FOCAL POINT CHARACTERISTICS AND HABITAT USE CURVES OF UNDERYEARLING BROWN TROUT (Salmo trutta) IN THE KAHUTERAWA STREAM.

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ABSTRACT

The physical focal point characteristics of underyearling brown trout (Salmo trutta) were examined by underwater observation in a nursery stream to determine the preferred depths, current speeds and substrates. Each focal point characteristic was analysed with respect to fish activity and age (in months after emergence). Underyearling brown trout in the Kahuterawa stream were found to use focal points with different physical characteristics for different activities. As they aged the Kahuterawa trout moved into swifter, deeper water.

The Physical Habitat Simulation (PHABSIM) of the Instream Flow Incremental Methodology (IFIM) was examined by obtaining habitat use curves from the focal point data, which were compared with habitat relative preference curves. Habitat relative preference curves examine habitat use in relation to habitat availability. It is concluded that habitat relative preference curves should be developed for each activity class of each life stage of the target species. In the case of brown trout, emergent fry should be considered a separate life stage from fingerlings. PHABSIM is criticized because it takes little account of cover and current shelter which are shown to be important factors in focal point choice.

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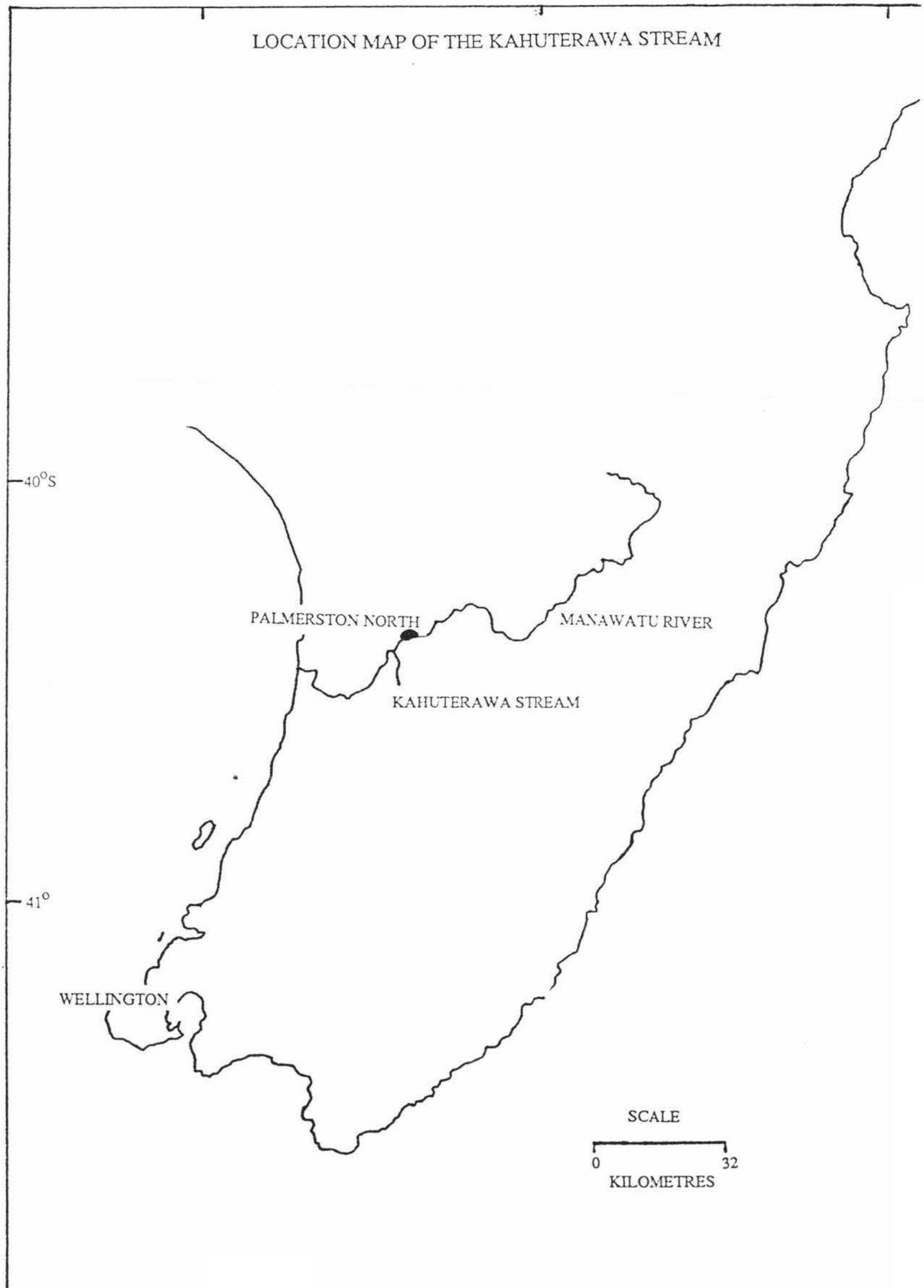
LOCATION MAP OF THE KAHUTERAWA STREAM
40°S
PALMERSTON NORTH
MANAWATU RIVER
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41°
WELLINGTON
SCALE
0
32
KILOMETRES
175°E
176°

CHAPTER 1
INTRODUCTION

With the increasing demands on water resources in New Zealand it is necessary to determine the effects of such river developments as hydro - electric power plants and water abstraction on the lotic biota. The consequences of these developments on the low river flows associated with summer are assumed to be important in determining the biological productivity of rivers (Giger 1973). At present. methodologies for predicting the effects of flow changes in streams. particularly on fish. are being developed and refined (e.g. Scott and Shirvell 1986; Binns and Eiserman 1979; Newcombe 1981). Of these the instream flow incremental methodology (IFIM) (Bovee and Cochnauer 1977) is potentially the most useful. IFIM was developed by the cooperative instream flow group (IFG) of Fort Collins Colorado. to ensure that adequate information was available to assess the effects of proposed flow changes in rivers. The methodology uses a sophisticated hydraulic modelling technique to predict depths. current speeds and substrates within stream reaches at varying flow rates. This hydrological model of the stream is then combined with fish habitat preferences to produce a weighted usable area (WUA) and predict changes in usable habitat. For example a reduction in the streamflow will result in a reduction in water depths. Deep water may be essential for larger trout and hence the fishery values will decrease as habitat for large trout is reduced. Fish habitat preferences are related to the stream model via habitat preference curves which attempt to estimate the most preferred values of each physical habitat characteristic. Thus. WUA is an index of the physical habitat quality and availability.

The ability to predict. in a quantitative fashion changes in usable habitat due to flow variations makes IFIM a potentially valuable tool for river managers. However determination of fish habitat preferences. remains a major problem with this methodology at the present time. Mathur et al. (1985. 1986) criticized IFIM on the grounds that the methodology violated several of assumptions upon which it is based. For example they note that there is little evidence to suggest that WUA is correlated with fish biomass. However such recent IFIM studies as Scott and Shirvell (1986) and Irvine et al. (1987) point out that IFIM aims to simulate only changes in the quality and quantity of fish habitat and not changes in biomass. Scott and Shirvell (1986) discuss the assumptions of the physical habitat component (PHABSIM) of IFIM. They conclude that PHABSIM (and therefore IFIM) has several serious drawbacks, most of which are related to fish habitat preferences. Important habitat variables are not incorporated into the model, habitat is modelled above the points at which many fish spend most of their time, habitat variables are assumed to be independent when it has been demonstrated that they are often not (Orth and Maughan 1982) and the value of areas not occupied by fish is underrated.

Further problems relate to the construction and employment of habitat use curves, the IFIM indices of habitat suitability. Mathur et al. (1986) criticize habitat use curves on the grounds that they vary between streams, over time, and in response to prey, predators and other biological stimuli. Moreover, Moyle and Baltz (1985), Orth and Maughan (1982), Baldrige and Amos (1982) and Mathur et al. (1985) note that extreme care must be taken to ensure that habitat use curves are derived from fish preferences and not simply fish abundance. To determine fish preference one must examine habitat availability in conjunction with habitat use. There are other complications that must be considered when deriving or using habitat use curves. For instance fish use different habitat types as they age (Rimmer et al. 1983; Gosse and Helm 1982) and fish use different parts of the habitat for different activities (Kalleberg 1958; Baldes and Vincent 1969). Hence habitat use curves for every life stage and activity of a target species are necessary for PHABSIM to make accurate predictions on potential changes in habitat.

In many countries, including New Zealand, salmonids form important recreational and commercial fisheries. Because of this, salmonids frequently feature in work regarding preferred habitat, although most data currently available is derived from the Northern Hemisphere, where many ecologically similar species of salmonids co -

exist (e.g. Baltz and Moyle 1984; Bovee 1978; Sheppard and Johnson 1985; Fausch and White 1981). New Zealand contains six species of introduced salmonids (McDowall 1978) of these only two, brown trout (Salmo trutta) and rainbow trout (Salmo gairdneri), are common throughout both the North and the South Islands. In most cases one species is dominant in a river system. For example the Manawatu river system, in which the present study was undertaken, supports both species although rainbow trout are very rare (Wellington Acclimatization Society Annual Reports). Interference and competition between salmonids such as that described by Fausch and White (1981), Hearn and Kynard (1986) and Cunjak and Green (1983), could render Northern Hemisphere habitat information inapplicable to New Zealand. This situation has led researchers to call for the collection of information on the habitats chosen by salmonids in New Zealand (e.g. Glova 1982; Jowett 1982; Mosley and Jowett 1985; Tierney 1982; Shirvell and Dungey 1983).

Trout have been shown to spend 95% of their time in small subsets of the available habitat (Whickham 1967). These areas are termed focal points. The focal point was considered by Whickham (1967) to be "**an area used much more extensively than others**", however this definition is considered too broad for the present study. Focal point is defined here as the exact location of a fish not making progress over the substrate. Focal points can thus be occupied only by fish which are stationary or swimming against the current at zero net velocity. Any fish that is making progress (in relation to the substrate) either with or against the current is not deemed to be occupying a focal point. Focal points are differentiated from potential focal point positions; which are areas of the stream containing favourable physical characteristics for use as a focal point. Focal points, usually defined as the position of the fish's head, are held with great precision. For example, Kalleberg (1958) stated for atlantic salmon (Salmo salar) and brown trout fingerlings holding station that "**... it could easily be seen that the optical axes of the eyes of the fish retained a constant direction, while the body oscillated in the eddies. This produced the peculiar impression of the fish being suspended in the current with the eyeballs acting as universal joints**". Bachman (1984) found that in 11 photographs of brown trout focal points, taken over a period of 15 months, the position of a fish's eye ranged less than 40 mm. The focal point concept is important from management and ecological perspectives. Shirvell and Dungey (1983) and Baldes (1968, quoted in Giger 1973) have suggested that the number and quality of potential focal points may determine population abundance. Thus, if the number of high quality potential focal points available in a given stream can be increased the carrying capacity may also increase. Conversely it is assumed that by decreasing the quantity and increasing the quality of potential focal points a manager may improve the size and condition of fish taken from that fishery.

Baldes and Vincent (1969) defined microhabitat as the physical conditions immediately surrounding an animal at a given time and place. As trout spend much of their time at focal points (Whickham 1967), the microhabitat of a stationary trout is usually equivalent to its focal point. However if a fish is moving relative to the substrate its microhabitat is also moving. In consequence, microhabitat may be very difficult to quantify. Most published works consider microhabitat to be synonymous with focal point. Although this is generally the case, microhabitat should be considered to encompass focal points and movements between or away from them.

For the focal point concept to be useful to fisheries researchers and managers it must be demonstrated that trout have preferred positions within the habitat. Jenkins (1969) demonstrated that brown trout have habitat preferences when he removed all the trout from a section of stream and discovered that when fish were introduced singly they chose one of the few primary potential focal points available. Shirvell and Dungey (1983) also concluded that trout partly chose feeding positions for their physical characteristics, citing as evidence feeding positions which have similar physical properties between rivers. An underlying assumption for the present study is that fish have preferences for certain physical characteristics such as depth, velocity and substrate size (Sheppard and Johnson, 1985). It is accepted, however, that focal point location may be dependent on non physical factors for certain activities. For example, feeding focal points may be more often determined by lines of drift (Jenkins 1969).

Despite the complex instream interactions between physical characteristics (e.g. current speed and substrate size) Shirvell and Dungey (1983) and Gosse and Helm (1982) have provided evidence which suggests that focal point characteristics are chosen independently from each other. The present study attempts to examine each constituent physical character separately. finally combining them to form a picture of their total effects on the focal point selection by brown trout. Data are analysed with respect to the energy maximization strategy proposed by Jenkins (1969) and further developed by Bachman (1984) and Faush (1984). The strategy. which is derived from optimality theory (Maynard Smith 1978). assumes a fish in a lotic environment will attempt to maximize its net energy gain. To achieve this. a feeding fish could minimize energy used in swimming against the current. while maximizing energy gained. by eating. In other activities. such as resting. cost minimization will be very important. Bachman (1984) has suggested that the principal method for trout to maximize net energy gain is to minimize energy expenditure. This enables predictions to be made regarding the relative magnitudes of focal point characteristics associated with feeding and other activities.

The uniqueness of New Zealand rivers (Winterbourn et al. 1981) may have some effect on the physical characteristics of brown trout focal points. For example. in the present study underyearling brown trout longer than 15 cm were seen during March and April in the study area. Many of the studies cited in the following chapters found that 1 and 2 year old fish occupied a similar length range. As focal point preferences are related to fish size (Rimmer et al. 1984: Moyle and Baltz 1985; Gosse and Helm 1982; Symons and Heland 1978; Everest and Chapman 1972; Griffith 1972; DeGraaf and Bain 1986). overseas data pertaining to yearling rather than underyearling salmonids may be more useful in describing the focal point characteristics of underyearling salmonids in New Zealand. It is also likely that due to differences in physical or biological environmental conditions. overseas focal point data may not be applicable to New Zealand. Information on the focal point characteristics of trout in New Zealand is sparse. Only one published study has determined fish focal point characteristics (Shirvell and Dungey 1983) and this related to adult brown trout. No empirical information is available regarding native fish, other introduced species, or pre - adult stages of brown trout.

Brown trout spawn from late May to the end of July in the study area. The resulting eggs hatch from late July through to the end of August. Alevins then remain in the substrate for three to four weeks using their yolk sac for sustenance (Frost and Brown 1967). In August or September, when the yolk sac is absorbed, the fry emerge from the gravel and begin to feed in the nursery stream. Many fry stay in the nursery stream until the early autumn (April) when they move into the main Manawatu river system (pers. obs.). There has been little, if any, information available from either overseas or New Zealand regarding changes in focal point requirements, over the first summer of the life of brown trout.

Wankowski (1979) describes the juvenile life stage of atlantic salmon as a period primarily concerned with feeding and growth. There is no reason to suggest that underyearling brown trout are different from atlantic salmon in this respect. Estimates from the present study support Wankowski's conclusions as 85.5% of fish found were engaged in feeding or in a situation that may be interpreted as feeding related. It may be surmised then that focal point positions will be strongly influenced by food availability.

The aims of the present study are: (1) to identify focal point characteristics so that fisheries managers will have information on which to base their decisions: (2) to identify any activity related changes in the physical characteristics of brown trout focal points: (3) to identify any changes over the first summer of life in the physical characteristics of brown trout focal points: and (4) to compare habitat use with habitat availability and relate this to habitat preference indices. This study will also compare the two most common approaches - the gross habitat and focal point approaches - used to construct habitat preference curves for IFIM. The present study, combined with that of Shirvell and Dungey (1983), will provide baseline focal point data for local water resource management enabling the utilisation of the latest lotic simulation techniques to predict the effects of any instream modifications on one of New Zealand's most economically important freshwater fish species.

CHAPTER 2
STUDY AREA

2.1 LOCATION.

The present study was undertaken in the Kahuterawa stream, a tributary of the Manawatu river. It flows westward from headwaters in the Tararua ranges (N.Z.M.S. 260 S24 288-721), and joins the Manawatu river opposite the Palmerston North city refuse tip (N.Z.M.S. 260 T24 294-871), a distance of some 23 kilometres. The Kahuterawa is a third order stream (sensu Strahler) with a catchment area of approximately 43 km^2 (Manawatu Catchment Board, unpublished data). Most of the upper catchment is forested, however the lower reaches are farmland. Discharge rates obtained in June and July 1978 (Manawatu Catchment Board, unpublished data) ranged from 0.459 to 1.454 m^3/s. Estimates taken, for the present study, in January 1987 varied between 0.3 and 1.1 m^3/s.

The study stream was chosen because of its importance as a brown trout spawning and nursery tributary of the Manawatu river. An added advantage is the low density of adult fish outside the spawning season (Kroos 1985) which have been shown to interfere with underyearling focal point choice (Gosse and Helm 1982).

2.2 GEOLOGY

The Tararua ranges, which the Kahuterawa stream drains, are composed of highly folded argillites (mudstones) and greywackes (sandstones) laid down in a geosyncline during the lower Mesozoic era (Hall 1964). The foothills comprise softer sediments, remnants of an extensive peneplain, which date from the tertiary era (Heerdegan 1972; Cowie 1978). Basement rocks are predominately greywake faulted into blocks over which tertiary sediments are laid in a series of synclines and anticlines. A large horst dominates the ranges which are bounded by the Wellington fault to the east, and a number of smaller faults to the west (Heerdegan 1972). At least one of these smaller faults bisects the Kahuterawa stream. The stream itself has incised into the tertiary sediments and is now found at the bottom of a flat floored valley (Cowie 1978). Two major soil types can be found in the Kahuterawa stream catchment area, recent soils and yellow grey earths with associated steepland soils (Cowie 1978). The latter are found primarily in the head waters, upper and middle reaches with the recent soils occurring in the terraces and lower reaches.

2.3

DISSOLVED OXYGEN AND pH.

Measures taken in December and January showed dissolved oxygen levels in the Kahuterawa stream were at saturation or approaching saturation (97 - 100%) throughout its middle and lower reaches. Currie and Gilliland (1980) did not record oxygen saturation levels below 90%, in January and early February 1978. During summer the pH of the stream varied between 6.8 to 7.4, well within the range acceptable to salmonids (Hooper 1973). Water temperatures ranged from 7°C in late July to 21°C in late January.

2.4

CLIMATE

Weather in the Manawatu area can be categorized as a high rainfall mountain climate of warm summers and mild winters (Saunders 1964). The local weather is largely governed by the anticyclones (high pressure systems) and depressions (low pressure systems) which approach from the west. The prevailing winds are west to north-westerlies with frequent gales.

Rainfall recorded from the Palmerston North D.S.I.R during the period 1928 - 1980 averages to 1000 mm per year and has an annual variation of less than 15% (Saunders 1964). However, due to the orographic nature of the area's precipitation annual rainfall in the headwaters and upper reaches of the stream ranges from 1140 mm to 2040 mm (Cowie 1978). Most rainfall occurs in the winter months of May, June, July, and August. The driest month is March. Air temperatures, also recorded at the Palmerston North D.S.I.R. (1918 - 1980), average 13.2°C and ranging from 8.5°C in July to 18.1°C in February.

2.5 STREAM BIOLOGY

Vegetation in the catchment consists of pasture in the lower reaches and a mixture of exotic forest plantations (Pinus radiata) and regenerating native bush in the middle and upper reaches. In summer, instream vegetation is primarily algae (Oetogonium and Spirogyra) which blooms between freshets, however these species are largely absent throughout the rest of the year. Streambank plants such as willow (Salix spp.), blackberry (Rubus spp.) and tree lupin (Lupinus aboreous) extend into parts of the river.

The stream supports at least nine and possibly ten species of fish, eight of which are indigenous. The only introduced fish species known to be present in the river is the brown trout. It is possible that rainbow trout are present, as the Wellington Acclimatisation Society released this species into the stream as recently as the 1970s (Barker and Forlong 1985). The indigenous species are the common and redfinned bullies (Gobiomorphus cotidianus and G. huttoni), the longfinned and shortfinned eels (Anguilla dieffenbachii and A. australis), the shortjawed kokopu (Galaxias postvectis), and the inanga (G. maculatus) (Kroos 1985). In addition I have observed both the common smelt (Retropinna retropinna) and the lamprey (Geotria australis).

During the summer months the dominant invertebrates appear to be the Ephemeropterans Coloburiscus humeralis and Deleatidium spp., the Trichopterans Pycnocentrodes spp., Olinga spp. and Beraeoptera roria, Hydora (Coleoptera, Elmidae) and Chironimidae (Manawatu Catchment Board unpublished data).

Human use of the stream is largely confined to pastoral farming of the banks, bathing and picnicking. There is an open fishing season in the Kahuterawa stream from 1 October to 30 April, but Kroos (1985) found that only 1 out of 152 people surveyed in a creel census was fishing.

2.6 STUDY SITES.

Four primary study sites were used throughout the study. Study sites 1, 2 and 3 were chosen primarily because they contained sufficient numbers of underyearling trout, but accessibility was also taken into account and attempts were made to choose sites that were representative of the river in its middle and lower reaches. Site 4 was selected because it had been identified by Kroos (1985) as an intensive spawning area.

In the following description all habitat types are named using the system proposed by Bisson et al. (1982). Substrates are described according to the scale shown in Table 1 of Chapter 3.

STATION 1. KEEBLES BUSH.

POSITION N.Z.M.S.260 S24 297865.
LENGTH 120 METRES.

Keebles station consists of a long cobbly glide with a maximum depth of 0.8 metres. Downstream the glide is followed by a small riffle/glide/riffle section which enters a deep (1.7 m) plunge pool containing a large amount of woody debris. Below the pool is a glide followed by a small riffle that enters a trench pool. The trench pool undercuts the true left bank for 25 m and has a maximum depth of 1.3 m with a predominantly large gravel substrate. The pools make up approximately 55% of the survey area in this station. Unlike the two upstream sites, the substrate at this station is relatively uniform with no greywake outcrops in the stream bed. The mean current speed of the study site is 23 cm/s with a range of 0 - 97 cm/s.

