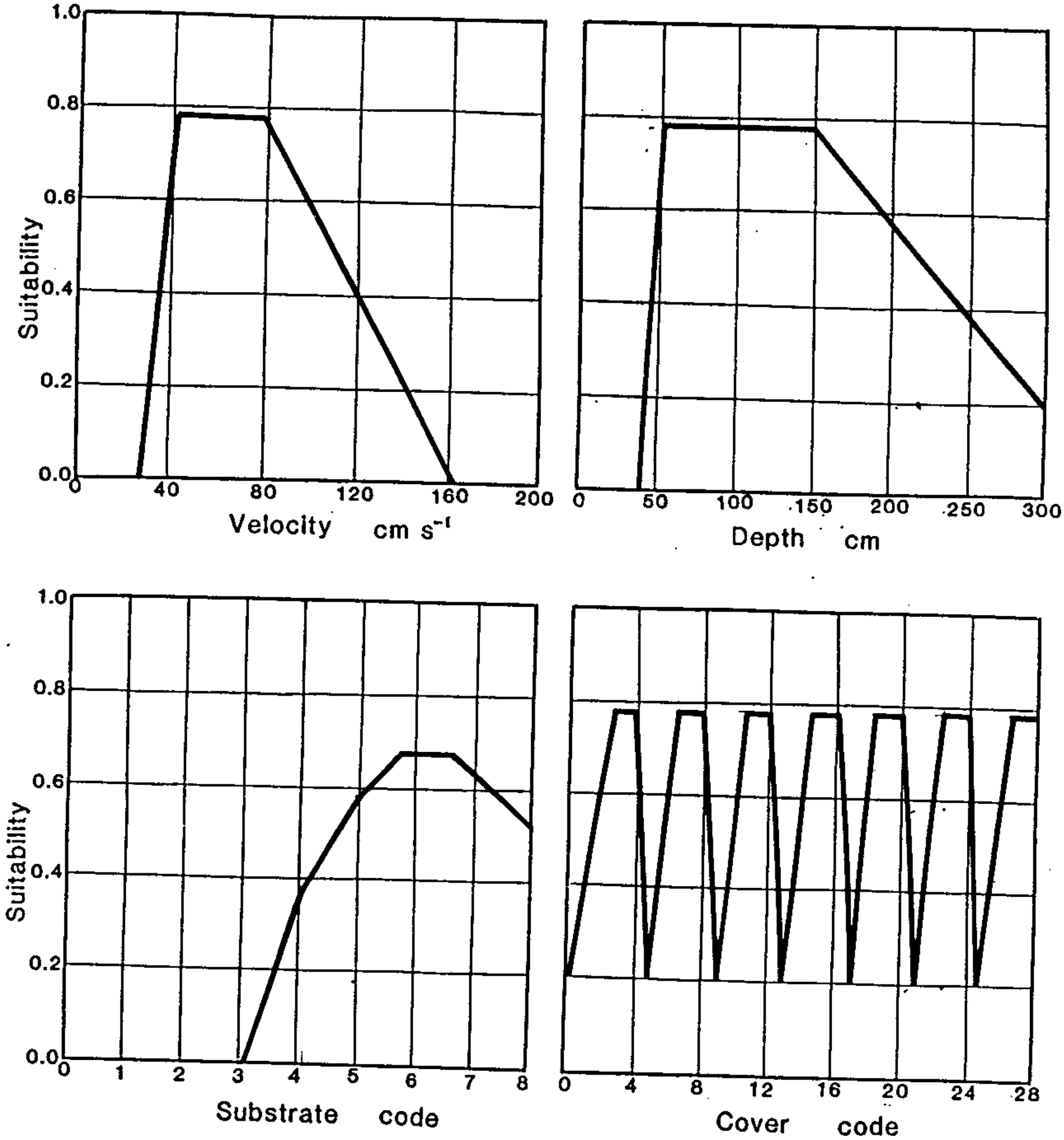


Fig. 9 Possible PHABSIM suitability curves for adult brown trout.

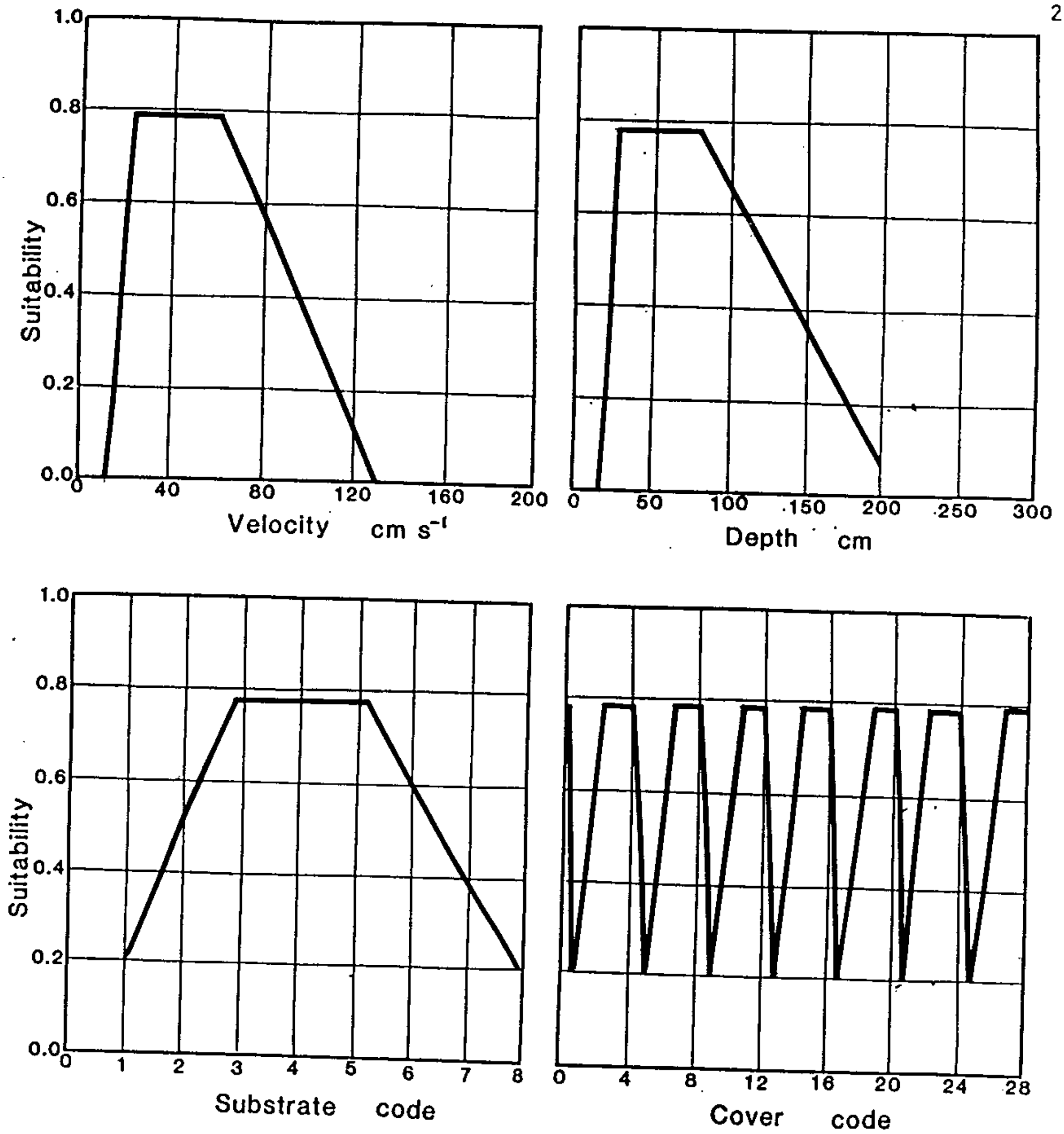


Fig. 10 PHABSIM suitability curves for juvenile brown trout.

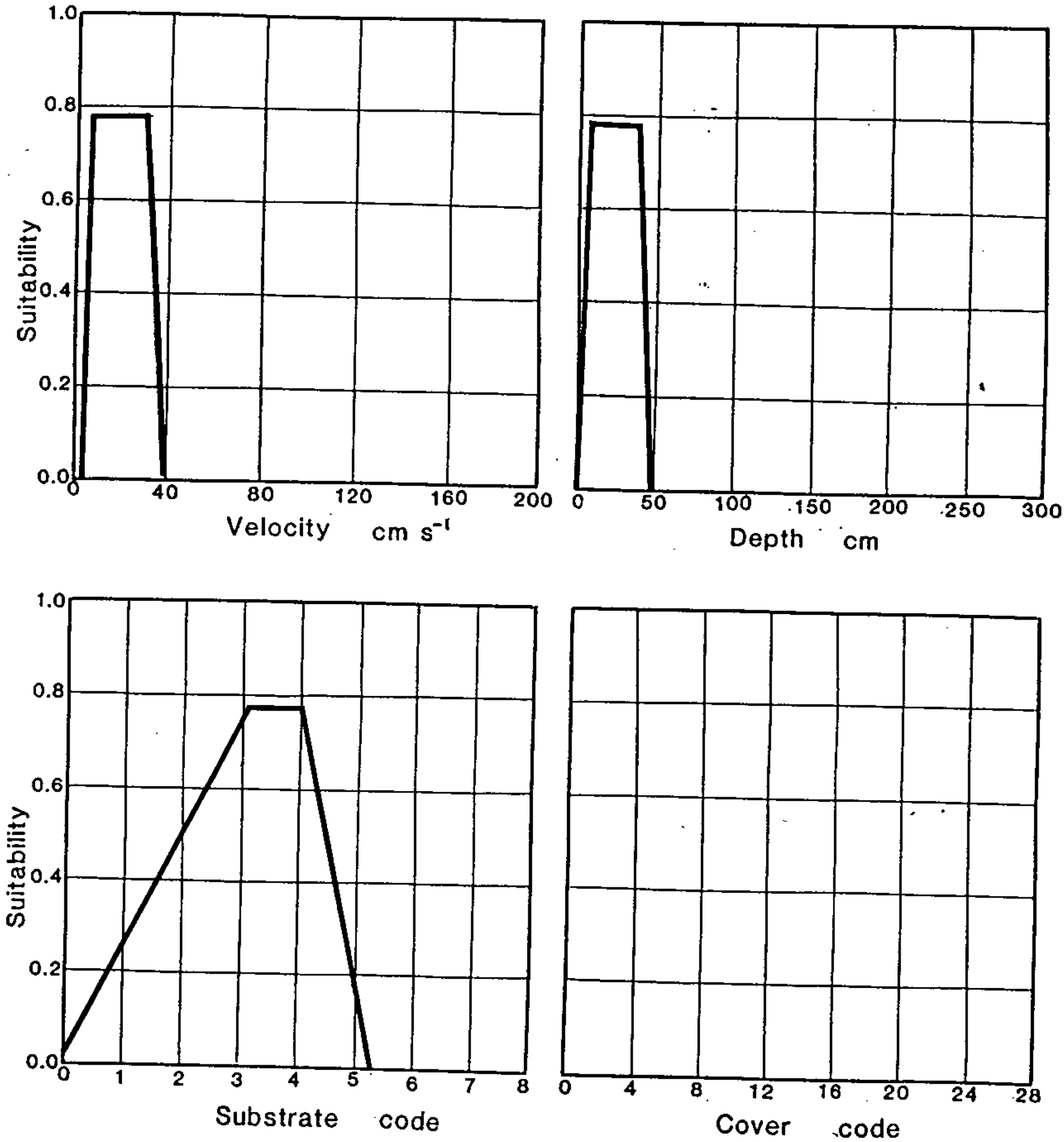


Fig. 11 PHABSIM suitability curves for brown trout fry.

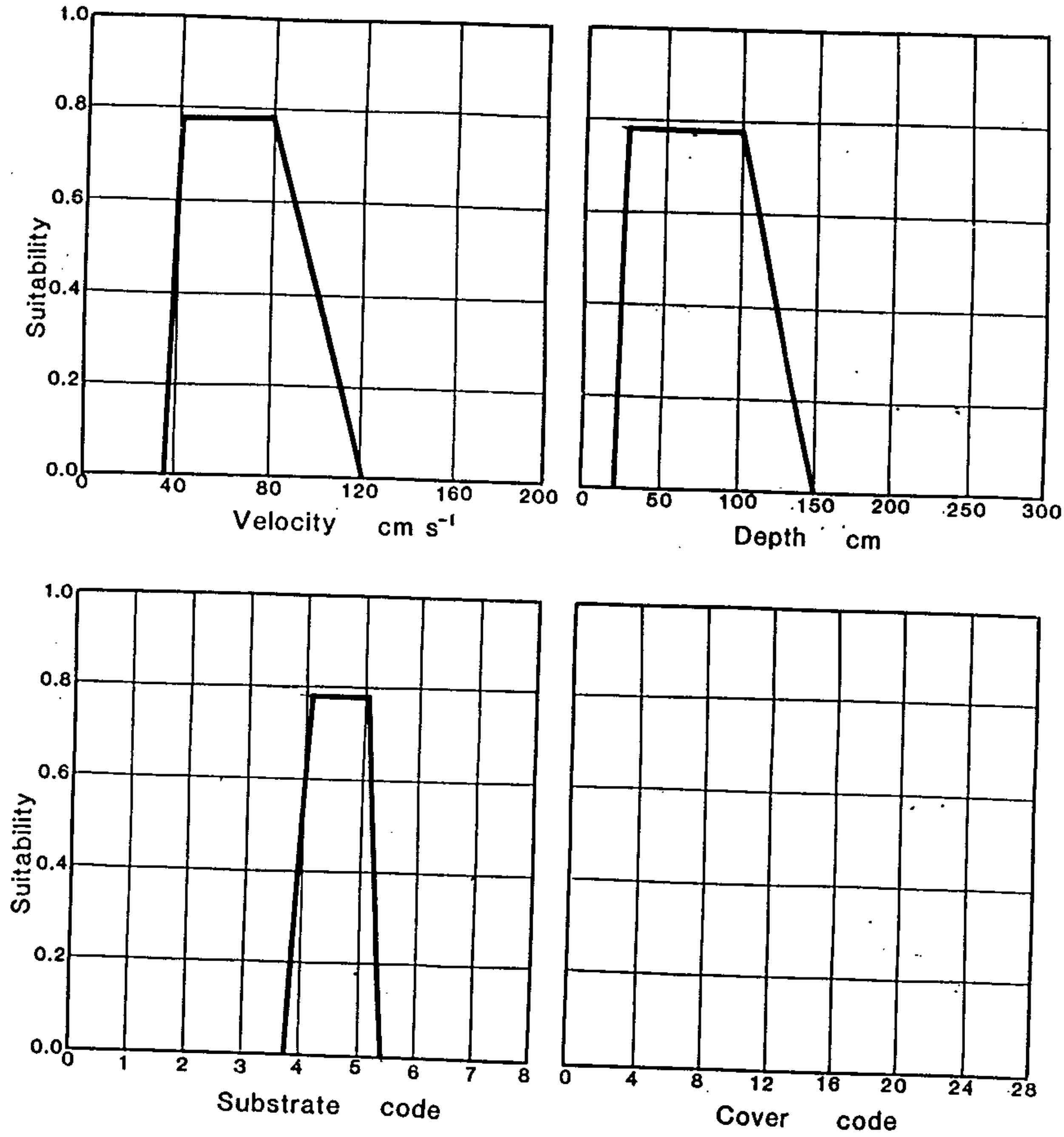


Fig. 12 PHABSIM suitability curves for brown trout spawning.

