INTERACTION BETWEEN ANGLERS AND COARSE FISH POPULATIONS IN TWO GRAVEL-PIT LAKES

by

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ABSTRACT

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The population biology of the coarse fish species in two gravel-pit fisheries (A and B) in Suffolk was studied from 1974 to 1977. Simultaneously the fish caught by anglers and their angling techniques were monitored by census. Environmental factors were recorded on each census occasion and the crustacean zooplankton in lake A assessed in 1975 and 1976.

Explanations for the relatively poor recruitment of rudd, perch and tench and for fluctuations in roach stocks are advanced. The growth rates of most fish were good, and appeared to be density dependent; the implications of predation for maintenance of growth are discussed.

Stocking with roach and bream increased biomass and production in lake A. Other aspects of stock introductions were investigated. Production of all species in lake A was about 30 g m^{-2} yr^{-1}, with about 30% of cyprinid production being consumed by pike.

Anglers caught all species of fish, which became vulnerable at 0+ or 1+ years; the timing and size at recruitment being affected by growth rates, hook and bait sizes. The catchability (catchability index) of rudd, tench and perch was generally high compared with roach or bream, e.g. being 28.4% for rudd and 2.3% for bream (1976).

Angling success was influenced by many variables, in particular stock density and water temperature; predictive models for catch rate variation are presented. It was not surprising that catch rates were often low during matches.

Fish caught by angling often suffered mouth damage but the condition of survivors with mouth damage was not consistently worse than those without. Evidence for learnt hook avoidance behaviour was slight.

Recommendations for the management of standing-water coarse fisheries are discussed and the application of census methods evaluated.

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CONTENTS

CHAPTER 1

INTRODUCTION

1.1 General Introduction

Angling is an increasingly popular leisure-time activity in the United Kingdom (National Angling Survey, 1971; Welcomme and Henderson, 1976) and it is therefore important to develop new fisheries and improve management techniques so that existing resources may be properly maintained.

With notable exceptions (Ayton, 1972, 1974; Axford, 1974b; Moore, 1971, 1973; Easton and Morgan, 1974 and Parry, 1974) few studies have examined the relationship between angling and populations of British coarse fish (i.e. Non-salmonid freshwater species). In particular the influence of coarse fish population densities or species composition upon angling success (see later) has rarely received attention. In the United States however, studies of angling and angling-related management problems on non-salmonid freshwater sport fisheries have progressed for many years (e.g. Swingle and Smith, 1941; Ricker, 1942b; Lagler and de Roth, 1953; Bennett, 1954, 1970; Byrd, 1959; Anderson and Heman, 1969; Elrod, 1971).

Sand and gravel extraction for the construction industry has increased steadily over the past fifty years even in rural counties (e.g. Swain, Way and Horstead, 1977), and the many gravel-pit lakes created have been developed for angling, wild-life conservation (Catchpole and Tydeman, 1975) or other activities e.g. boating and water-skiing.

Recent research in aquatic biology at the City of London Polytechnic (CLP) has concentrated on the biology of gravel-pit lakes located in and close to Greater London. Gee (1976, 1978) completed a survey of age and growth of coarse fish in 39 gravel pits where roach (Rutilus rutilus) were the dominant species; subsequently he studied the structure and production of coarse fish populations in 6 gravel pits during 1973.

About the same time, Barber (1976) studied the invertebrate and fish fauna of a single gravel-pit lake in Hampshire; he found that year 2 and 3 roach were the main planktophagous fish in the lake and were feeding size-selectively on Daphnia longispina. Northcott (PhD in preparation) has studied the limnetic and littoral zooplankton in several gravel pits in relation to the growth and diet of young cyprinids and perch; her study extends the earlier work of Cook (1979) on the interrelationship between young (0+ to 1+) coarse fish and the limnetic crustacean zooplankton of four gravel-pit lakes.

In addition, the gravel-pit study group at CLP have investigated the phytoplankton of a single group of lakes (Goodridge; PhD in preparation), surveyed the molluscs in 44 lakes (Powell and South, 1978) and studied the parasites of gravel-pit coarse fish (Sweeting, 1976). No angling studies have previously been undertaken with gravel pit coarse fish populations by the CLP group, although a census of angling on a put-and-take trout fishery has been recently completed (O'Grady and Hughes, 1980). The present work contributes to the CLP research programme by examining the factors that affect angling success, the effect of angling on coarse fish populations and general fish biology in gravel-pit lakes outside the group of lakes normally studied (see Fig. 1).

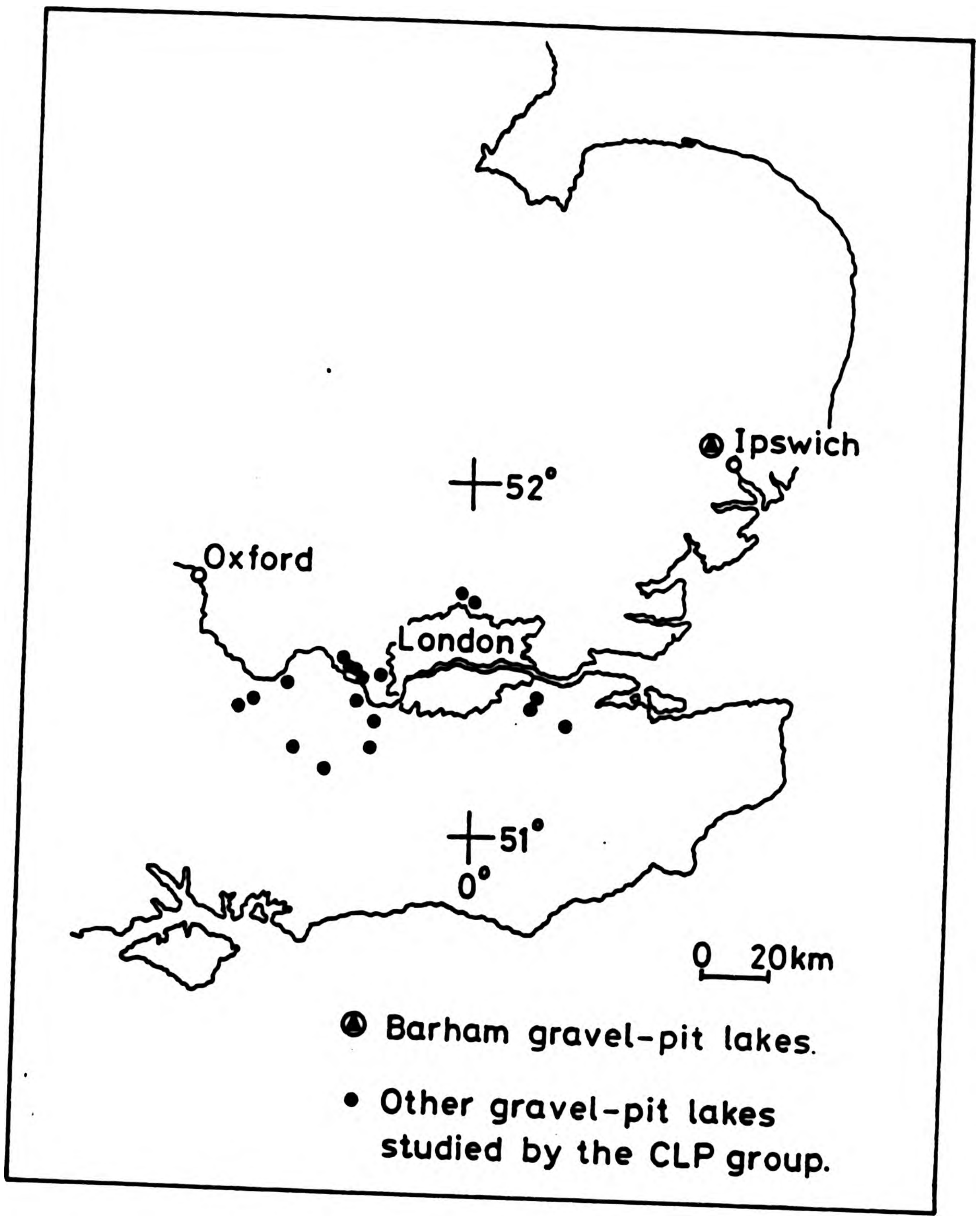

Fig. 1 Map to show the location of Barham gravel-pit lakes relative to those studied previously by the CLP group.

1.2 Fish populations

The growth characteristics of coarse fish in the British Isles have often been described (e.g. Jones, 1953; Mann, 1973, 1974, 1976a, 1976b; Goldspink, 1978; Gee, 1978) since Hartley's (1947) investigations but, most of the work has been concerned with the common species such as roach and perch. Growth performance is important because it indicates the health and success of fish stocks (Welcomme and Henderson, 1976).

The determination of fish age is necessary for the assessment of growth rates and age related mortality. Methods of ageing coarse fish are well documented (e.g. Tesch, 1971; Jones, 1953; Cragg-Hine and Jones, 1969; Le Cren, 1947) but information on the following coarse fish species is relatively scarce: rudd (Gee, 1976, 1978; Burrough, Bregazzi and Kennedy, 1979; Steinmetz, 1974; Hartley, 1947), tench (Gee, 1976, 1978; Weatherley, 1958; Kennedy and Fitzmaurice, 1970) and crucian carp.

Scales, opercular bones, otoliths, fin rays and other boney structures of teleost fish living in temperate zones usually develop discontinuities (checks or annuli) at year intervals but, despite their regular use for age determination comparatively little is known of their production (Simkiss, 1974). Moreover, cyprinids (Mathews and Williams, 1972; Cragg-Hine, 1965) and centrarchids (Regier, 1962) at least may fail to form annual checks on their scales and other structures. On the other hand, extra checks may be induced by variations in water temperature (Beckman, 1943), feeding and light period (Bilton and Robins, 1971) spawning (Jones, 1953) or because of other environmental changes. It is therefore essential to validate age determinations and, this has received special attention in the present study.

There are a number of methods to validate ageing (see Mann, 1973; Cragg-Hine and Jones, 1969; Hellawell, 1974) but, the Walford plot method (Walford, 1946) derived from the Von Bertalanffy growth model

(Von Bertalanffy, 1938; Ricker, 1975), is widely used to identify first and second year checks which may be hidden by the thickening of bones and scales common in older fish. Furthermore, length/frequency histograms often confirm the presence of distinct year classes if the fish are fast growing.

Two types of sampling method, angling and seine net, were used in the present study to reduce the effect of selective bias (Lagler, 1971). As a result it also became possible to assess the relative selectivity of the two capture methods.