The stream bank has been fenced off to exclude stock on the true right side while the left side borders Linton military camp. At the stream borders the vegetation is predominantly tree lupins (Lupinus aboreus), some of which overhang parts of the stream, with some blackberry (Rubus spp.). Linton military camp has its explosive range nearby but the noise did not appear to alarm the fish (at least not to the extent it alarmed the observer).

STATION 2. LIONS DOMAIN.

POSITION N.Z.M.S.260 T24 323811.
LENGTH 100 METRES.

The Lions domain station is typical of the upper middle reaches of the Kahuterawa stream. At the upstream end of the section is a large glide which follows a small riffle. The major substrate types in both the riffle and glide are cobble and gravel with some larger rocks also present. Following the upstream glide there is a second riffle partially dammed at the downstream end by large outcrops of greywake bedrock, which forms a small back water pool. This is followed by a very small rapid (approx. 1 m long) and a large lateral scour pool with a maximum depth of 1.5 m. Station 2 is 70% pool and 30% riffle. The major substrate types in the downstream section of this station were bedrock outcrops and large gravels. Current speed for the site ranges between 0 - 120 cm/s with a mean of 27 cm/s.

Stream - bank conditions are affected by the steep pasture covered hills on the true left side of the river. Due to the high rainfall and steep slopes in the area slips are common and consequently there are often 1 - 5 m high cliffs on the true left bank. The vegetation on the true right bank is predominantly regenerating bush except for some grass species in a picnic area of the domain.

STATION 3. STOCKYARDS.

POSITION N.Z.M.S. 260 T24 320802
LENGTH 40 METRES.

This station was physically similar to station 2. At the upstream end of stockyards reach is a lateral scour pool with a maximum depth of 1.3 m. Substrate in this pool varies from silt to bedrock. The true right bank borders on pastoral land with some undercut banks, while the true left bank consists of a bedrock cliff up to 4 m high. Following the pool there is a rocky rapid approximately 50 m long. The rapid accounts for approximately 65% of the total length of the station with the pool making up the remainder. Mean current speed for the site is 25 cm/s (range 0 - 64 cm/s). Streambank vegetation is pasture grasses on both sides.

STATION 4. BROWN HOUSE.

POSITION N.Z.M.S.260 T24 318792.
LENGTH 50 METRES.

This site differed from the others in that it is not a pool - riffle section but a low velocity glide and run. It includes some undercut banks on the true left side where the maximum depth is approximately 1 m in summer and 1.5 m in winter. Current speed varies between 0 and 120 cm/s with a mean of 22 cm/s. Substrate is predominantly small cobble to rock and the stream bank vegetation is again pasture species.

This area was chosen because it is one of the most popular spawning areas in the river. More than twenty redds were reported in the lower part of this site by Kroos (1985) during the spawning season of 1985.

PLATE 1

THE UPSTREAM SECTION OF STUDY SITE 1, KEEBLES.

PLATE 2

THE MAIN POOL AT STUDY SITE 2, LIONS DOMAIN.

PLATE 3

STUDY SITE 3, STOCKYARDS.

PLATE 4

THE LOW VELOCITY GLIDE IN STUDY SITE 4, BROWN HOUSE.

CHAPTER 3
METHODS

3.1 INTRODUCTION

Early investigations of salmonid focal points were stream tank studies. The value of these studies is limited because they contain only a small diversity of focal point characteristics. For example, Baldes and Vincent (1969) found that brown trout preferred depths of approximately 20.3 cm, but the mean depth of their stream aquarium was only 23.9 cm. In comparison, recent in situ studies such as those performed by Hermansen and Krog (1984), Faush and White (1981) and Wangaard (1982), have shown that salmonids prefer depths of up to 1.5 m. A second fault of aquariums is that they may not contain the relevant physical and biological cues to which trout may respond in the wild (Shirvell and Dungey 1983). Because these problems override the difficulties inherent in field studies, inclement weather and such other uncontrollable factors, the present study was conducted in the field.

This study used in situ observation as the method for the collection of data. Underwater observation was used in preference to other methods because if carried out carefully, it gives a highly accurate estimate of focal point position with little disturbance to the fish. The drawback of this method is that it is impractical at depths of less than 15 cm. However, other common techniques such as seine netting, electric fishing, rotenone poisoning and spot concussion offer no significant advantages to underwater observation and often result in the trout being moved from its focal point either in an attempt to escape or by being washed downstream. Surface observation was also rejected (except for a special case mentioned below) primarily because brown trout associate strongly with overhead cover (Gosse and Helm 1982) and this makes viewing difficult. Surface observation is especially difficult for underyearling brown trout as their preferred habitat appears to be riffles in which surface water turbulence renders accurate observation impossible. These difficulties are further compounded by the small size (2 - 15 cm) and cryptic colouration of the fish.

3.2 FIELD METHODS.

3.2.1 FOCAL POINT SAMPLING

The focal points of underyearling brown trout were examined from shortly after the alevins emerged from the gravel (in September 1986). until they left the nursery stream (in late April 1987). Following methods similar to Keenlyside (1962) Gosse and Helm (1982) and Moyle and Baltz (1985) focal point data was obtained in - situ by direct underwater observation. I measured the physical characteristics of trout focal points by wearing snorkeling apparatus and crawling slowly upstream. This movement did not appear to disturb the fish much as trout tend to face into the current. However if fish were irritated (disturbed individuals were recognized by a blotchy colour pattern. rapid gill movements and 'flighty' behaviour) they were not examined further. Fish within a radius of approximately 50 cm of a disturbed individual were also not investigated. The best results were achieved when movement upstream was slow and I anchored to the substrate for some minutes before approaching any fish. Using this technique most fish could be approached to within 50 cm before they showed signs of irritation. Depending on water temperature. observation periods extended to a maximum of four hours.

After encountering a fish. it was observed for a few minutes to accurately determine its focal point with reference to natural markers. Fish were classified. with respect to size and behaviour. into emergent fry and fingerlings. This distinction was made on the basis of personal observations and the suggestion of Gosse and Helm (1982) that a separate age category for fish less than 3 grams be recognised in focal point studies. Emergent fry were defined by activity and so are analysed as an activity class; this further allows comparison of emergent fry focal points with those of fingerlings. Emergent fry were easily distinguished by their characteristic behaviour occupying a position on the substrate with occasional dashes into free water, presumably to intercept food. Fingerling activity was classified as resting, feeding or stationary swimming. A fish was said to be resting if it was stationary with no swimming motions. Stationary swimming involved holding a position with respect to the stream bed by swimming against the current. Fish were classified as feeding only if seen engulfing food. A fourth category, random swimming was also considered (Gosse and Helm 1982), however no fish were seen engaged in this activity during this study. There appears to be some confusion in the literature regarding resting and stationary swimming. Baldes and Vincent (1969) speak of resting microhabitat but upon close reading of their paper it is probable that what they call resting microhabitats is what I would term stationary swimming focal points. It is also questionable as to whether stationary swimming and feeding are separate activities. It could be argued that if a stationary swimming fish is watched for long enough it will feed and therefore there is no separation of stationary swimming and feeding. Yet stationary swimming and feeding have been regarded as separate activities by Gosse and Helm (1982) and Baldes and Vincent (1969). In the present study preliminary results indicated that there are important differences between the focal points of feeding and stationary swimming and feeding fish. For these reasons it was decided to analyse stationary swimming as a separate activity from feeding. Due to the short observation periods for individual fishes it was probable that some feeding fish were classified as stationary swimmers.

Focal points were described as per Table 3.1. The substrate type beneath each fish was recorded using the codes shown in Table 3.2. The codes in Table 3.2 were also used when identifying the materials (if any) used by the fish as shelter from the force of the current.

TABLE 3.1

ON SITE DATA FOR FOCAL POINT DETERMINATION.

1. reach location
2. reach temperature (Max. and Min. during observation period)
3. fish activity (resting, feeding, etc.)
4. total depth
5. focal point elevation (distance above the substrate)
6. focal point current speed (the current speed at the fishes nose)
7. maximum adjacent current speed (highest current speed within 50 cm.)
8. current speed at 0.6 of the depth (mean current speed of the water column occupied by the fish.)
9. type of shelter from the current (adjacent to the fish)
10. substrate type
11. fish size class
12. distance to escape cover

Note: Mean current speed, in compliance with usual hydrological practice, was measured at 0.6 of the total depth.

The codes in Table 3.2 were used in preference to the more popular method of recording substrate (a modified Wentworth particle scale) because the Wentworth scale was not sensitive enough for the present study. From September to December 1986 the distance from the focal point to the nearest escape cover was also noted. Escape cover was defined as any cover capable of concealing more than 80% of the fish's length. By early December 1986 it was found that the distance to escape cover was not a useful measure because, when deliberately frightened, the fish seldom fled to what the observer perceived to be the closest cover.

After collecting this data the fish was carefully approached, and the focal point elevation and total water depth at the focal point were recorded ($\pm$ 0.5 cm) using a graduated rod. Although fish left the focal point when approached they often did so slowly and showed little sign of irritation. Fingerlings (> 3 months after emergence) often reoccupied their focal point soon after the observer moved away, while fry (< 3 months) often found new focal points close by. A lead weight was left to mark the position of the focal point and the observations were continued. At the conclusion of the dive, the mean, maximum adjacent, and focal point water speeds were measured using a propeller driven Ott current speed meter. By using the position of the weight in conjunction with the focal point elevation measurement the exact positions for current speed readings could be determined. Unfortunately the construction of the flow meter prevented the measurement of focal point current speed of fish closer than 3 cm to the substrate. This was particularly important for emergent fry and resting fingerlings as these were most often in contact with the substrate. Algae were periodically a problem in mid summer as they reduced visibility and occasionally fouled the flow meter.

TABLE 3.2

SHELTER AND SUBSTRATE CODES.

CODE	SHELTER OR SUBSTRATE TYPE
0.	SMALLER THAN GRAVEL. (<5 mm)
1.	SMALL GRAVEL (5-10 mm)
2.	GRAVEL (10-20 mm)
3.	LARGE GRAVEL (20-50 mm)
4.	SMALL COBBLE (50-80 mm)
5.	COBBLE (80-100 mm)
6.	LARGE COBBLE (100-150 mm)
7.	ROCK (150-300 mm)
8.	LARGE ROCK (>300 mm)
9.	OTHER
10.	NO SHELTER

Previous research has spoken of current velocity rather than speed (e.g. Morantz et al. 1987. Baldes and Vincent 1969). This is misleading as velocity implies a directional component and it is difficult to identify if this component is determined relative to the fish or to the river as a whole. For example a fish in a position in which the current is running counter to the overall flow of the stream could be considered to be in water of negative velocity. To avoid any confusion the present study will refer to current speed. however all fish examined were either facing into. or at a slight angle to the current.

Fish in very shallow water such as small side braids could not be examined by underwater observation. For these fish a shore based surface observation procedure was used to collect similar data. Both procedures demand a high level of water clarity and so the focal points of brown trout at night and during freshes and floods could not be investigated by either method.

3.2.2

HABITAT SAMPLING

In addition to fish focal point. the total habitat available to the fish was sampled. Total depth. current speed. and substrate type were sampled on transects at fifteen metre intervals along each study site and sample points one metre apart across the stream. Until December 1986 habitat availability was assessed when the stream flow rate was representative of the proceeding two weeks. From January 1987 habitat availability data was collected at every sampling period. Habitat availability in flood conditions was not recorded. Shelter. focal point current speed. and focal point elevation are not applicable to habitat availability as they are defined in terms of fish use.

3.3

STATISTICAL TESTS

The Chi^2 statistic was used to analyse contingency tables to search for any changes in focal point between activities and over the first summer of life. For testing age data was pooled into four approximately equal sized sections (September and October 1986, December 1986, January 1987, and February March and April 1987). Habitat use was compared with habitat availability by a Chi^2 test of homogeneity.

CHAPTER 4
CURRENT SPEED

4.1 INTRODUCTION

A number of lotic habitat studies have identified stream current speed as an important component of fish microhabitat. Lewis (1969) considered mean current speed and total cover to be the two most significant determinants of the variation between trout populations in different river pools. Shirvell and Dungey (1983) also concluded that the current speed may be the most important variable used by trout when selecting focal points. Gosse and Helm (1982) stated that focal point current speed is more valuable in describing focal points than other measures of water speed (e.g. mean current speed, surface current speed, etc.), depth or light intensity.

Current speed affects salmonids in two major ways. Firstly the current brings energy and nutrients to the fish by way of invertebrate drift. Giger (1973) and Church et al. (1979) found that water speed has a major effect on trout food availability, maximum subsurface drift occurring between 30 and 75 cm/s. Secondly, the current forces fish to use energy to maintain position, usually by swimming against the flow. It follows that a fish in slow water which is close to faster water should be able to satisfy its metabolic maintenance requirements more easily than fish in slow or very fast water. When metabolic maintenance requirements are fulfilled the fish may spend more time under cover, so reducing the risk of predation, or continue to feed and devote energetic profit to growth (Faush and White 1981; Faush 1984; Rimmer et al. 1984; Jenkins 1969). Either alternative may enhance its survival chances and reproductive fitness.

With this framework in mind I expected the range of current speeds used by trout to be very narrow with focal point current speed significantly lower than both mean and maximum adjacent current speed. Focal point current speed should be lowest for resting fish, where energy conservation is important, and for emergent fry where the muscles may not be sufficiently developed to contend with high water speeds. Highest focal point current speeds should be used by feeding fish as they are able to 'trade off' between energy used in swimming against the current and extra energy gained by feeding in a profitable position. Mean current speed will incorporate some of the characteristics of both the focal point current speed and the speed of the feeding current so it is expected to exhibit similar patterns of usage. However as mean current speed is not often directly used by the fish the pattern may be weaker. If maximum adjacent current speed is, as hoped, an indicator of feeding current then it would be predicted to be maximal for feeding trout. It is difficult to make predictions in the case of maximum adjacent current speed for other activities as it is not known if emergent, resting, or stationary swimming fish use this section of the water to any major degree.

Many studies of trout microhabitat (e.g. Rimmer et al. 1983 1984; Baltz and Moyle 1984; Moyle and Baltz 1985; Gosse and Helm 1982; Bovee 1978) have found that focal point current speed, mean current speed, and maximum adjacent current speed increase with fish size. This is attributed to either the physical limitations of smaller fish or competitive exclusion from optimal habitats and predation by larger fish (Jenkins 1969; Gosse and Helm 1982). The aim of this part of my study is to examine the effects of activity and age on the water speeds chosen by the fish and, where applicable, the relationship between the habitat used and that available.

4.2 RESULTS

4.2.1 CHANGES WITH ACTIVITY

Mean current speed varies significantly with fish activity (Chi^2 contingency table: $p < 0.001$). Figure 4.1 graphs mean current speed against percent usage for emergent fry and the fingerling activities of resting, stationary swimming, and feeding. Mean current speeds for all activities were never under 5 cm/s or over 60 cm/s and most values fall in the 5 - 40 cm/s range. Mean current speeds for resting fish are higher than those used for stationary swimming. As predicted mean water speed is relatively low ($\overline{X}$ = 20.4 cm/s) for emergent fry and relatively high ($\overline{X}$ = 30.6 cm/s) for feeding fish.

Focal point current speed was found to differ significantly ($p < 0.01$) between emergent fry and all fingerling activities. Figure 4.2 shows focal point water speed for emergent trout, and fingerlings engaged in the three activities mentioned above. Focal point water speeds ranged from 0 - 35 cm/s with the majority of observations falling in the 5 - 20 cm/s range. As expected focal point water speed was relatively high for feeding (X = 16.1 cm/s) and low for emergent activities ($\overline{X}$ = 9.9 cm/s). Focal point current speeds used by resting fish were similar to those occupied by stationary swimmers ($\overline{X}$ = 12.8 cm/s and $\overline{X}$ = 12.6 cm/s respectively).

Maximum adjacent water speed varies with activity ($p < 0.001$), and between fingerlings and emergent fry, but these patterns are complex. Figure 4.3 displays maximum current speed and percent users for each activity. Most maximum adjacent current speeds were between 30 to 60 cm/s area with an overall range of 5 - 15 cm/s.

As found by Jenkins (1969) still water was not popular for any activity. No fish were found in water slower than 2.7 cm/s. Although still water was available in the study sites it was relatively uncommon and often very shallow and this may have contributed to its lack of use.

Table 4.1 summarises current speed findings.

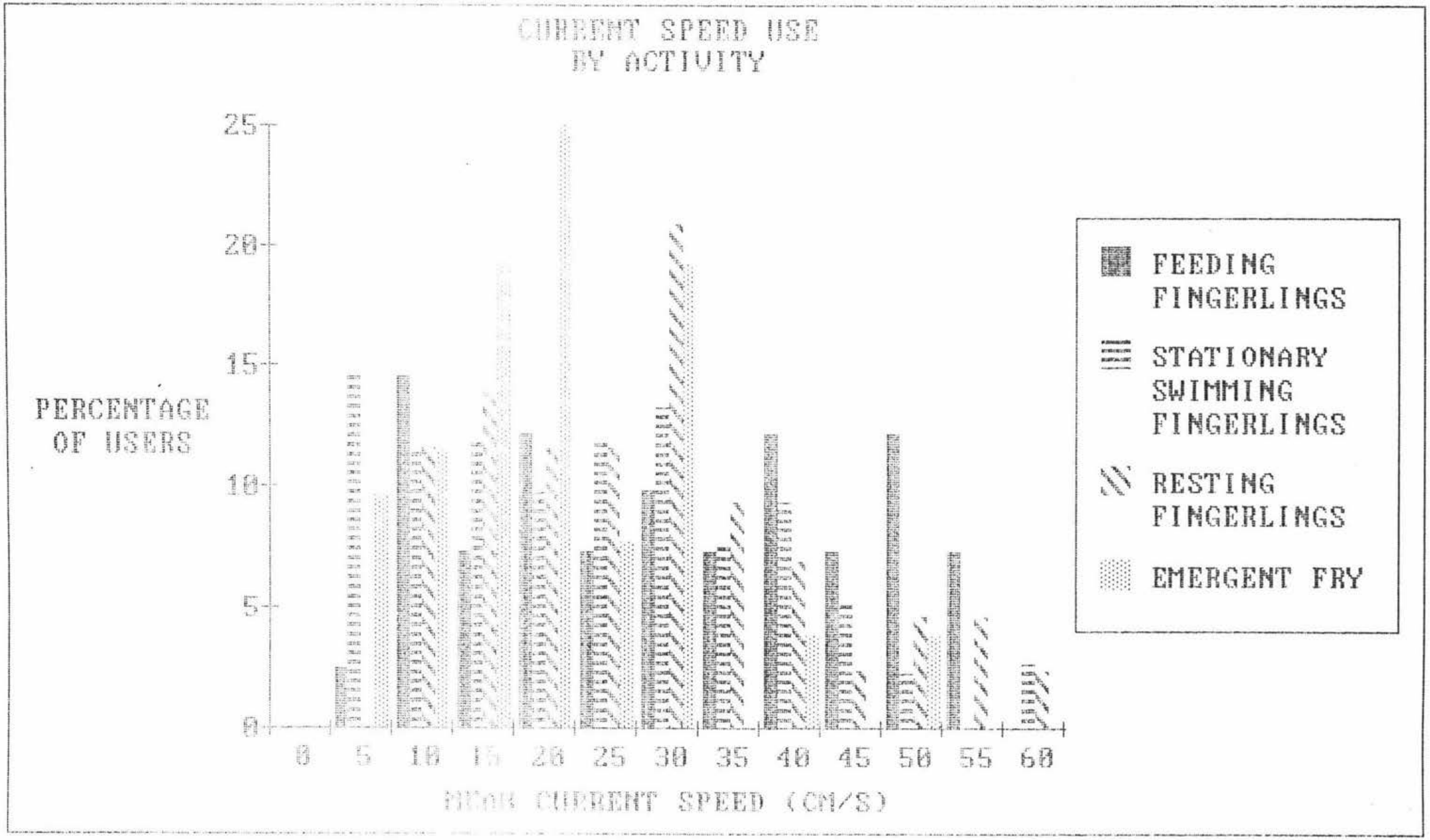
TABLE 4.1

CURRENT SPEED USE BY ACTIVITY

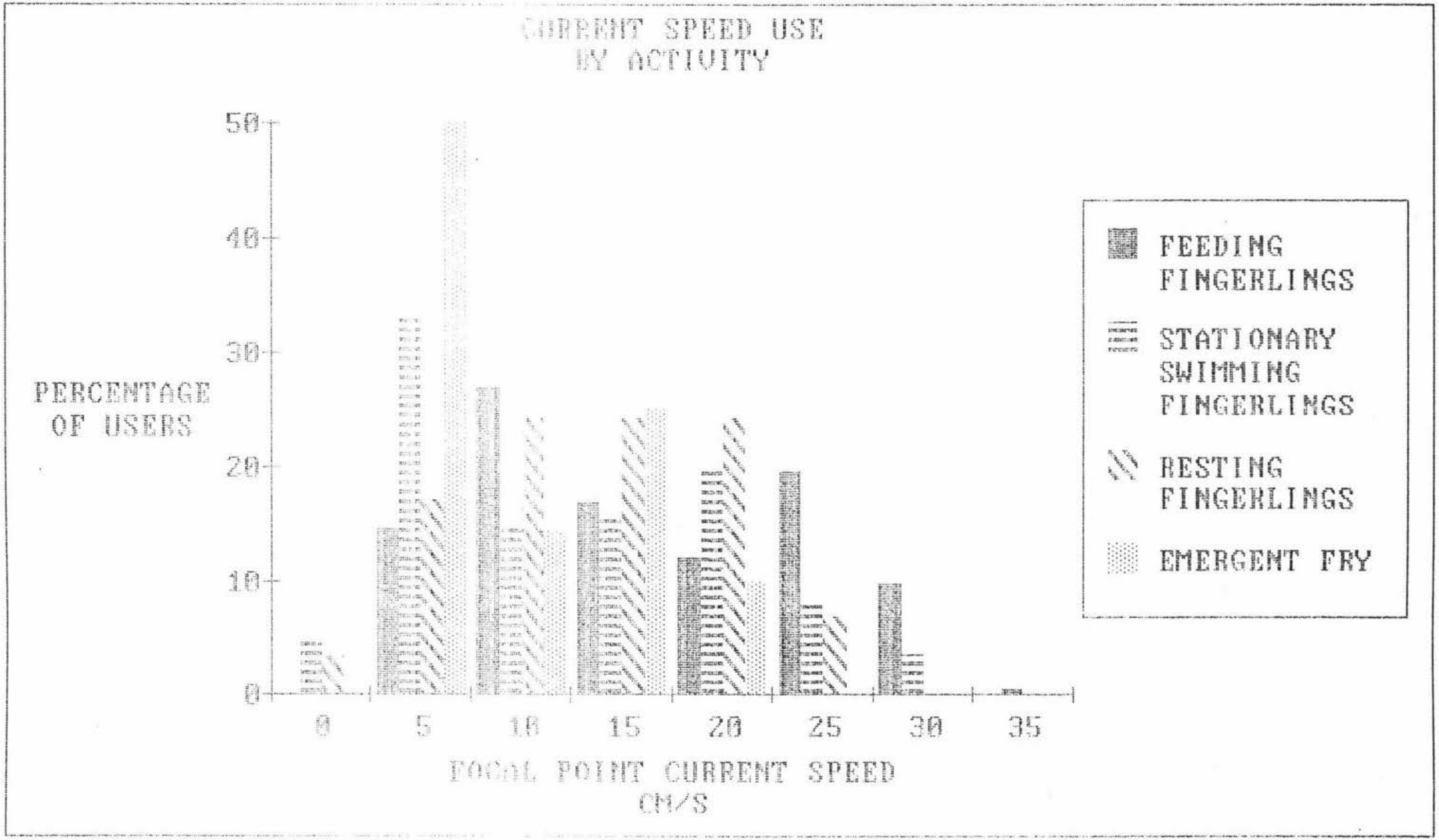
MEAN CURRENT SPEED				
ACTIVITY	N	MEAN (CM/S)	ST.DEV.	RANGE TO NEAREST 5CM/S
EMERGENT	52	20.4	10.4	5 - 50
RESTING	43	28.2	13.2	10 - 60
STAT. SWIM.	226	24	14	5 - 60
FEEDING	41	30.6	15.2	5 - 55