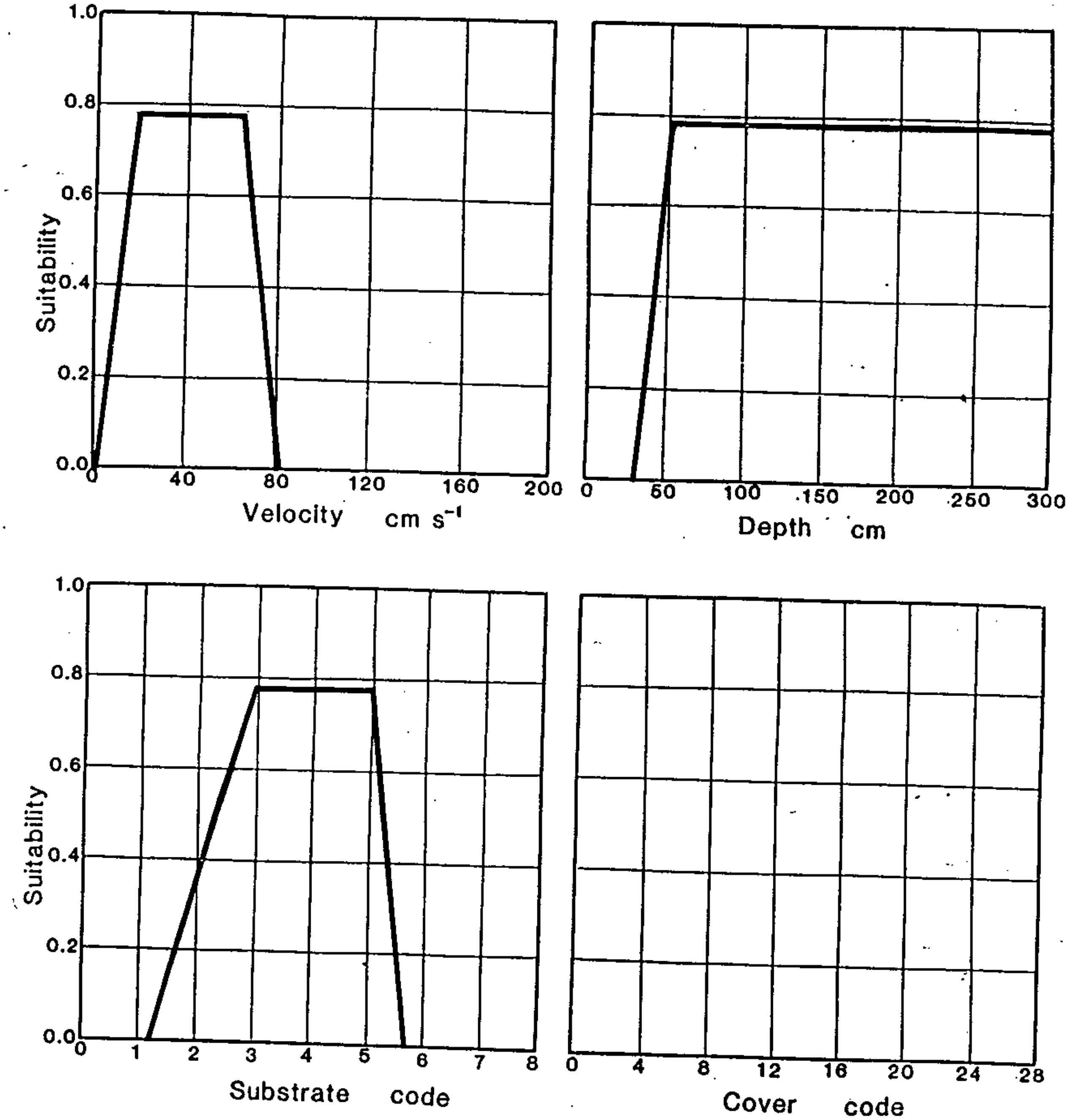


Fig. 13 PHABSIM suitability curves for adult grayling.

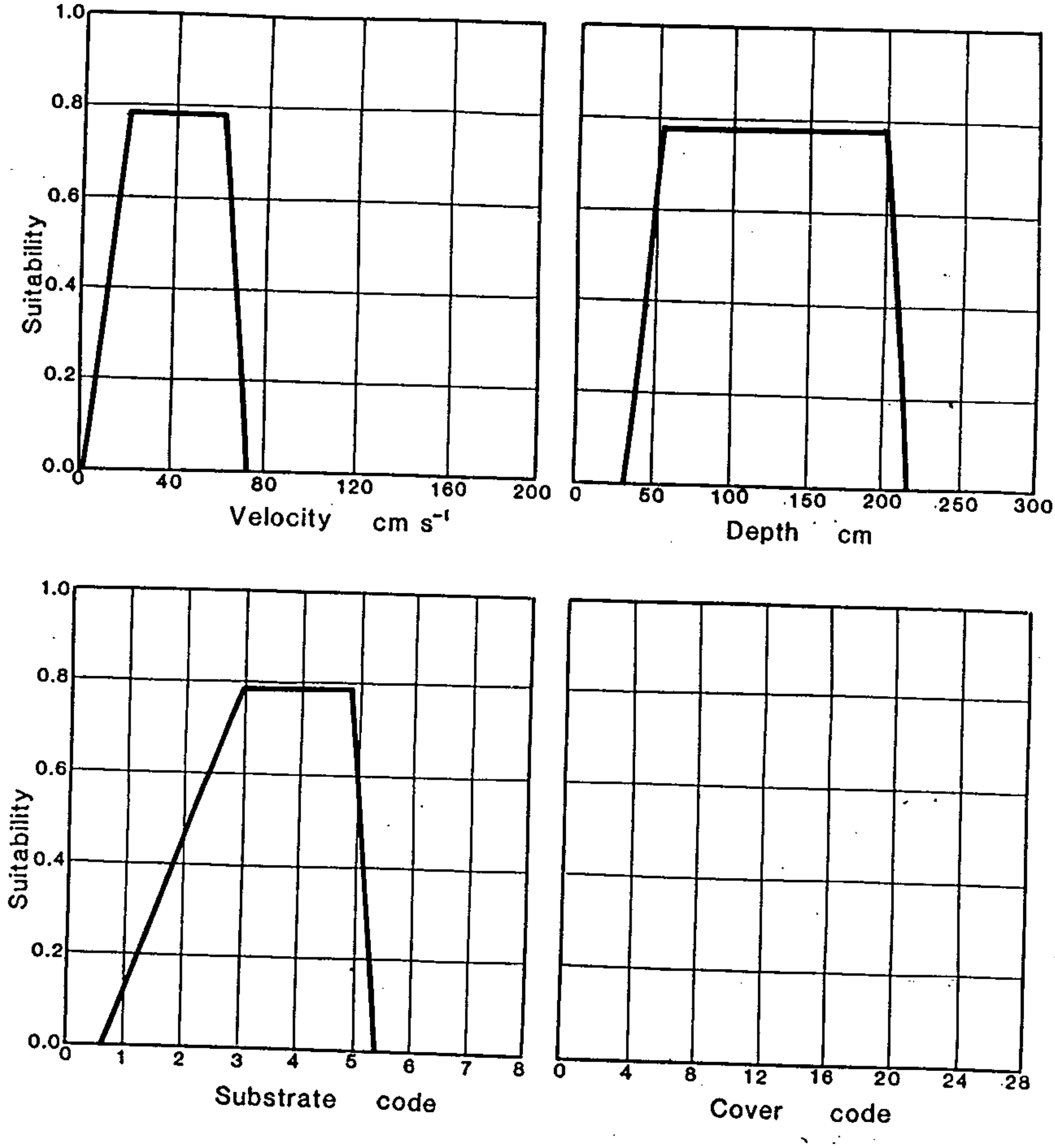


Fig. 14 PHABSIM suitability curves for juvenile grayling.

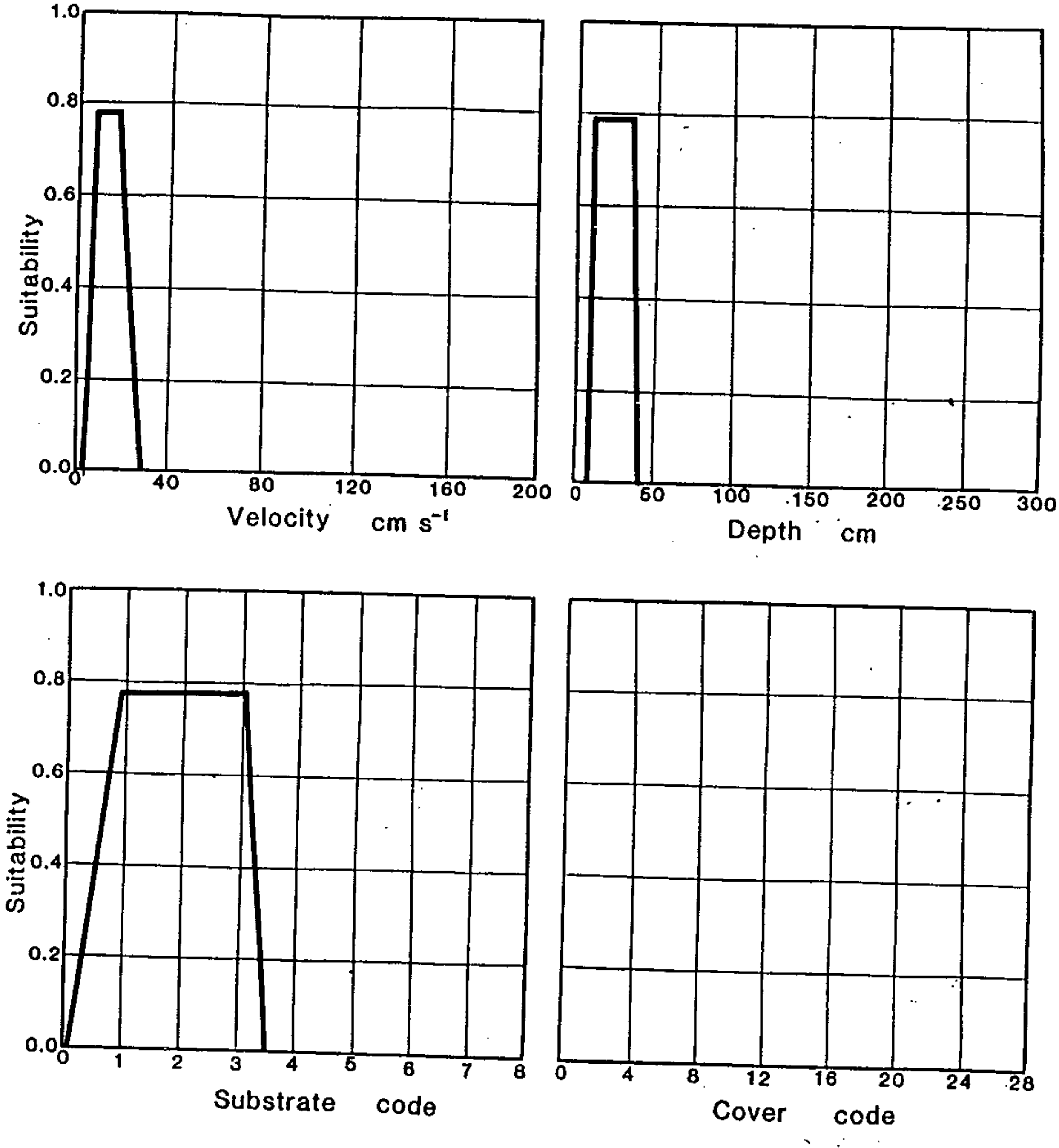


Fig. 15 PHABSIM suitability curves for grayling fry.

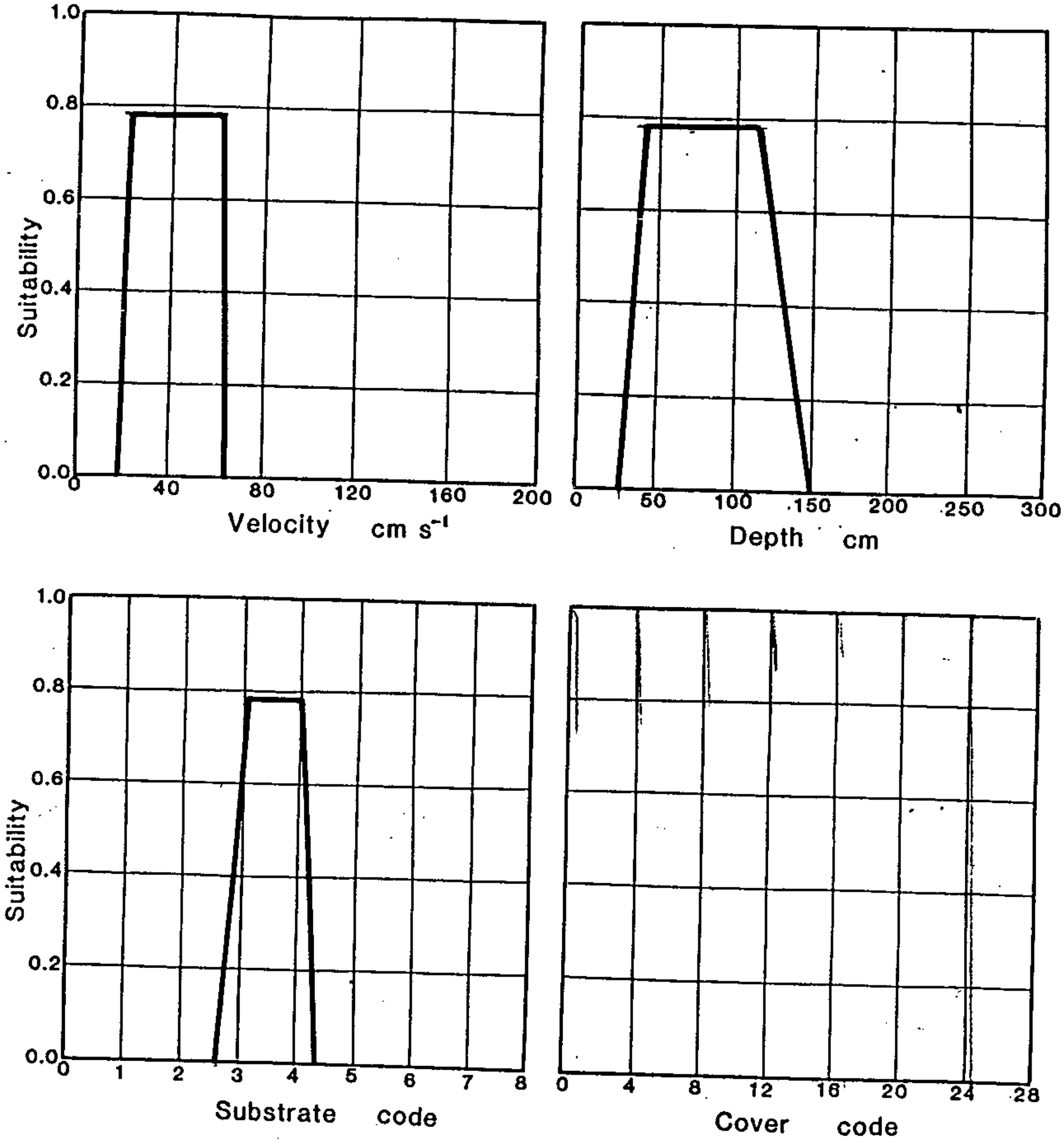


Fig. 16 PHABSIM suitability curves for grayling spawning.