Growth rates may be determined by finding the lengths of fish at successive (e.g. yearly) time intervals by back-calculation (Tesch, 1971; Gee, 1976). Back-calculation of length at each annual scale check requires that the size of the structure used for ageing is in some way proportional to the length of the fish; the body/scale relationship varies from species to species and between populations and should therefore be determined empirically for each situation (see Segerstrale, 1933; Hile, 1970; Tesch, 1971). The body/scale relationship may vary according to the position on the body that the scales are removed from, it is therefore essential to take scales from a fixed location (key scales) whenever back-calculation is used. The zone of the scale selected for measurement is also important; for example Hofstede (1974) found that measurements in the posterior field of roach and dace scales produced the most reliable body/scale relationship.

Back-calculation of growth is regarded as superior (Ricker, 1975; Gee, 1976) to the practice of compounding growth rates from the mean length of aged fish sampled over a period of time because the latter method obscures growth differences between year classes unless large samples are obtained. There may however be discrepancies in back-calculated data for example, Lee's phenomenon (Tesch, 1971), where back-calculated lengths at a given age become smaller the older the fish for which they are computed. This may arise particularly if an inappropriate body/scale relationship is used, sampling biased or the population exposed to size-selective mortality. Lee's phenomenon may be reversed if the smaller fish in a year class are selectively removed. Careful inspection of the data should reveal such defects and back-calculation of length at age has been used successfully with roach, dace, chub, bream, tench, rudd, grayling and perch (Mann, 1973, 1974, 1976; Gee, 1976; Le Cren, 1947; Steinmetz, 1974; Hofstede, 1974 etc). Back-calculation has been employed and further evaluated in this study.

The quantity and quality of food available to fish is an important factor controlling growth. Young perch and roach grow fast when suitable supplies of crustacean zooplankton are available (Cook, 1979) and Elliott (1976) has shown experimentally that the growth of brown trout may be affected by quantitative changes in diet. Alm (1946) and Barber (1976) noted improved growth of perch and roach respectively when transferred from densely-populated lakes to low density situations and they felt that the apparent density dependence of growth could be ascribed to problems of food supply. Growth may also be dependent on abiotic factors particularly water temperature (Cook, 1979; Broughton and Jones, 1978).

Growth standards for coarse fish have been published for Holland (Hofstede, 1974), Sweden (Kempe, 1962) and recently for the British Isles (Hickley and Dexter, 1979); they are useful in the assessment of the relative success of species in different waters but more data is required to compile standards for the less common species e.g. crucian carp.

Length/weight relationships for each species in a community may be determined and used in the calculation of condition, biomass and production. The length/weight relationship for fish may be described by an equation of the type:

$$w = al^b$$

or

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$$w = al^b$$

or

$$\text{Log}_{10}w = \log_{10}a + b(\text{Log}_{10}l) \quad \text{(Le Cren, 1951)} \qquad (1)$$

where w = weight, l = length, a = intercept and b = slope of the length/weight regression.

If the slope (b) of a length/weight regression equals 3, growth of the fish will be isometric; any significant deviation from 3 implies allometric growth i.e. change of body form with growth. The value of the slope may change within a population, seasonally, during development or between sexes (Le Cren, 1951; Van Den Avyle and Carlander, 1977) but may remain constant within these categories.

The well-being or relative plumpness of individual fish has often been assessed by condition factors in experimental investigations (e.g. Axford, 1974a). Condition factors may be calculated in several ways e.g.

$$K = \frac{w}{l^3} \qquad \text{where } w = \text{weight}, \; l = \text{length} \qquad (2)$$

and K = coefficient of condition ≡ a in equation (1) if the slope of the length/weight regression equals 3. Equation (2) may be modified to compact results according to the units of measurement. If the cube law is not obeyed, calculated condition will vary with length and not reflect changes in nutritional condition. Genetic, age or sex factors may influence K by affecting the value of the slope in the length/weight regression, rendering comparisons of K between populations or intra-population groups of doubtful value (Le Cren, 1951). Selective sampling, disease and other environmental factors may also affect K and the interpretation of K may be expected to be difficult in field investigations. Le Cren (1951) proposed a 'relative condition factor', K_n which avoids some of the disadvantages of K by being based on empirically determined length/weight regressions i.e.

$$K_n = \frac{w}{al^b} = \frac{w}{\hat{w}} \qquad (3)$$

where K_n = relative condition factor, l = length, w = weight, a = intercept and b = slope of length/weight regression; $\hat{w}$ = expected weight for length derived from the length/weight regression. K_n therefore measures the deviation of an individual fish from the average weight for length rather than the deviation from the weight of an 'ideal' fish.

Where there is homogeneity of b (slope) between groups, group data may be pooled and the value of a (intercept) for the pooled length/weight regression may be compared for the various groups as a way of measuring their relative condition. With heterogeneity of b this approach is invalid.

Because variability of b has such an impact on condition factors, Weatherley (1972) has argued that K_n offers little real advantage and, K (equation (2)) has been used to detect seasonal patterns of condition in largemouth bass (Van Den Avyle and Carlander, 1977) and tench (Weatherley, 1958) whenever isometric growth has been approximately maintained.

Annual cycles of condition (K_n) have been found for roach, dace, chub, pike (Mann, 1973, 1974, 1976a, 1976b) and perch (Le Cren, 1951); immature roach had a single and mature roach a two-phased cycle, the latter probably resulting from the loss of gonadal products followed by recovery (Mann, 1973).

While the difficulties (see above) of condition analysis were recognised, it was considered that an attempt should be made to assess the condition of fish with and without mouth damage caused by angling because previous attempts to find significant differences in length/weight regressions for such groups have failed (Moore, pers. comm.).

Reliable estimates of absolute numbers of fish are required for the estimation of biomass, production, mortality and absolute densities. They may also be used to explain changes in growth rates, species composition and catch rates. Absolute numbers of coarse fish have occasionally been estimated for running waters (Hunt and Jones 1974; Hart and Pitcher, 1973) and recently for standing waters (Gee 1976;

Barber, 1976) but most investigations of standing water coarse fish populations (e.g. Banks, 1970; Goldspink, 1978, 1979; Linfield, 1980a) have either not estimated abundance or have based estimates on the number of fish in samples.

Mark-recapture (see below), catch-depletion (De Lury, 1947) and area sampling (Bagenal, 1974; Cook, 1979) have been used to estimate fish population numbers, but mark-recapture has been widely used in the United States (e.g. Ricker, 1942b, 1945a; Eschmeyer, 1942; Cooper, 1953; Waters, 1960) and the theory and practice of the method is well documented (e.g. Dahl, 1919; Lincoln, 1930; Schnabel, 1938; Schumacher and Eschmeyer, 1943; Bailey, 1951; Chapman, 1952, 1954; Fisher and Ford, 1947; Jolly, 1965; Serber, 1965; Gee, 1976) with several excellent reviews (Cormack, 1968; Parr, Gaskell and George, 1968; Ricker, 1975; Begon, 1979).

Mark-recapture methods depend on the probability of capture being the same for marked and unmarked fish and random sampling. These conditions are hard to satisfy, for example catching and marking fish may subject them to stress (see later) and alter their subsequent behaviour.

Two groups of mark-recapture methods exist: single and multiple census. The former methods are conceptually simple: if the population is fixed, $^{M}/N$ is the proportion of marked fish in the population and $^{R}/C$ the proportion of marked fish in a sample (where N = population at time of marking; M = number of fish marked; C = number in sample and R = number of marked fish in sample) then $^{M}/N = {}^{R}/C$ and the population may be estimated by:

$$\hat{N} = \frac{MC}{R} \quad \text{(Lincoln, 1930)} \tag{4}$$

or

$$\hat{N} = \frac{M(C+1)}{(R+1)} \quad \text{(Bailey, 1951)} \tag{5}$$

Bailey's (above) and Chapman's (1952) modifications of the basic formula avoid the situation where R = 0 and tend to reduce positive bias. Robson and Regier (1964) consider estimates from the modified formulae to be unbiased if $MC > 4N$ and Ricker (1975) if $R > 3$ or 4. The conditions necessary to achieve any desired precision of estimate have been calculated (Robson and Regier, 1964) but their realisation may often be impractical.

Population estimates are possible in the absence of recaptures (Bell, 1974); marked animals may not be recaptured due to random sampling error but if the conditions for mark-recapture hold and a animals from a population N have been marked and released and later n are caught, none with marks, the probability that the first capture will be unmarked is $(N - a)/N$ and the second is $(N - a - 1)/(N - 1)$. The probability (p) of all n recaptures being unmarked is:

$$p = \frac{(N - a)}{N} \cdot \frac{(N - a - 1)}{(N - 1)} \cdots \frac{N - a - (n - 1)}{N - (n - 1)}$$

$$= \frac{(N - a)!/(N - a - n)!}{N!(N - n)!} = \frac{(N - a)!(N - n)!}{N!(N - a - n)!} \qquad (6)$$

Bell suggests setting $p = 0.5$ and solving equation (6) for N by iteration. Such an estimate has an equal probability of being larger or smaller than the population. 95% confidence limits may be obtained by solving for N with $p = 0.025$ and $p = 0.0975$.

Mark-recapture estimates generally improve as the proportion of marked fish in a population rises but because it may not be possible to catch and mark enough fish on a single occasion, multiple census methods involving sampling and marking on more than one occasion, have been developed (Schnabel, 1938; Schumacher and Eschmeyer, 1943; Bailey, 1951; Fisher and Ford, 1947; Jolly, 1965). Of course, a population may be estimated by a single census method each day in a series of days but, as the sampling effort increases, estimates become more reliable with the result that elements in a series of estimates are incomparable. Schnabel (1938) therefore suggested using equation (7) to provide a maximum likelihood estimate of population size:

$$\hat{N} = \frac{\Sigma(C_i M_i)}{\Sigma R_i} \qquad (7)$$

where i = sampling time - 0,1,2 ... k, C_i the sample size, R_i the number of previously marked fish in i^{th} sample, M_i the marked fish in the lake on the i^{th} occasion. The denominator may be replaced by $(\Sigma R_i) + 1$ (Chapman, 1954) to give a better estimate.

More sophisticated models are available such as Bailey's (1951) Triple Catch method which assumes constant rates of recruitment and death. In recapture terms:

$$\hat{N}_2 = \frac{M_2(C_2 + 1)(R_{13})}{(R_{12} + 1)(R_{23} + 1)} \qquad (8)$$

where $\hat{N}_2$ = estimate of population on the second sampling occasion. However, Gee (1976) and others have shown the method to be unreliable where the numbers of fish caught on the three occasions are very different. Gee (1976) has proposed a model where, unlike Bailey's Triple Catch, a deterministic death rate (γ) applies to marked fish instead of all fish, as the mortality of unmarked fish during the course of a population estimate will normally be negligible. During the time interval $t = t_2 - t_1 = t_3 - t_2$, Gee's model becomes:

$$N_2 = N_1 - M_1(1 - e^{-\gamma t})$$

$$N_3 = N_2 - M_2(1 - e^{-\gamma t})$$

$$\text{and} \quad N_1 = N_2 + (M_1 - M_1\mu)$$

where $\mu = e^{-\gamma t}$ = mortality acting on marked fish. In recapture terms

$$\hat{N}_1 = \frac{M_2R_{13}}{R_{23}}\left[\frac{C_2}{R_{12}} - 1\right] + M_1 \qquad (9)$$

with an unbiased estimate of μ obtained from:

$$\hat{\mu} = \frac{M_2.R_{13}}{M_1(R_{23} + 1)} \qquad (10)$$

The model may also be used to assess the behaviour of marked fish. According to Gee, $\mu = 1$ implies total survival and integration of marked fish into the population whereas $\mu < 1$ suggests decreased and $\mu > 1$ increased catchability of marked individuals.