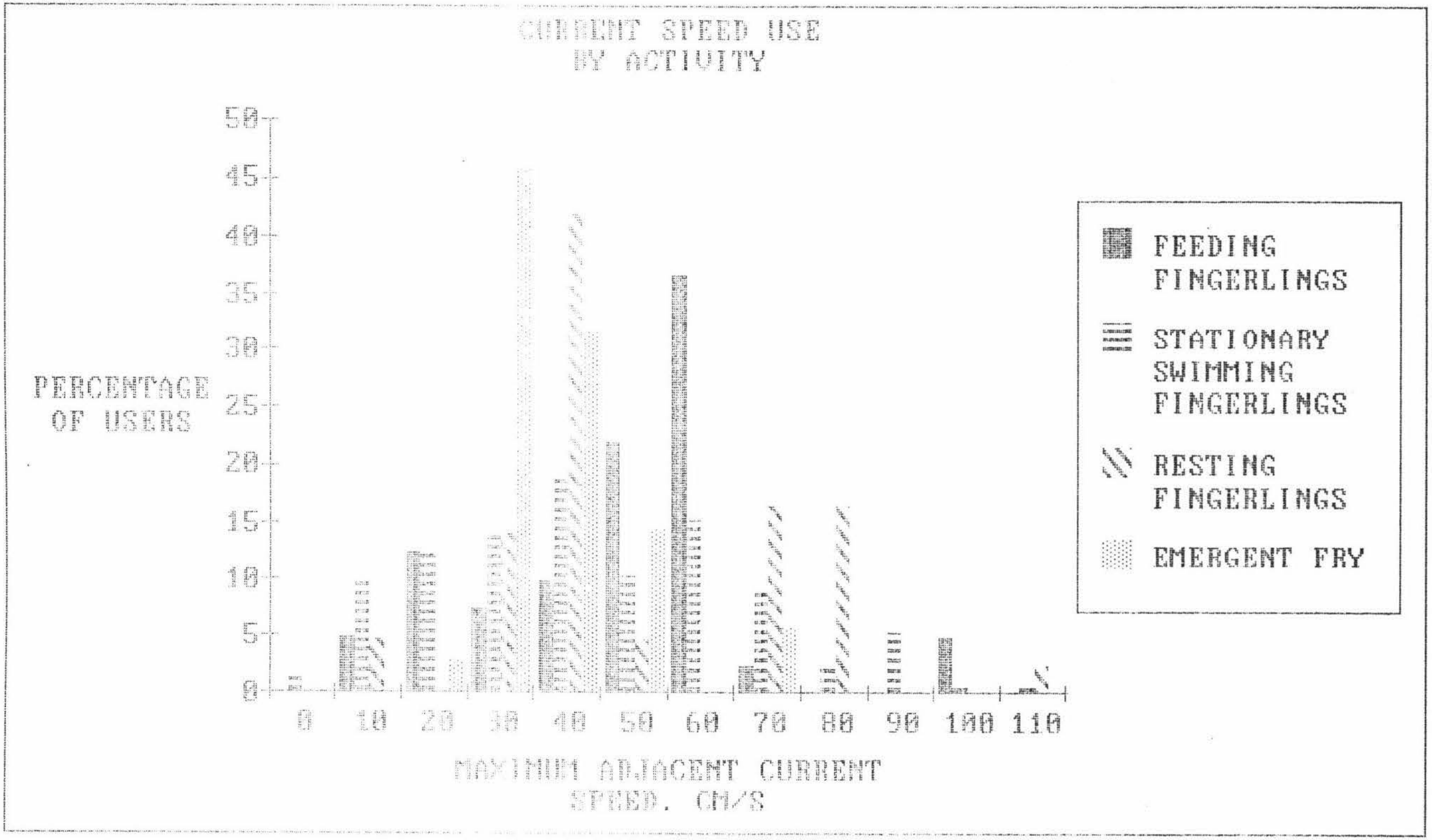
FOCAL POINT CURRENT SPEED				
ACTIVITY	N	MEAN (CM/S)	ST.DEV.	RANGE TO NEAREST 5CM/S
EMERGENT	28	9.9	5.1	5 - 20
RESTING	29	12.8	6.1	0 - 25
STAT. SWIM.	224	12.6	7.9	0 - 35
FEEDING	41	16.1	8.2	5 - 30

MAXIMUM ADJACENT CURRENT SPEED				
ACTIVITY	N	MEAN (CM/S)	ST.DEV.	RANGE TO NEAREST 5 CM/S
EMERGENT	35	41.2	11.1	25 - 75
RESTING	43	53.1	21.5	15 - 115
STAT. SWIM.	226	45.1	22.4	5 - 115
FEEDING	41	50.4	19.5	15 - 100



CURRENT SPEED USE
BY ACTIVITY
PERCENTAGE
OF USERS
25
20
15
10
5
0
0 5 10 15 20 25 30 35 40 45 50 55 60
MEAN CURRENT SPEED (CM/S)
FEEDING FINGERLINGS
STATIONARY SWIMMING FINGERLINGS
RESTING FINGERLINGS
EMERGENT FRY


CURRENT SPEED USE
BY ACTIVITY
PERCENTAGE
OF USERS
0
10
20
30
40
50
0
5
10
15
20
25
30
35
FOCAL POINT CURRENT SPEED
CM/S
FEEDING
FINGERLINGS
STATIONARY
SWIMMING
FINGERLINGS
RESTING
FINGERLINGS
EMERGENT FRY



CURRENT SPEED USE
BY ACTIVITY
PERCENTAGE
OF USERS
50
45
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
100
110
MAXIMUM ADJACENT CURRENT
SPEED, CM/S
FEEDING
FINGERLINGS
STATIONARY
SWIMMING
FINGERLINGS
RESTING
FINGERLINGS
EMERGENT FRY

4.2.2

CHANGES WITH AGE

A Chi^2 test on pooled data determined that mean current speed preference increased significantly ($p < 0.01$) from September 1986 to April 1987. There was no significant change in focal point current speeds occupied over the first eight months of life ($p > 0.1$), however there was a significant increase in maximum adjacent current speeds over the year ($p < 0.001$).

4.2.3

RELATIONSHIP TO HABITAT AVAILABILITY

A Chi^2 test of homogeneity determined a significant difference ($p < 0.001$) between available and used water speeds. As the difference was found in pooled data it was checked by performing a Spearman rank correlation on data collected at the same site on the same day. The non pooled data analysis also indicated a significant difference between fish use and habitat availability although it was not as great as pooled data ($p = 0.05$).

4.3

DISCUSSION

It is often very difficult to compare data generated in this study with that derived in other studies, primarily because the data is presented in insufficient detail: data presented as frequency histograms with means and standard deviations added, rather than means or histograms alone would be much more useful. Given these difficulties, the results of the present study appear to be within the range of overseas data.

4.3.2

FOCAL POINT CHARACTERISTICS

Overseas data indicate that focal point water speeds preferred by juvenile salmonids are in the region of 5 cm/s to 20 cm/s with some estimates ranging as high as 40 cm/s (DeGraaf and Bain 1986). However there appears to be general agreement on focal point current speed upper limit at approximately 30 cm/s. In the case of brown trout, Gosse and Helm (1982), Kalleberg (1958) and Bovee (1978) found focal point current speeds range between 5 and 20 cm/s and mean water speeds from 20 to 40 cm/s (see Table 4.2). Mean current speeds for salmonids range between studies from still water to flows of 90 cm/s. Maximum adjacent current speeds for brown trout have not been estimated by studies other than the present one. However the present study has found similar mean and focal point current speeds to previous investigations (Bovee 1978; Gosse and Helm 1982; and Kalleberg 1958), suggesting that New Zealand brown trout underyearlings prefer focal points with similar current speeds to those in North America. Table 4.2 is a summary of previous findings regarding salmonid focal points. Many of the studies shown in Table 4.1 differ in significant aspects of their data collection techniques and analysis to the present study. The following section highlights these differences and compares previous results with those generated here.

Kalleberg's (1958) pioneering stream aquarium study of underyearling salmonid behaviour was, as he pointed out, "not so much a reasoned scientific investigation as a series of partially connected observations and experiments". His determination of preferred focal point current speeds of atlantic salmon and brown trout were not measured but estimated. It is also interesting to note that Kalleberg (1958) found that areas of irregular substrate contained a higher density of fish than areas of homogeneous substrate. This was interpreted as due to visual isolation (i.e. fish that can not be seen by others are less likely to be driven away from their focal points). An equally convincing explanation is that sections of heterogeneous

Table 4.2. CURRENT SPEED USE (CM/S) BY UNDERYEARLING SALMONIDS
Data are presented as means and standard deviations (signified by ±) or ranges (signified by -)

FPCS#	MACS#	MCS#	Source	Species	Activity
<30			Kalleberg (1958)	*S. trutta*	
6 ± 5.94		24 ± 16.8	Gosse & Helm (1982)	*S. trutta*	resting
15 ± 8.5		27 ± 17	Gosse & Helm (1982)	*S. trutta*	stat. swim
18 ± 9.14		34 ± 18.2	Gosse & Helm (1982)	*S. trutta*	feeding
9 ± 9.78		21 ± 21.9	Gosse & Helm (1982)	*S. trutta*	rand. swim
		30*	Bovee (1978)	*S. trutta*	
9.9 ± 5.1	41.2 ± 11.1	20.4 ± 10.4	This study	*S. trutta*	emergent fry
12.8 ± 6.1	53.1 ± 21.5	28.2 ± 13.2	This study	*S. trutta*	resting
12.6 ± 7.9	45.1 ± 22.4	24 ± 14	This study	*S. trutta*	stat. swim
16.1 ± 8.2	50.4 ± 19.5	30.6 ± 15.2	This study	*S. trutta*	feeding
7 ± 8.2		10.3 ± 11.7	Baltz & Moyle (1984)	*S. gairdneri*	
7.5 ± 8.6		13 ± 17.5	Moyle & Baltz (1985)	*S. gairdneri*	
		15*	Bovee (1978)	*S. gairdneri*	
	30 - 45	15 - 30	Everest & Chapman (1972)	*S. gairdneri*	
0 - 15	15 - 30		Bustard & Narver (1975)	*S. gairdneri*	
10 - 30	20 - 50		Rimmer et al. (1983)	*S. salar*	
		20 - 40	Symons & Heland (1978)	*S. salar*	
0 - 40		0 - 90	Degraaf & Bain (1986)	*S. salar*	
12.1 ± 7.9		31.6 ± 21.2	Morantz et al. (1987)	*S. salar*	
9		21	Wangaard (1982)	*O. tschawytscha*	

* Read from habitat preference graph were raw data is not presented.
# FPCS = focal point current speed.
# MCS = mean current speed.
# MACS = maximum adjacent current speed.

substrate produce more areas with the preferred current speed characteristics so allowing a greater density of fish to occupy a given area.

Everest and Chapman's (1972) and Symons and Heland's (1978) data are included in Table 4.1 although they primarily used the gross habitat approach to data collection and so emphasize sections of the stream not used as focal points (e.g. feeding water and unused water) more than microhabitat studies. Thus their data are derived from examinations of salmonid habitat and should be regarded as an indication of the physical characteristics of preferred reaches of the stream rather than preferred points within a reach.

Bovee's (1978) estimates of current speeds are collated from published information and reports made available to the IFG Fort Collins, Colorado. Details of data collection methods are not available and so cannot be compared with those used in the present study.

The underwater observation techniques used by Baltz and Moyle (1984), Moyle and Baltz (1985), Bustard and Narver (1975), Gosse and Helm (1982), DeGraaf and Bain (1986) and Morantz et al. (1987) formed the basis of the methodology of the present study. However in the present study some different aspects of focal points were measured. In their investigation of the winter microhabitat of steelhead (sea run rainbow) trout and coho salmon (Oncorhynchus kisutch), Bustard and Narver (1975) did not measure mean current speed. Their estimate of maximum adjacent current speed was taken only 30 cm from the focal point (I recorded maximum adjacent current speed up to 50 cm from the focal point).

Gosse and Helm (1982) used an electronic current meter which enabled them to measure focal point current speeds directly thereby eliminating errors caused when the focal point is determined using markers and focal point elevation. They found that focal point current speed was more accurate than mean current speed in describing the focal points of brown trout. Mean current speed was not considered important in describing the focal point characteristics of brown trout, but they included mean current speed in their analysis because many habitat evaluation models depended on it. Their methodology and activity classifications were very similar to the present study.

DeGraaf and Bain (1986) found that both focal point and mean current speeds were largely related to the habitat types available. Both these measures of current speed were lower in a slow weedy river than in a faster rocky river. They also found that mean current speed is a poor descriptor of focal point characters. In contrast. Morantz et al. (1987) found that preferred focal point current speeds of juvenile atlantic salmon were similar in six "morphologically diverse streams" in Nova Scotia and New Brunswick. Canada.

4.3.3

CHANGES WITH ACTIVITY

My results indicate that underyearling brown trout choose different focal point current speeds for different activities. As predicted. feeding fish were found in the fastest water. Stationary swimming results are difficult to interpret as it is not known how stationary swimming is related to feeding or resting (see chapter 3). The small sample size makes it difficult to draw conclusions from the data regarding resting current speeds although fish chose higher current speeds for this activity than expected. This may reflect the resting fingerlings and emergent fry's close association with the substrate. highlighting the problems of the design of the flow meter. As trout use back currents and eddies surrounding instream obstructions it is important to measure focal point current speed as near as possible to the position of the fish's nose. In an effort to get a reading the flow meter may have inadvertently been placed higher in the water column than the focal point position. which would have resulted in erroneous measurements. In addition. resting fish were often difficult to see because of their strong thigmotactic response and cryptic colouration. so some fish resting close to the substrate and therefore in low current speed may not have been examined. It is also possible that a number of fish classified as resting were in fact hiding after being alarmed my presence. Between thirty and fifty fish which would have been termed resting were disqualified from analysis because they showed signs of distress. Stationary swimming and feeding fish were not seriously affected by the shortcomings of the current meter as they were located higher in the water column. It is interesting that the lowest published focal point current speeds (Gosse and Helm 1982) were found by using electronic current meters with probes rather than propeller driven devices.

Mean current speeds followed a pattern similar to focal point current speed. Resting fish were still located in faster currents than expected. This cannot be accounted for in the same way as focal point current speed as there was no difficulty measuring current at 0.6 of the total depth. However it may be that mean current speed plays little or no part in the selection of resting focal points by underyearling brown trout in the Kahuterawa stream. The gross location of focal points appears to be related to lines of drift and areas of cover (Jenkins 1969) however their precise position may be related to focal point current speed, shelter from the current and overhead cover. That is, those factors which are directly related to the fish. Conventional wisdom would suggest that trout choose slower reaches of the stream in which to rest. The morphology of the Kahuterawa stream is such that undercut banks are rare and there are few fallen trees and little overhanging vegetation to act as instream shelter of the type resting trout have been shown to use intensively (Jenkins 1969; Whickham 1967). Thus the trout in the Kahuterawa stream primarily use the substrate for their shelter and cover requirements. To be useful cover must conceal the majority of a fish's length and as a general rule larger spaces between particles are associated with larger particle sizes which are found in faster water. Therefore it is possible that underyearling brown trout use faster regions of the stream to rest because of the availability of suitable cover and shelter from the current.

Scott, cited in Church et al. (1979), suggested that the minimum feeding current speed for underyearling trout is approximately 15 - 20 cm/s. These estimates are supported by the present study in which maximum adjacent current speeds were never lower than 15 cm/s. However, maximum adjacent current speed as measured here is not a good indicator of the speed of the feeding current. In general trout were seen to move distances of only 2 to 3 body lengths to intercept food particles. Given this information it may be that mean current speed is a better indication of the feeding current especially for very young trout. As fish grew they ventured further to intercept drift, so the measure of maximum current speed within 50 cm of the fishes nose may be appropriate for adults but not for underyearlings. It is recommended that attempts to measure the feeding current take into account fish size. The above maximum adjacent current speed results may reflect the morphology of the stream: data range up to 115 cm/s with a mean of 40 - 50 cm/s which is similar to the surface current speeds of the study sites.

4.3.4

CHANGES WITH AGE

Sheppard and Johnson (1985), Gosse and Helm (1982), Baldes and Vincent (1969), and Hooper (1973) found that preferred current speeds increase with age. Comparison of the preferred current speeds of emergent fry with those of fingerlings, in the present study, is consistent with this assertion. All three measures of current speed are higher for fingerlings than for fry.

Gosse and Helm (1982) found that adults occupied focal points with higher current speeds than juveniles and underyearlings. Mean current speeds were higher for underyearlings than either juveniles or adults which was related to the fact that 87.5 % of underyearlings were either stationary swimming or feeding. This is compared with 47% of adults and 73% of juveniles. Their explanation for this is that smaller fish may use less energy than adults in stationary swimming and feeding and thus have a higher net energy gain per food unit. Consequently they are able to feed during the periods of the day when invertebrate drift is at low levels.

The change in preferred current speeds over the summer was complex. From September to December 1986 focal point current speeds increased, but they fell again during January and February 1987. Low rainfall in the late summer which reduced the streamflow may have been responsible. Reduced water area appeared to force fish from the preferred riffle habitat into slower pool reaches. Campbell and Scott (1984) present evidence that this micro-migration is prompted by a lowering in riffle current speed to less than 30 cm/s. Habitat availability data from the present study suggest that the mean current speed of riffles was most often less than 30 cm/s over the period September 1986 to March 1987, suggesting the possibility that other factors, such as depth, may be the cause of micro - migration.

CHAPTER 5
DEPTH

5.1 INTRODUCTION

Water depth has traditionally been accepted as one of the important features of salmonid focal point selection. One of the pioneering studies of salmonid microhabitat (Baldes and Vincent 1969) found that water depth exerted a significant influence over site selection in an experimental flume. Everest and Chapman (1972) discovered that water depth correlated significantly with the distribution of underyearling steelhead trout and chinook salmon. They considered depth to be an important component of the physical characteristics of the focal points of steelhead trout. Since those early studies, water depth has been a factor in virtually all examinations of lotic fish habitat and focal point requirements (e.g. Moyle and Baltz 1984; Shirvell and Dungey 1983; Hermansen and Krog 1984; Rimmer et al. 1983 1984; Wangaard 1982; and Bovee 1978). The importance of depth has been somewhat overshadowed by current speed, yet its value can be realised when focal point elevation is considered. The latter is among the most stable of measured focal point variables often having a standard deviation of only 2 - 3 cm.

Depth could be important for a fish in that it offers a form of overhead cover. A large amount of water above a fish may offer protection from such terrestrially based predators as birds and mammals including humans (Everest and Chapman 1972). Depth may also be important for trout food organisms, indirectly affecting trout focal point selection. Hooper (1973) suggested that a good food producing area will have a depth range of 15 - 90 cm. Most published surveys find that underyearling salmonids are located within this range (Moyle and Baltz 1985; Baltz and Moyle 1984; Rimmer et al. 1983 1984; Gosse and Helm 1982; DeGraaf and Bain 1986; Bustard and Narver 1975; Bovee 1978; Everest and Chapman 1972; and

Morantz et al. 1987). Giger (1973) further refines this 'ideal' food producing depth as approximately 30 cm. While trout are not restricted to food producing areas. for invertebrates can drift considerable distances with the current. it would certainly be an advantage during the crucial first year to hold a focal point in an area of high food abundance.