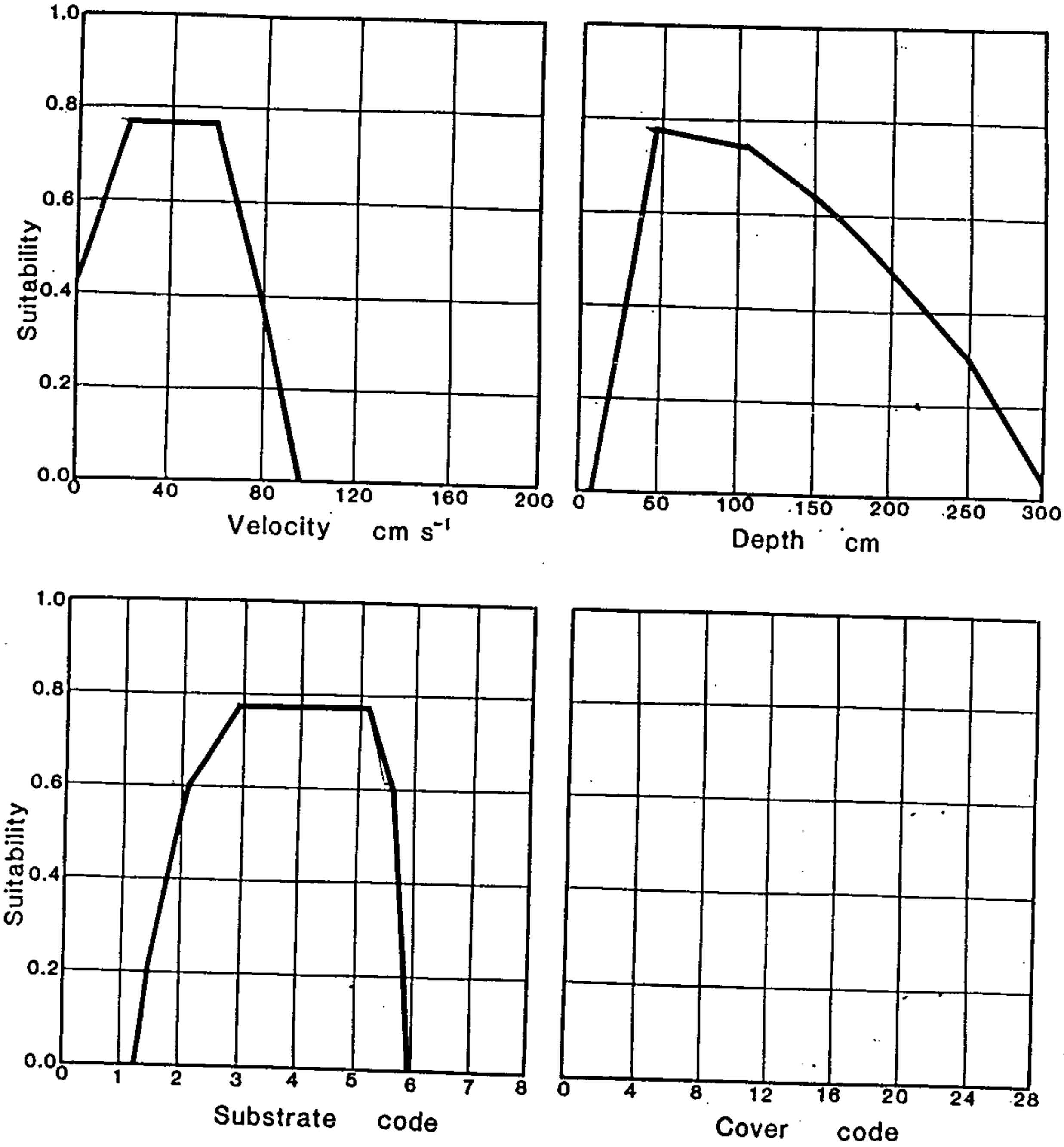


Fig. 17 PHABSIM suitability curves for adult dace.

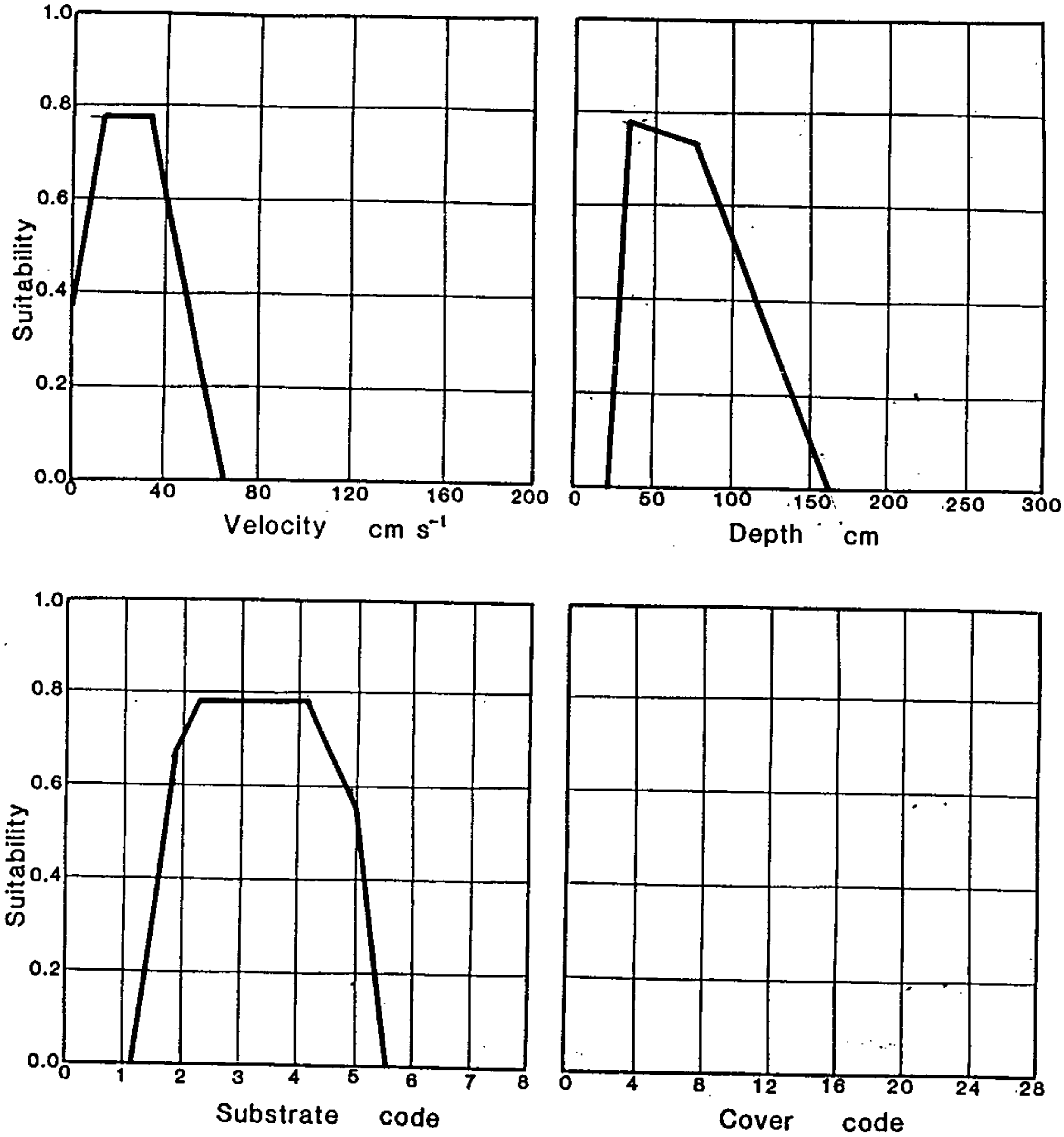


Fig. 18 PHABSIM suitability curves for juvenile dace.

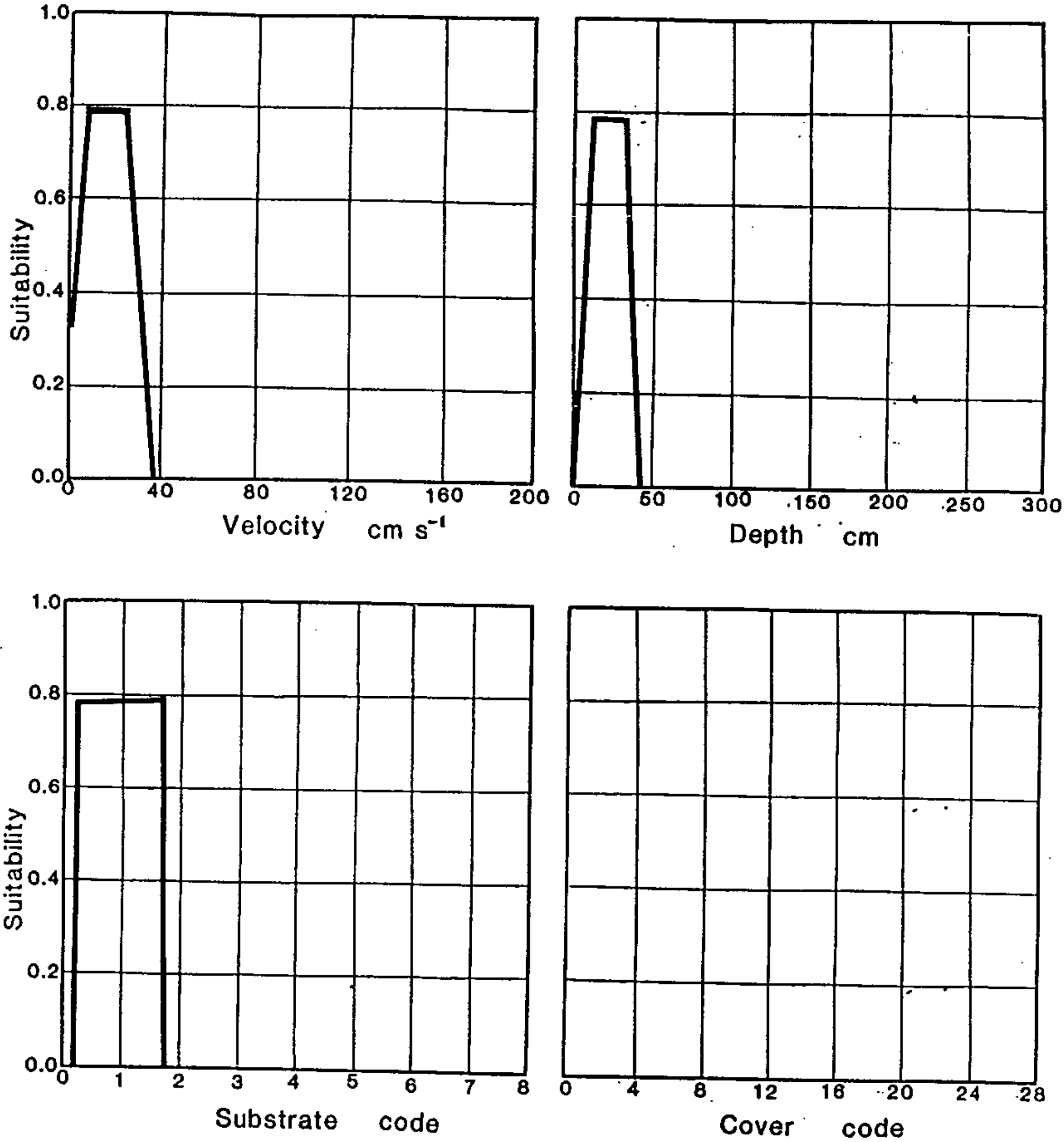


Fig. 19 PHABSIM suitability curves for dace fry.

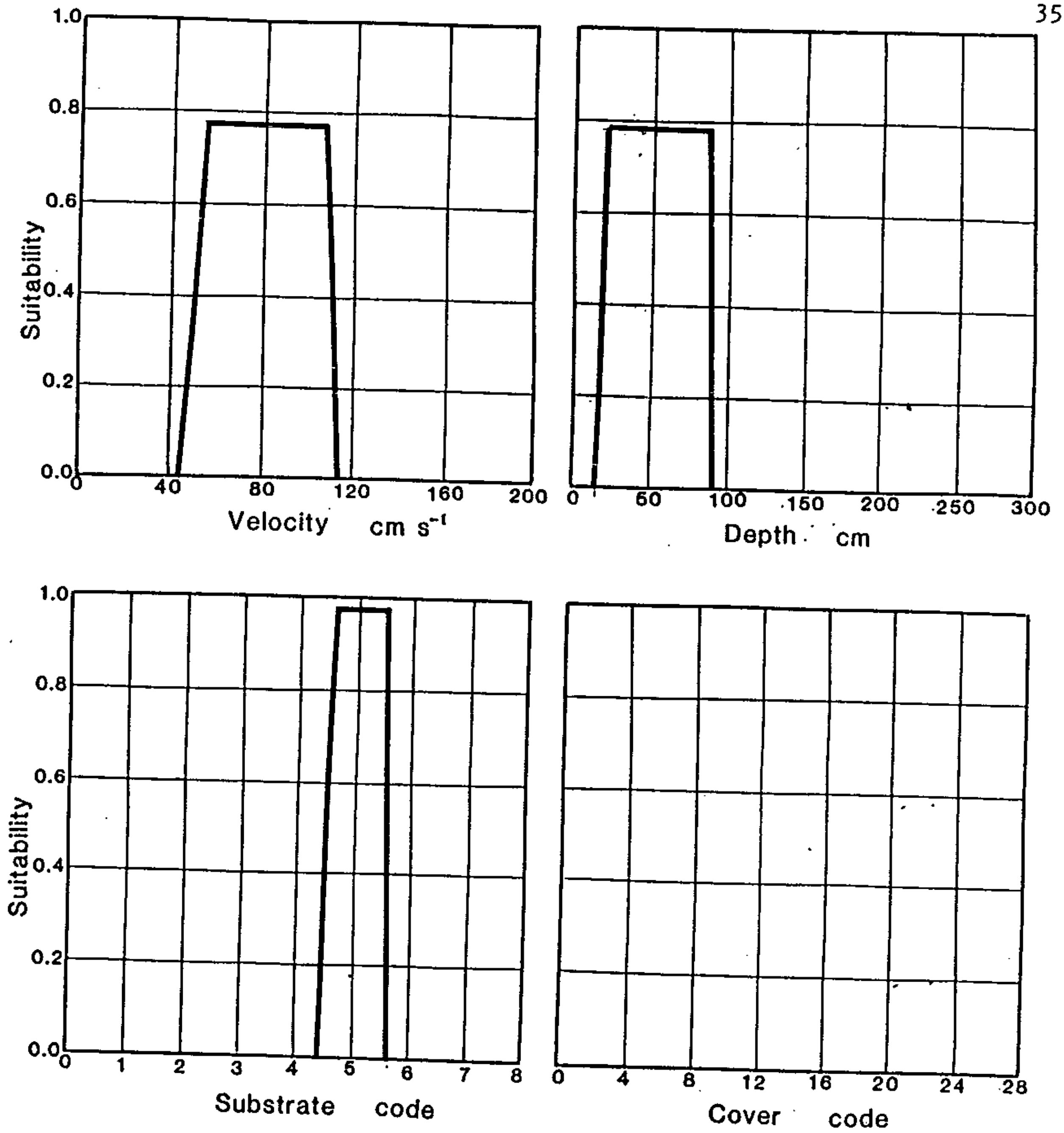


Fig. 20 PHABSIM suitability curves for dace spawning.