Stochastic models where the survival of individual animals over a period is expressed as a probability (Jolly, 1965; Serber, 1965) may be more realistic than deterministic models but offer little advantage when sampling and marking is limited to a few occasions (Cormack, 1968; Gee, 1976).

Mark-recapture methods have been assessed 'in the field' on several occasions. Buck and Thoits (1965) found that Lincoln index estimates of known populations of small and largemouth bass, bluegills and brown bullheads were usually negatively biased but positively biased for yellow perch. Sampling was always by seine net and differences in species catchability and homing behaviour were suggested as explanations for bias. Others (e.g. Ricker, 1975; Beukema, 1970a) have observed similar effects due to increased and decreased catchability of marked fish. Beukema and de Vos (1974) observed however that the effects of unequal catchability on mark-recapture estimates were reduced by using different gear to capture and recapture the carp used in their experiments. Other authors (Ricker, 1942b; Waters, 1960; Westers, 1963) have also reported advantages of using mixed gear. Interestingly, seine sampling selectively produced gross under-estimates of brown bullheads (Carlander and Lewis, 1948) a predominately benthic species.

Gee (1976) compared mark-recapture estimates for several models with an estimate obtained by a fundamentally different method (Catch-depletion) and advised the use of simple Lincoln index models and his own Triple Catch method (see above).

Mark-recapture methods obviously depend on fish remaining marked for the duration of an experiment. Fin clipping serves as a batch mark which may be recognised even after regeneration (Stuart, 1958); recently cold-branding with tools cooled in liquid nitrogen has been used to batchmark salmonids (Mighell, 1969; Piggins, 1972; Nahhas and Jones, 1980) with little ill effect (Laird, Roberts, Shearer and McArdle, 1975). The subcutaneous application of inks and dyes has also been widely used since Hart and Pitcher (1969) reported the suitability of panjet inoculators for that purpose, and alcian blue marks applied by panjet may persist for >3.5 years (Pitcher and Kennedy, 1977); however, the durability of such marks may be species dependent. Gee (1976) noted for example that indian ink and alcian blue marks lasted longest on small-scaled fish e.g. tench, if the dye reached the sub-scale pocket. He also observed that small cyprinids were sometimes killed by panjet marking if the dye penetrated to the body cavity. Injections of coloured latex (Gerking, 1958) and acrylic paints (Lotrich and Meredith, 1974) by hypodermic syringe have been used successfully but are slower than panjetting. Marks on some fish may be expected to fade and Thorpe (1974a) has demonstrated a 38% loss of alcian blue panjet marks from brown trout through a single angling season.

Fish may be individually marked by numbered tags, but their use may result in severe damage if the tag wound becomes infected (Roberts, McQueen, Shearer and Young, 1973a) or if anglers remove the tag clumsily (Axford, 1974a; Hunt and Jones, 1974). Apart from increased mortality due to tagging, tagged fish may grow slowly (De Roche, 1963) although this may not always be true (Axford, 1974a). Handling fish may stress them sufficiently to increase mortality without considering the effects of marking and anaesthesia; Soivo and Oikari (1976) reported that handling pike for 1.5 minutes was enough for the pike to show haemo-concentration and elevated blood glucose and lactate.

Published estimates of biomass and production of coarse fish populations in standing waters are relatively scarce for the British Isles (Gee, 1976; Hickley and Bailey, 1977) and probably reflect the scarcity of population estimates (see above). Production may be defined as the total fish tissue elaborated during a time interval and includes tissue formed by individuals that do not survive the interval (Ivlev, 1966). Chapman (1971) has reviewed the methods available for the estimation of production. Estimates of annual production will be approximate if instantaneous growth rates, numbers of fish and biomass are found at infrequent intervals through the year.

1.3 Angling Studies

The effects of commercial fishing on marine and freshwater fish stocks have been intensely studied over a long period of time (e.g. Cushing and Walsh, 1976; Ricker, 1975) but the effects of angling, where the catch is returned alive to the water after capture, has only been investigated over the past decade (see 1.1). Considerable work has been carried out in the United States (e.g. Bennett, 1970) but the situation there is fundamentally different because until recently (Holbrook, 1976) most fish caught have been retained i.e. harvested.

On commercial, game and other fisheries where the catch is removed, the concept of exploitation is valid and Ricker (1975) has defined exploitation rate as the fraction of fish in a population caught and killed by man in specified time and he found, for example, that exploitation rates for 2+ to 3+ yellow perch ranged from 18 to 56% (Ricker, 1945a) on one water studied. Exploitation may be a generally useful term in coarse fishery management but, exploitation rates (above) may be expected to be very low if fish are handled carefully. Linfield (1980b) estimated exploitation rates of 0.326 (32.6%) for common carp, however, this was not a true exploitation rate because the carp were returned alive after capture. Moore (1973) recognised that exploitation rates can not be directly applied to catch-and-return coarse fisheries but has argued that the capture of a fish on one occasion may affect the probability of catching it subsequently. Moore proposed that exploitation be defined as 'the extent to which the catch size reduces the future catch size'. In his view exploitation would be influenced by short-term effects on individual fish due to capture e.g. hook avoidance behaviour and long-term effects on the population. He tried to estimate the proportion of River Nene roach caught by angling by finding the proportion caught with hook damaged mouths; his results suggested that roach big enough to be caught would experience capture at some time in their lives.

The ease of capture or catchability of a species of fish is of particular interest to anglers and fishery managers. Catchability may be defined as the fraction of a vulnerable (see below) species population caught by a unit of fishing effort or may simply be referred to in terms of relative angling success (i.e. Catch per Unit effort: not population related). Catchability may be thought of as similar to exploitation rate but on a catch-and-return fishery the assessment of absolute catchability may generally be impractical because of the difficulty of marking all fish individually (necessary for the identification of recaptures).

Catch per unit effort as a measure of angling success has been reported in many forms, for example:

(i) number of fish caught per rod hour, e.g. catch h^{-1} or catch rod h^{-1} (Ayton, 1974; Parry, 1974; Bennett, 1970)

(ii) weight of fish caught per rod hour e.g. Kg h^{-1} (Ayton, 1974; Bennett, 1970)

(iii) number or weight of fish caught per unit area with or without time e.g. catch rod h^{-1} ha^{-1} (Bennett, 1970)

(iv) number or weight of fish caught per angler visit e.g. catch rod^{-1} (Bennett, 1970)

Angling success may also be reported as total catch or % anglers with catch (Ayton, 1974) and the method selected depends on the situation, however, standardisation is desirable in the interest of comparability of results.

Fish are recruited into a fishery i.e. become vulnerable to angling, when either their mouths are large enough to accommodate anglers' baits or their behaviour allows them to be caught. The timing of recruitment into a fishery may therefore be regulated by growth.

Roach in the River Nene become vulnerable during their second year (Moore, 1973) with the fastest growing individuals recruiting first. Little information appears to be available regarding the recruitment and vulnerability of other species.

Scale loss (Axford, 1974b) and hook-damaged mouths (Moore, 1973) are types of injury normally found in fish subjected to angling, but it has been difficult so far (see above 1.1) to demonstrate that condition declines because of such injuries. Hooks may remain lodged in the guts of fish and become encapsulated in gut tissue (Walker and Alexander, 1974) or occasionally pass through the gut (Axford, 1974b) but hooking injuries may result in an immediate or delayed death. Actual mortalities due to angling noted in the literature (Moore, 1973; Axford, 1974b) appear to depend on the size and species of fish captured and the conditions in which they are held.

Angling success for a particular species (catchability) may be governed by many factors. Exposure to capture may affect susceptibility to recapture; Anderson and Heman (1969) found that largemouth bass (>300 mm) could learn to avoid being hooked but that catchability differences between fished and unfished groups faded after about 6 months. Bennett (1954) observed that the decline of bass catch rate over the first few days of a season in Ridge Lake could not be accounted for by population reduction, instead he ascribed the effect to a lowered catchability of survivors whereas Martin (1958) felt that good early season catch rates were due to the presence of an easily harvested segment in the bass populations. La Faunce, Kimsey and Chadwick (1964) however suggest that the decline in angling success may not be a universal occurrence at the start of a season.

Resistance to recapture by angling has been claimed for several coarse fish: common carp (Beukema, 1970a), pike (Beukema, 1970b) roach and gudgeon (Moore, 1973). In a series of angling experiments with common carp, Beukema (1970a) found that catch rates declined sharply

Roach in the River Nene become vulnerable during their second year (Moore, 1973) with the fastest growing individuals recruiting first. Little information appears to be available regarding the recruitment and vulnerability of other species.

Scale loss (Axford, 1974b) and hook-damaged mouths (Moore, 1973) are types of injury normally found in fish subjected to angling, but it has been difficult so far (see above 1.1) to demonstrate that condition declines because of such injuries. Hooks may remain lodged in the guts of fish and become encapsulated in gut tissue (Walker and Alexander, 1974) or occasionally pass through the gut (Axford, 1974b) but hooking injuries may result in an immediate or delayed death. Actual mortalities due to angling noted in the literature (Moore, 1973; Axford, 1974b) appear to depend on the size and species of fish captured and the conditions in which they are held.

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Resistance to recapture by angling has been claimed for several coarse fish: common carp (Beukema, 1970a), pike (Beukema, 1970b) roach and gudgeon (Moore, 1973). In a series of angling experiments with common carp, Beukema (1970a) found that catch rates declined sharply over five consecutive fishing days, and the experience of a single capture was sufficient to decrease the catchability of carp over a full year. Wild carp appeared to be less catchable than domestic strains (Beukema, 1969). Pike learnt to avoid recapture on artificial baits (lures) but not if live or dead fish were used as bait (Beukema, 1970b). Roach and gudgeon from the River Nene developed resistance to recapture which persisted for approximately two weeks (Moore, 1973), but in both cases, some fish were recaptured within 24 hours.

Waters (1960) has shown that brook trout acquire hook avoidance behaviour as a result of being hooked and lost, however, their avoidance behaviour was much reduced after a two-week 'rest' from angling.