Shirvell and Dungey (1983) observed that the shallowest focal points are from small streams and artificial flumes which only have a limited range of available depths. The Kahuterawa stream is not a large waterway and available depths are limited in the study areas to a maximum of 1 - 2 m. Thus it is probable that total depth results analysed in this chapter may not be applicable to deeper waterways.

DeGraaf and Bain (1986) and Jenkins (1969) noted that larger fish tend to exclude small trout from the most preferred positions. It can be expected then. that the presence of larger fish will restrict the depths into which underyearling trout may safely venture. Gosse and Helm (1982) found that underyearlings occupied significantly deeper water in areas with a low number of adults. This potential restriction does not appear to be a significant factor in the Kahuterawa stream for there are very few overyearling trout in the study sites during the period that underyearling fish are present.

It is difficult to make predictions regarding changes in total depth over the first year of life due to the conflicting information available. Giger's (1973) review of streamflow requirements of salmonids stated that smaller fish prefer shallower water. Baltz and Moyle (1984) concurred with this suggesting that larger rainbow trout use deeper water than small conspecifics. However Rimmer et al. (1984) considered that age. and therefore size. does not greatly affect depths chosen by atlantic salmon in Canada.

It could be assumed that preferred water depths will be variable above a minimum value needed for a degree of overhead cover. If this is so then preferred total depths are expected to be highest for resting. an activity that requires considerable overhead cover. However it was not practicable to test this hypothesis due to difficulties associated with snorkeling in shallow depths. Such an idea needs to be tested in a controlled situation such as a stream aquarium or flume diversion.

In addition to interacting with total depth to form cover, focal point elevation is related to shelter from the current. In a waterway the current speed is lowest near the bottom (Petts 1983). If the channel bottom is rough (e.g. bouldery) bottom current speed may be lowered even more, particularly around obstructions. For reasons of energy conservation it would be advantageous for a trout to spend a large proportion of its time at or near the slower currents of the stream bottom. Hooper (1973) indicated that brook trout (Salvelinus fontinalis) spend 70% of their time on the bottom, brown trout 80% and rainbow trout 65%. Shirvell and Dungey (1983), in a New Zealand survey, found that 97% of feeding brown trout occupied positions on, or within 15 cm of the substrate.

Energy conservation strategy suggests that underyearling brown trout focal point elevation should be low (close to the bottom) in order to take full advantage of slower bottom current speeds. Resting fingerlings should be found closest to the bottom as energy conservation is most important for this activity. Feeding focal point elevations should be the most variable as a fish may be able to endure greater current speeds if enough energy from drifting food can be gained. Focal point elevation is also expected to increase over the first year of life as fish become more able to cope with the associated increase in current speeds.

5.2

RESULTS

5.2.1

CHANGES WITH ACTIVITY

Total depth differed significantly between all activities (Chi^2 $p < 0.001$) except stationary swimming and resting (Chi^2 $p > 0.5$). There was also a significant difference between depths used by emergent fry and each fingerling activity. Figure 5.1 shows the percent usage of total depth for each activity class. Table 5.2 summarizes total depth by activity. Total depth was lowest for emergent fry and highest for feeding fingerlings. No values are lower than 10 cm and few are below 20 cm. Maximum total depth roughly corresponds with maximum available depth. although a deep (>2 m) plunge pool in study site 1 was not used at all.

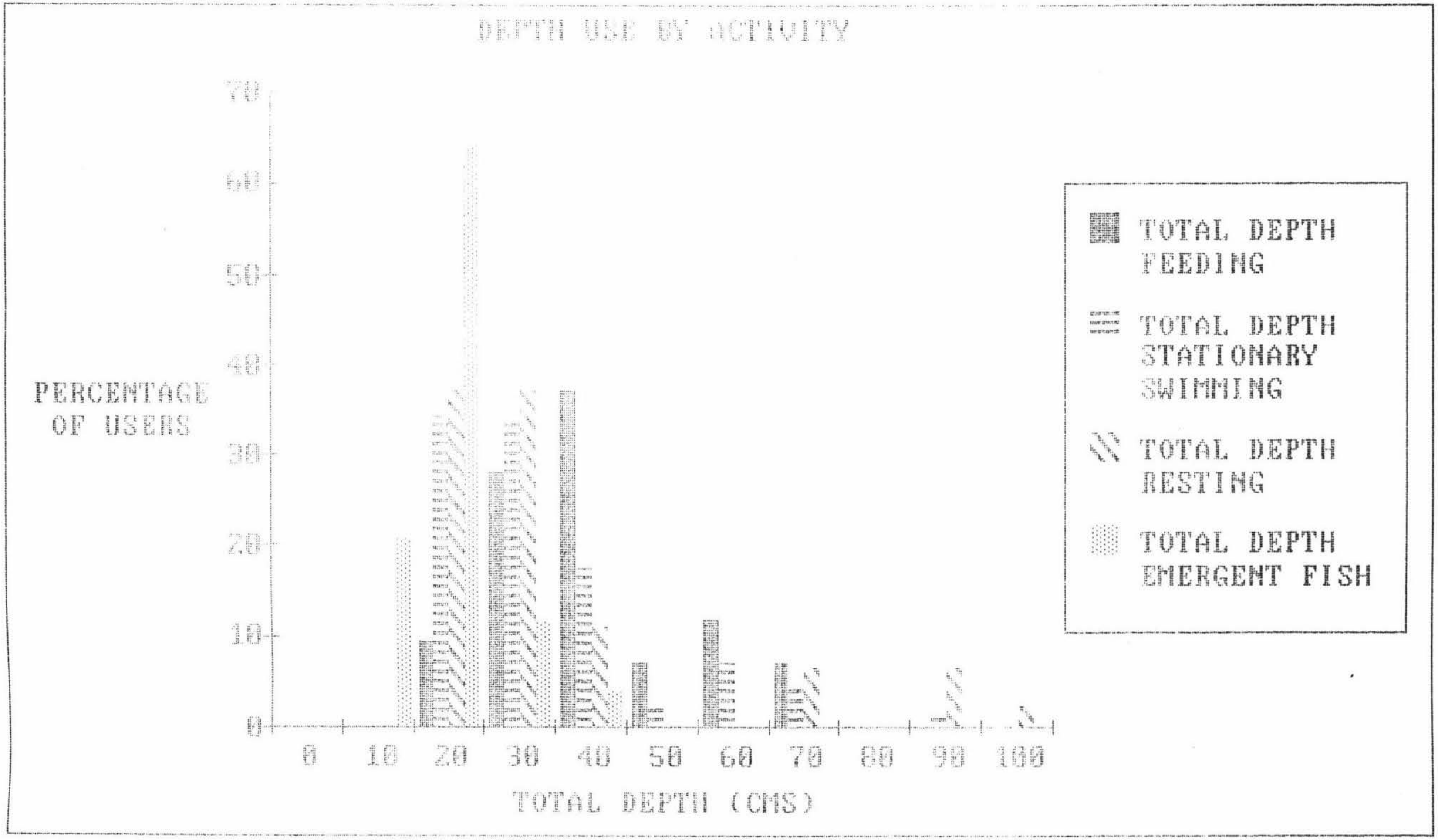
Focal point elevations differed between activities (Chi^2 $p < 0.001$) except feeding and stationary swimming (Chi^2 $p < 0.5$). Emergent and resting fish occupied focal point elevations that were not significantly different (Chi^2 $p < 0.1$). Focal point elevation ranged from 0 to 32 cm. the majority of data falling in the 0 - 10 cm range. Figure 5.2 and Table 5.1 indicate focal point elevations for each activity.

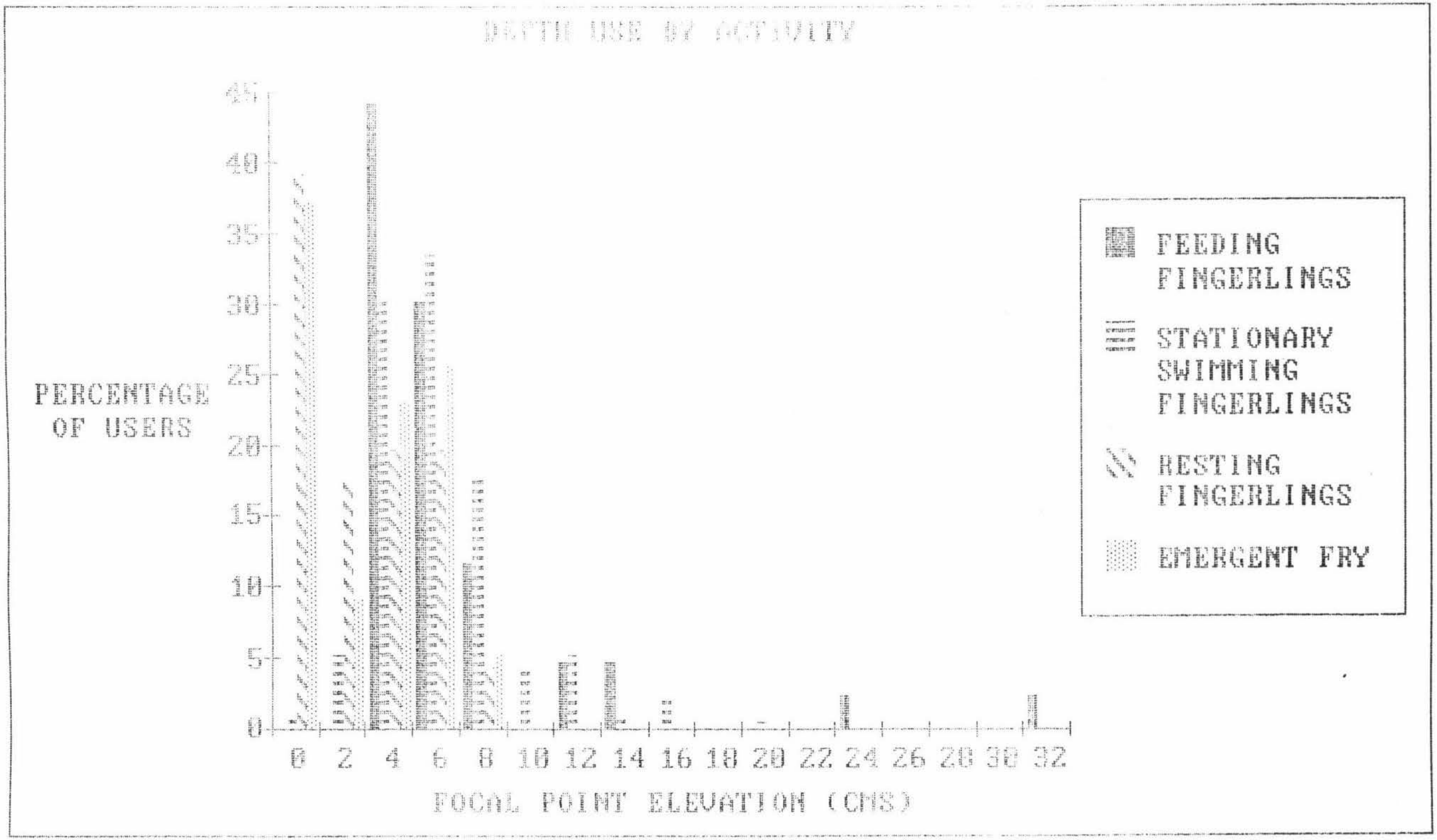
TABLE 5.1

DEPTH USE BY ACTIVITY

		TOTAL DEPTH		
ACTIVITY	N	MEAN (CM.)	STD. DEV.	RANGE TO NEAREST 10 CM.
EMERGENT	78	19.8	7.4	10 - 40
RESTING	46	34.8	20.2	20 - 100
STAT. SWIM.	230	33.1	14.7	20 - 90
FEEDING	43	39.9	13.2	20 - 70

		FOCAL POINT ELEVATION		
ACTIVITY	N	MEAN (CM.)	STD. DEV.	RANGE TO NEAREST 2 CM.
EMERGENT	78	2.95	2.6	0 - 8
RESTING	46	2.48	2.4	0 - 8
STAT. SWIM.	230	5.9	2.9	0 - 20
FEEDING	43	6.6	5.5	4 - 32


DEPTH USE BY ACTIVITY
70
60
50
40
30
20
10
0
PERCENTAGE OF USERS
0 10 20 30 40 50 60 70 80 90 100
TOTAL DEPTH (CMS)
TOTAL DEPTH FEEDING
TOTAL DEPTH STATIONARY SWIMMING
TOTAL DEPTH RESTING
TOTAL DEPTH EMERGENT FISH



DEPTH USE BY ACTIVITY
PERCENTAGE OF USERS
0
5
10
15
20
25
30
35
40
45
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32
FOCAL POINT ELEVATION (CMS)
FEEDING FINGERLINGS
STATIONARY SWIMMING FINGERLINGS
RESTING FINGERLINGS
EMERGENT FRY

5.2.2

CHANGES WITH AGE

Both preferred total water depth and focal point elevation of brown trout increased (Chi^2 $p < 0.001$ in both cases) from September to April.

5.2.3

RELATIONSHIP TO HABITAT AVAILABILITY

Data was pooled for emergent fry and all fingerling activities and a Chi^2 test of homogeneity was used to compare the total depth of water at the focal point position with the available depths. Fish used deeper water in significantly higher proportions than its availability ($p = 0.001$).

5.3

DISCUSSION

5.3.1

FOCAL POINT CHARACTERISTICS

Investigations of salmonid focal point have determined total depth preferences which range from 10 - 200 cm (see Table 5.2). Most reports of underyearling salmonid depth preferences are between 20 - 60 cm. Brown trout preferences range from 25 - 80 cm. with one study (Gosse and Helm 1982) which examined a range of activities finding different preferred depths for different activities. Estimates of focal point elevation have a considerably lower range between studies (0 - 30 cm). with the majority in the 5 to 10 cm region. Brown trout focal point elevations appear slightly lower than other salmonid species between 0 and 10 cm for in situ studies.

Rimmer et al. (1984) found that in the case of juvenile atlantic salmon, peaks existed in the depth distributions at 24 - 36 cm. This is similar to the present study although available depths were restricted in the Kahuterawa stream. Bustard and Narver (1975) state that preferred total depths were highly variable, however they found that underyearling coho salmon (Oncorhynchus kisutch) were rarely found in water shallower than 15 cm.

Gosse and Helm (1982) found that total depth was very unstable with high standard deviations and suggested that depth use will vary according to its availability. They draw a different conclusion for focal point elevation, however, which is so stable that they suggest stream variables may be measured at predicted focal point elevations for habitat evaluations. DeGraaf and Bain (1986) and Morantz et al. (1987) concluded that total depth was probably not a limiting factor for underyearling atlantic salmon, within the ranges that they sampled (up to 140 cm).

As can be seen from the above information, many investigations of salmonid focal points include depth measures, however few make any comment about its value as a focal point determinant. Table 5.2 is a summary of previous information regarding underyearling salmonid depth preferences.

Preferred depths in the Kahuterawa study are similar to those reported by Bovee (1978) but significantly shallower preferred depths than those found by Gosse and Helm (1982). This is probably because in the present study there is little deep water (> 1.5 m) available in any of the study sites. It appears that total depth preferences are quite indistinct, especially in larger rivers where a variety of water depths are available. For example, preferred total depths determined by Wangaard (1982) in a large river, range up to 2 m: considerably deeper than in the studies in smaller rivers detailed in Table 5.2. This suggests that underyearling salmonids can tolerate a wide variety of total depths. Further study is needed to determine if there

Table 5.2. DEPTH USE (CM) BY UNDERYEARLING SALMONIDS
Data presented are means and standard deviations (signified by ±) or ranges (signified by -)

Total depth	Focal point elevation	Source	Species	Activity
	5 - 30	Kalleberg (1958)	*S. trutta*	
25 - 30*		Bovee (1978)	*S. trutta*	
47 ± 22.6	0.3 ± 0.775	Gosse & Helm (1982)	*S. trutta*	resting
62 ± 23.2	4.7 ± 3.45	Gosse & Helm (1982)	*S. trutta*	stat. swim
73 ± 39.8	5.9 ± 3.08	Gosse & Helm (1982)	*S. trutta*	feeding
83 ± 54.3	9.6 ± 8.63	Gosse & Helm (1982)	*S. trutta*	rand. swim
19.8 ± 7.4	2.95 ± 2.6	This study	*S. trutta*	emergent fry
34.8 ± 20.2	2.48 ± 2.4	This study	*S. trutta*	resting
33.1 ± 14.7	5.9 ± 2.9	This study	*S. trutta*	stat. swim.
39.9 ± 13.2	6.6 ± 5.5	This study	*S. trutta*	feeding
35.5 ± 16.7	8.1 ± 8.8	Moyle & Baltz (1985)	*S. gairdneri*	
58.2 ± 29.3	9.5 ± 1.1	Baltz & Moyle (1984)	*S. gairdneri*	
22 - 60*		Bovee (1978)	*S. gairdneri*	
15 - 90!		Everest & Chapman (1972)	*S. gairdneri*	
31.7	5	Bustard & Narver (1975)	*S. gairdneri*	
45 - 85		Sheppard & Johnson (1985)	*S. gairdneri*	
18 - 36		Sheppard & Johnson (1985)	*S. gairdneri*	
30.2		Rimmer et al. (1984)	*S. salar*	
30.9		Rimmer et al. (1984)	*S. salar*	
15 - 50!		Keenlyside (1962)	*S. salar*	
10 - 80!		Degraaf & Bain (1986)	*S. salar*	
72.7	25	Bustard & Narver (1975)	*O. kisutch*	
35.1 ± 13.1		Morantz et al. (1985)	*O. kisutch*	
60 - 200!		Wangaard (1982)	*O. tshawyt*	
30		Giger (1973)	Salmonids	

* Read from a habitat preference graph where raw data was not presented.

are true preferences for total depths. It may be that total depth "preferences" are not preferences at all, but rather a reflection of preferred current speed, substrate size and shelter type.

There are potential biases in the total depth values in relation to the minimum depths found in the present study. It is impractical to snorkel in depths of less than 15 cm. Because the minimum preferred depths found in this study approximate 15 cm it is possible that these are not true fish preferences but are related to the inadequacies of the sampling method.

In keeping with other published surveys, focal point elevation was the most stable measured focal point variable. Everest and Chapman (1972) noted that steelhead trout were rarely found more than 15 cm from the stream bottom. Shirvell and Dungey (1983) suggest that fish may occupy feeding positions close to the bottom because of reduced current speeds near the stream bottom or food being more easily sighted from near the substrate. They cite Faush (1984), who determined that trout feed in a fan shaped area in front and above them, as evidence for the latter explanation.

5.3.2

CHANGES WITH ACTIVITY

Emergent fry used the shallowest water. There are a number of possible reasons for this. Firstly, this could be by choice, for emergent fry may gain some benefit from shallow water. Secondly, it is possible that emergent fry are found in habitats similar to that in which their parents spawned. To determine if this is the case more research must be done to compare spawning microhabitat and emergent focal points before further comment can be made. This is most pressing as current habitat evaluation models do not recognise emergent fry as a separate group from fingerlings and it is essential to determine if a separate age category is needed to determine habitat preference curves. Finally, the channel morphology could be such that shallow depths were most available to the emergent fish, although in the present study this appears not to be a valid explanation as there was a statistically significant difference between available and used depths.

Focal point elevation is lowest for emergent fry and resting fingerlings. These fish are expected to be in areas of low current speed to conserve energy. Resting fingerlings were located near the bottom possibly because of the reduced current speeds found there. However, proximity to the bottom also enables them to be near the major instream cover types used. Stationary swimming and feeding fingerlings were found highest in the water column and this probably relates to food. Such fish may have sacrificed reduced current speeds near the substrate to be higher in the water column and so near the main lines of invertebrate drift.

5.3.3

CHANGES WITH AGE

In common with previous studies the present research found that juvenile brown trout prefer deeper water as they age. This may be related to an ability to tolerate increased water speeds or a desire to be near shelter areas. Also larger fingerlings may be better able to avoid predation and defend a territory. However it is probable that the increase in water depths used over the first summer is related to the late summer habitat change from shallow riffles to deeper pools which is related to reduced flows.

The increase in focal point elevation over time occurs mainly because emergent fry moved higher in the water current from the substrate in early September. This movement was related to the onset of fingerling activities such as stationary swimming and was used to mark the emergent fry/fingerling changeover. There appears to be little change in focal point elevations after November.

CHAPTER 6
SUBSTRATE AND COVER

6.1 INTRODUCTION

Unlike current speed and depth, the significance of substrate size in salmonid focal point choice has been recently challenged. Substrate is seen to be important to salmonids for spawning (Frost and Brown 1967; Shirvell and Dungey 1983), and so has been included, often by default, in many investigations of the focal points of salmonid life stages and other fish taxa. Recently, some workers have concluded that except in the special cases of spawning and periods of winter quiescence, substrate per se is not an important factor in the focal point choice of juvenile and adult brown trout (Gosse and Helm 1982) and juvenile atlantic salmon (Rimmer et al. 1984). Measures of substrate were included in the present investigation because such other studies as Moyle and Baltz (1985) found substrate to be an important factor in focal point choice of rainbow trout. In addition Harshbarger and Bhattacharyya (1981) found that the area of the stream bottom covered by rocks was a most significant factor in explaining the standing crop of salmonids in some United States streams.

Substrate could be important to young fish for food production, shelter from the current, and escape cover. Giger (1973) found that highest food productivity was located in substrates of 6.5 - 27 cm particle diameter. As mentioned earlier it would be advantageous for a trout to live downstream of productive areas. The food producing aspects of substrates are, however, outside the scope of this study.