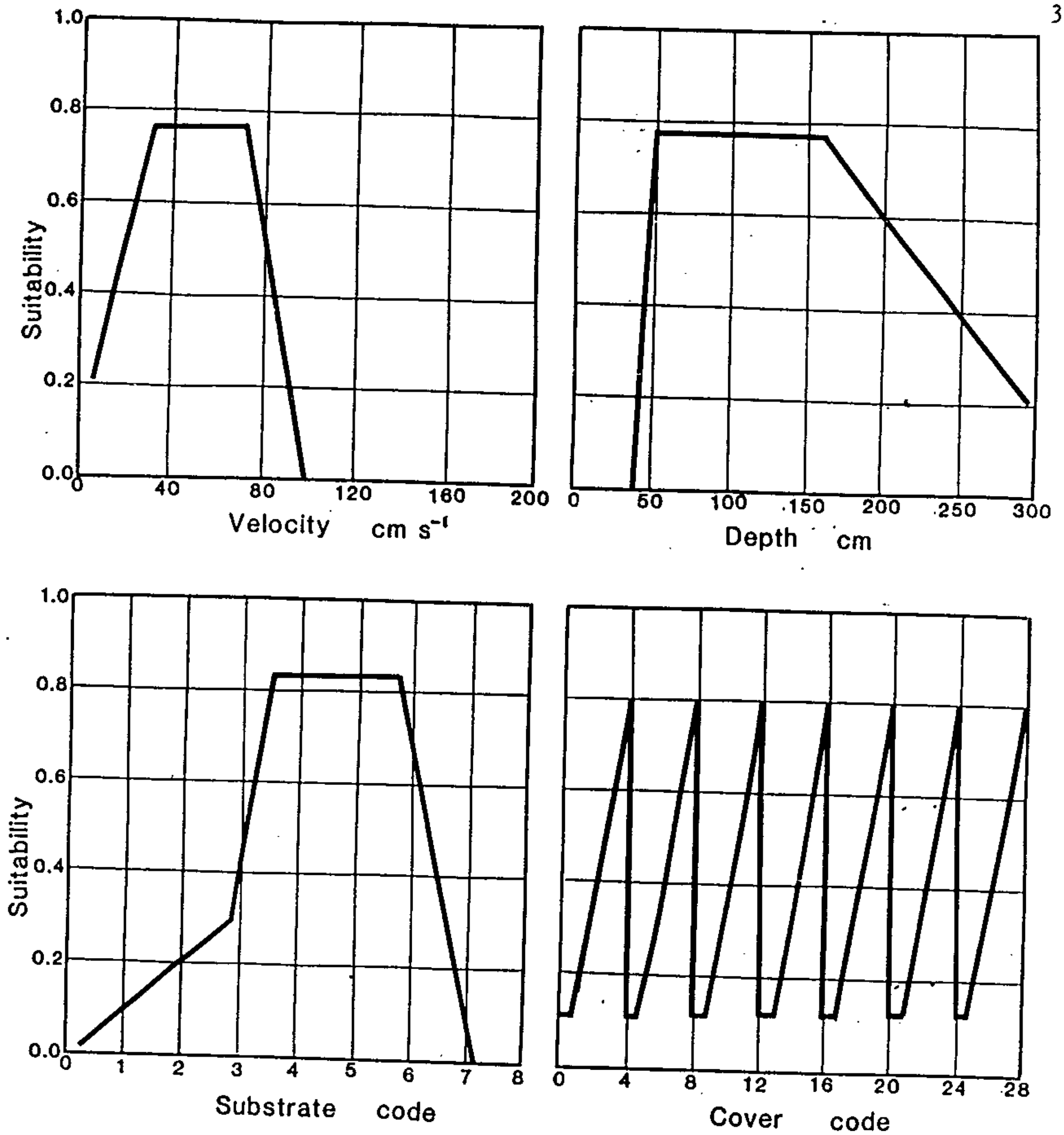


Fig. 21 PHABSIM suitability curves for adult and juvenile chub.

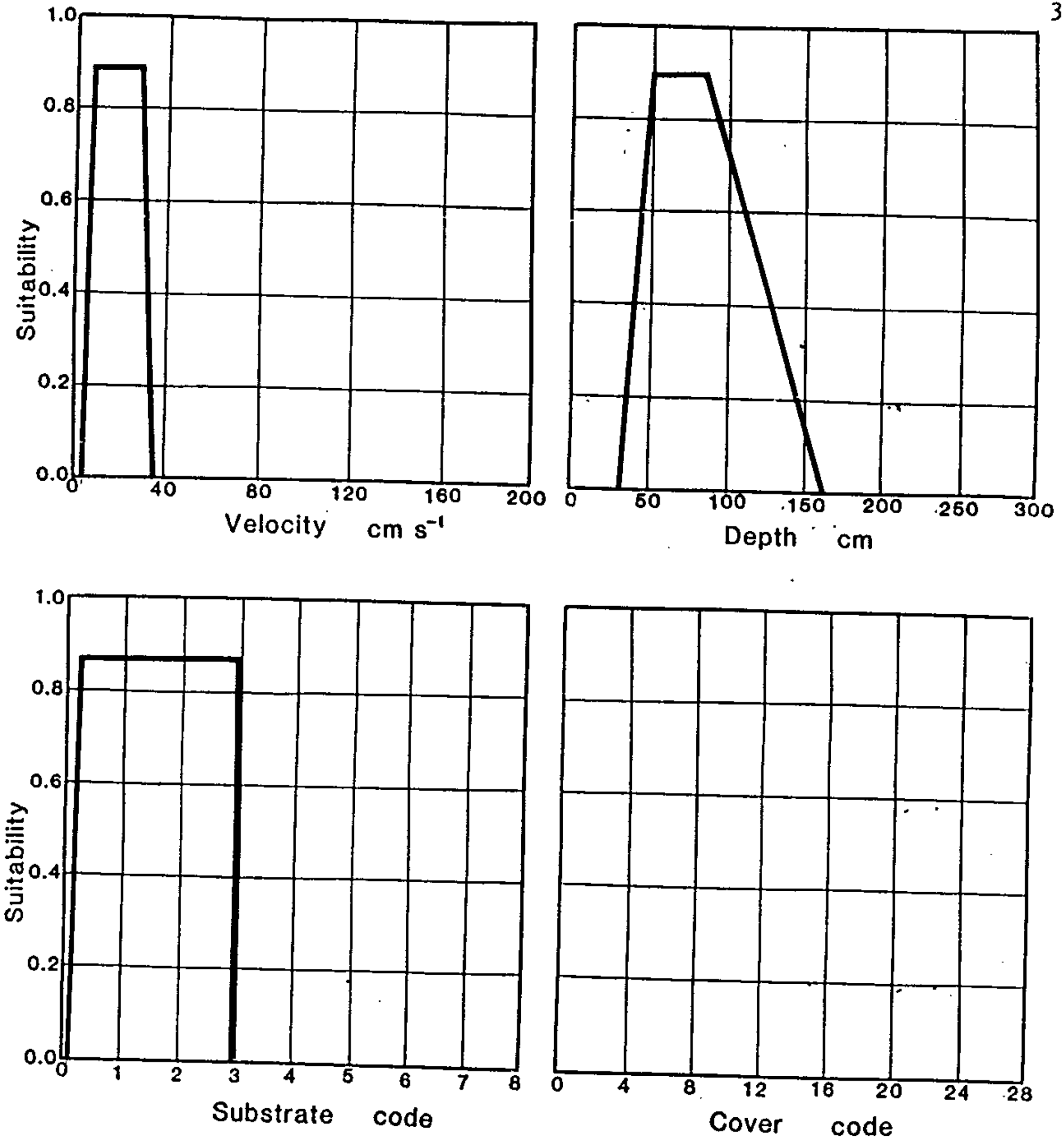


Fig. 22 PHABSIM suitability curves for chub fry.

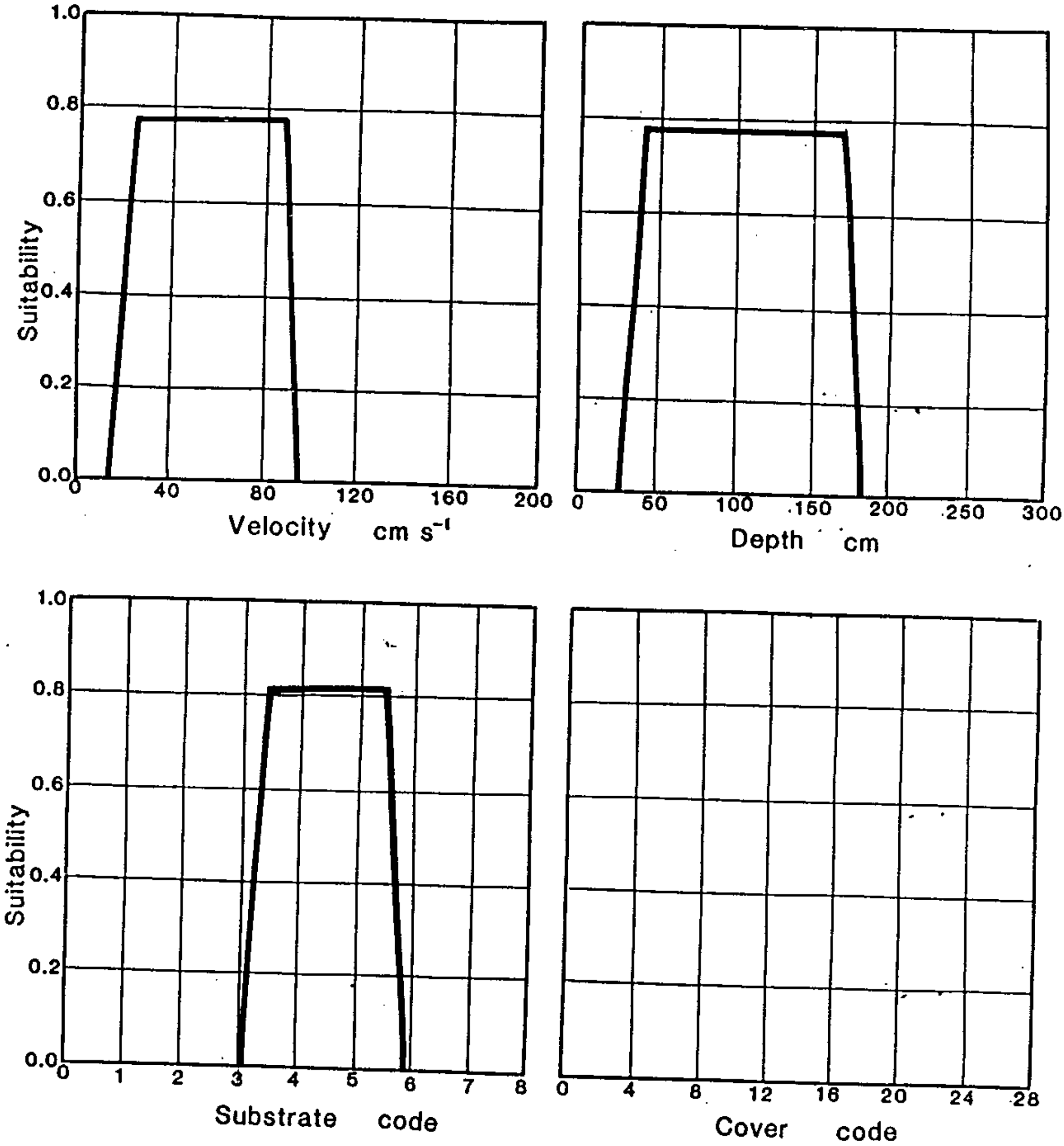


Fig. 23 PHABSIM suitability curves for chub spawning.

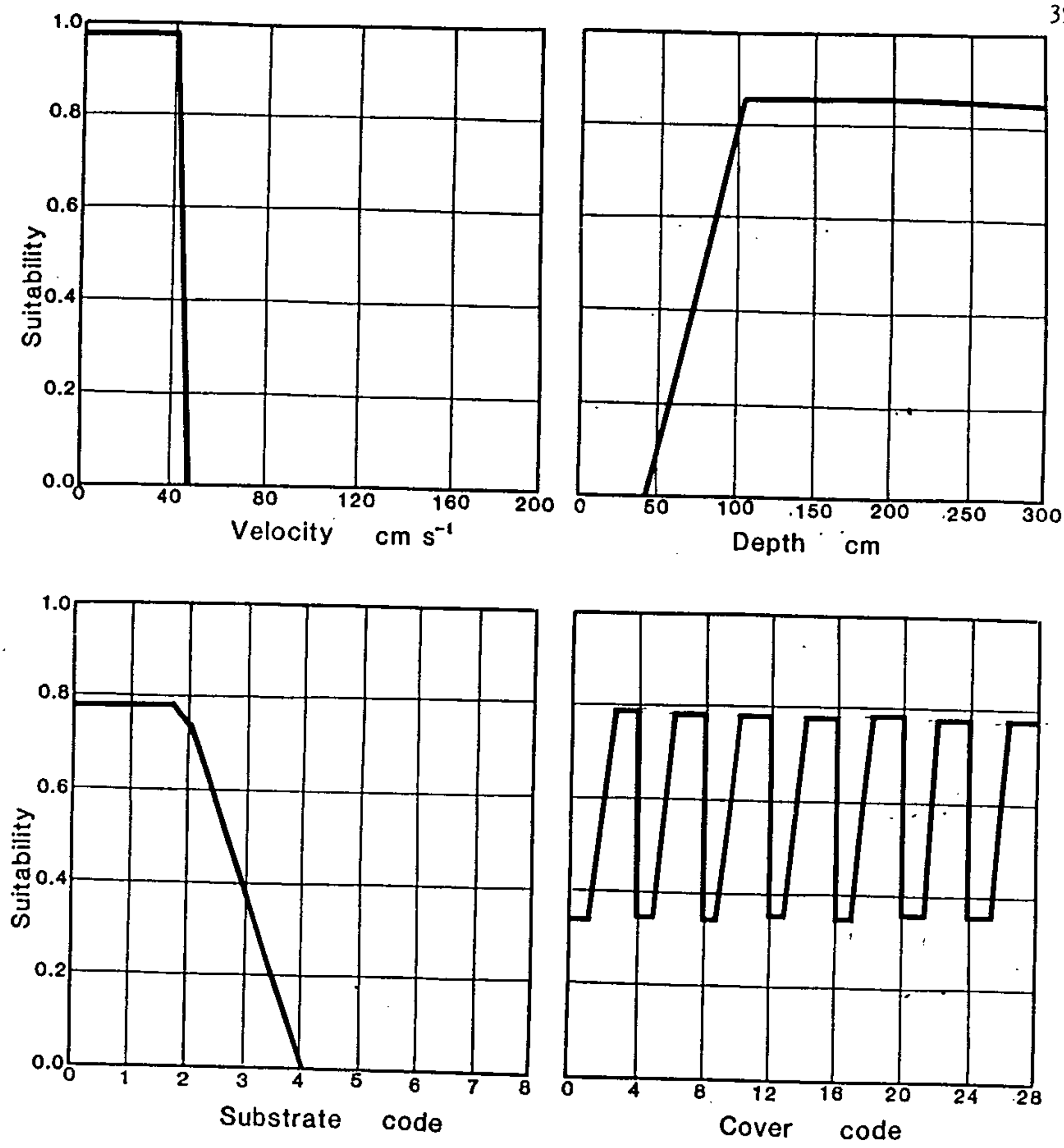


Fig. 24 PHABSIM suitability curves for adult and juvenile roach.