In view of the possible effect of hook avoidance behaviour on angling success, Beukema (1970a) has advised that fish should not be returned to the water after capture. It is interesting to note that Westman, Smith and Harrocks (1956 from Bennett, 1970) have shown that catch rates of bass fall whether the fish caught are returned or not, and it may be best to ignore Beukema's advice until information is available for a full range of coarse fish.

Regardless of hook avoidance behaviour, certain species may be innately more catchable than others. Ayton (1974) reported that despite roach being more numerous than gudgeon in a stretch of canal, the catch rates for the former were low compared with those of the latter. Buckley and Stott (1977) also found that the catch rates for roach were lower than expected in relation to population size but higher for other species e.g. rudd.

Catch rates and population density for vulnerable fish are often assumed to be positively correlated although Lagler and de Roth (1953) were only able to find such a relationship at low population densities of largemouth bass. La Faunce et al (1964) found that catch rates and population estimates for largemouth bass did not correlate, and concluded that catch-per-unit-effort would be unlikely to indicate bass population sizes. Little is known about catch rate/ stock density relationships for coarse fish, but waters are still regularly stocked in the hope that catch rates will improve. Where the fate of coarse fish stocked into canals has been studied (Ayton, 1974, 1976) few have been recaptured, and in rivers, recaptures of stock fish may decline quickly after their introduction (Parry, 1974); low survival and dispersion probably account for these observations.

Investigations of the success of stocking standing waters with coarse fish for angling are few but Barber (1976) found that roach stocked into a gravel-pit lake containing roach, perch, rudd and tench, grew as well as the resident roach, with similar survival rates; however, the fish were not subjected to angling. The observations on other waters (see above) suggest that initially at least, stock fish may be more catchable than residents.

Catch generally increases with angling effort (e.g. Fleming-Jones and Stent, 1975; Bennett, 1970) but catch rates may be negatively influenced by an increase in angling pressure (Bennett, 1970); presumably fewer fish are caught because of disturbance by anglers. On the other hand, coarse fish catch rates increased with effort over three months on a lake re-opened to angling after several years closure (Howard, pers. obs.). This unusual observation may be explained by the fish learning to accept baits as a regular food.

On several fisheries a few anglers have been shown to catch most of the fish (Lagler and de Roth, 1953; Bennett, 1970; Crisp and Mann, 1977a). As well as being skilled in the use of tackle and selection of baits, anglers influence their own success by fishing at certain times (Lagler and de Roth, 1953) and possibly by choosing certain places to fish on a water. Experience may be important, with regular visitors to a fishery being the most likely to catch fish (Crisp and Mann, 1977a). Unfortunately many aspects of angler behaviour that may affect success are hard to quantify.

Much of the angling literature is concerned with giving advice on bait selection, preparation, collection and presentation (e.g. Walker, 1975) but the effectiveness of baits and tackles for coarse fishing have rarely been studied (Coulson, 1971) although Parry (1974) found that maggots (larvae of various Diptera) were the most widely used bait by coarse anglers in Yorkshire.

The abundance of natural food has been recognised as an important factor affecting catch rates to anglers; its availability may affect angling in three principal ways:

(i) when food is abundant, feeding increases and anglers' baits are taken readily (Bennett, 1970)

(ii) fish become preoccupied with feeding on particular foods and ignore anglers' baits (Barber, 1976; Bennett, 1970)

(iii) low supplies of natural food encourage fish to eat anglers' baits.

Incidental support for (i) may be found in the excellent catch rates enjoyed on new reservoirs which support the rapid growth of fish. High catchability may be associated with fast growth; it has been reported (e.g. Bennett, 1970) that stunted fish are less liable to take anglers' baits, however, this may not apply to cyprinids. The impact of preoccupation on anglers' catches may be expected to vary through the year as different foods are eaten (see Hartley, 1947; Barber, 1976).

Most coarse fish may be considered partially planktophagous (Barber, 1976; Cook, 1979) and size-selective predation of crustacean zooplankton by fish has been intensely studied recently (e.g. Brooks and Dodson, 1965; Galbraith, 1967; Brooks, 1968; Stenson, 1972; Noble, 1975; White, 1975; Nilsson, 1978; Cook, 1979). Zooplankton and zoobenthos abundance may therefore influence angling success, but there appears to be little published work on this topic.

In addition to the factors mentioned above, other physical, chemical and climatic factors may affect angling success/catchability. With many possibly interacting factors involved, identification of the importance of single factors is unlikely to be straightforward.

Water temperature, clarity and dissolved oxygen are variables which may affect catch rates through effects on fish behaviour, although they may be secondary in importance compared to food supply (Lux and Smith, 1960). Stone (1976) found however that variables such as air and water temperature, wind (speed and direction) rainfall and tide patterns were variously retained in predictive models of menhaden catch and accounted for much of the data variation. In the field of insect ecology, Davidson and Andrewartha (1948b) used multiple regression to show that 78% of the spring variance in catches of thrips was explained by four physical environmental variables. Correlation analysis has been used to assess the factors controlling the upstream migration of salmon (Davidson, Vaughan, Hutchinson and Pritchard, 1943) and Parry (1974) has used multiple correlation to assess the impact of river flow, water temperature, clarity and season on coarse fish catch rates; he found water temperature to be the most important. Stott (1969) also noted that catches of roach and perch in unbaited traps were regulated by water temperature and he ascribed this to the general increase in the activity of poikilotherms with rising temperature.

Reduced water clarity (≡ increase in turbidity) due to algal blooms or suspended solids may affect the growth of bass (Buck, 1956, from Bennett, 1970) and reduce the feeding activity of species that predominately depend on vision to find food e.g. pike and perch. With cyprinids whose activity may be high under low light conditions (Kukko, 1974), a reduction in water clarity may be expected to have the opposite effect.

Many environmental variables show seasonal variation and may thus affect catches. Byrd (1959) found catch rates for bluegills and bass to be highest in autumn and winter, but reports of seasonal changes in angling success for the British Isles are sparse. If changes in the statutory close season were proposed, it would be essential to know seasonal catch patterns. Moore (1973) and Axford (1974b) have respectively reported that catch rates for roach and dace may be low at spawning time, and Hartley (1947) observed the lowest percentage of dace with stomachs containing food in March to April. On the other hand, Cragg-Hine (1964) has reported increased feeding at spawning times and it is possible that infrequency of sampling has obscured the spawning fast.

The primary aims of this study were to investigate the effects of angling on mixed-species coarse fish populations, to estimate the catchability and vulnerability of each species and to assess the importance of population size and structure over angling success. In addition the study was designed to determine the influence of angler behaviour (i.e. choice of bait), seasonal and other environmental factors on rates of catch. Data on angling and the fish populations were collected by a number of methods to permit assessment of their relative value to fishery management. Parry's (1974) angling census for example, detected a ten-fold reduction in roach catches between 1966 and 1969, clearly demonstrating the value of the method, but unfortunately it was not possible to assess the sensitivity of his census because population estimates were not available for the water concerned.

To execute the aims of the study it was necessary to find a water that was well stocked, intensively fished by anglers, suitable for seine netting and population estimates (i.e. relatively small and shallow; closed to immigration/emigration of fish). To complement the findings of the City of London Polytechnic research group (see above) a group of gravel-pit lakes were selected within easy travelling distance of Ipswich (the study base). Barham gravel-pit lakes were chosen because they satisfied the above criteria, and the society responsible for the management of angling there was willing for two of the lakes to be used for long-term scientific studies.

Fish populations were estimated at the start and end of three angling seasons by simple mark-recapture methods e.g. Bailey's (1951) modified Lincoln Index, as recommended by Gee (1976), with sampling by seine net. Angling effort, methods and catches were assessed by census based on methods described by Lagler and de Roth, 1953; Lagler, 1956; Bennett, 1954, 1970; Best and Bales, 1956; Parry, 1974; Ayton, 1974, and continued over four years. The use of 'test anglers' (a small selected group of ánglers agreeing to report their catches) was suggested by work carried out on ponds and lakes in Illinois (Hansen, Bennett, Webb and Lewis, 1960; Hansen, 1966).

Concurrent with the census and population estimates the species composition, size and abundance of crustacean zooplankton was estimated through two summers, in an attempt to correlate variation in the food supply with angling success. Zooplankton was chosen because even the size of fish likely to be vulnerable to angling were known to be, at least occasionally, highly planktophagous (e.g. Thorpe, 1974b; White, 1975; Barber, 1976) and sampling was relatively easy (Barber, 1976; Cook, 1979) compared with sampling zoobenthos; limited time prevented sampling both.

Sampling of the fish population by a variety of methods was managed to determine size composition, age, growth (by back-calculation) population densities, biomass and condition, and was sufficiently frequent to allow estimates of production, survival and mortality for several species. Furthermore, the regular introduction of stock fish into Barham provided a rare chance to study the success of stocking and its effects on angling and the pre-existing fish communities. The removal of large numbers of fish for the study of their diet was unacceptable to the angling society, but small numbers of fish for this purpose became available as a result of mortality due to capture and handling.

Dissolved oxygen, water temperature, air temperature, water clarity and several climatic factors were measured each census day to support an analysis of their effects on angling success.

CHAPTER 2

MATERIALS AND METHODS

2.1 The gravel-pit lakes

The gravel-pit lakes used for this study are at Barham, near Claydon, Suffolk (Ordnance Survey Sheet 155, 1:50 000; grid reference 122511) and owned by Eastall and Company Ltd. (sand and gravel contractors). The lakes are small, 1.74 and 2.29 ha for lakes A and B respectively with maximum depth of 5 to 6 m (Table 1; Figs. 2 and 3). There are other lakes on the site e.g. lake C (Fig. 2) but they were not investigated.

The oldest lake (A) had contained water since 1956 and excavation was completed soon afterwards; the extraction of gravel from lake B was not completed until 1969, but it was 'wet' before that time. High banks and trees around lake A provided shelter from wind action but made access to the north-west shore difficult.

The geology of the catchment around the lakes comprised boulder clay, chalk and glacial alluvial gravels and ensured that the waters were neutral to alkaline and base rich. The lakes were eutrophic with a high ionic concentration.

Dissolved oxygen (DO) varied seasonally with the low mean values given in Table 1 being recorded in August 1975 and June 1976 for lakes A and B respectively. On one occasion in 1976 (Fig. 5b) DO and pH were monitored over 24 hours and both underwent diurnal changes. The greater change in lake B was probably due to the abundance of macrophytes and algae.