Substrate irregularity is an important factor in cover and shelter. This may be due to the increased visual isolation, caused by irregular substrate size. Visual isolation is thought to decrease agonistic behaviour which, in turn, allows higher fish density

(Kalleberg 1958; Giger 1973). A potentially more significant consequence of a heterogeneous substrate is that it will contain areas of slow or even 0 current speed, thus allowing a fish to be in an zone of low current speed yet near a band of high current speed.

Substrate size is related to current speed (Townsend 1980): smaller substrate particles (silts, sands, and small gravels) are mobilized by high current speeds and deposited in areas of low current speed. The energy maximization strategy of Jenkins (1969), Faush (1984) and Bachman (1984) predicts that feeding fish will prefer to be in an area of medium to slow current speed yet near a zone of faster water and that fish engaged in all other activities will prefer low current speeds. These models do not make any comment on the value of substrate in focal point choice, although it has been shown that substrate may be a good indicator of current speed.

Cover is widely accepted as an important constituent of the focal point positions of salmonids, yet it is difficult to quantify, often making empirical studies of its effects impracticable. Giger (1973) noted that focal points are very often associated with the presence of 'high quality' cover and Cunjak and Power (1986) found that virtually all the fish in their study were close to escape cover. Overhead cover provides shadow areas along stream margins often with slow currents. These areas may be optimal for resting or feeding (Giger 1973). Studies such as Gosse and Helm (1982) and McCrimmon and Kwain (1966) have found a correlation between preferred cover and low light intensities. A major problem in measuring cover is the lack of a suitable definition. Cover can be divided into two distinct parts: escape cover, defined as any area in which the fish uses to conceal itself from either a predator or competitor; and shelter, which is any area that allows the fish respite from the current. As mentioned in chapter 3 an attempt was made to measure the distance to escape cover. This was not successful, as frightened fish fled to cover not perceived by the observer as the closest. These problems were further compounded by the size (20 - 100 mm) of underyearling brown trout in the Kahuterawa stream, which allows them to use objects as small as large gravels (20 -

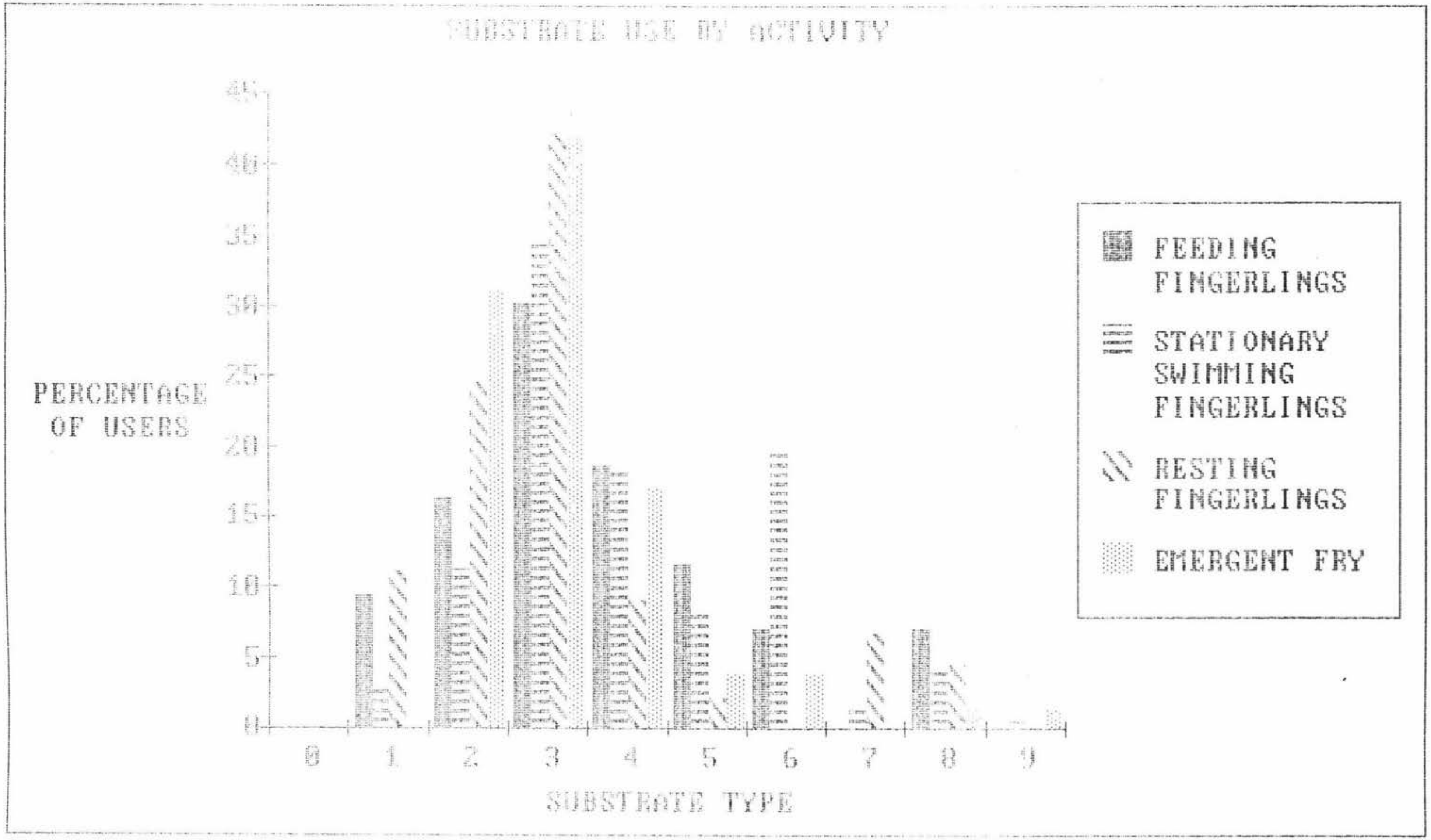
50 mm) for shelter and escape cover. Habitat assessment suggests that 70% of the stream substrate is bigger than large gravels and thus escape cover for underyearling trout is abundant. Newly emerged trout may seek cover near even smaller objects. Consequently, most instream objects could be regarded as potential cover.

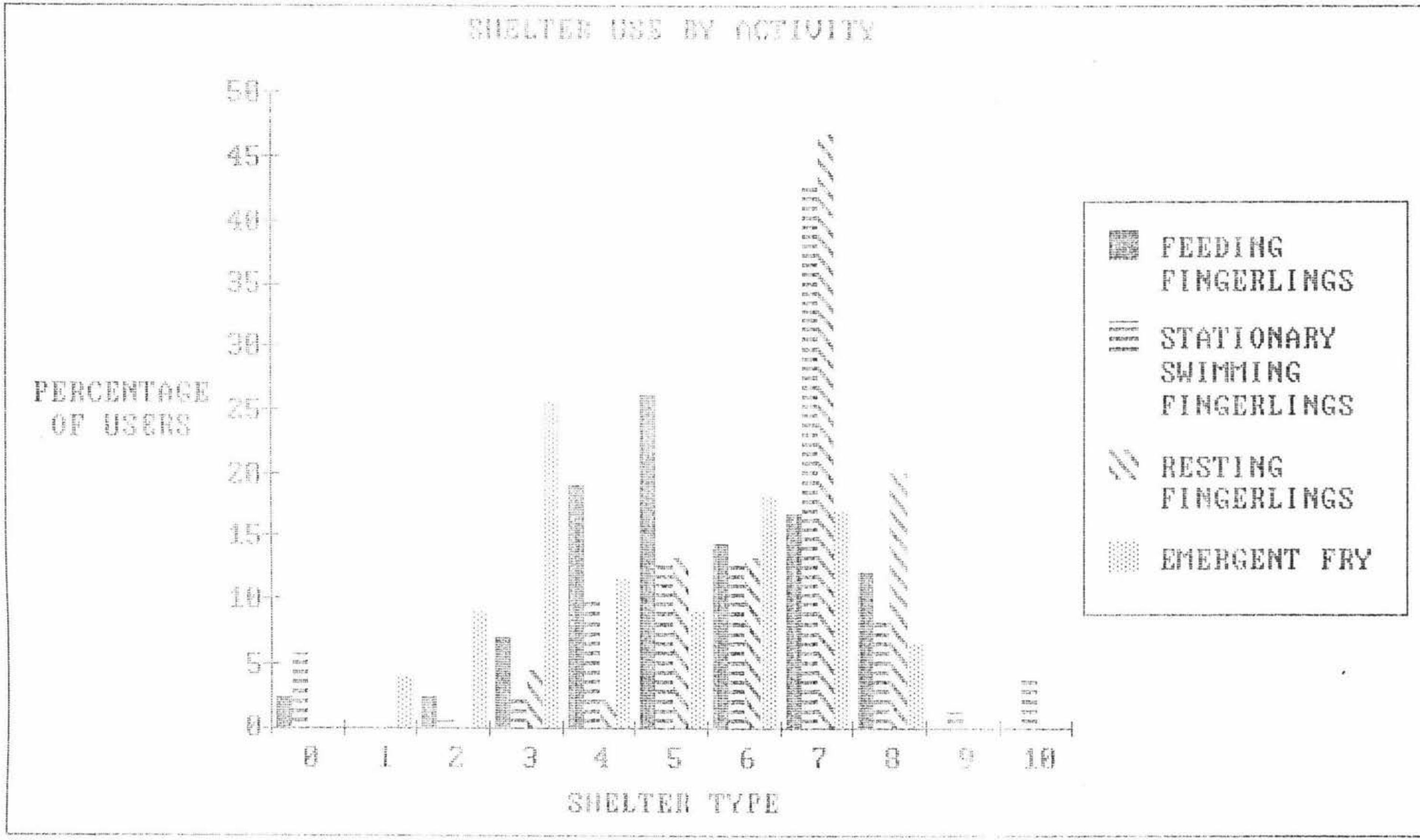
6.2 RESULTS

6.2.1 CHANGES WITH ACTIVITY

Changes in substrate preference with activity are complex. Overall there was a significant difference between activities (Chi^2 $p < 0.001$). However when the activities were examined in pairs, no significant difference was found between resting and feeding (Chi^2 $p > 0.5$), or between stationary swimming and feeding (Chi^2 $p > 0.5$). The most commonly used substrate type for all activities was large gravels. Substrate preferences of emergent fish were not significantly different to resting (Chi^2 $p > 0.5$) or feeding fingerlings (Chi^2 $p > 0.1$). Preferred substrate types are shown in figure 6.1.

Shelter types used were found to differ between emergent fry and all fingerling activities, and between fingerling activities (Chi^2 $p < 0.001$). When activities were analysed in pairs significant differences were found between all activities except resting and stationary swimming (Chi^2 $p > 0.1$). Shelter types used by emergent fry ranged in size from small gravels to boulders. Shelter used by resting and stationary swimming fish were predominantly rocks or large rocks. Stationary swimming fish also spent some time near wood and other instream cover such as concrete debris. Feeding fish used a wide range of shelter types up to and including large rocks but often sheltered behind objects smaller than those used during other


SUBSTRATE USE BY ACTIVITY
PERCENTAGE OF USERS
45
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
9
SUBSTRATE TYPE
FEEDING FINGERLINGS
STATIONARY SWIMMING FINGERLINGS
RESTING FINGERLINGS
EMERGENT FRY


SHELTER USE BY ACTIVITY
PERCENTAGE OF USERS
0
5
10
15
20
25
30
35
40
45
50
0
1
2
3
4
5
6
7
8
9
10
SHELTER TYPE
FEEDING FINGERLINGS
STATIONARY SWIMMING FINGERLINGS
RESTING FINGERLINGS
EMERGENT FRY

activities. See Figure 6.2.

6.2.2.

CHANGES WITH AGE

There was a significant increase (Chi^2 $p < 0.001$) in preferred substrate size over the first eight months of life.

Use of shelter materials varied significantly with time (Chi^2 $p < 0.001$). This is partially due to the use of such new shelter materials as wood and undercut banks as the fish aged.

6.2.3

RELATIONSHIP TO HABITAT AVAILABILITY

The availability of substrate types was compared with their use by underyearling brown trout in the Kahuterawa stream using a Chi^2 test of homogeneity. A statistically significant difference between substrate use and availability was found ($p < 0.001$). Small gravels and gravels were used in greater proportion than their availability while cobbles, rocks and sand were used less than their availability.

6.2.4

TRENCHES AS SHELTER

Following field observations, many fish were found in natural depressions in the substrate, so from January 1987 information was collected on the use of these natural trenches for shelter from the current. 78% (N = 164) of fish occupied trenches as well as sheltering behind or in front of other objects.

6.3

DISCUSSION

6.3.1

INTRODUCTION

This study recognises two separate components grouped under the loose heading of cover. These are escape cover and focal point shelter. Escape cover is used to hide from potential predators. Focal point shelter is shelter used to gain respite from the current while holding position at the focal point. The substrate is most often a component of focal point shelter, however submerged objects such as large boulders can sometimes be substituted for overhead (escape) cover Giger (1973). Escape cover should not be thought of only as overhead cover. Fast, deep water has also been shown to provide a form of escape cover (Everest and Chapman 1972). Jenkins (1969) found that brown trout often sought holes or depressions in the substrate when disturbed although most refuge positions consisted of spaces between or underneath large rocks or beneath undercut banks. I have also observed some trout which are easily visible from above exhibiting behaviour associated with hiding.

Focal point shelter has not been investigated extensively in the literature, although it is widely recognised as being important. Jenkins (1969) found that shelter from the current allowed fish to remain in areas with far higher mean current speeds than those in which they could normally hold position. In the present study, focal point shelter appeared to be very significant especially in faster reaches of the stream. All fish not using either stream bed materials or depressions in the substrate for shelter were found to occupy water columns with mean current speeds of less than 20 cm/s.

6.3.2

FOCAL POINT CHARACTERISTICS

The studies shown in Table 6.1 have determined that preferred substrates of underyearling salmonids are in the range of gravel to cobble although Moyle and Baltz (1985) found that sand and gravel were the most popular substrate types. Results for brown trout indicate that they may use slightly smaller substrates than other salmonid species.

The substrate usage described by Rimmer et al. (1983). Symons and Heland (1978). Sheppard and Johnson (1985). Bovee (1978). Bustard and Narver (1975) and Everest and Chapman (1972) is derived using the habitat approach: that is they mapped the predominant substrate in the reach in which the fish was found. Those of Baltz and Moyle (1984). Morantz et al. (1987). DeGraaf and Bain (1986). Gosse and Helm (1982) and Moyle and Baltz (1985) are determined using the focal point approach. specifically the substrates directly underneath the fish. The present study used the latter approach. although comparisons between the present study and gross habitat studies may be made using habitat availability data.

In addition to the information summarized in Table 6.1. qualitative studies such as Keenlyside (1962) and Giger (1973) have found that underyearling salmonids are attracted to aquatic vegetation and gravel to sand sized substrates. Jenkins (1969) found holding areas (focal points) were generally located over a rising bottom. in pockets in the substrate near projecting rocks. or in sluggish areas of pools.

TABLE 6.2

MODIFIED WENTWORTH PARTICLE SCALE

(AFTER BOVEE 1978)

1	PLANT DETRITUS/ORGANIC MATERIAL
2	MUD SOFT CLAY
3	SILT
4	SAND
5	GRAVEL
6	COBBLE RUBBLE
7	BOULDER
8	BEDROCK
9	MACROPHYTES

Graduations between codes refer to the proportion of substrate types. For example 5.6 means 60% cobble 40% gravel.

Very little quantitative information regarding cover preferences of salmonids is available. Bustard and Narver (1975) determined (with apparently considerably more success than the present study) distances from the focal point to the nearest available cover for juvenile coho salmon and steelhead trout. They found that the majority of both species were located in cover or were closer than 50 cm to it when the water temperature was less than 7°C. Gosse and Helm (1982) have provided information on preferred light intensities of brown trout in the field. They determined that underyearlings prefer light intensities of between 4.2% and 36.8% of full sunlight depending on activity. Apart from these two studies most information pertaining to cover is of a qualitative nature.

In his study of albino brook trout Wickham (1967) noted that focal points were associated with turbulent surface water, large (> 45 cm) rocks and submerged logs. Giger (1973) found that for small salmonids, stones in riffles and aquatic vegetation

Table 6.1. SUBSTRATE USE BY JUVENILE SALMONIDS

Substrate (modified wentworth particle scale)	Source	Species	Activity
4 - 5	Bovee (1978)	_S. trutta_	
3 - 5	Gosse & Helm (1982)	_S. trutta_	resting
3 - 6	Gosse & Helm (1982)	_S. trutta_	stat. swim
3 - 6	Gosse & Helm (1982)	_S. trutta_	feeding
3 - 6 + some at 9	Gosse & Helm (1982)	_S. trutta_	rand. swim
4	This study	_S. trutta_	emergent fry
6 - 7	This study	_S. trutta_	resting
6 - 7	This study	_S. trutta_	stat. swim
6	This study	_S. trutta_	feeding
6 - 7	Rimmer et al. (1983)	_S. salar_	
6 - 7	Bustard & Narver (1975)	_S. gairdneri_	
6.8	Baltz & Moyle (1984)	_S. gairdneri_	
5	Bovee (1978)	_S. gairdneri_	
6	Everest & Chapman (1972)	_S. gairdneri_	
5 - 6*	Sheppard & Johnson (1985)	_S. gairdneri_	
5	Symons & Heland (1978)	_S. salar_	
5.6 0.9	Morantz et al. (1987)	_S. salar_	
5 - 6	Degraaf & Bain (1986)	_S. salar_	
5 - 7*	Sheppard & Johnson (1985)	_O. kisutch_	

* Read from habitat preference graph where raw data is not presented.

are the main cover types used. Association with cover appears to be less in summer than in winter when fish compete for postions near high quality cover (Rimmer et al. 1984; Cunjak and Power 1986). Consequently it is important to study cover use and availability, in New Zealand streams, during the winter months, when this resource is most likely to become scarce.

6.3.3

CHANGES WITH ACTIVITY

Emergent fry used most substrate sizes as shelter from the current whereas fingerlings used mainly the larger grain sizes. This is probably related to the small size of emergent fry which allows them to use such small objects. Emergent fry were normally located on the bottom where current speed is slowest and this may have allowed them to use marginal shelter materials. Resting fingerlings appeared to be most closely associated with cover and they also used the largest shelter types. This is in compliance with the energy conservation strategy, although if resting fish were avoiding a predator (the observer) larger grain sizes would be necessary for concealment. Feeding fish often sheltered behind smaller objects than those for other activities. Which when combined with the higher focal point current speeds of feeding fish suggests that they were prepared to accept a higher current speed in the quest for increased food. This also is in general agreement with the cost minimization strategy.

6.3.4

CHANGES WITH AGE

Both the present study and Gosse and Helm (1982) found that preferred substrate size increases with age. This increase is probably related to fish choosing increased water speeds as they get larger.

Low light intensities have been shown to be important for adult salmonid focal point choice (Gosse and Helm 1982). Gosse and Helm (1982) found that resting adult brown trout preferred light levels at less than 5% of full sunlight. Wickham (1967) also found that brook trout prefer shade to sun although his study used albino subjects which may be more sensitive to light than normally pigmented fish. Atlantic salmon were found to occupy illuminated areas in summer, and shady areas in winter (Rimmer et al. 1984). Baldes and Vincent (1969) discovered a strong thigmotactic response (positioning near or in contact with an object) in brown trout which could account, by virtue of shadows, for the low light intensities found by other researchers. Hooper (1973) and Faush and White (1981) have suggested that trout may maintain position at the edge of the shadow caused by the overhead cover and look into the light area because drifting food may be more easily seen from a shady position.

The importance of overhead cover to underyearlings is not so clear. Both Bachman (1984) and Gosse and Helm (1982) found that as trout aged they spent considerably more time under cover. McCrimmon and Kwain (1966) determined that fingerling rainbow trout showed no response to overhead cover although yearlings preferred darker areas. In the present study, underyearlings were not strongly associated with overhead cover until early December, some three months after emergence. This shift toward association with overhead cover was dramatic. From the beginning of the study careful examination was made of all likely trout lies and positions with overhead cover were considered of high value. Surprisingly, few fish were found in areas with abundant overhead cover in the first 3 months of the study. Unfortunately because of bad weather at the end of November 1986 no dives were made between the 24/11/86 and the 8/12/86. However the dive on the 8/12/86 found about 40 - 60 fingerlings under one small fallen tree, and from that time on approximately 30% - 50% of fingerlings were found under or near overhead cover. This is an observation only and further studies are necessary to determine if this is a regular phenomenon. If so it would be important to pinpoint the timing of this ontogenetic shift toward overhead cover use.

CHAPTER 7
HABITAT PREFERENCE CURVES

7.1 INTRODUCTION

The instream flow incremental methodology (IFIM) attempts to assess the physical and biological effects of potential changes in river discharge. This is achieved by combining a detailed hydraulic model of the river with 'habitat use curves' to determine an index of fish habitat known as the weighted usable area. The IFG developed habitat use curves as a way of determining the most popular depths, current speeds and substrates of target species. Bovee and Cochnauer (1977) suggest that a set of habitat use curves is a description of fish habitat preferences. Generally, such a set contains habitat use curves for mean current speed, temperature, total depth and substrate size of the life stages fry, juvenile, adult spawning and incubation of eggs. However, habitat use curve sets do not generally take into account cover and shelter, two important physical habitat variables. Habitat use curves may be unreliable as trout often use a wide range of microhabitats. For example, Mathur et al. (1985) criticize habitat use curves on the grounds that they vary between streams, over time, and in response to prey, predators and other biological stimuli. Anon (n.d.), in an introduction of IFIM to water resource managers, noted that the results generated using IFIM are only as good as the habitat preference data. It has been shown in earlier chapters that underyearling brown trout focal point use is dependent on fish activity and season (see also Campbell and Scott 1984) and it is probable that focal point use also changes during freshes and floods.