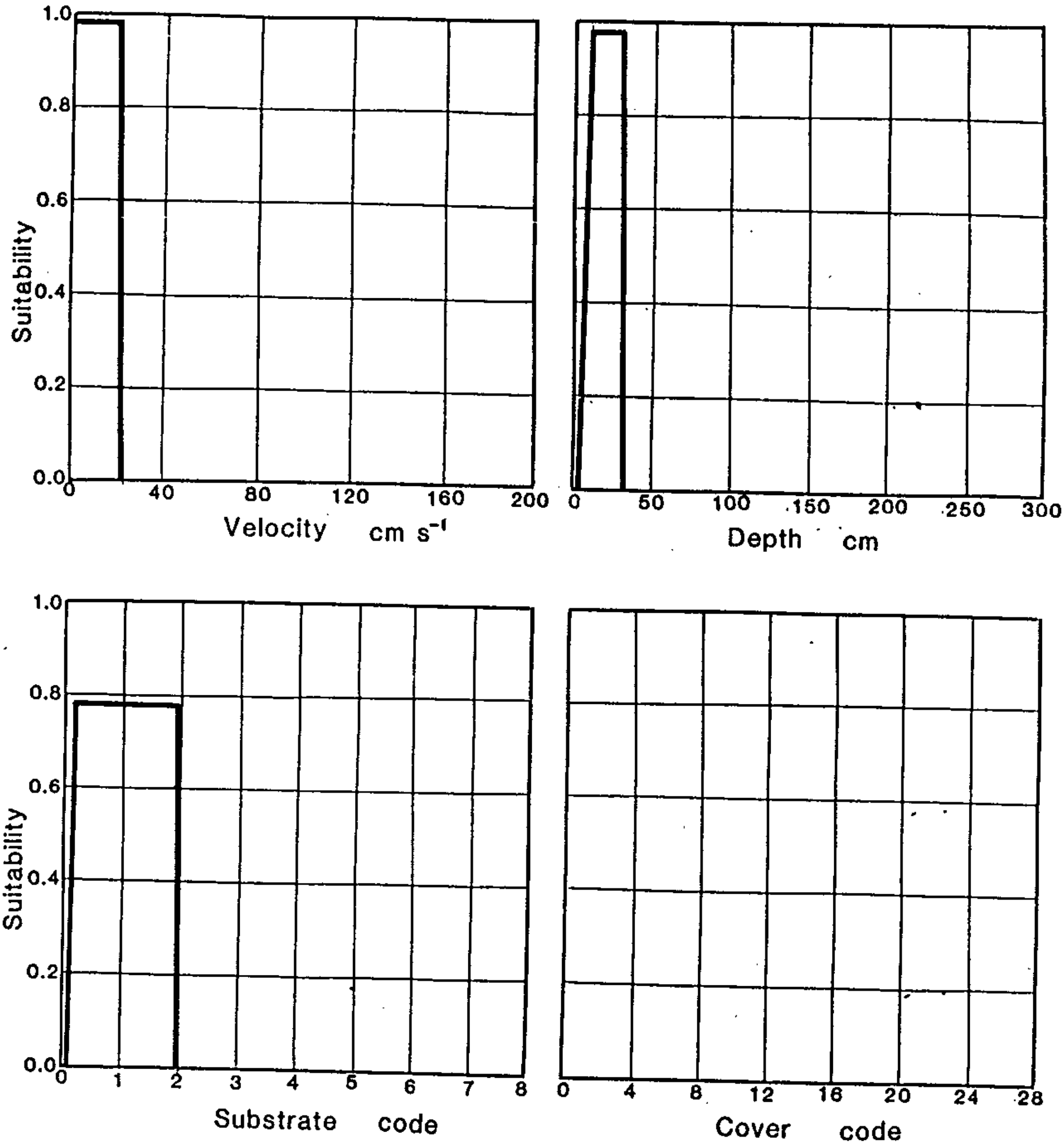


Fig. 25 PHABSIM suitability curves for roach fry.

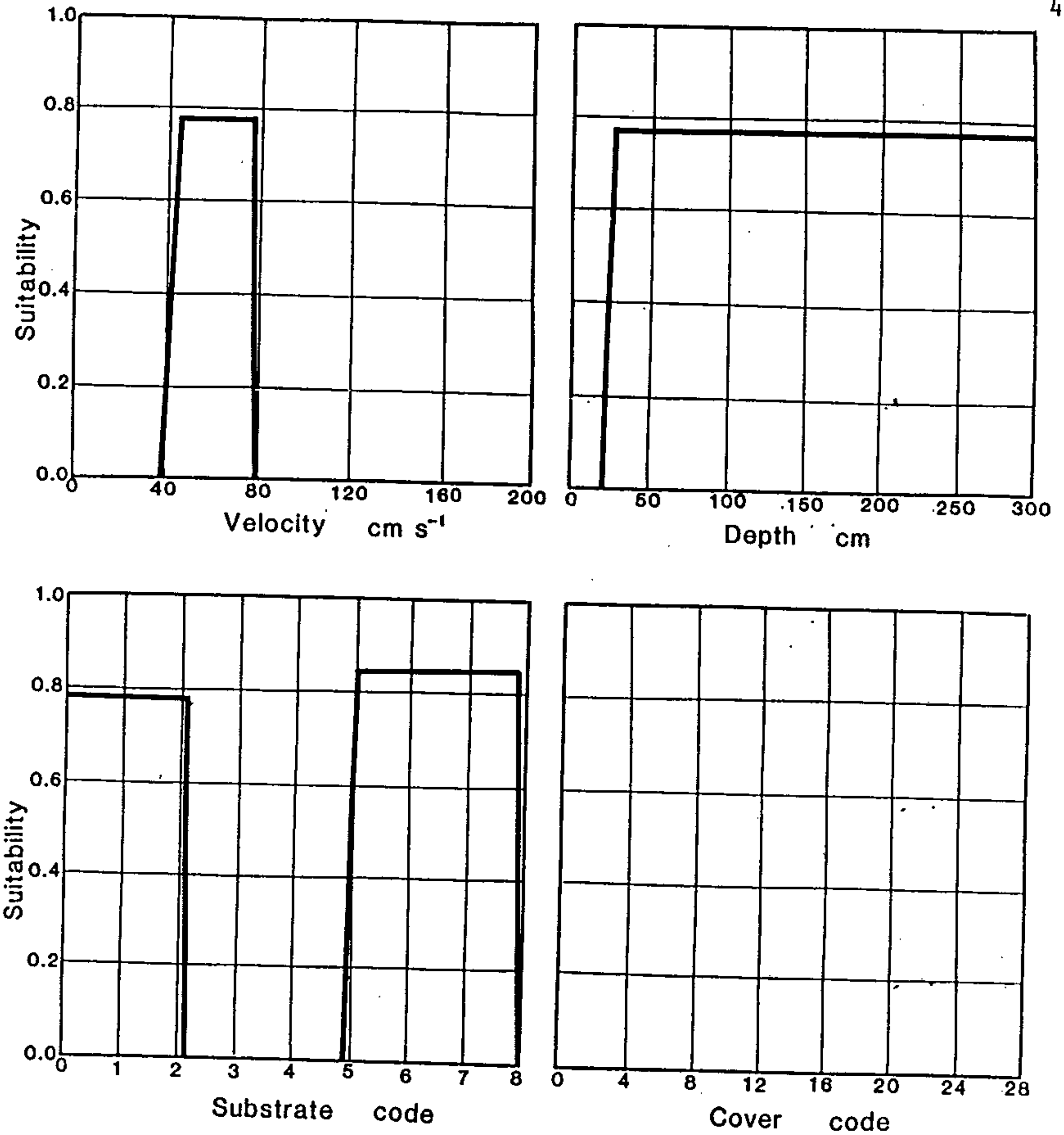


Fig. 26 PHABSIM suitability curves for roach spawning.

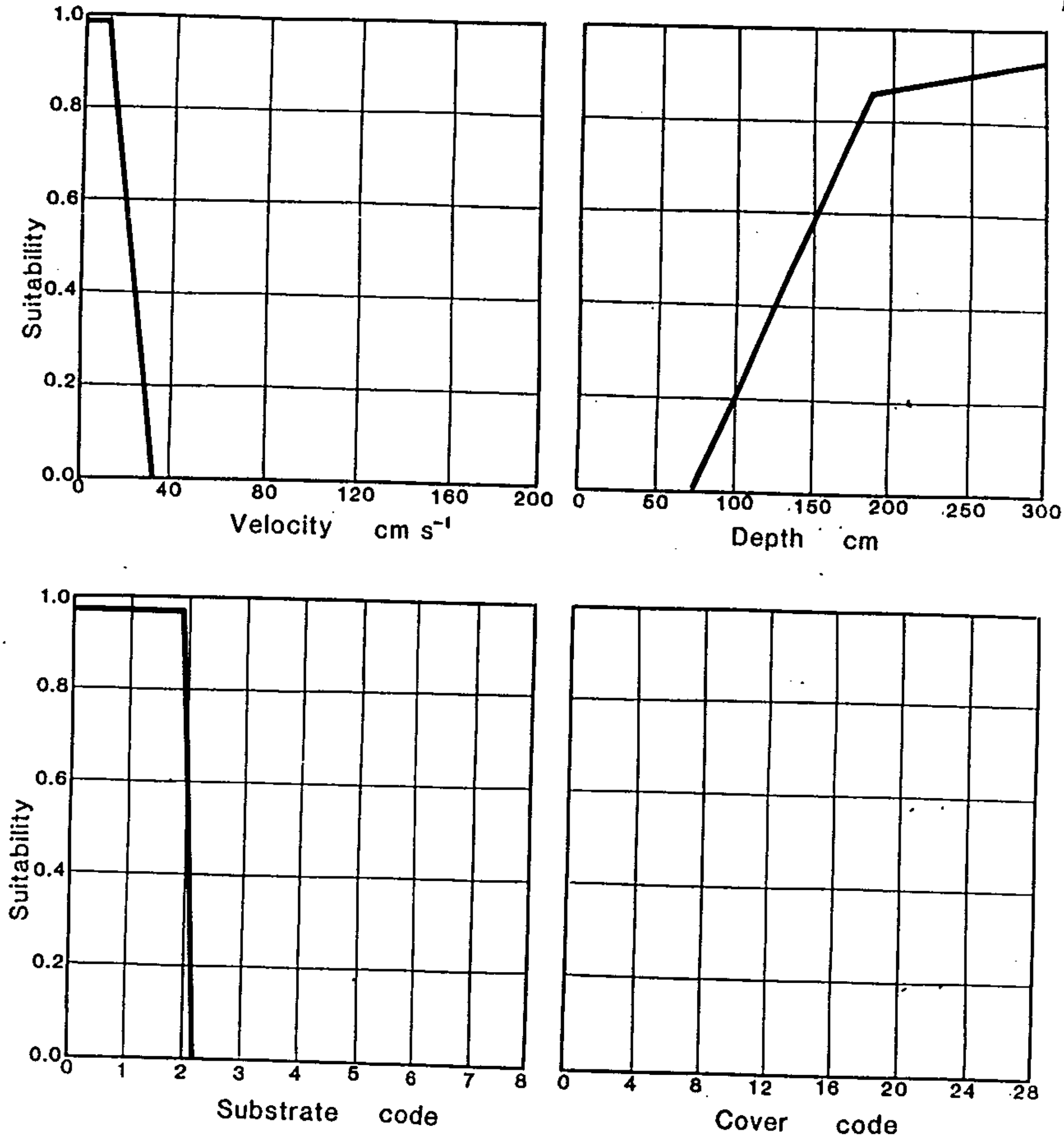


Fig. 27 PHABSIM suitability curves for adult bream.

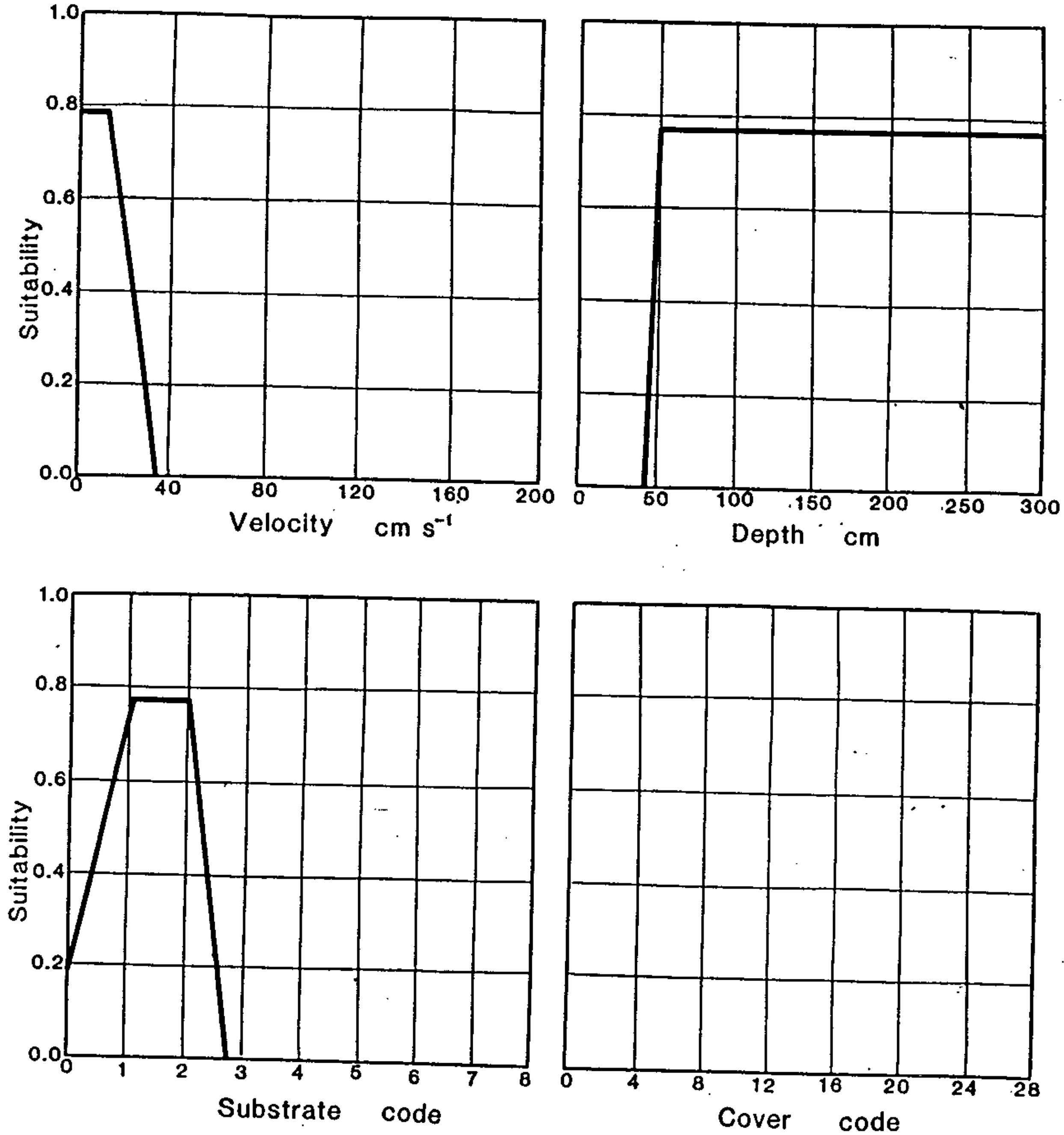


Fig. 28 PHABSIM suitability curves for juvenile bream.