Submersible temperature and oxygen recording equipment (STORE) was operated in the deepest part of lake A during July 1976 and detected very low DO and temperatures. This prompted an investigation on 27 July 1976 (Fig. 5a) but on that occasion there was no evidence of thermal stratification and the low DO was probably a temporary phenomenon

Table 1 Physical and chemical characteristics of Barham gravel-pit lakes

(a)

Lake	Area 1975 m^2	(ha)	Decrease in area 1975 to 1977 m^2	Average depth m	Shoreline (inc. islands) m
A	17367	(1.74)	538[1]	2.3	837 (865)
B	22924	(2.29)	420[2]	-	1523 (1661)

(b)

	Lake A	Lake B
Nitrate (N) mg l^{-1}	1.0 - 2.0	1.0 - 2.0 (14.0)* [3]
Phosphate (P_2O_5) mg l^{-1}	2 - 4	2 - 7 [3]
Calcium hardness mg l^{-1}	390 [4]	-
Magnesium hardness mg l^{-1}	50 [4]	-
Dissolved oxygen mg l^{-1}	5.3 -15.0	9.8 -19.2 [5]
Water temperature °C	4.7 -25.2	4.9 -21.0 [5]
Secchi disc visibility cm	33 - 80	40 - 140+[6]
Conductivity µmhos	1131	750[7]

<u>Notes</u>

1 due to silting

2 " " back-filling

3 range of 3 samples - 11, 22, 30 July 1976

* high value, 6 February 1977. Lake flooded

4 single determination, 12 July 1976

5 range of mean values determined through the census 1974 to 1977 (see Appendix 4); means based on 3 measurements.

6 range of values determined during the census, 1975

7 single determination, June 1977.

(associated with hot calm weather) restricted to that small area of the lake >3 m deep.

Lake A provided water for a gravel-washing plant and received the effluent from the same plant (suspended solids - 8000 mgl^{-1}, 12 August 1976) accordingly lake A was turbid. The substrate of lake A was soft silt over gravel and around the effluent out-fall the accretion of silt was approximately 10 mm per week (June 1976). Lake B became turbid (algal blooms) during 1976 but, in 1974 and 1975 water clarity had been high allowing submerged macrophytes e.g. Ceratophyllum sp. to colonise much of the lake.

Both lakes were supplied with water by percolation through the gravel strata and lake B was connected to the River Gipping, often flooding when the river was in spate. Lake A was not liable to flooding but the water level dropped 0.5 m from the springtime level during the drought in the summer of 1976.

The common emergent and submerged macrophytes in the lakes were identified according to Clapham, Tutin and Warburg (1962), listed (Table 2) and the distribution of emergent macrophytes shown on Fig. 4 for lake A. The silt banks formed near the effluent out-fall reduced the area of lake A (Table 1) and were rapidly colonised by Typha latifolia, Salix spp. and Juncus spp.

The planktonic algae of lake A were sampled each month from June to September inclusive, 1976 (Table 3) and each year (1974 to 1977) during spring, benthic algae were released and floated to the surface in both lakes. These algae were undoubtedly important, serving as a food resource for invertebrates and fish.

The invertebrate fauna of lake A was sampled qualitatively in the littoral zone with a hand net, but an Ekman grab was used to collect invertebrates from water >1 m deep. The species and groups identified are given in Table 4; the number of species was not high but the sampling effort was low. Benthic invertebrates, as well as zooplankton, are an

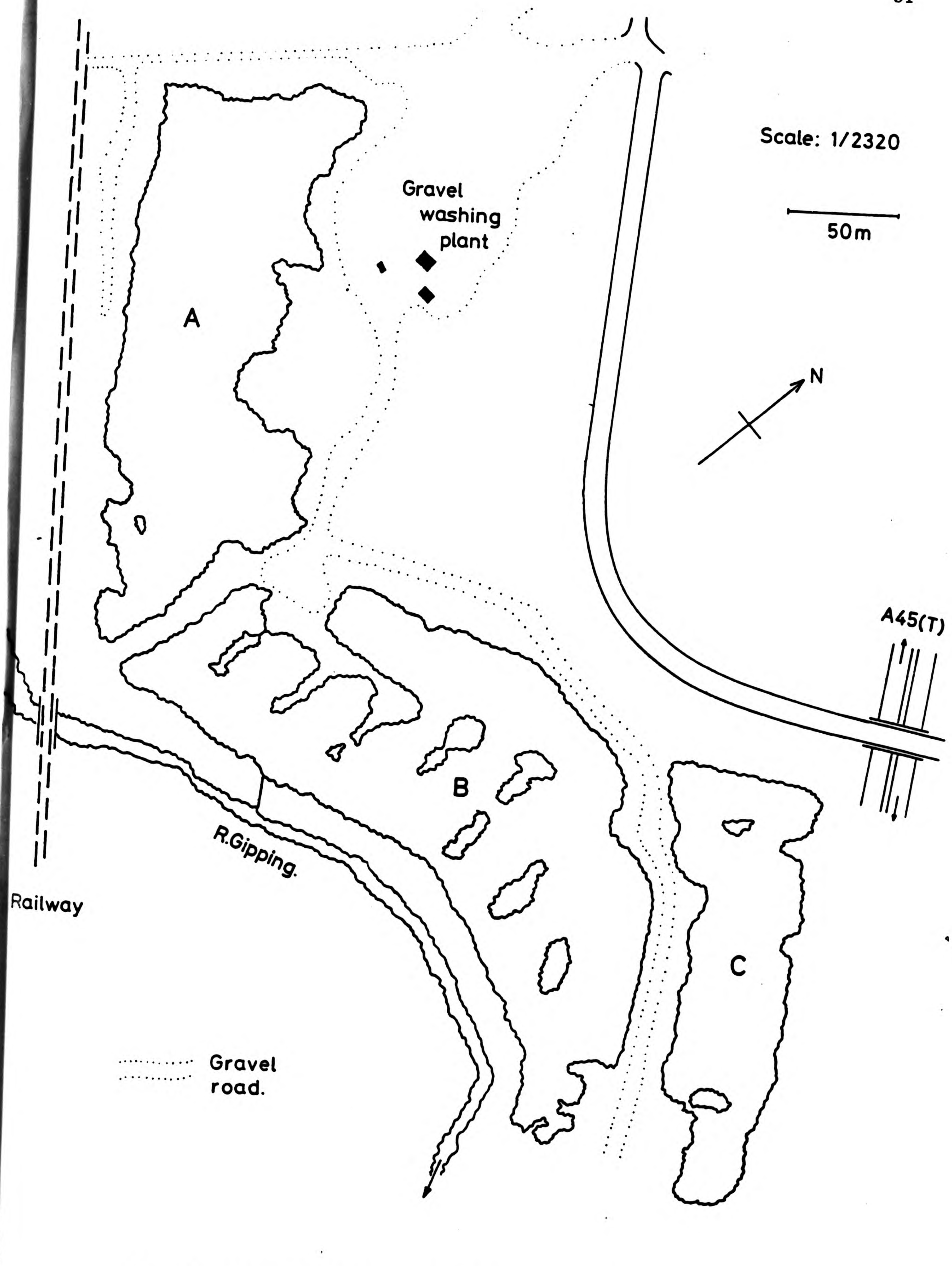
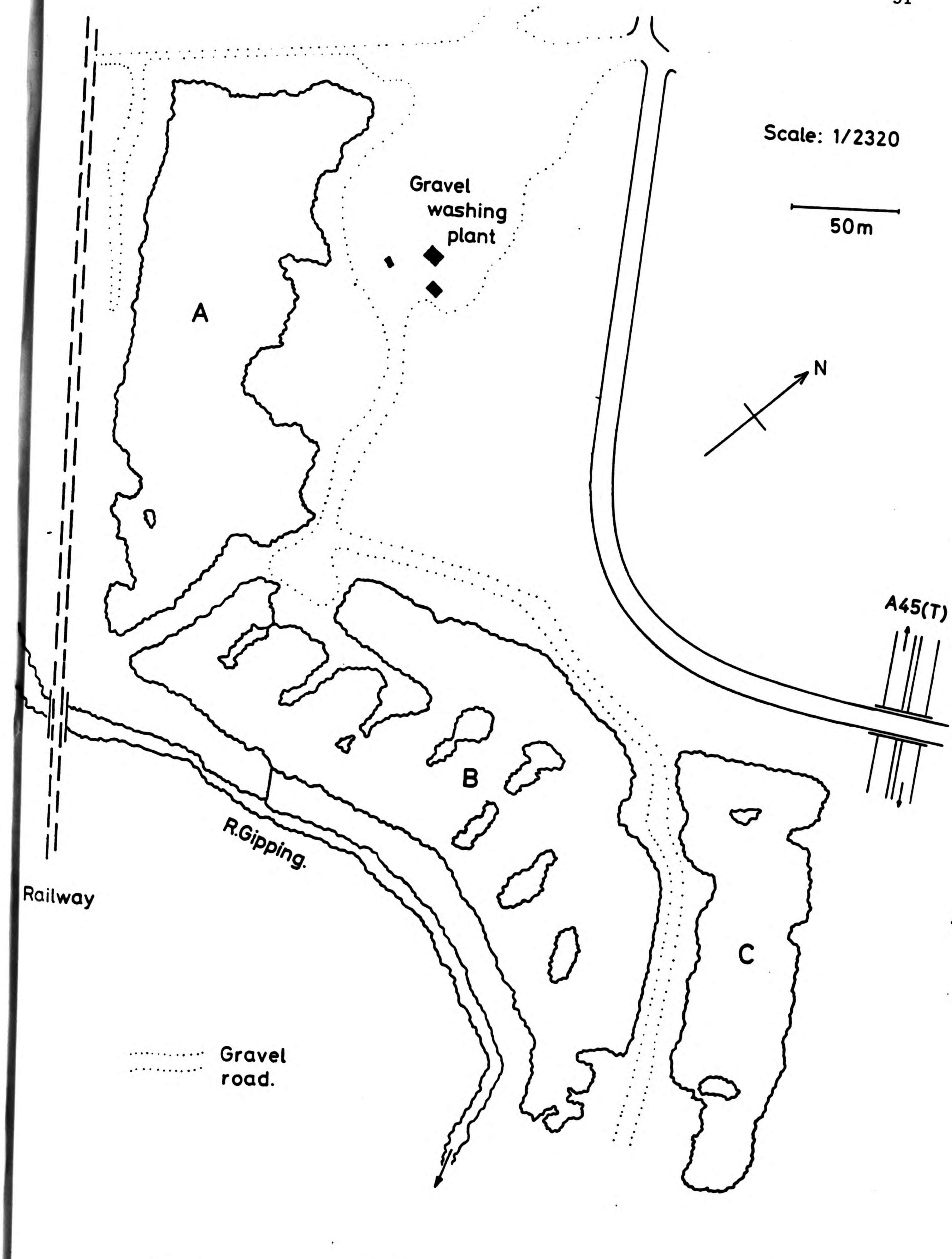


Fig. 2 Map of Barham gravel-pit lakes, showing access roads and associate features.