Habitat use curves are derived using two major approaches: the habitat approach and the microhabitat approach. The habitat approach involves collecting information relating to the physical properties of the pool or riffle in which the target species was sampled. This usually incorporates such techniques as electric fishing, spot concussion and gill netting, none of which are suitable for microhabitat measures as they cause individuals to be moved from their focal points. The habitat approach has advantages in that it takes some account of all the water used by the target species rather than just that of the focal point. In the microhabitat approach, data are collected directly at fish focal points by surface or underwater observation. This has the effect of undervaluing areas of the habitat in which the fish spend little time such as resting and hiding areas, places in which fish shelter from spates, and the current which carries the food of the fish. Any river without these vital components of trout habitat could not be expected to support a large population. If a conventional habitat use curve were constructed from data obtained in the Kahuterawa study it would have been severely biased in favour of the focal points of stationary swimming fingerlings. It is not necessarily correct to assume that an activity (e.g. resting) or area of water in which a fish spends little time is less important than one (e.g. stationary swimming) in which a fish spends the majority of its time.

The current popularity of the microhabitat approach to constructing habitat use curves has given rise to suggestions that focal point current speed replace mean current speed as the water speed indicator in the physical habitat simulation component (PHABSIM) of IFIM (DeGraaf and Bain 1986). This practice would only increase the bias against habitat requirements for feeding and resting, which use focal points with different characteristics and are less often encountered than stationary swimming focal points. Moreover, the effectiveness of measuring the current speed close to the substrate as an estimate of focal point current speed is questionable as trout focal points tend to be located in small micro-currents which river simulation models would be unlikely to predict.

7.2

DERIVATION OF HABITAT PREFERENCE CURVES

7.2.1

INTRODUCTION

Conventional habitat use curves have been derived in five primary ways:
(1) FREQUENCY ANALYSIS (Bovee and Cochnauer 1977) - in which curve smoothing techniques are applied to a histogram of use of a habitat variable:
(2) RANGE AND OPTIMUM ANALYSIS (Bovee and Cochnauer 1977) - is used where the only information available is the range and optima of habitat characteristics. The optima are given a value of 1 and the limits of use 0 and a smooth curve is then drawn to link these points:
(3) PARAMETER OVERLAP (Bovee and Cochnauer 1977) - uses descriptions of habitat types and relative abundance of the target species in each habitat type which are then combined to estimate habitat use curves. For example if species A is found often in fast riffles but seldom in slow pools. fast shallow water will get a higher rating than slow deep water:
(4) INDIRECT PARAMETER ANALYSIS (Bovee and Cochnauer 1977) - involves estimating one parameter from another (e.g. current speed in the redd from mean current speed) and then using this information with one or more of the above systems:
(5) EXPERT ANALYSIS (Jowett pers. com.) - experts construct habitat use curves from their own experience.

If used alone. the above systems of generating habitat use curves are seriously flawed. as they do not take into account habitat availability. Thus habitat use curves do not achieve their aim: that is they are not a description of habitat preferences. This has been identified as a major weakness of many available habitat use curves (Orth and Maughan 1986: Glova 1982: Orth et al. 1982: Baldrige and Amos 1982: Moyle and Baltz 1985). Fortunately. it appears that habitat preference curves generated in New Zealand have considered available habitat to some extent (Glova 1982: Glova and Duncan 1985). The methods developed by Baldrige and Amos

(1982) and DeGraaf and Bain (1986) to incorporate habitat availability into the construction of habitat use curves were modified as described below.

7.2.2

METHODS

Available habitat was defined as any area of the stream bed containing water, as underyearling brown trout were found in water as shallow as 5 cm and the upper limit of depth, if it exists are not sufficiently documented to be excluded. For current speed there are no known lower limits of tolerance and upper limits are imposed by focal point current speed rather than mean current speed. Substrate size limitations for underyearling brown trout, if they exist, are also unknown. Hence all current speeds and substrates were considered to be available.

Habitat use curves for each activity were derived using the frequency analysis method of Bovee and Cochnauer (1977). To form **habitat relative preference curves**, habitat use and habitat availability data for a given variable (e.g. current speed), are coded into as many classes as practicable and the percentage in each class for both habitat availability and habitat use is calculated. The percent use is divided by percent available for each class to calculate **habitat relative preference** (see equation 1).

EQUATION 1 CALCULATION OF HABITAT RELATIVE PREFERENCE.

% POPULARITY OF USE / % AVAILABLE = HABITAT RELATIVE PREFERENCE

Finally, habitat relative preference is graphed against the habitat characteristic concerned. If habitat relative preference is less than 1, fish are using areas of that habitat characteristic class less than its availability. If habitat relative preference is equal to 1, fish are using areas of that class in proportion to its availability. If habitat relative preference is greater than 1, fish are using areas of that class in greater proportions than its availability. These are termed **habitat relative preference curves**, to avoid confusion with **habitat use curves** which are sometimes erroneously referred to as **habitat preference curves**.

It is assumed that individual trout will select areas within the stream which have the most favourable combinations of physical habitat variables (Bovee and Cochnauer 1977). If this assumption is valid the method of graphical display used here for habitat relative preference curves allows the reader to see at a glance which levels of a habitat variable are selected (preferred) by the fish.

Habitat use and **habitat relative preference curves** are not suitable for categorical habitat variables. For example, two categories of substrate, 'woody debris' and 'other' (algae, aquatic macrophytes and such man made objects as forty four gallon drums) do not fit into the scale of substrate size and it would be misleading to plot them on the same graph. Habitat relative preferences for these categories are given as discrete numbers and not displayed graphically.

7.3 RESULTS

7.3.1 MEAN CURRENT SPEED

Figures 7.1, 7.2, 7.3 and 7.4 show habitat use curves and habitat relative preference curves for each activity category of underyearling brown trout examined. The

FIGURE 7.1

COMPARISON OF HABITAT USE CURVE AND HABITAT RELATIVE PREFERENCE CURVE OF MEAN CURRENT SPEED FOR EMERGENT FRY

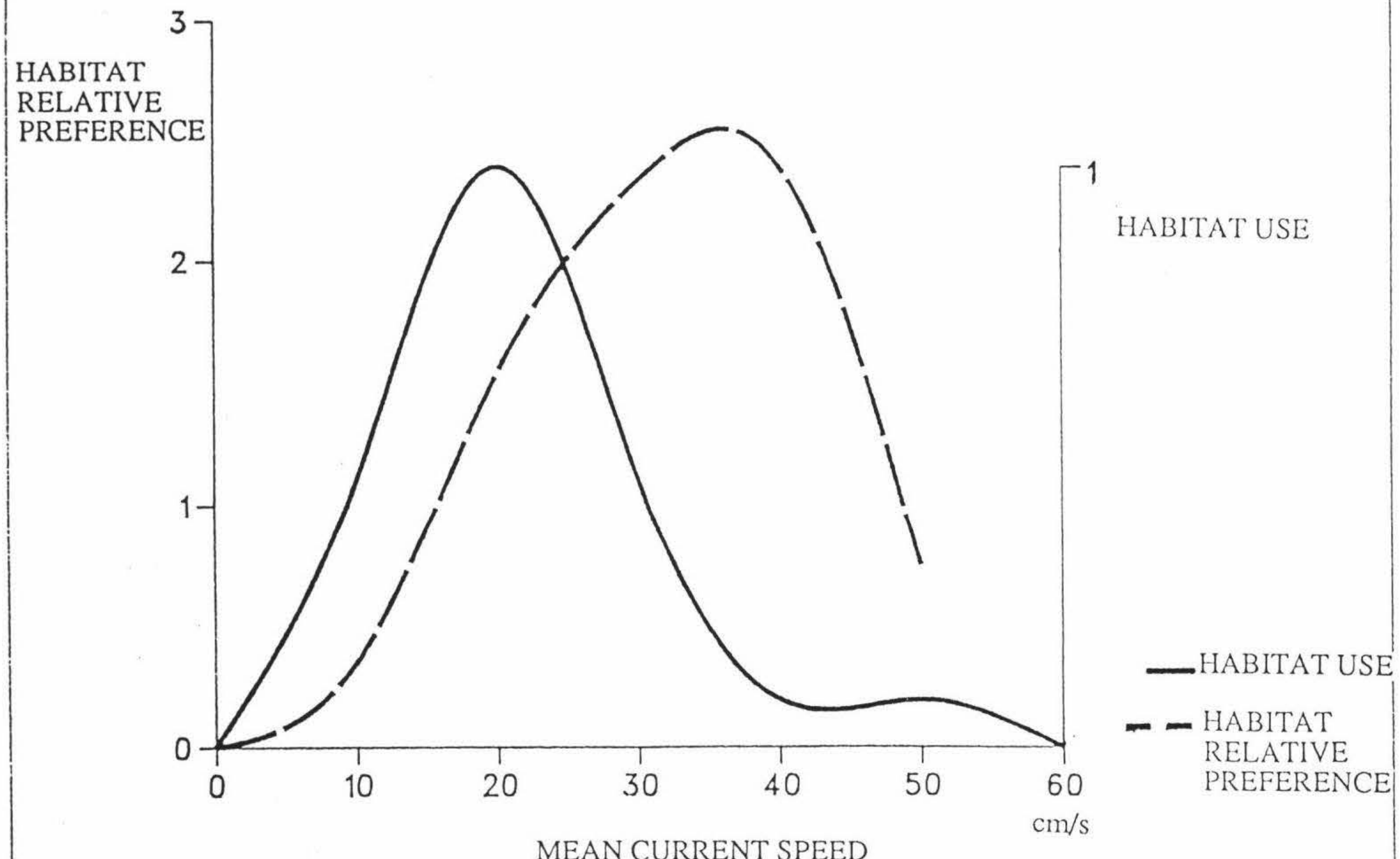


FIGURE 7.2

COMPARISON OF HABITAT USE CURVE AND HABITAT RELATIVE PREFERENCE CURVE OF MEAN CURRENT SPEED FOR RESTING FINGERLINGS

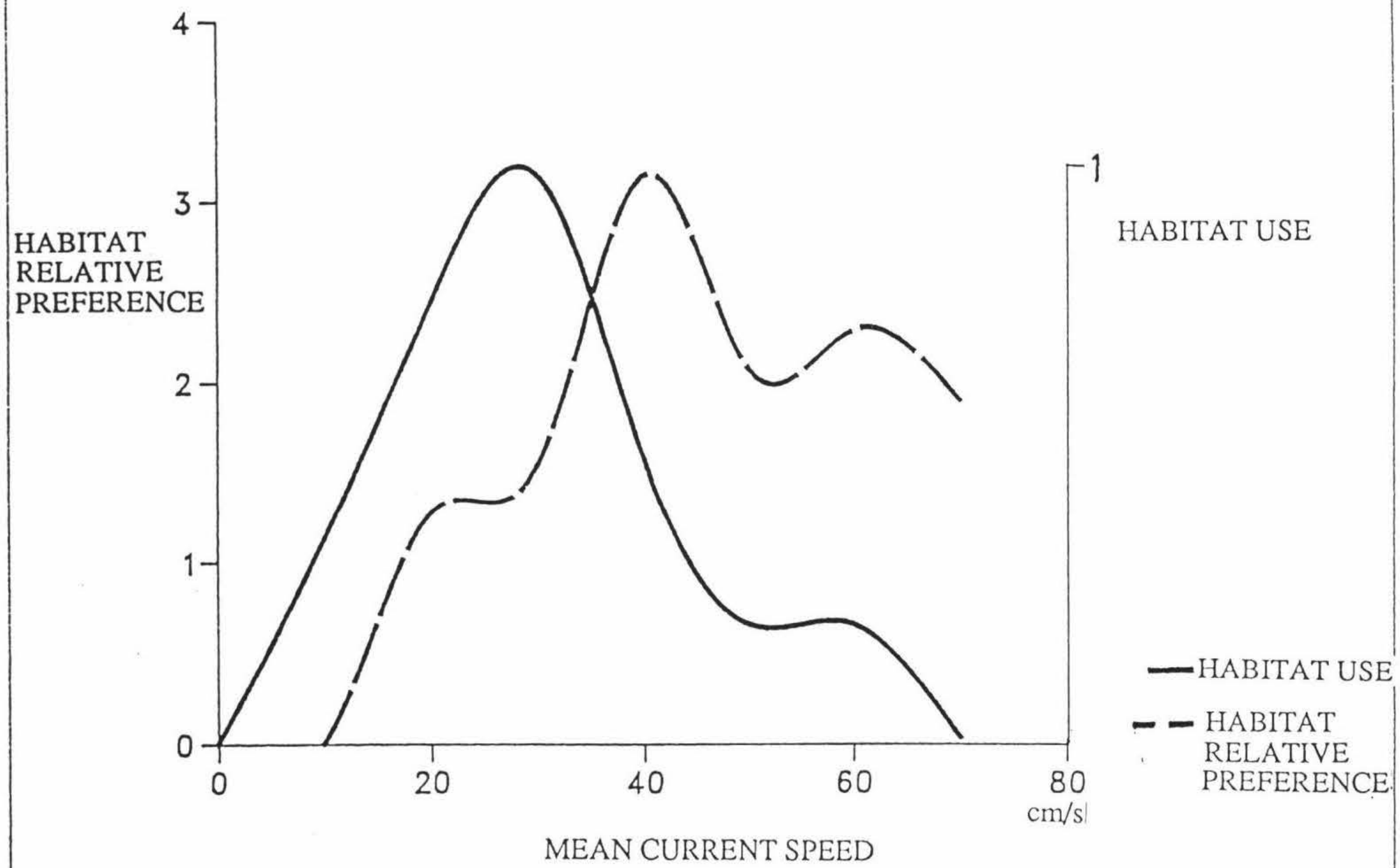
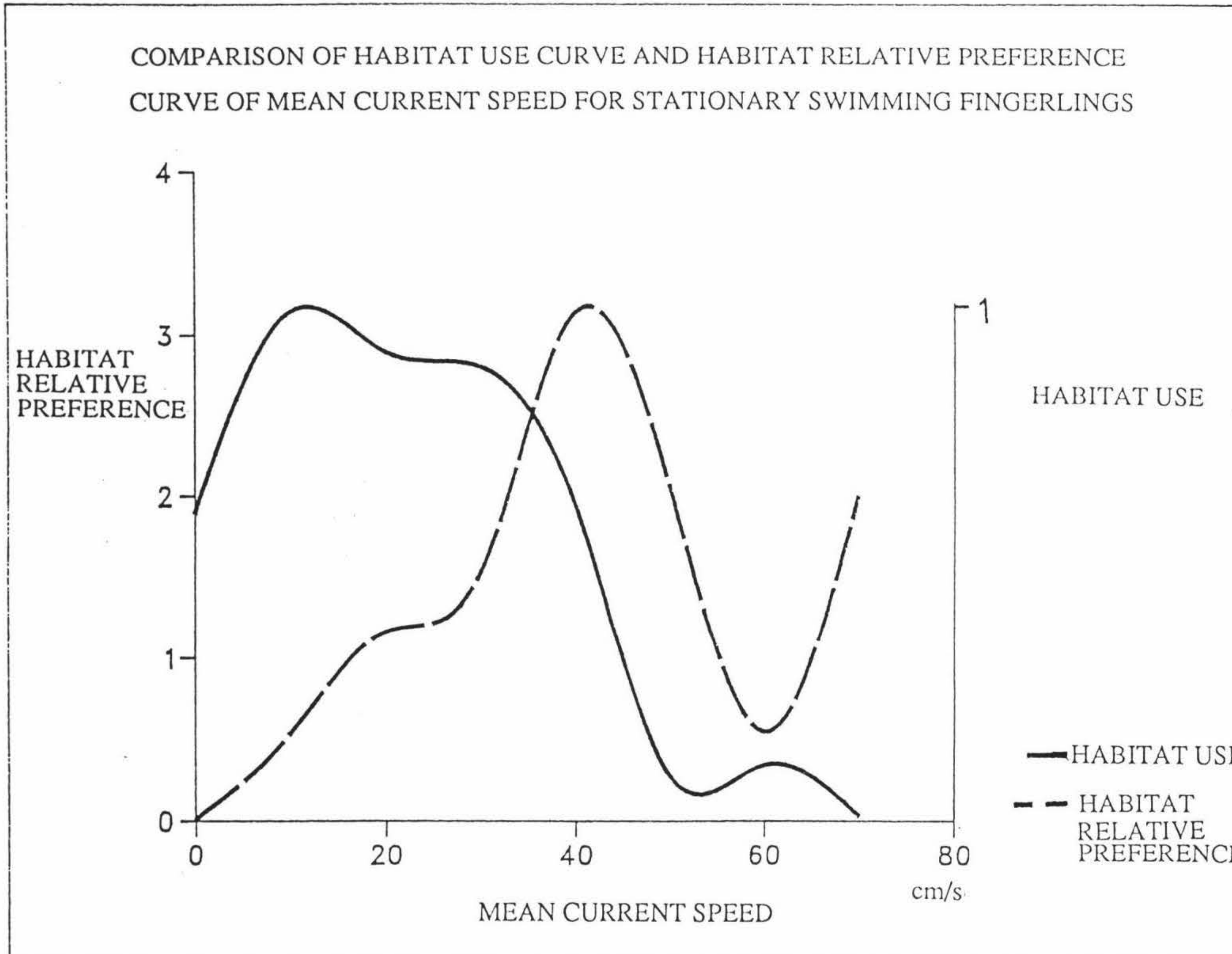


FIGURE 7.3


COMPARISON OF HABITAT USE CURVE AND HABITAT RELATIVE PREFERENCE
CURVE OF MEAN CURRENT SPEED FOR STATIONARY SWIMMING FINGERLINGS
HABITAT
RELATIVE
PREFERENCE
4
3
2
1
0
0
20
40
60
80
cm/s
MEAN CURRENT SPEED
1
HABITAT USE
HABITAT USE
HABITAT
RELATIVE
PREFERENCE

current speed of maximum use was different from the current speed of maximum relative preference. Emergent fry and resting fingerlings use mean current speeds of up to 60 cm/s in greater proportions than their availability. however habitat use curves suggest that only current speeds under 40 cm/s are important for these fish. The most marked contrast between habitat use and habitat relative preference curves can be seen for feeding fingerlings. Habitat use data suggests that all values between 10 cm/s and 50 cm/s are of approximately equal value. yet habitat relative preference information suggests that the most preferred mean current speeds are 50 - 60 cm/s.

7.3.2

TOTAL DEPTH

Total depth use curves and relative preference curves (figs 7.5. 7.6. 7.7 and 7.8) are also different. Habitat use curves suggest that preferred depth for both emergent and fingerling brown trout in the Kahuterawa stream are 20 - 30 cm/s. Habitat relative preference curves show that fingerling trout in the Kahuterawa stream select the deepest water available in which to live. Habitat relative preference curves and habitat use curves appear to be in general agreement for emergent fish depths. Both suggest that emergent fry select depths of 10 - 30 cm.

7.3.3

SUBSTRATE SIZE

Habitat use curves reveal that all categories of underyearling brown trout studied except resting fingerlings are found primarily over areas of cobble substrate. Resting fingerlings are found over gravel substrates. However habitat relative preference curves indicate that. with the exception of stationary swimming fingerlings. which showed a wide range of substrate preferences; gravel substrates are far more important than cobble.