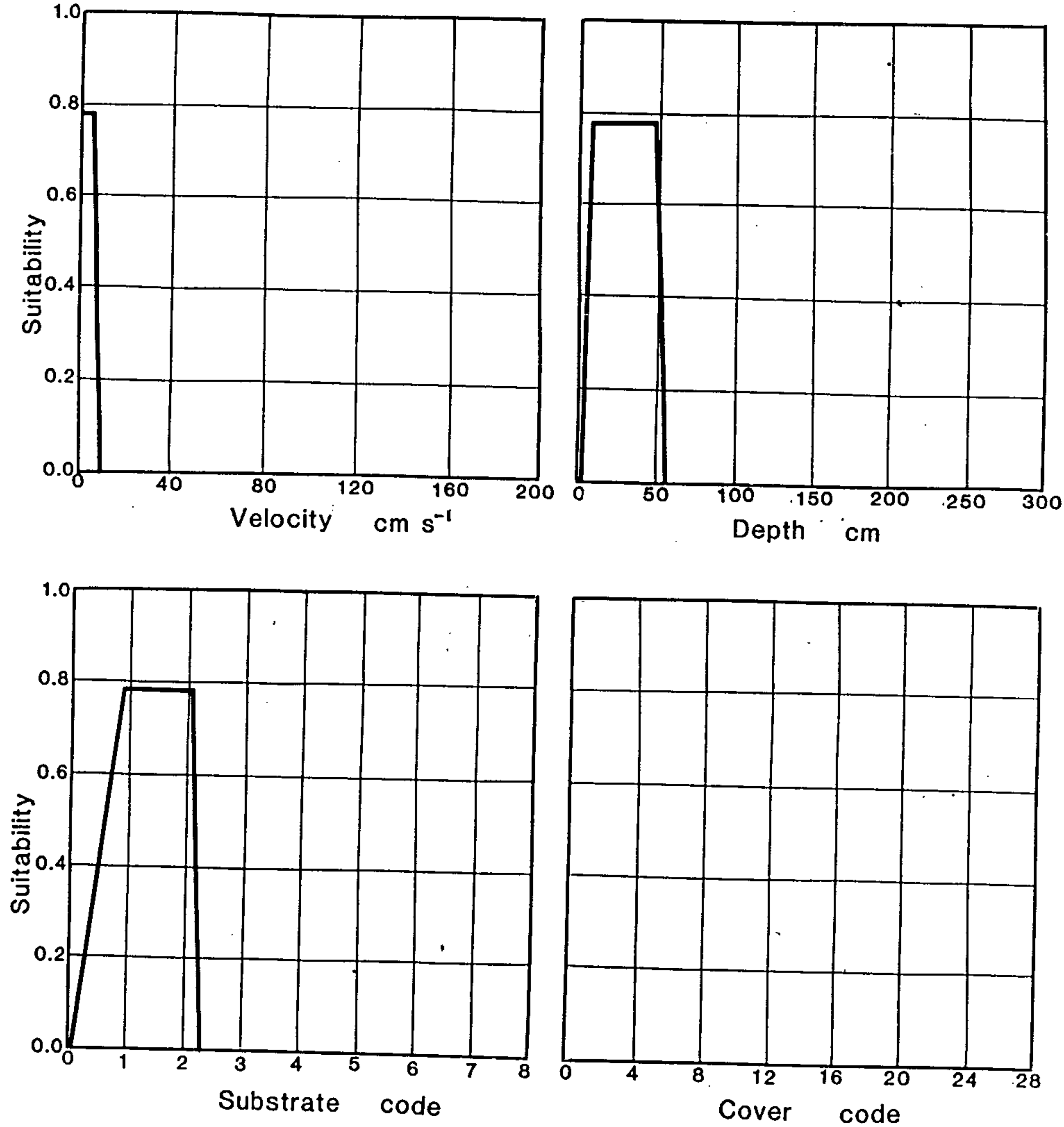


Fig. 29 PHABSIM suitability curves for bream fry.

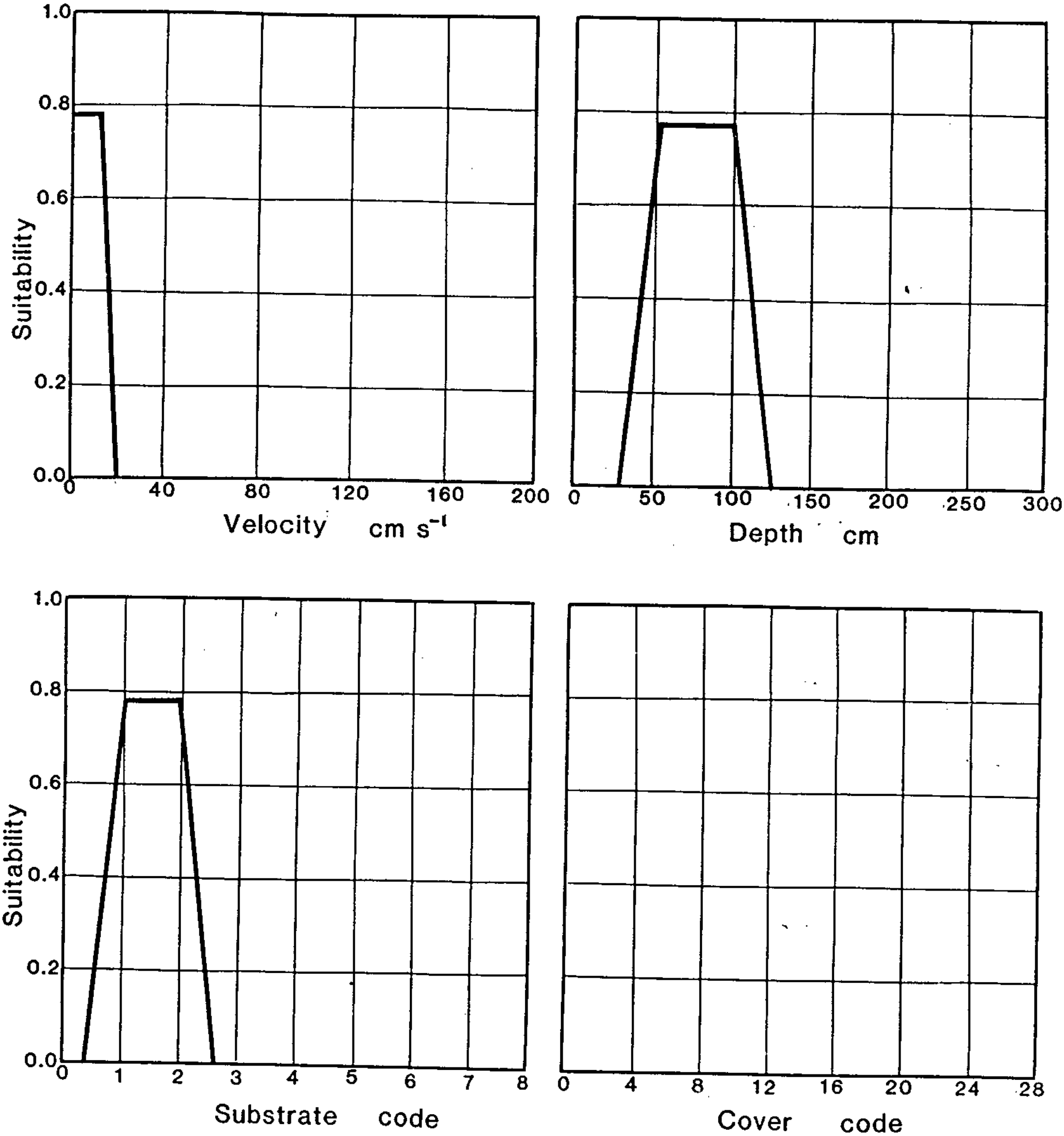


Fig. 30 PHABSIM suitability curves for bream spawning.

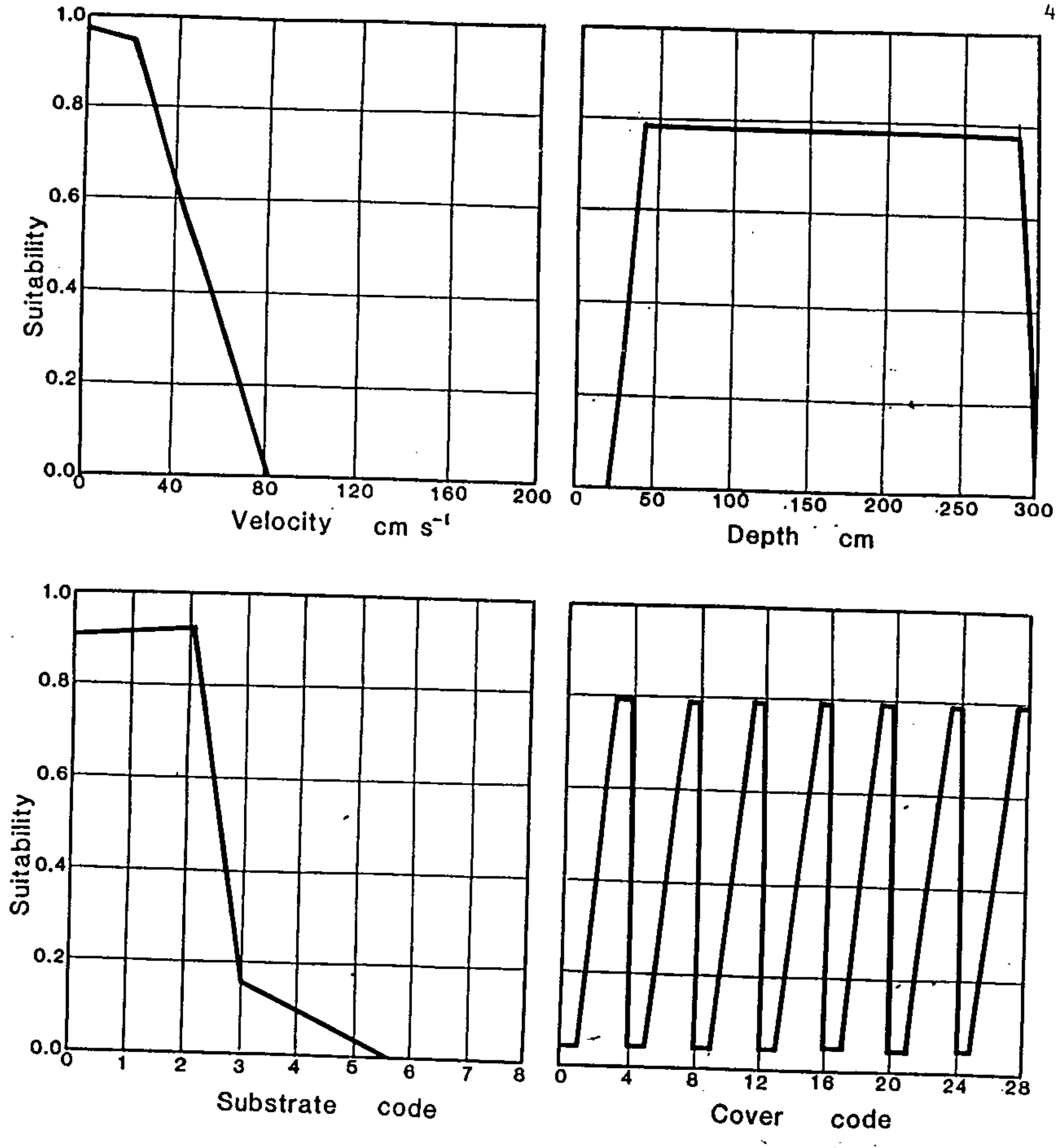


Fig. 31 PHABSIM suitability curves for adult pike.

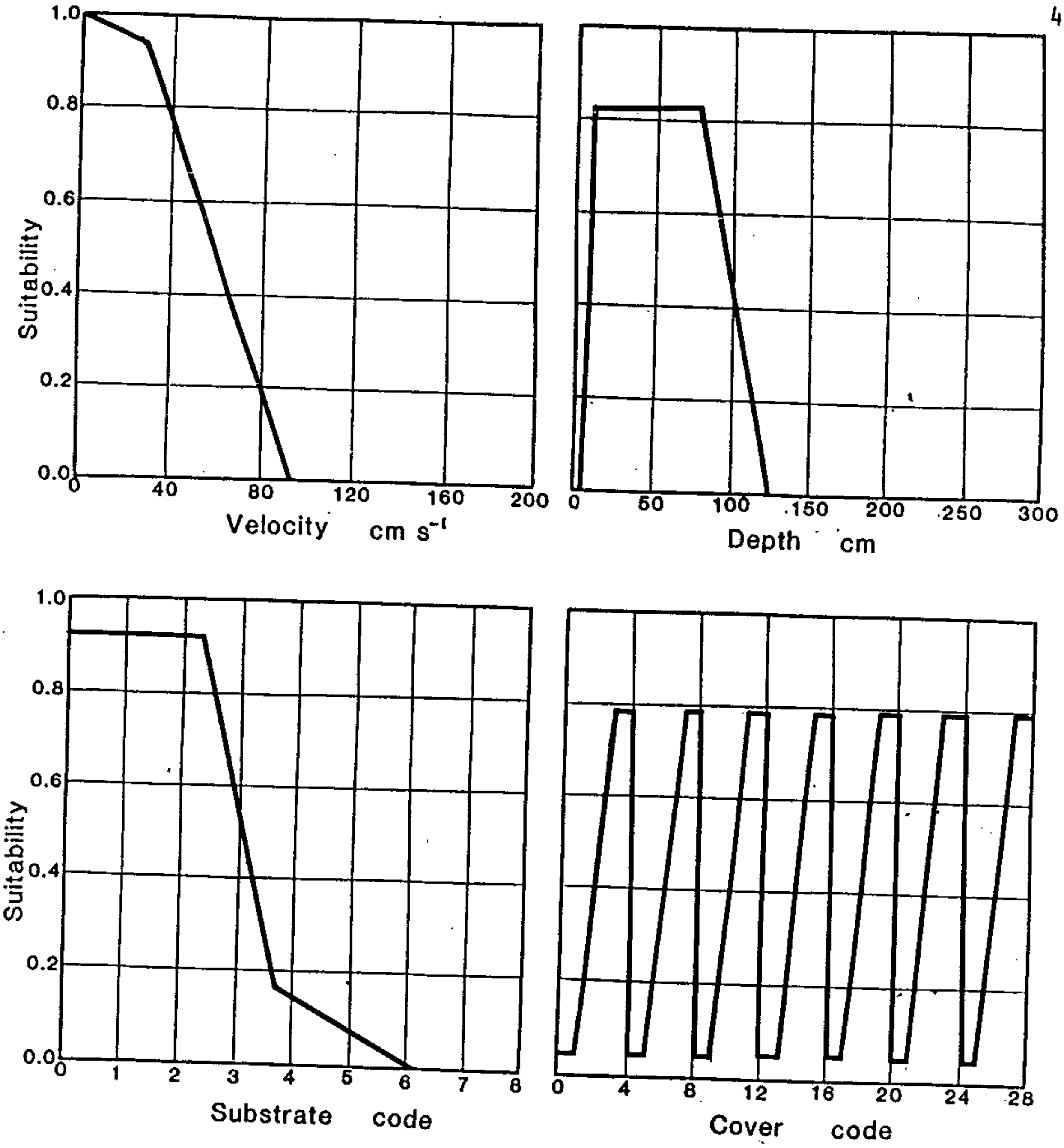


Fig. 32 PHABSIM suitability curves for juvenile pike.