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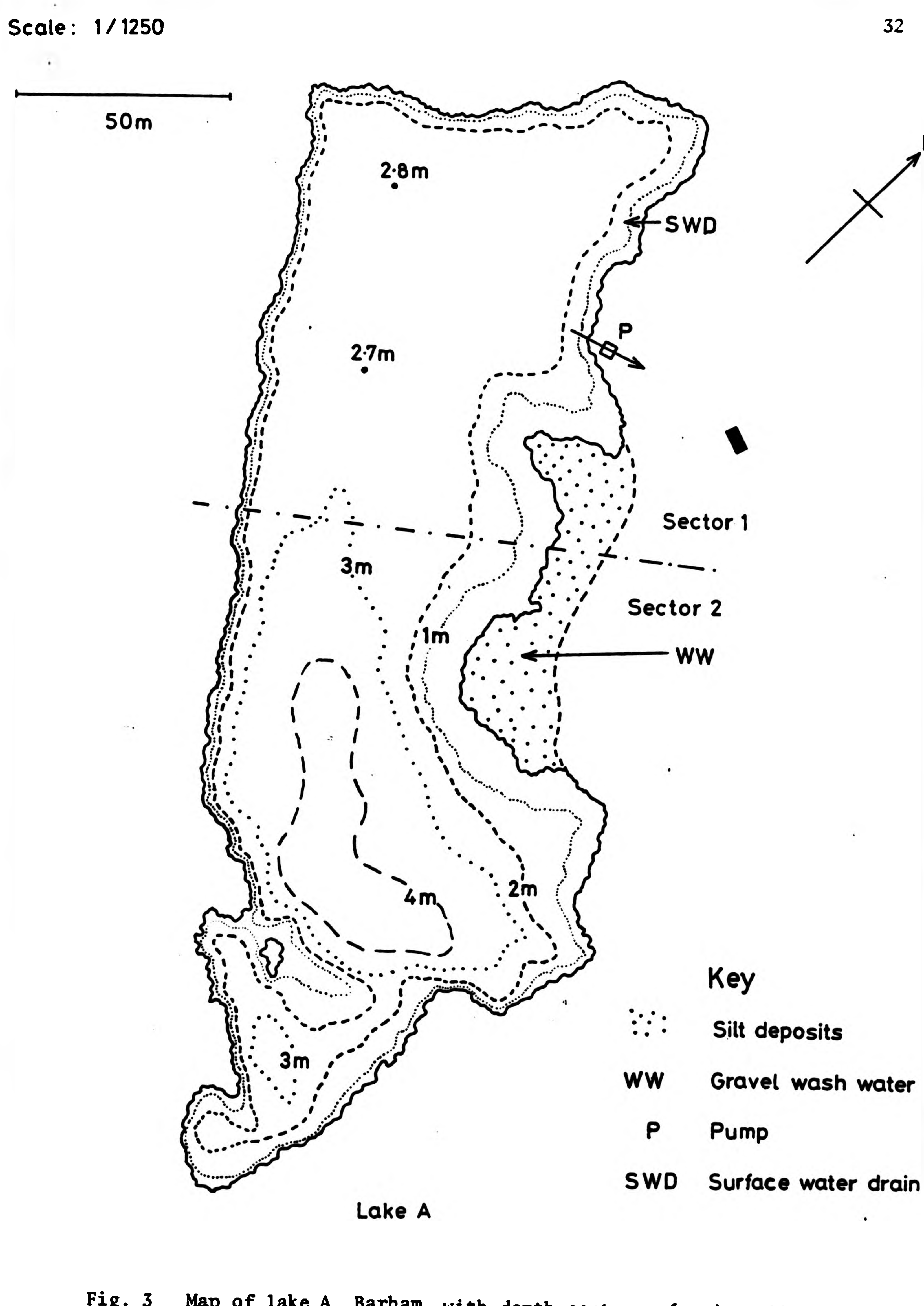

Fig. 3 Map of lake A, Barham, with depth contours (spring, 1977).

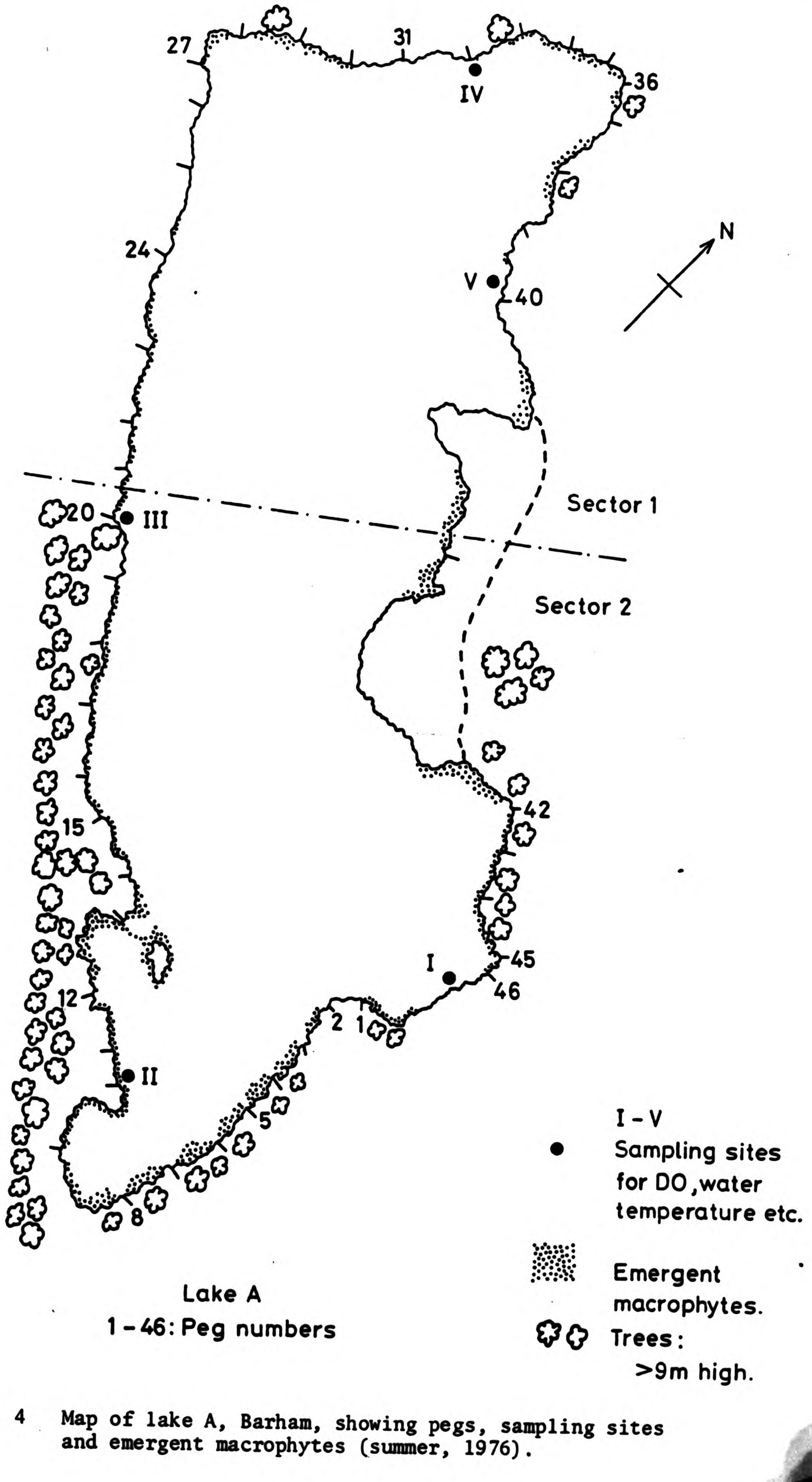

Fig. 4 Map of lake A, Barham, showing pegs, sampling sites and emergent macrophytes (summer, 1976).

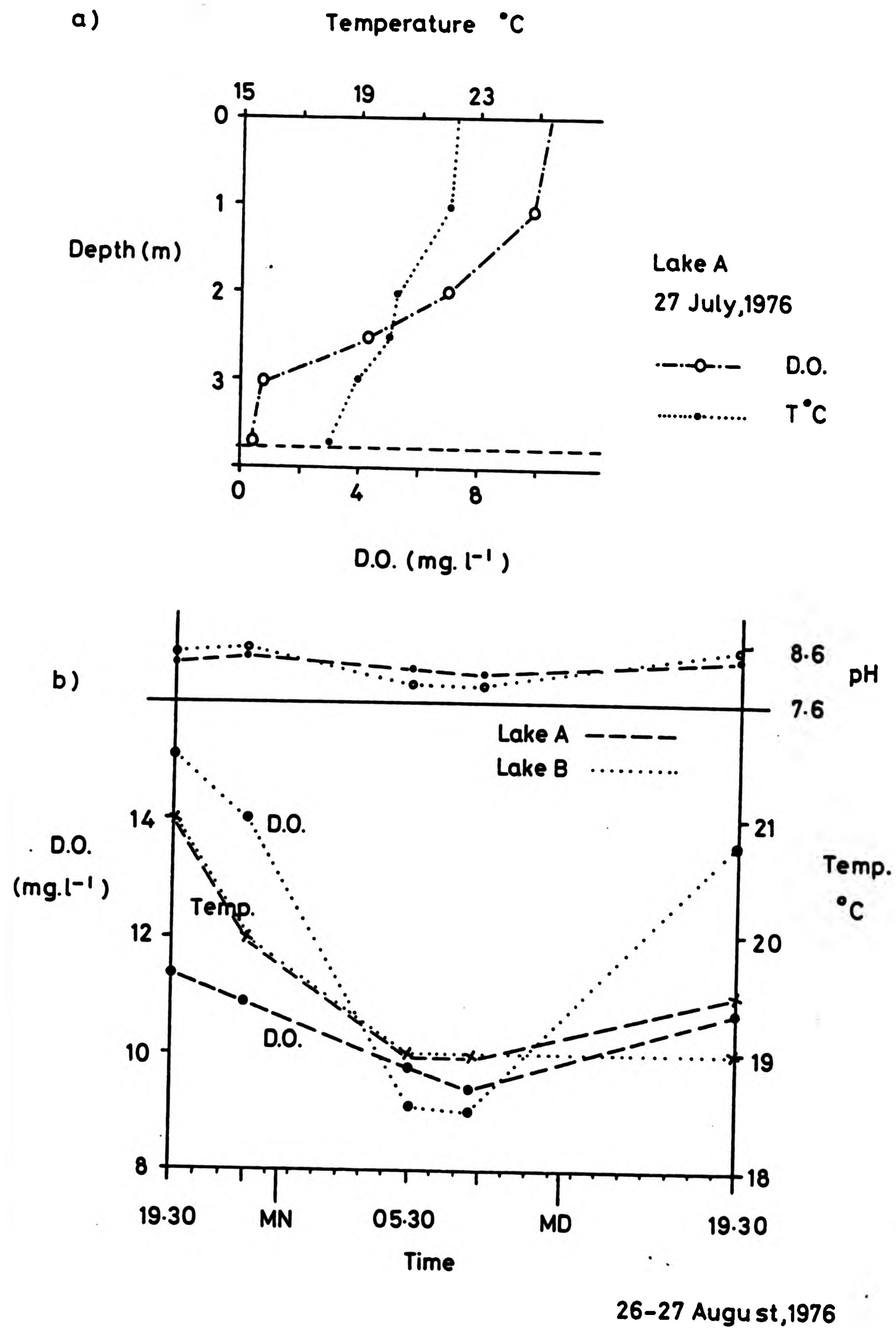

Fig. 5 (a) Water temperature and dissolved oxygen (DO) changes with depth in the deepest part of lake A on 27 July 1976.