FIGURE 7.4

COMPARISON OF HABITAT USE CURVE AND HABITAT RELATIVE PREFERENCE CURVE OF MEAN CURRENT SPEED FOR FEEDING FINGERLINGS

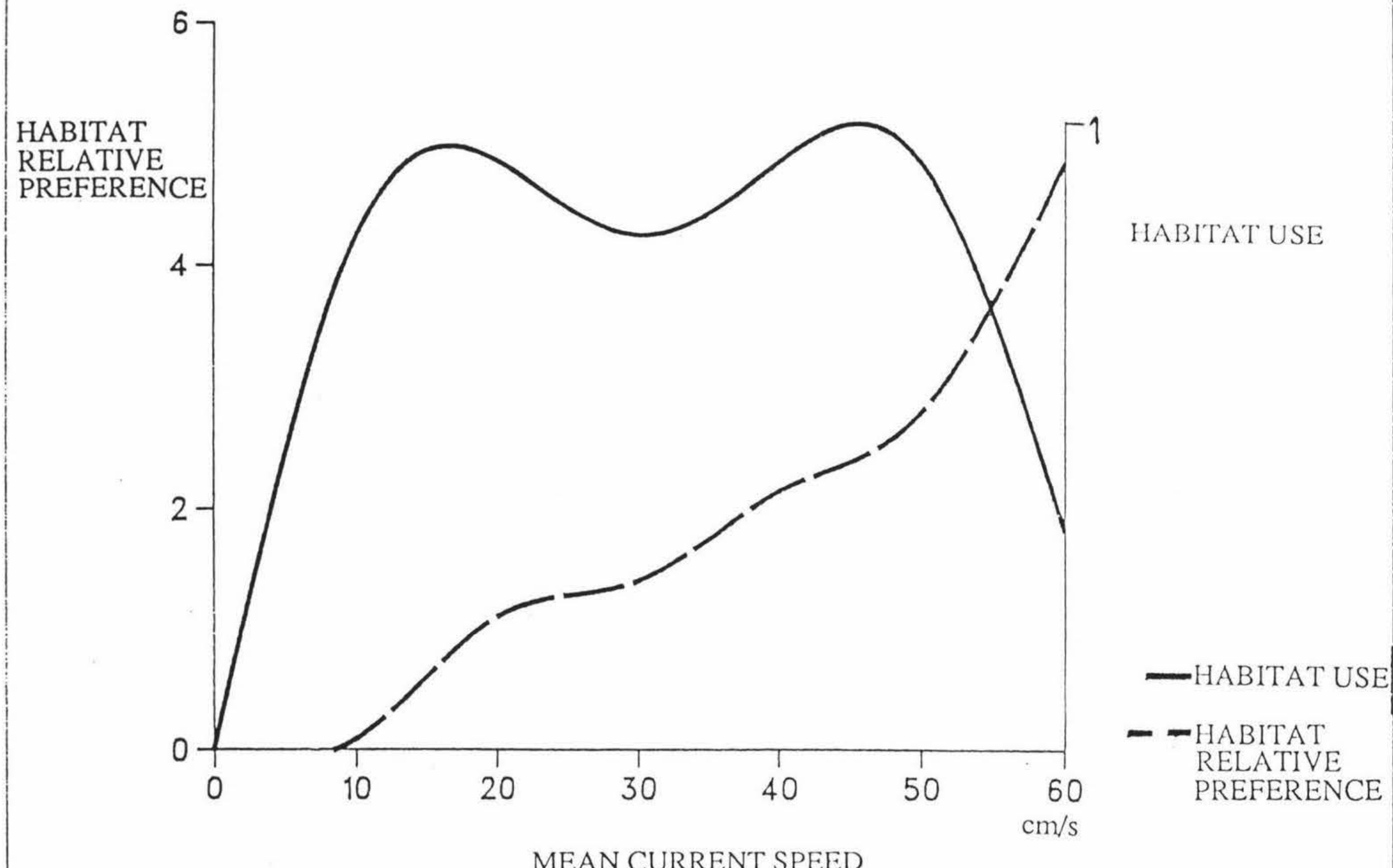


FIGURE 7.5

COMPARISON OF HABITAT USE CURVE AND HABITAT RELATIVE PREFERENCE CURVE OF TOTAL DEPTH FOR EMERGENT FRY

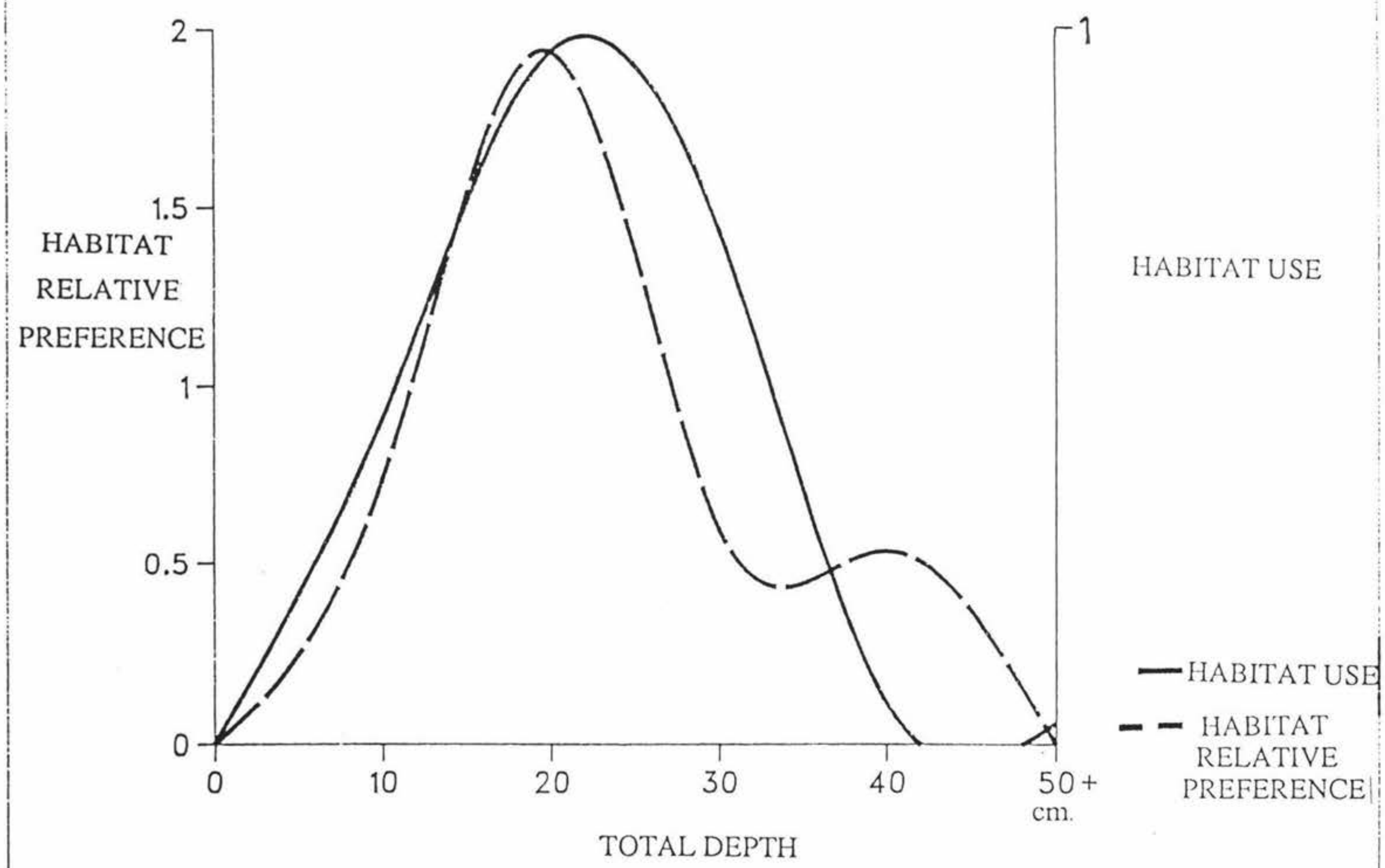


FIGURE 7.6

COMPARISON OF HABITAT USE CURVE AND HABITAT RELATIVE PREFERENCE CURVE OF TOTAL DEPTH FOR RESTING FINGERLINGS

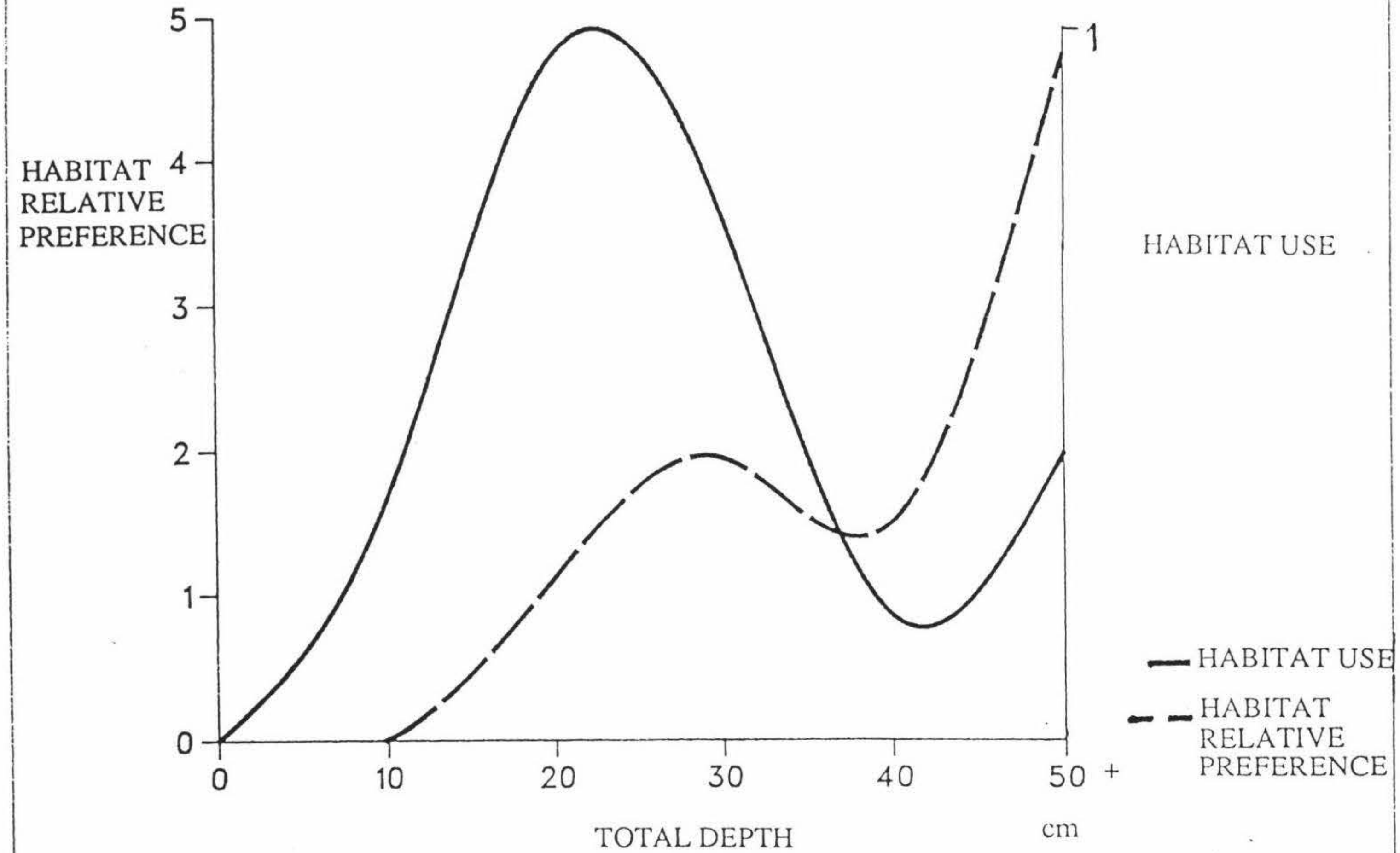


FIGURE 7.7

COMPARISON OF HABITAT USE CURVE AND HABITAT RELATIVE PREFERENCE CURVE OF TOTAL DEPTH FOR STATIONARY SWIMMING FINGERLINGS

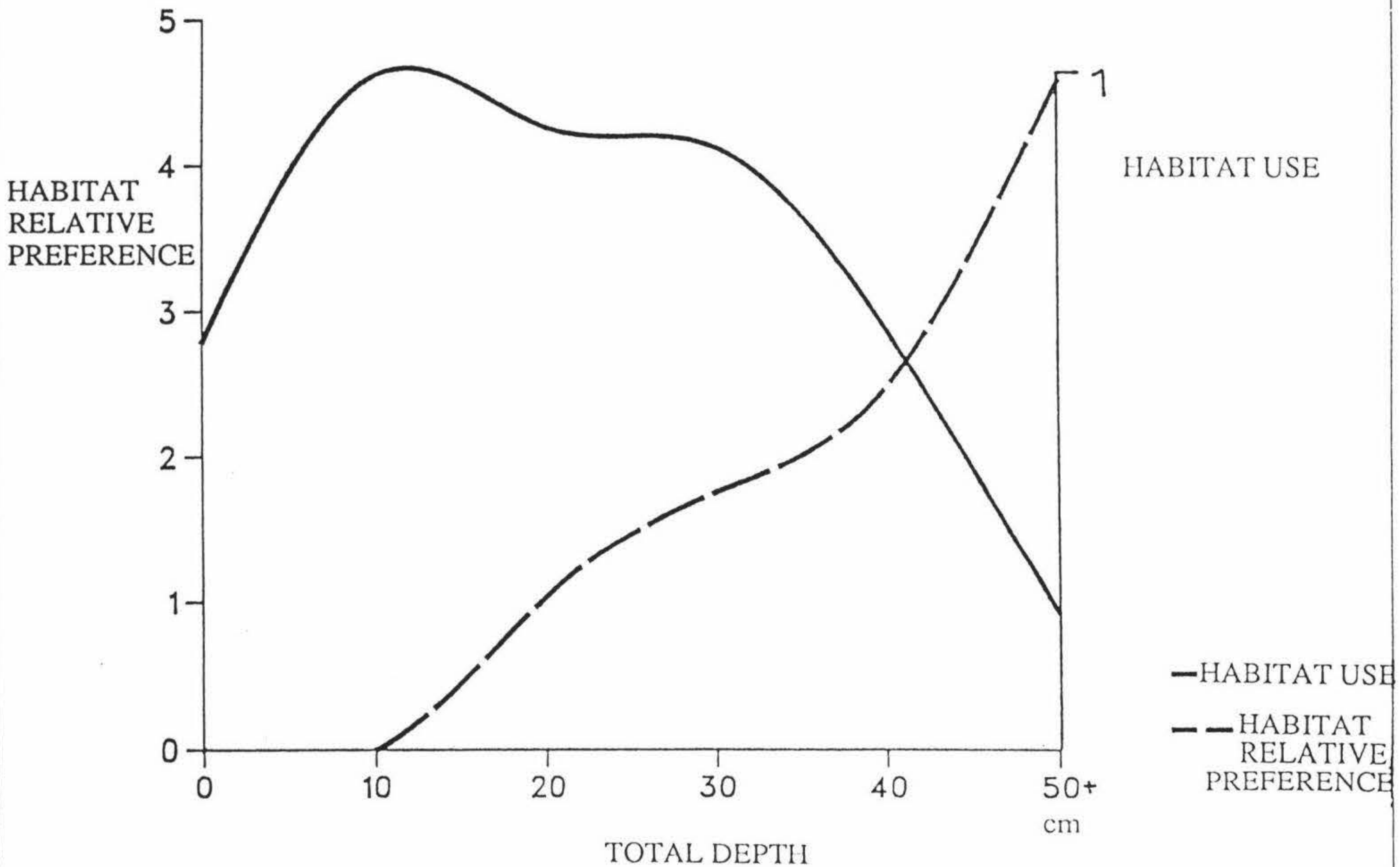


FIGURE 7.8

COMPARISON OF HABITAT USE CURVE AND HABITAT RELATIVE PREFERENCE CURVE OF TOTAL DEPTH FOR FEEDING FINGERLINGS

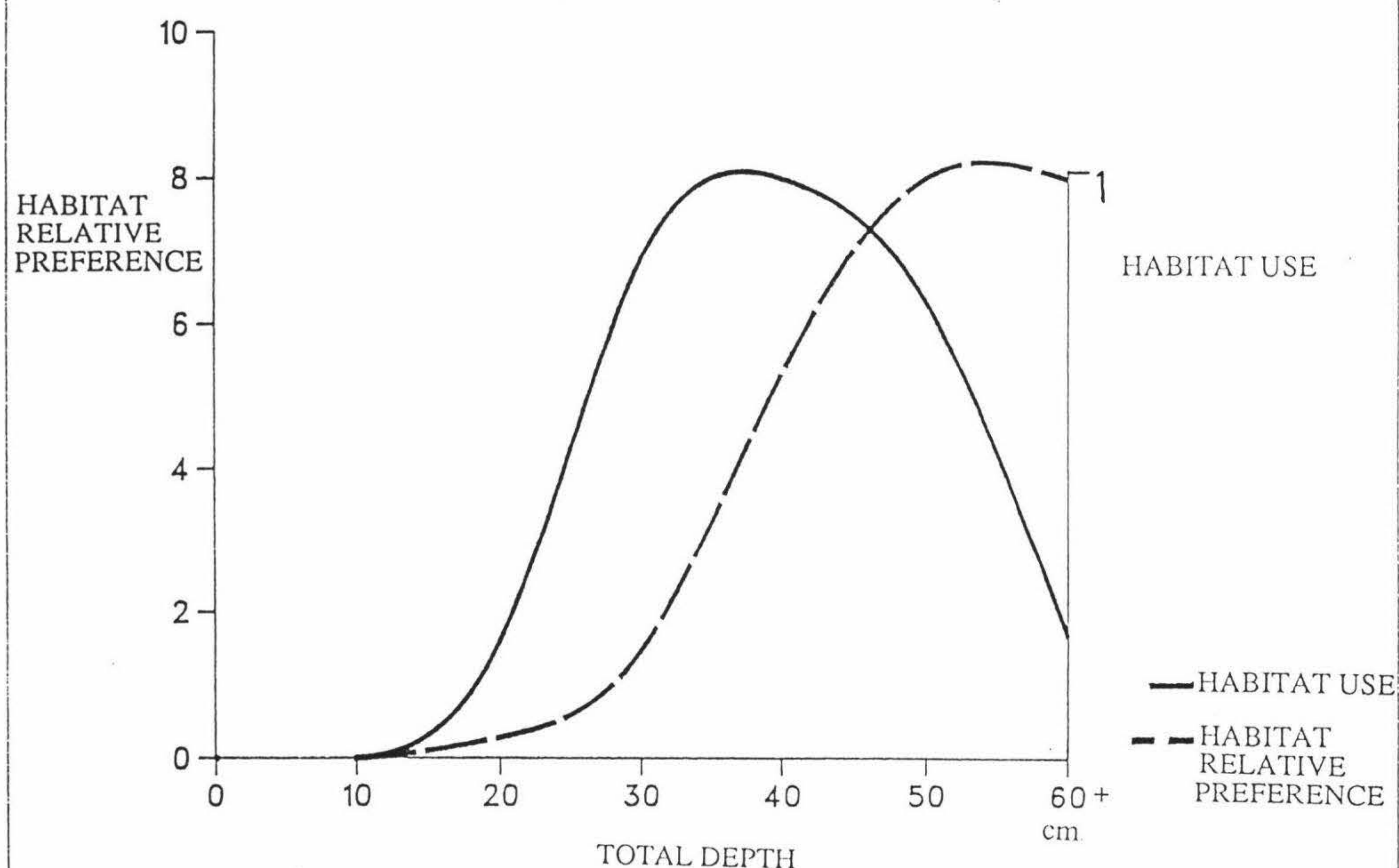
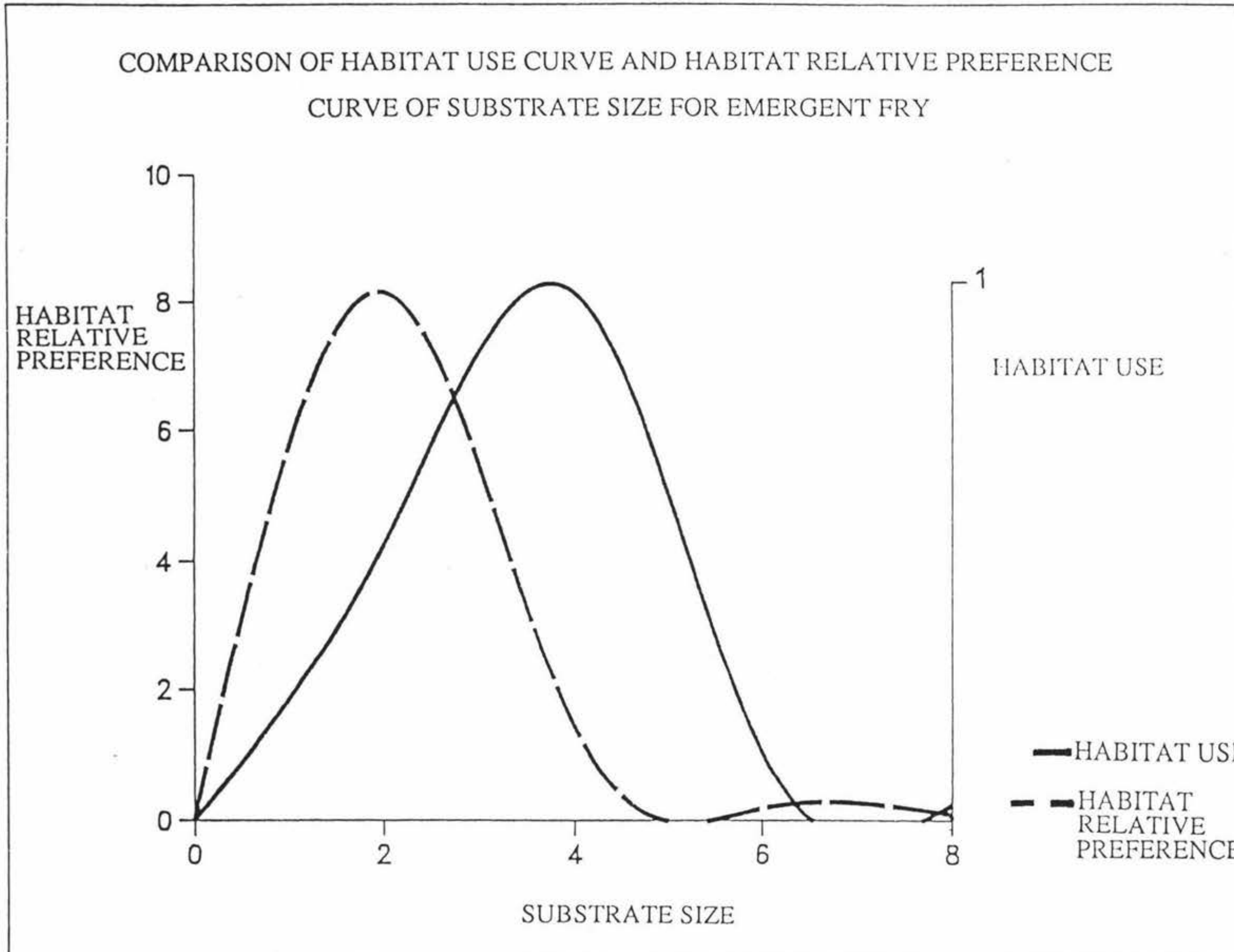


FIGURE 7.9



COMPARISON OF HABITAT USE CURVE AND HABITAT RELATIVE PREFERENCE
CURVE OF SUBSTRATE SIZE FOR EMERGENT FRY
HABITAT RELATIVE PREFERENCE
10
8
6
4
2
0
HABITAT USE
1
0
2
4
6
8
SUBSTRATE SIZE
HABITAT USE
HABITAT RELATIVE PREFERENCE