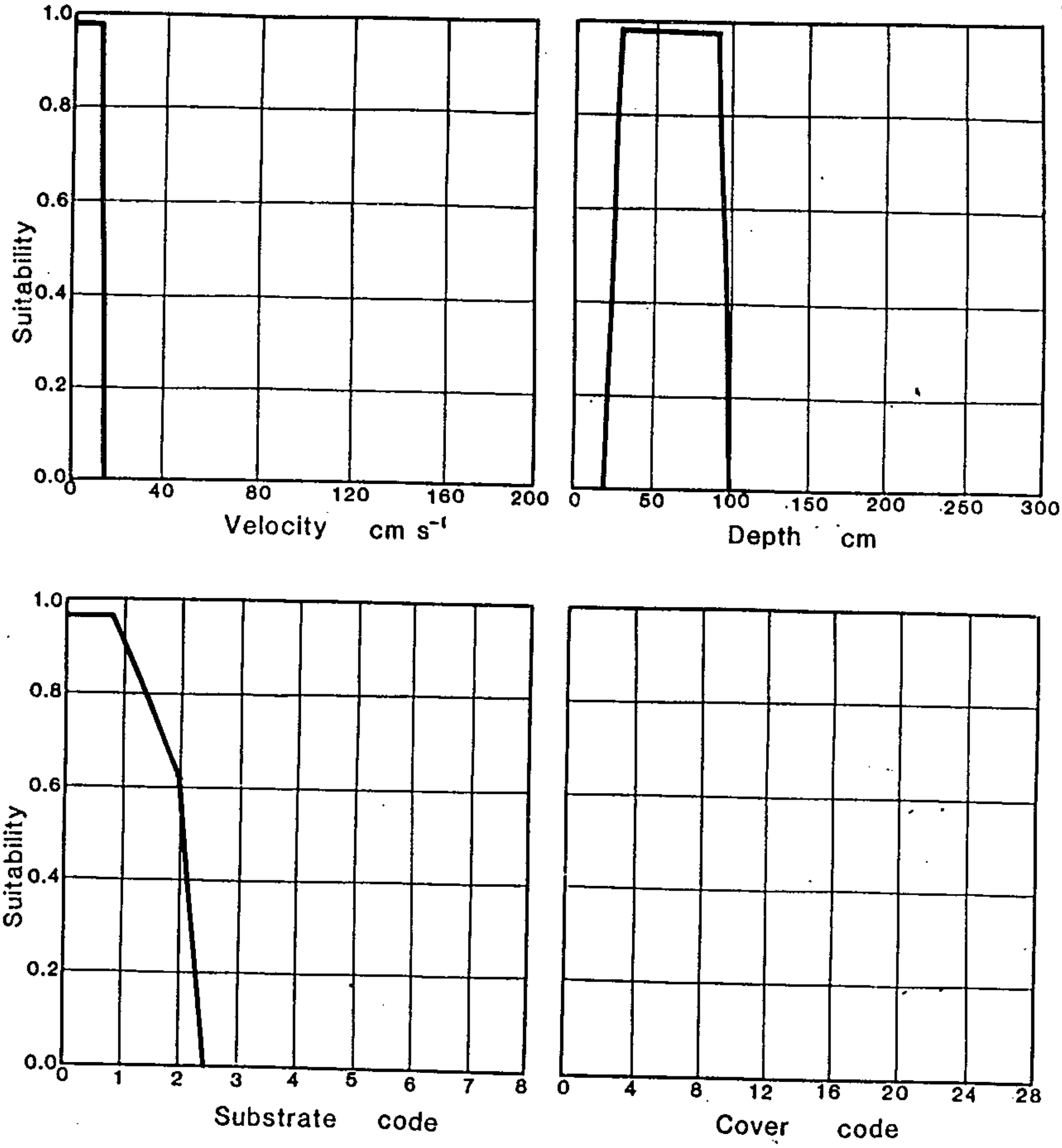


Fig. 33 PHABSIM suitability curves for pike fry.

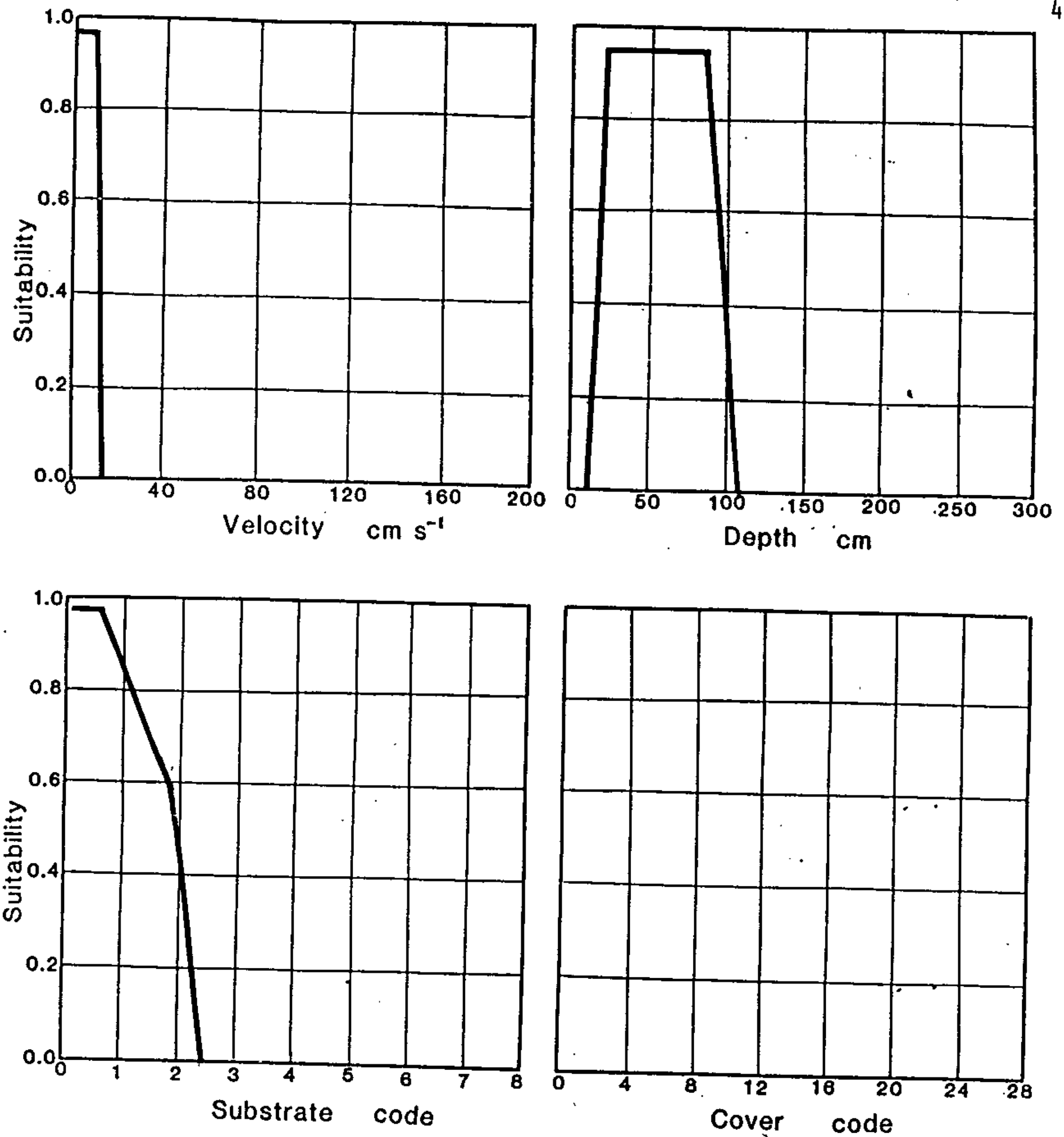


Fig. 34 PHABSIM suitability curves for pike spawning.

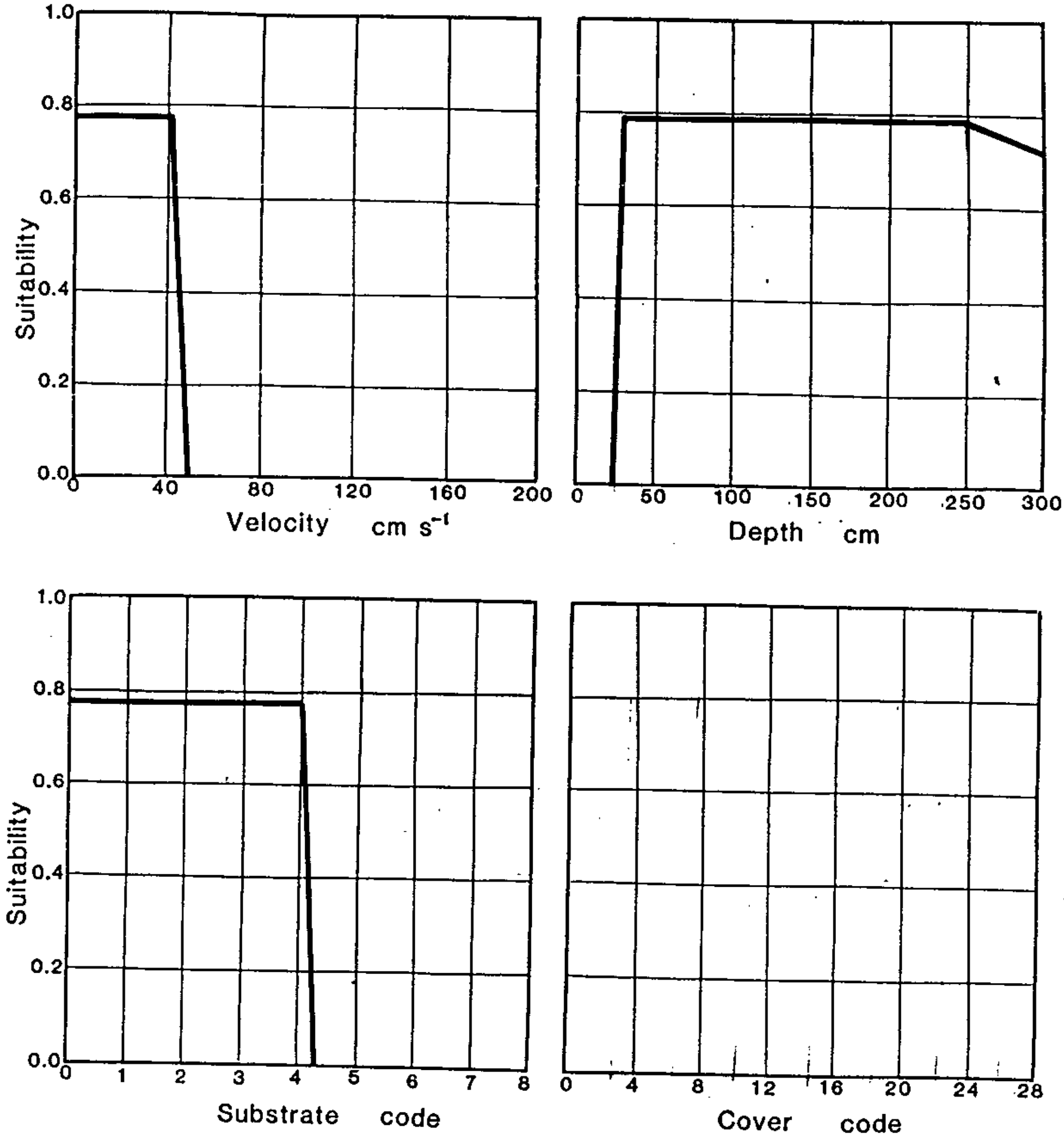


Fig. 35 PHABSIM suitability curves for adult perch.

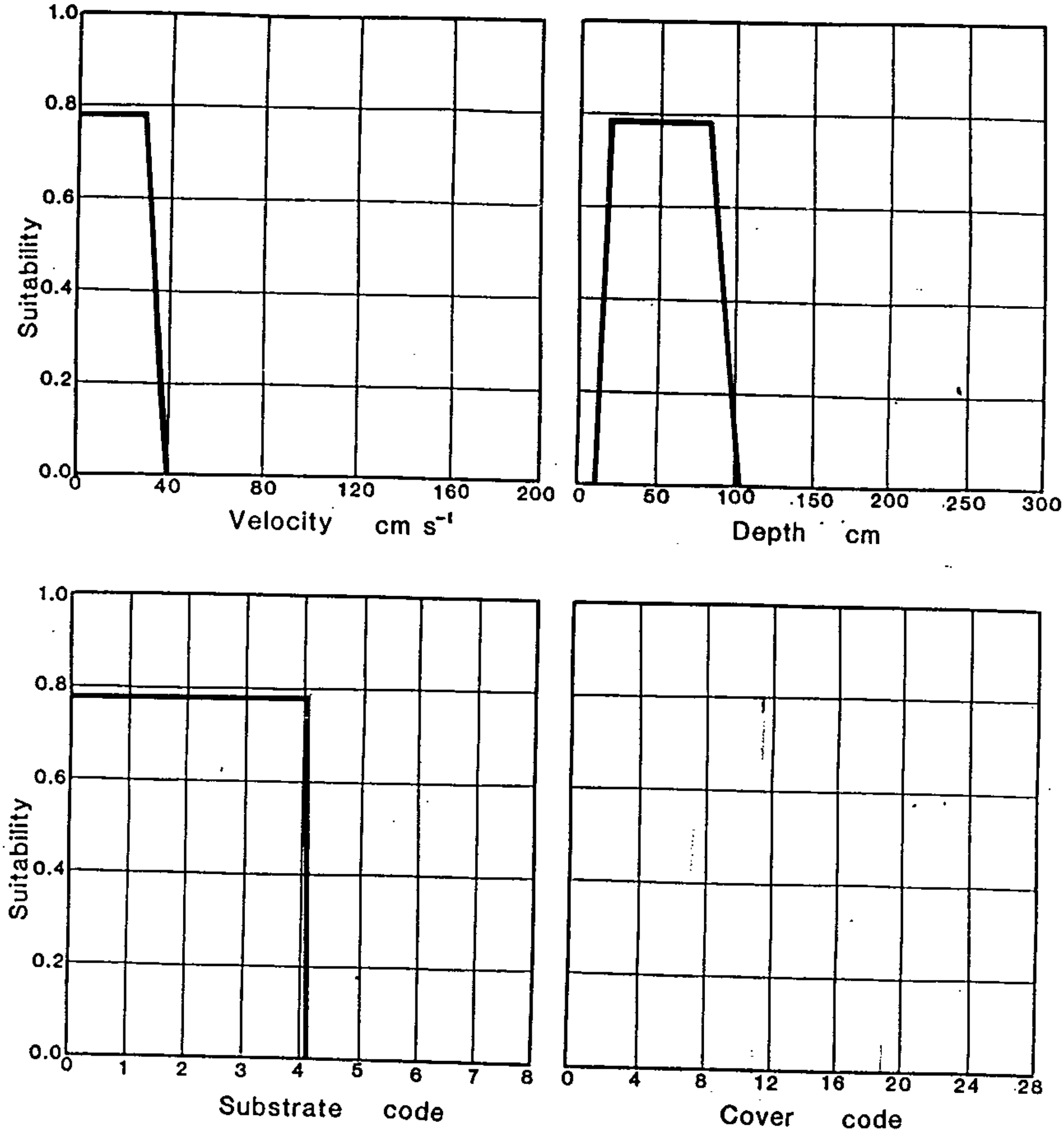


Fig. 36 PHABSIM suitability curves for juvenile perch.