(b) Diurnal changes in water temperature, dissolved oxygen (DO) and pH between 19.30 h 26 August and 19.30 h 27 August, 1976; lakes A and B.

Table 2 Aquatic macrophytes. Barham gravel-pit lakes, June to August 1976

	Lake A	Lake B
Emergent		
Schoenoplectus lacustris (L.) Palla.	-	++
Typha latifolia L.	++++	++++
Sparganium erectum L.	++++	++
Sparganium mínimum. Wallr.	++	-
Alisma plantago-aquatica (L.)	++	+
Equisetum palustre L.	++++	+
Epilobium hirsutum L.	++++	++++
Lythrum salicaria L.	++	++
Mentha aquatica L.	++	++
Lycopus europaeus L.	+	+
Phalaris arundinacea L.	+	-
Juncus inflexus L.	++	++
Salix spp	+++	+++
Carex spp	++	++
Floating-leaved		
Potamogeton natans L.	++	++
Nuphar lutea (L.) Sm.	-	+++
Lemna spp	+	+
Polygonum amphibium L.	++	+
Submerged		
Ceratophyllum demersum (L.	++	++++
Elodea canadensis.Michx.	++	++
Potamogeton pusillus L.	++	-
Callitriche sp	+	-

++++ = abundant
+++ = very common
++ = common
+ = present/rare
- = absent

Table 3 Phytoplankton. Lake A, 1976

Month	Ceratium sp	Anabaena sp
June	+	-
July	++	+
August	++	++
September	++	+++

+ = present, ++ = common, +++ = very common

Table 4 Aquatic invertebrates identified in samples from lake A

Sponges
- *Spongilla* sp

Annelids
- Oligochaetes - various
- *Glossiphonia* sp
- *Erpobdella* sp
- *Piscicola geometra*

Crustaceans
- *Diaptomus* sp
- *Diaptomus gracilis*
- *Cyclops* spp.
- *Daphnia* sp.
- *Daphnia hyalina* var. galeatea
- *Daphnia pulex*
- *Ceriodaphnia* sp.
- *Bosmina longirostris*
- *Eurycercus lamellatus*
- *Chydorus* sp
- *Alona* sp.
- Ostracods - various
- *Argulus foliaceus*
- *Gammarus pulex*
- *Asellus aquaticus*

Insects
- *Caenis* sp.
- *Cloëon* sp.
- *Ischnura* sp.
- *Aeschna* sp.
- Trichoptera - various cased species
- *Ranatra linearis*
- *Nepa cinerea*
- *Notonecta* sp.
- *Corixa* spp.
- Chironomidae
- *Chironomus* sp.
- *Chaoborus* sp.
- *Sialis lutaria*

Molluscs
- *Sphaerium* sp.
- *Anodonta* sp.
- *Lymnaea stagnalis*
- *Lymnaea pereger*
- *Bithynia tentaculata*
- *Planorbis* sp.

Arachnids
- Hydracarina

Rotifers
- *Asplanchna* sp.
- *Anuraea* sp.

important food resource for fish and a major component of aquatic ecosystems but there was insufficient time to study them quantitatively.

The fish species present in the lakes are given in Table 5 and are the typical species found in the freshwaters of lowland Eastern England with the exception of common carp, which have been stocked into many waters, including Barham. Eels may have been present in lake A but none were caught during the census. Similarly, gudgeon (*Gobio gobio* (L.)) were absent from catches although present in the River Gipping.

Table 5 Species of fish in Barham gravel-pit lakes, 1974 to 1977

Scientific name	Common name	Lake A	Lake B
Cyprinidae			
Cyprinus carpio L. *	Common carp	+	+
Carassius carassius (L.) *	Crucian carp	+	-
Tinca tinca (L.) *	Tench	+	+
Abramis brama (L.) *	Bream	+	+
Scardinius erythrophthalmus (L.) *	Rudd	+	+
Rutilus rutilus (L.)	Roach	+	+
Leuciscus cephalus (L.)	Chub	-	+
Leuciscus leuciscus (L.)	Dace	-	+
Percidae			
Perca fluviatilis L.	Perch	+	+
Esocidae			
Esox lucius L.	Pike	+	+
Anguillidae			
Anguilla anguilla (L.)	Eel	-	+

* introduced by stocking
\+ present
\- absent

The Gipping Angling Preservation Society (GAPS) was responsible for the management of lakes A, B and C at Barham and members of the society were normally allowed to fish the lakes from 16 June to 14 March. The rules of the society required anglers to fish only at specially constructed fishing places (pegs), each being marked with a numbered stake (see Fig. 4 for location of pegs).

Maps of the lakes were prepared as follows: an aerial photograph of the site taken on 5 July 1975 was obtained from the Ordnance Survey and traced to produce Fig. 2, which was then scaled by measuring, on the ground, the distance between landmarks shown on the photograph. The outline of lake A in Fig. 3 was found by projection - enlargement of the relevant part of Fig. 2 which had previously been drawn on transparent plastic. The soundings for the depth contour map (Fig. 3) -were made during spring 1977 with a 'Heathkit' echo sounder and plumb-line.

2.2 Field methods

(i) Population estimates

Mark-recapture population estimates were an essential part of the investigation and were carried out at the times stated below:

1974, August	Lake A	1976, April	Lake A
1975, February	Lake A	1976, October	Lake A
1975, June to July	Lake A and B	1977, September	Lake A

To allow for the random distribution of marked fish through the population, which is a basic assumption of mark-recapture methods (see Chapter 1.2), 1 week was usually allowed between sampling visits on each of the above occasions.

Fish were caught with a seine net (45.8 m x 3.7 m; 19 mm knot to knot) provided with a central bag. As many fish as possible were caught by systematically fishing the lakes, making use of inlets and bays to aid the entrapment of fish. The net was set from the stern of a rowing boat

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Fish were caught with a seine net (45.8 m x 3.7 m; 19 mm knot to knot) provided with a central bag. As many fish as possible were caught by systematically fishing the lakes, making use of inlets and bays to aid the entrapment of fish. The net was set from the stern of a rowing boat on as many as 16 occasions on any one day, but by 1976 it was possible to catch more fish in lake A for less effort.

The captured fish were removed from the net, washed clean of mud if necessary, and held in plastic holding tanks ($\sim$600 x 400 x 230 mm) containing clean lake water. The water was gently oxygenated and changed at intervals, particularly in warm sunny weather when shade was also provided.

A small handnet was used to transfer fish from the holding tanks to a small tank containing MS-222 anaesthetic solution (concentration selected to give loss of equilibrium within 2 to 5 minutes). Small fish (<280 mm) were then measured to the nearest 1 mm (fork length) by making a prick mark on a sheet of wet, waxed graph paper pinned to a measuring board. This method of measurement was rapid, facilitated counting and, the construction of length/frequency histograms; in the laboratory data were read off the wax sheets with the aid of a light table.

Larger fish were measured on a measuring board and weighed to the nearest gram on a fulcrum-type balance. Key scales were removed from rudd, roach, bream and pike (and rarely from tench), with fine forceps; 1 to 2 scales were taken from the third row above the lateral line, just forward of an imaginary line drawn vertically downwards from the anterior edge of the dorsal fin. The scales were stored in small envelopes labelled with details of the fish e.g. species, date, lake, fork length etc. Scales from small fish were also taken, in the laboratory, from fish killed during sampling (see below).

While still anaesthetised, large fish were panjet marked at various points on the caudal peduncle with indian ink. After panjetting, they were wiped with wet tissue paper to check that a clear mark was present. Small fish were marked by clipping a pelvic fin (e.g. left pelvic clip on day one and right pelvic clip on day two of a three-day population estimation exercise); occasionally large fish were marked in the same way.

Tench >200 mm were sexed by observation of the pelvic fin structure but, other species were only sexed if ova or milt were observed flowing from the vent.

After examination and marking, fish were placed into tanks of clean oxygenated water to recover; they were then transferred to a netted-off section of the lake and released after seine netting was completed. Dead or dying fish were retained and preserved in 10% formalin (later reduced to 4%). The number of dead fish with marks was recorded and subtracted from the total marked, producing the number of marked fish released into the lake on a particular day (see Appendix 2a for mark-recapture data).

Owing to their delicate nature, most 0+ cyprinids were not marked; only their fork lengths were recorded before release. When large numbers of 0+ fish were caught however, only a sample was measured and the remainder were counted.

Treatment of stock fish: prior to 1974, fish introduced to the lakes were neither marked or counted reliably but when bream and roach were stocked into lake A in June 1975, they were measured and panjet marked with alcian blue (anaesthetic was not used). Roach, rudd and perch were stocked in October 1976 and while it was not possible to mark them, they were counted. In April 1976, roach and bream were introduced; they were measured then the larger fish were panjet marked and the smaller fish injected with indian ink. On that occasion it was possible to mark 459 fish in ~3 hours using 3 panjets, 1 syringe and 7 operators.

Stock fish were marked posterior to the dorsal fin on the right or left side. Scales were removed from small samples of stock fish. Details of fish stocked into lake A are given in Chapter 3 (Tables 32 and 33).

A description of the experimental marking of fish by the injection of inks and paints will be considered here. During early 1975, 12 rudd (75 to 150 mm) were test marked by injecting them sub-cutaneously with indian ink, vinyl and acrylic emulsion paints. The marked fish were held in aquaria (11-20°C) and examined at monthly intervals. All types of mark faded within 1 month in some fish but persisted in others for up to 3 months, when the experiment ended. The results suggested that an injection marking system would permit the identification of recaptures for at least 1 month after marking.

Tissues from the mark sites were removed from fish killed by prolonged immersion in MS-222 and fixed in formol-saline. After decalcification in 5% nitric acid they were embedded in paraffin wax, sectioned at 5 to 10 μm and stained with Haematoxylin and Eosin. Ink and paint deposits were clearly visible in the sub-scale pockets, confirming that the materials were located in a position that might aid their retention.