FIGURE 7.10

COMPARISON OF HABITAT USE CURVE AND HABITAT RELATIVE PREFERENCE CURVE OF SUBSTRATE SIZE FOR RESTING FINGERLINGS

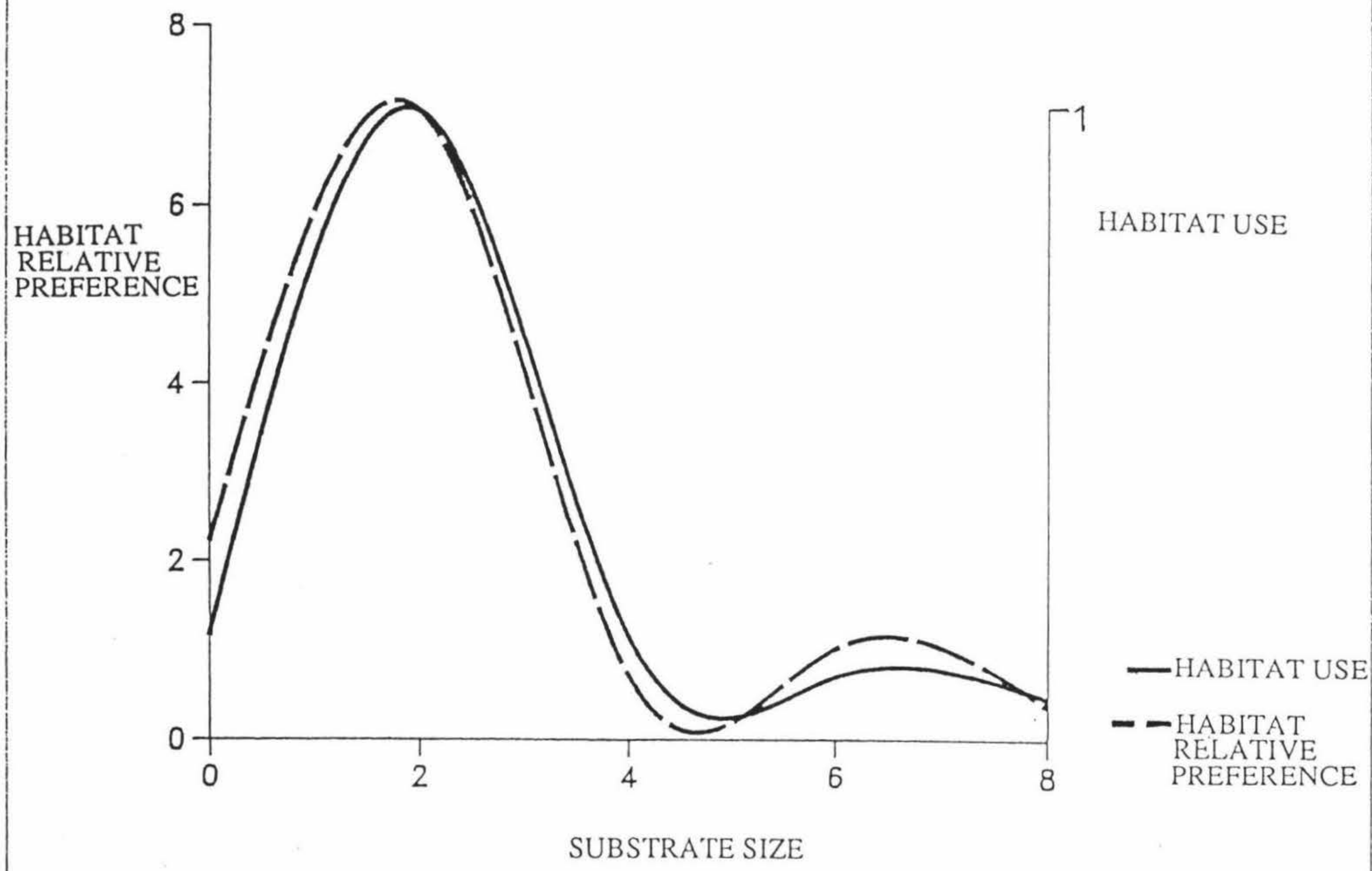


FIGURE 7.11

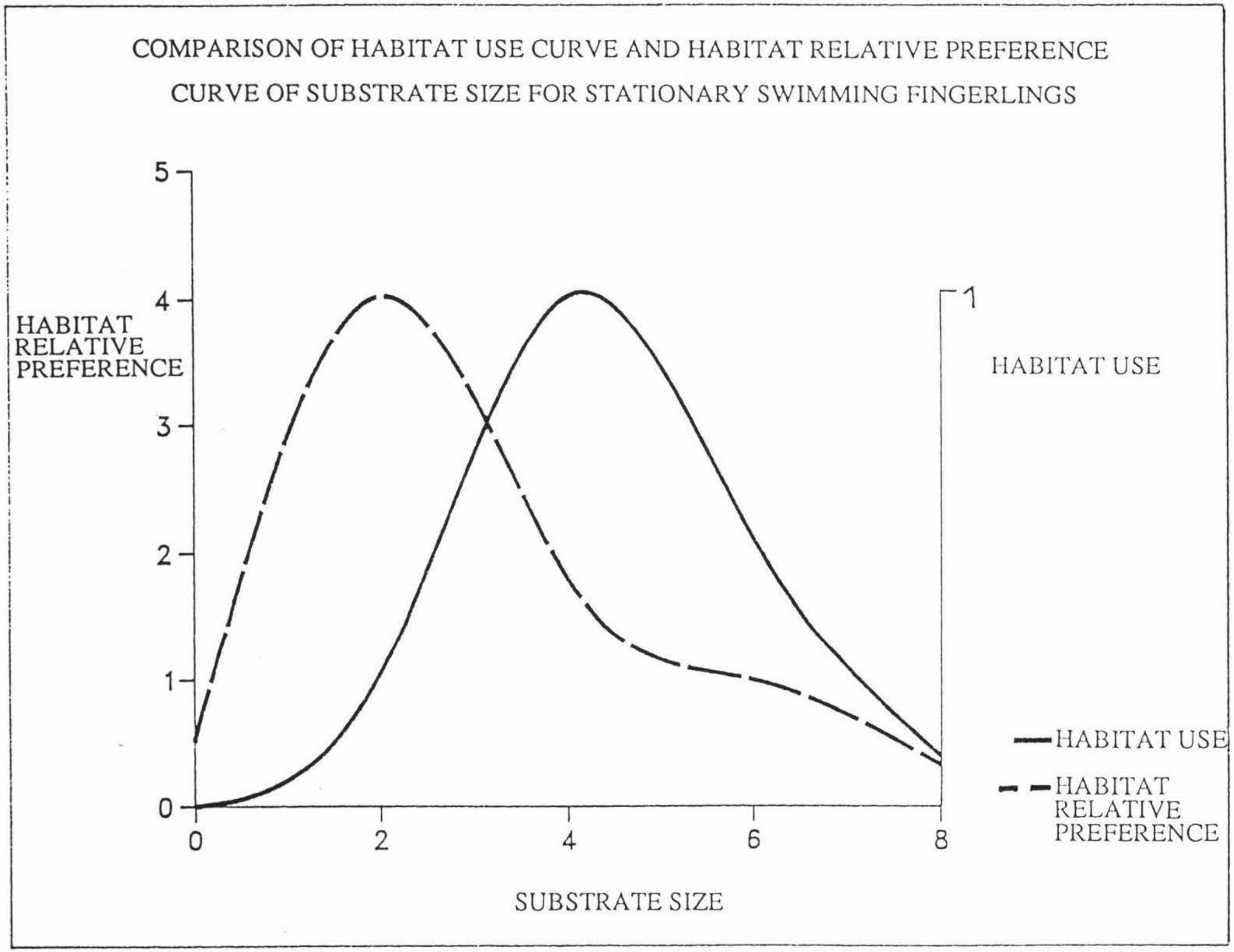
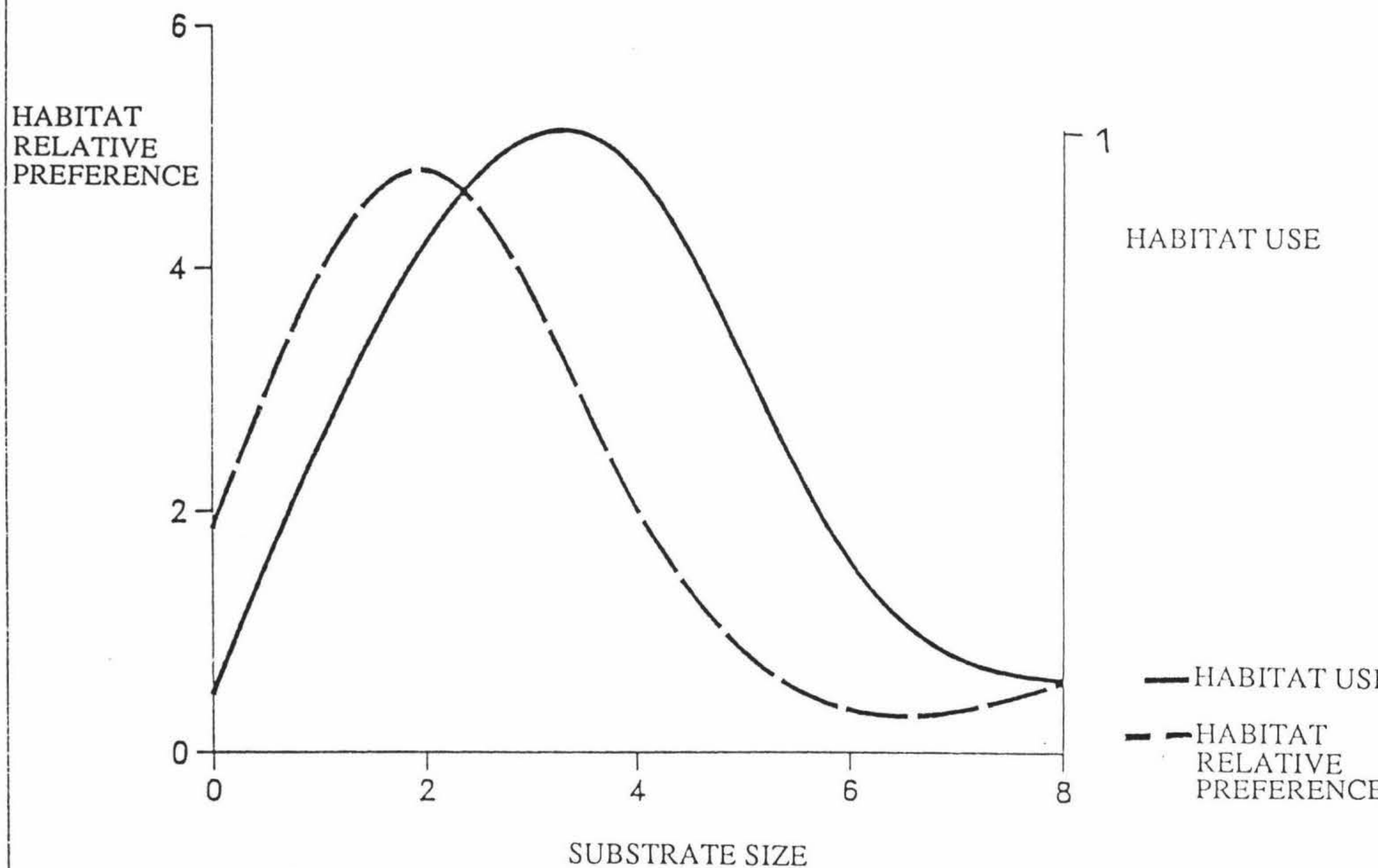

COMPARISON OF HABITAT USE CURVE AND HABITAT RELATIVE PREFERENCE
CURVE OF SUBSTRATE SIZE FOR STATIONARY SWIMMING FINGERLINGS
HABITAT RELATIVE PREFERENCE
5
4
3
2
1
0
0
2
4
6
8
1
HABITAT USE
SUBSTRATE SIZE
HABITAT USE
HABITAT RELATIVE PREFERENCE

FIGURE 7.12

COMPARISON OF HABITAT USE CURVE AND HABITAT RELATIVE PREFERENCE CURVE OF SUBSTRATE SIZE FOR FEEDING FINGERLINGS



7.4 DISCUSSION

7.4.1 INTRODUCTION

Limitations of habitat relative preference curves are similar to those of habitat use curves (described in Scott and Shirvell 1986). However the method of plotting habitat relative preference curves eliminates some of the problems of habitat use curves. For example, habitat relative preference curves are not treated as probability functions but rather habitat is regarded as selected if the habitat relative preference is greater than one and avoided if the habitat relative preference is less than one. The degree of preference can also be easily found from the graph. Habitat use curves show how the trout use the habitat at that site at that time. However habitat preference curves are not site and time dependent, they are primarily a function of trout behaviour and secondarily a function of the river.

Fish use different parts of the habitat for different activities and thus large amounts of data must be collected over a wide range of hydraulic conditions and fish activities for habitat relative preference curves to be useful. Data on salmonid behaviour and habitat use at night and during spates is of major importance but little information is known about habitat use during these times. Hence it is imperative that data be collected from a range of flow conditions and seasons times of day.

Fisheries managers often have little time in which to analyse the potential effects of river developments on the aquatic biota so it would be of considerable value to have habitat relative preference curves available for both native and introduced fish species in New Zealand. However further studies along the lines of DeGraaf and Bain (1986) must be carried out to determine if habitat relative preference curves can be developed for a geographical area or a stream 'type' before this can be done.

It can be seen from the above results that interpretation of habitat relative preference curves and habitat use curves can lead to different conclusions from the same data. My results suggest that much of the currently available habitat use data (e.g. Bovee 1978) is not applicable to the Kahuterawa stream. Accurate habitat preference curves are vital if IFIM is to achieve its aims. Indeed, much of the criticism of IFIM is based on the fact that many habitat preference curves are inaccurate or highly variable (Mathur et al. 1985, 1986; Scott and Shirvell 1986). It is suggested that the application of Bovee's (1978) habitat use curves be immediately discontinued and habitat relative preference curves be developed for all species of freshwater fish present in New Zealand. In notes to an introductory IFIM course, Anon (n.d.) stated that 'the results [of IFIM] are only as good as the habitat preferences'. For these reasons, habitat preference curves should be the focus of much further study, particularly if the popularity of IFIM as a management tool for lotic systems continues to increase.

7.4.2

MEAN CURRENT SPEED

Habitat relative preference curves suggest that underyearling brown trout in the Kahuterawa stream have a greater range of preferred mean current speeds than published information (Gosse and Helm 1982; Bovee 1978) indicates. Information derived from habitat relative preference curves suggests that slow water (< 20 cm/s) is not as valuable as Bovee's (1978) habitat use curves imply. There are two possible reasons for this either the trout populations examined in North America behave differently to those in New Zealand or habitat use curves are inferior to habitat preference curves. This has implications for both river managers and the users of IFIM as it suggests that any IFIM habitat assessment based on the habitat use curves of Bovee (1978) for underyearling brown trout may be erroneous in the New Zealand situation. Thus any minimum discharges set on the basis of IFIM recommendations may produce unexpected effects on fisheries. This is especially important when it is considered that IFIM has a poor record of determining changes in fish biomass with changes in discharge (Scott and Shirvell 1986; Mathur et al. 1985 1986).

7.4.3

TOTAL DEPTH

Underyearling trout chose the deepest water available in the Kahuterawa stream. This is not unexpected if deeper water is used as a form of cover. Choosing the deep water available may also be related to current speed choice. Orth and Maughan (1982) found that current speed and total depth are often positively related and the Kahuterawa trout appear to be choosing faster water than expected from earlier studies. It may be that in rivers larger than the Kahuterawa, underyearling trout are excluded from the deepest water by competition and predation by other species of trout and older conspecifics, as has been documented by Kalleberg (1958) and Jenkins (1969). This must be considered when interpreting WUA's for juvenile trout.

7.4.4

SUBSTRATE SIZE

All categories of fish prefer gravel as a substrate. This is consistent with the observation that emergent fry and resting fingerlings often sheltered in the lee of large rocks and boulders where gravel is often found. Stationary swimming and feeding fingerlings were seen more often in relatively unsheltered areas compared to fry and resting fingerlings and thus may be expected to use larger substrate sizes. It is possible that the strong preference of emergent fry and resting fingerlings for gravel may also be an effect of current speed. Townsend (1980) noted that there is a strong relationship between substrate size and water speed. so it is possible that the above 'preference' for gravels is. in fact. a preference for slow current speeds. It may be that substrate particle size is a more sensitive measure of focal point current speed (where the focal point is close to the bottom) than my Ott current meter.

CHAPTER 8
CONCLUSIONS

8.1 FOCAL POINT CHARACTERISTICS

The relative value of focal point characteristics is difficult to objectively assess. Many authors (e.g. Gosse and Helm 1982; Morantz et al. 1987; DeGraaf and Bain 1986) suggest that narrow preference zones for a focal point characteristic (e.g. focal point current speed) indicate that focal point choice is biased in favour of that characteristic. Conversely, the wide zones of preference found for substrate size would suggest that substrate is taken into account less frequently in focal point selection. This assumes that there is sufficient variability in the river from which salmonids may choose their preferred ranges. The preference zone system can be unreliable in some cases because of the complex interrelationships between focal point characteristics. For example both focal point elevation and focal point current speed are very stable yet the lowest current speeds are found near the bottom of a stream so the two factors are related. Hence one can only make informed guesses at their relative importance and little comment can be made about focal point characteristics.

Current speed and depth are universally seen by trout ecologists to be important factors in focal point choice although there is some doubt over the importance of substrate for non - spawning salmonids (Gosse and Helm 1982; Rimmer et al. 1984). The present study has shown that substrate may be undervalued if it is examined in isolation. Substrate is often seen merely as a spawning medium, yet it also provides current shelter and overhead cover, particularly for small trout. If the microhabitat approach is used to determine focal point characteristics and shelter type is not measured, misleading information may be obtained regarding the value of substrate as a focal point component. Gosse and Helm (1982) and Rimmer et al.

(1984) found that the substrate directly below the fish did not differ significantly from the available substrates. However in the Kahuterawa. substrate materials comprise a large proportion of both escape cover and current shelter. When current shelter is included in analyses it becomes clear that the substrate type is of considerable value in habitat and microhabitat studies. In the Kahuterawa stream only 16.8% of available substrate is cobble or larger but these substrate types are used by 50.5% - 93.3% (dependent upon activity) of brown trout fry to gain respite from the current. Because of this. further studies are needed to determine the significance of shelter and cover materials in relation to such physical focal point components as depth and current speed.

The focal point positions of underyearling brown trout in the Kahuterawa stream are generally consistent with the energy conservation strategy of Jenkins (1969). Only resting fingerlings occupied focal point positions which may have been incompatible with the strategy. although these results may have been due to the flow meter which was unable to accurately measure current speeds close to rocks.

8.2

HABITAT PREFERENCE CURVES

This study has found that habitat preference curves do not. in their present form. reasonably reflect underyearling brown trout focal point characteristics in the Kahuterawa stream. To improve the accuracy of habitat preference curves it is recommended that four factors be taken into account when using PHABSIM. (1) Emergent fry should be treated as a separate entity for IFIM management purposes Emergent fry in the Kahuterawa stream tend to have focal points in slower. shallower water with smaller substrates than that used by fingerlings. Emergent fry appear to use the same general habitat as spawning adults. so for management purposes they could be treated as similar. although further investigations would be needed to test if this is satisfactory.

(2) Habitat preference curves should be developed for different activities of each life stage of a target species. The previous chapters have shown that habitat use and preference curves for underyearling brown trout are dependent on activity. If habitat use curves are not developed for different activities results will be seriously biased in favour of the focal points of stationary swimming fish, which could lead to incorrect management decisions. Trout need to rest just as they need to feed.

(3) It is also vital that habitat preference curves be developed in New Zealand for introduced as well as native fish if IFIM is to be used in this country. Indications are that habitat use curves derived in North America are not applicable in New Zealand because New Zealand stream ecosystems appear to be different from Northern Hemisphere rivers in which most of the commonly used habitat use curves were derived (Winterbourn et al. 1981). As New Zealand streams are often unstable, overhead cover and shelter from the current may play a more important part in limiting trout populations than they do overseas.

(4) Habitat preference curves should be derived using a standardized microhabitat approach. Care must be taken to measure areas of the stream which are rarely used by the fish. The habitat approach is probably too broad to produce worthwhile habitat preference curves.

A major difficulty with IFIM is that it attempts to accurately describe trout habitat on the basis of just four variables (mean current speed, substrate, depth and temperature), ignoring two of the most important physical focal point variables, overhead cover and shelter. Virtually all trout ecologists acknowledge escape cover as an important determinant of focal point position. Hence PHABSIM must be expanded to include at least overhead cover before it can attempt to model the physical characteristics of trout focal points.

If habitat preference curves are developed for different activities, fish ages and seasons, IFIM looses much of its value as a fisheries management tool. IFIM is seen to be especially valuable for fisheries management because relatively little data collection is necessary in its present state. However, if the recommendations of the present study are employed IFIM would become very demanding in terms of resources.

IFIM does not make any allowance for trout to solve environmental problems. IFIM assumes that if a trout lives in a certain way in a certain river at the moment it cannot live in any different way in the same river. Brown trout have a wide distribution and live in many different types of river, lake and even the sea (Frost and Brown 1967). To survive in so many diverse environments they must be skilled at solving environmental problems and so habitat limitations may be wider than habitat preference curves would suggest.

Finally, from a management perspective one must also ask whether the **potential** amount of available habitat is a useful figure on which to base important management decisions. It appears not. Scott and Shirvell (1986) Irvine et al. (1987) and Mathur et al. (1985 1986) have found that there is often little or no correlation between weighted usable area and fish biomass. Scott and Shirvell (1986) and Irvine et al. (1987) note that WUA is an estimate of potential habitat and is not necessarily correlated with fish biomass. This raises the question of IFIM's value to the fisheries manager if the method can not be used to predict to some extent the effects on fish populations of changes in the flow regime. If fisheries managers can not gain an indication of changes in fish populations or population dynamics by using IFIM then they should not waste resources in its employment. Further work must also be undertaken to determine if and when IFIM can be used to aid river managers in their decisions. If IFIM is fulfil its potential as an indicator of available habitat much theoretical and practical research must be undertaken. In its present configuration IFIM can not be relied upon to produce the information its proponents claim.

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