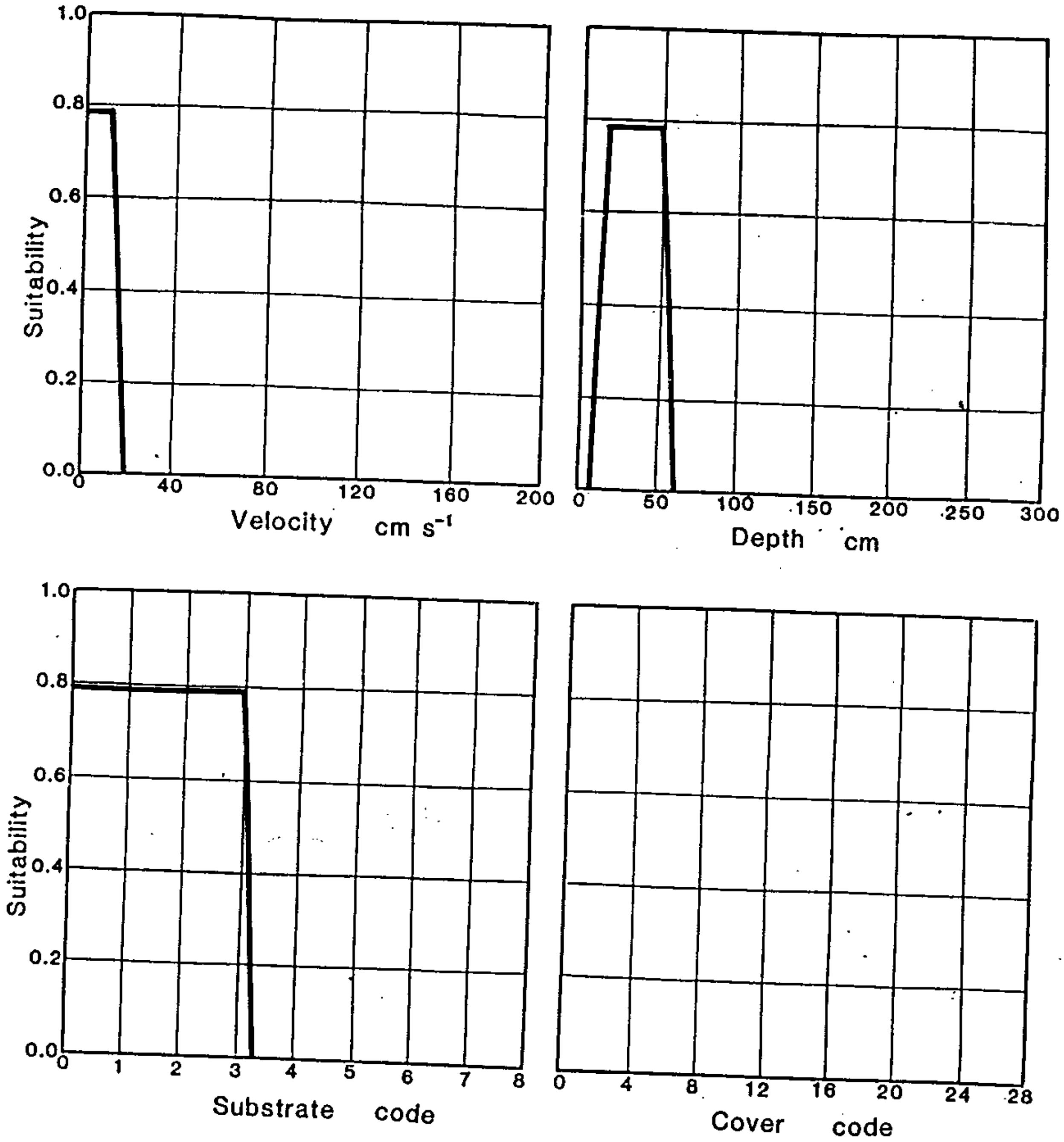


Fig. 37 PHABSIM suitability curves for perch fry.

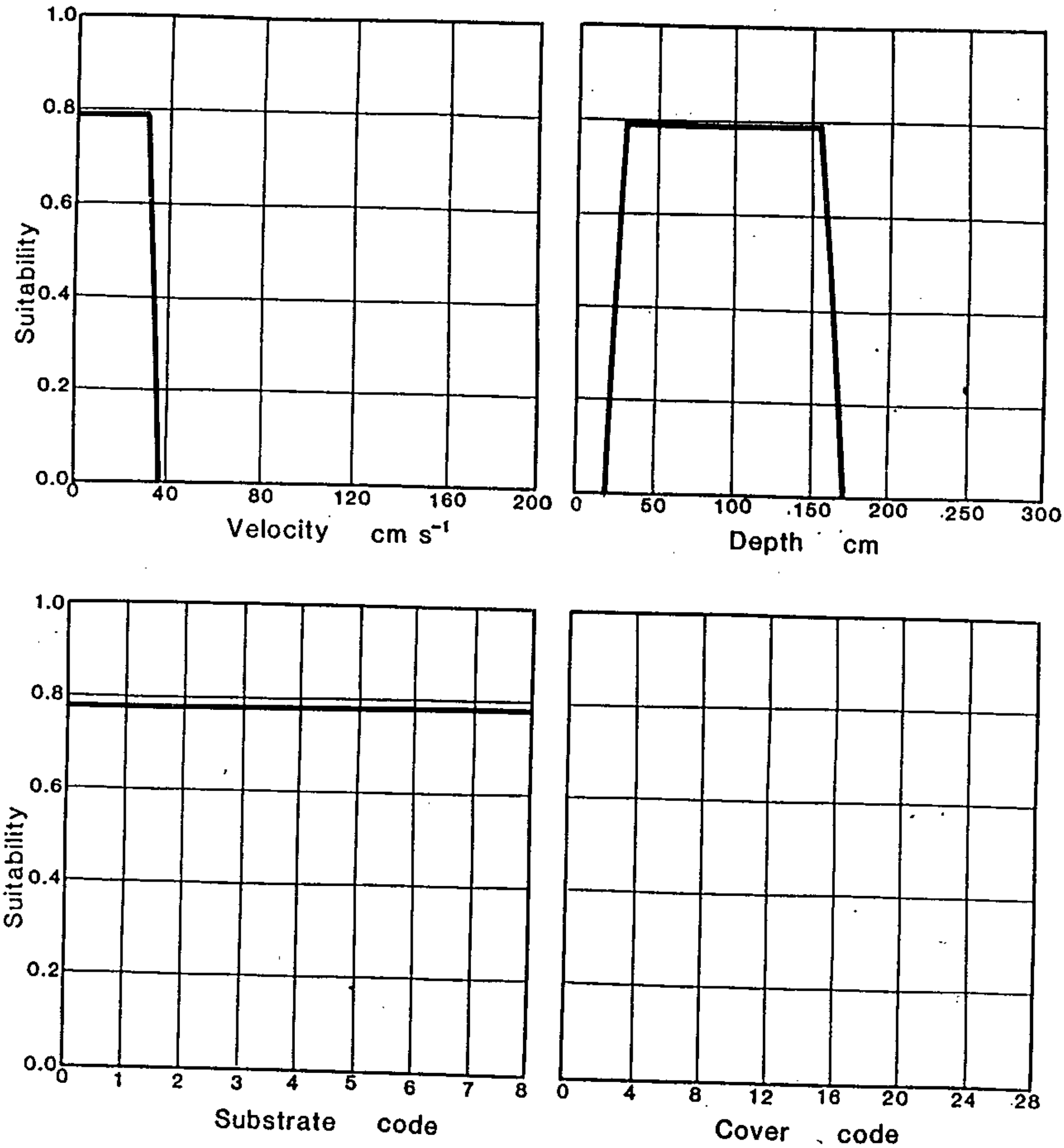


Fig. 38 PHABSIM suitability curves for perch spawning.

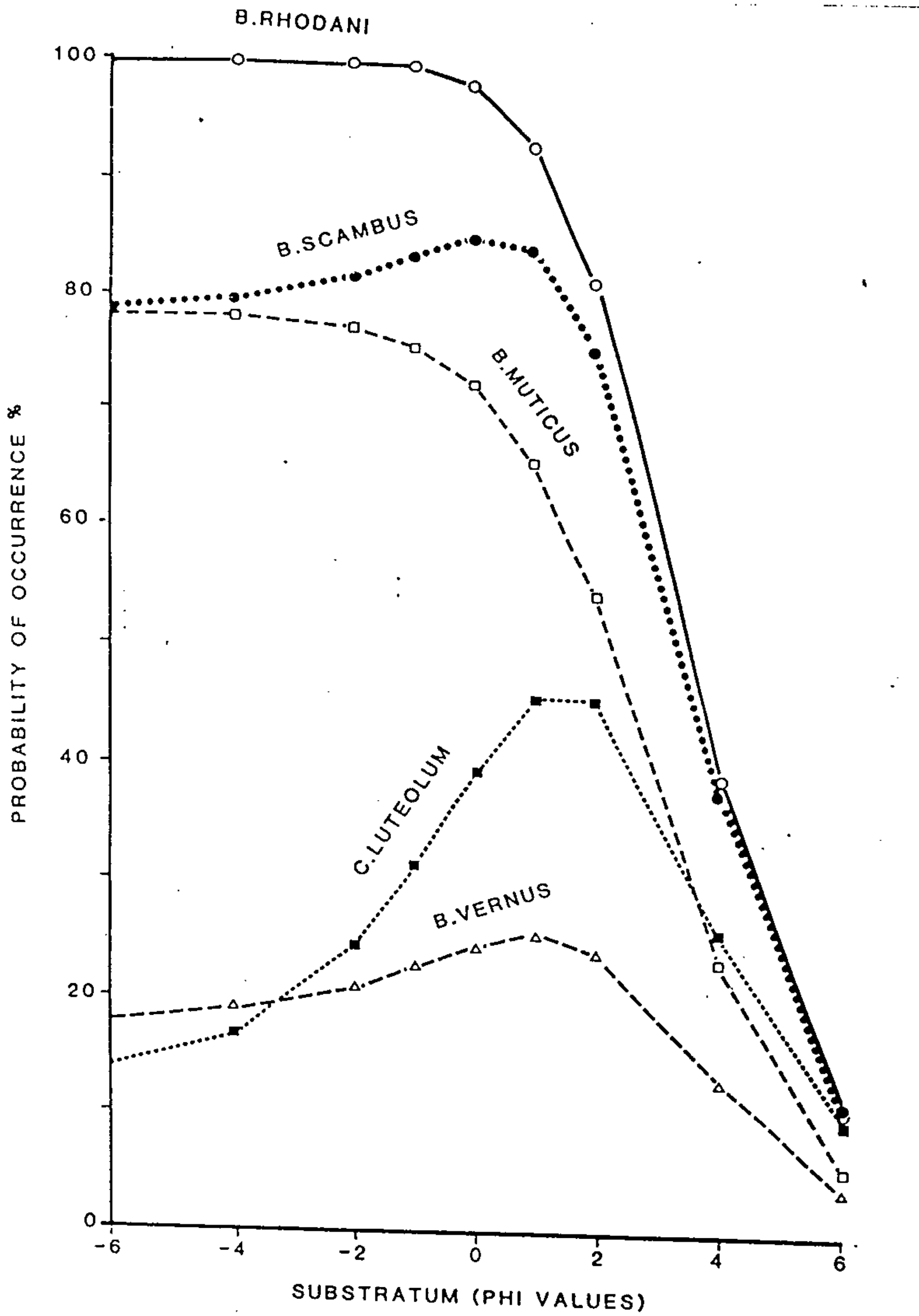


Fig. 39 The effect of simulated change in mean substratum particle size on predictions of the probability of occurrence of 5 species in the family Baetidae.

APPENDIX 1

Invertebrate sampling

At the same time that physical and hydraulic data were collected at the study reaches samples of invertebrates were also taken. Within the present contract constraints of time and money prevented the analysis of the faunal data. The samles have, however, been preserved and await the provision of funds to continue processing. Because of the intensity of sampling and associated detailed physical descriptions of habitat, this data set will provide much useful information on microdistribution patterns in contrasting river reaches.

APPENDIX 2

Fish populations of R. Gwash (Rutland Water)

*Brown trout
*Grayling
*Chub
*Dace
*Roach
*Bream

Fish populations of outflow to Blithfield Reservoir

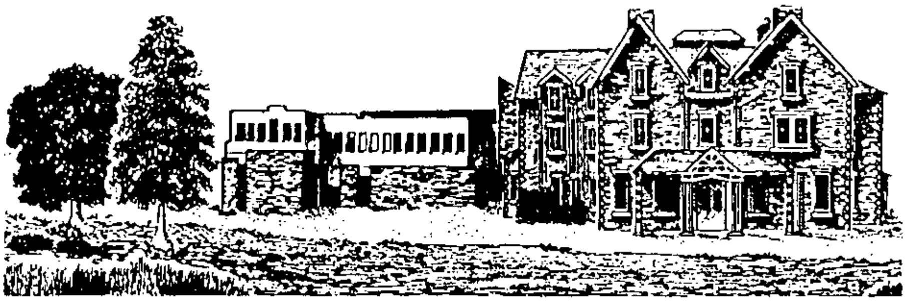
Near Reservoir
*Brown trout
*Dace
*Chub
*Roach
*Pike
*Perch

4-5 km downstream
*Brown trout
*Dace
*Chub
*Perch
Gudgeon
Minnow
Bullhead

Fish populations of outflow to Ladybower Reservoir

*Brown trout
*Grayling
Bullhead
Stickleback
Stone loach

*Figures and table available.



The **Freshwater Biological Association** is the leading scientific research organisation for the freshwater environment in the United Kingdom. It was founded in 1929 as an independent organisation to pursue fundamental research into all aspects of freshwater biology and chemistry. The FBA has two main laboratories. The headquarters is at Windermere in the Lake District and the River Laboratory is in the south of England. A small unit has recently been established near Huntingdon to study slow-flowing eastern rivers.

The FBA's primary source of funding is the Natural Environment Research Council but, in addition, the Association receives substantial support from the Department of the Environment and the Ministry of Agriculture, Fisheries and Food who commission research projects relevant to their interests and responsibilities. It also carries out contracts for consulting engineers, water authorities, private industry, conservation bodies, local government and international agencies.

The staff includes scientists who are acknowledged experts in all the major disciplines. They regularly attend international meetings and visit laboratories in other countries to extend their experience and keep up to date with new developments. Their own knowledge is backed by a library housing an unrivalled collection of books and periodicals on freshwater science and with access to computerized information retrieval services. A range of experimental facilities is available to carry out trials under controlled conditions. These resources can be made available to help solve many types of practical problems. Moreover, as a member of the Terrestrial and Freshwater Sciences Directorate of the Natural Environment Research Council, the FBA is able to link up with other institutes to provide a wider range of environmental expertise as the occasion demands. Thus, the FBA is in a unique position to bring relevant expertise together for problems involving several disciplines.

Recent contracts have involved a wide variety of topics including biological monitoring, environmental impact assessment, fisheries problems, salmon counting, ecological effects of reservoirs and other engineering works, control of water weeds, control of insect pests and effects of chemicals on plants and animals.

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