(ii) Angling census

The lakes were visited from August to October in 1974 and from June to October in 1975 and 1976 (all dates inclusive) for the purpose of the routine census (see Table 35; Chapter 3). In 1974 the census days, with the exception of match (competition) days, were selected at random. In 1975 and 1976 they were pre-selected with random variation of the first sampling day each week (Best and Bales, 1956). This system was chosen to cover the most popular angling days and, to prevent anglers deliberately avoiding the census. On the day selected a census was undertaken regardless of the weather conditions.

During the trial census in 1974, an attempt was made to patrol an entire lake on a census day, weighing,measuring and marking fish at their place (peg) of capture while simultaneously carrying out environmental assessments and gathering angler information. This approach was quickly discarded as being impractical for one person to manage. It was noticed that the majority of anglers fished lake A. Therefore, in 1975 and 1976, most effort was directed towards the census on that lake. Environmental assessments i.e. DO, water temperature were only measured at 3 stations (Fig. 4) and fish were collected and examined centrally (see below). Lake A was divided into two sectors (Fig. 4) for census purposes in 1975 and 1976. Sector 2 (southern sector) was routinely selected for the census because it was accessible and popular with anglers; the sector was patrolled at intervals from ∿12.30 hours until after dark and the anglers present were asked to state their names, time of arrival, baits and tackle used. They were also requested to retain their catch in a keepnet until the end of their fishing visit whereupon their catch was collected (in buckets) and transferred to central holding tanks to await (rarely >1 hour) examination.

The numbers of each species in an angler's catch were recorded into fixed size groups (see Appendix 6) on collection to speed up the procedure, an important consideration when several anglers were ready to leave at the end of their visit.

The information gathered from anglers, including peg fished, time of departure and details of their catch were recorded on forms (Appendix 3) similar to those used by Lagler (1956) and Parry (1974). None of the anglers approached during the census refused to give information; this was not surprising because they were all GAPS members, the census aims had been explained to them at society meetings and the person collecting the information was known to them. It was however essential to ask for census information politely and to gain the interest of anglers by engaging in conversation on angling and the census. The establishment of a good relationship was worthwhile because it encouraged anglers to give up their catch for inspection at the end of a visit; furthermore many anglers were prepared to assist in the operation of the census.

In an earlier census, Parry (1974) had noticed the reluctance of anglers to complete census forms, which they regarded as 'office work out-of-doors', therefore it was decided that for the routine census at Barham all information would be collected by a biologist (this also ensured objective data).

Fish collected during the routine census were examined as described for population estimation, with certain differences: a gas lantern was essential because many fish only became available for examination after sunset; wet-weights were determined on a single pan triple beam balance (accurate to 0.1 g on 1 Kg range) and week-specific batch marks were applied to the fish close to the fins to aid mark identification. Again, large fish were normally panjet marked and small fish (<150 mm) injected with dyes, inks or acrylic paints using a syringe fitted with a short (5 mm) needle (see Table 6 below for a typical marking programme).

Table 6 Marks applied to fish caught during the census June to September 1976

Mark: position and colour	Dates	Mark: position and colour	Dates
Left pectoral; black[1]	Jun. 16,17, 18,20	Left pectoral; blue[2]	Jul. 27,29
Right " ; "	Jun. 22,23, 25,27	Left pelvic; "	Aug. 9,11, 13,15
Left pelvic ; "	Jun. 29,30 Jul. 2	Right " ; "	Aug. 19
Right " ; "	Jul. 6,7,11	Left low tail; "	Aug. 24
Left dorsal ; "	Jul. 13,14	Right " " ; "	Sep. 5
Right " ; "	Jul. 22,24	" upper tail; "	Sep. 12

1 = Indian ink
2 = Alcian blue (panjet); blue acrylic paint (syringe)

During June 1976, it was noted that out of 17 tench caught bearing census marks, 3 carried faded black indian ink marks applied during 1975, however, they were easily distinguished from the 1976 marks.

Fork length, weight, sex, disease symptoms, fin/body damage, damage to the mouth and mark(s), added to or present on the fish, were recorded. Mouth damage which appeared to be recent was recorded as 'new hook damage', any other as 'old hook damage'; however, distinguishing them was difficult and only damaged and undamaged mouths were recognised for analysis.

After recovery, the fish were released into the lake, any dead fish being preserved and removed from the mark record as before.

Anglers usually observed the examination, marking and release of their catch, therefore it was important to handle the fish with sufficient care to ensure their survival. The occasional death of a fish was accepted by most anglers but, if the census had resulted in a high observed mortality of fish continuation of the study would have been threatened.

To assess the usefulness of various methods of gathering information on angling and anglers' catches, a voluntary census using test anglers (Hansen et al., 1960; Hansen, 1966) was arranged. Matches were also studied and angling events were specially organised to provide information on autumn, winter and close season angling.

Experienced anglers from the GAPS volunteered to serve as test anglers; this involved their recording lake used, date, time of visit, angling methods and catch on a census form (Appendix 3) for each of their visits to Barham; two padlocked steel census boxes were located on the site to receive completed forms. Test anglers were also asked to record details of marked fish in their catch and notes for guidance on mark recognition and fish measurement were issued with the census forms.

Fishing matches were held during the daytime (e.g. 08.00 to 13.00 hours) at the weekend. All pegs were usually occupied and at the end of a match, stewards recorded the weight of each angler's catch before returning the fish to the water. The numbers of fish caught were sometimes high, moreover they were often dispersed at pegs around the lakes which made their collection difficult even with additional manpower. On warm days it was not easy to transport fish to central holding tanks without raising mortality, therefore, as a compromise, only the fish caught in a particular lake sector or sequence of pegs were collected for examination (Moore, 1973). With the help of the match stewards it

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It was generally known that few anglers fished the lakes during late autumn and winter so a series of autumn and winter matches were arranged (see Table 35). A points system was used to encourage anglers to attend the matches: the anglers with the highest, second and third highest total weight in each match were awarded 8, 6 and 4 points respectively, but even unplaced anglers received 2 points as an incentive to continued attendance. Cash prizes and trophies (first, second and third places) were awarded to anglers with the highest number of points accumulated over the series. In addition, prizes were given for the greatest number of fish caught and for the heaviest single tench, roach, rudd, bream, perch or carp above specified qualifying weights. The matches were publicised in local fishing tackle shops and announced at society meetings; as a result they were adequately supported.

With the consent of the Anglian Water Authority it was possible to continue with special matches through the statutory close season in 1975 and 1977.

In all the special matches (above) any fish caught were collected, examined, marked and data recorded in a similar manner to that already described for the routine census. In line with the routine census, most effort was directed to lake A.

After the initial attempt to measure a range of environmental variables at each peg, they were measured at 3 stations out of the 5 allocated to lake A (Fig. 4), depending on the sector used for the census. On match days stations I, III and IV were used.

Dissolved oxygen, water temperature and clarity were measured on each census day when angling was in progress; in addition air temperature (in the shade), wind direction (8 point scale), wind speed (Beaufort scale), rainfall (4 point scale: 0, drizzle, light rain, heavy rain) and incident light (EEL Lux-meter) were determined at a central point soon after the start of a census visit. The latter measurements were relatively crude, but wind speed, rainfall, solar radiation and air temperatures were measured with greater accuracy at Levington Research Station (Fisons Ltd.) about 16 Km from Barham, and these measurements were used in analyses.

Dissolved oxygen was determined by a modified Winkler method (Golterman and Clymo, 1969) on samples taken from a depth of 0.5 m with a 'Cassela' sampler. Water temperatures were taken at the same time and estimated to the nearest 0.1 °C. Water clarity was recorded (in cm) as the depth of visibility of a 200 mm diameter Secchi disc on each census day from late 1975 to 1977 after various electrical devices had failed to give consistent measurements. The value of all variables (above) were recorded on the census form.

Phosphate and nitrate concentrations (Table 1) were determined on 4 occasions in July 1976 and once in February, 1977 for both lakes, using standard lovibond colourimeter discs and procedures. Analysis of calcium and magnesium ions in lake A was by the Schwarzenbach method (BDH). The concentration of suspended solids were found by gravimetric analysis; pH was measured with a portable pH meter. Depth poles were placed in each lake.

(iii) Zooplankton

The zooplankton in lake A was sampled at approximately month intervals from May to September 1975, but at weekly intervals from June to October in 1976. Zooplankton samples were therefore obtained during the time of maximum angling effort. No attempt was made to sample lake B because of limited manpower.

In May 1975 samples were collected by vertical hauls of a zooplankton net (27 cm dia.; 80 μm mesh) at 4 stations in lake A; however, because of the reported non-quantitative nature of net samples (e.g. Schwoerbel, 1970) pump and water core samplers were employed from July to September 1975.

The hand pump (Whale gusher) used was attached to a flexible tube with a wide bore (35 mm), this latter feature served to reduce the risk of zooplankton escaping from the zone of the tube orifice (Tonolli, 1971). The pump was calibrated in the laboratory and delivered 0.56 l per stroke; samples were collected sequentially from 0.25, 0.50, 0.75, 1.00, 1.50 and 2.00 m (where possible), from 3 stations in lake A. The pump was operated from a small inflatable boat and the samples were directed into a large funnel fitted with a filter device carrying 150 μm nylon mesh, the whole device being suspended part submerged over the side of the boat. The zooplankton were then flushed into specimen tubes and formalin added to give a 4% solution.

Water cores were taken at the same time and place as pump samples in 1975, in a manner similar to that previously described by Pennak (1962) and Cook (1979). A rigid plastic tube (65 mm internal diameter x 2100 mm) was rapidly lowered vertically into the water to within a few centimeters of the bottom. The top of the tube was then sealed with a bung and lifted until the bottom end could be plugged with another bung while still underwater. The contents of the tube were then filtered and preserved as before. The tube was graduated (0.1 m intervals) and it was possible to calculate the volume sampled by the height of the water column in the tube. The length of the tube was considered adequate for sampling much of lake A, particularly in the summer of 1976, when the water level was relatively low.

The tube sampler removed integrated water samples compared with those taken by the pump and was easier to use. Estimates of numbers of daphnids, calanoid and cyclopoid copepods derived from pump and tube samples (Appendix 18) suggested that the tube sampler was more effective, supporting Cook's (1979) assumption that it would catch all groups of crustacean zooplankton with 100% efficiency. For the above reasons only the tube sampler was used in 1976.

A system of stratified random sampling was adopted in 1976 as follows: a map of lake A was divided into two sectors, sector 1 and sector 2 were subdivided respectively into 25 and 20 equal-sized numbered squares. Prior to each sampling visit, 6 sampling sites were selected for sector 1 and 5 for sector 2 by random numbers; the 11 core samples were then combined to provide a pooled preserved sample for counting (see later) representative of the zooplankton in the lake.

The above system of sampling was used to avoid the bias that may occur if the clustering of sample sites, possible with simple random sampling, coincides with a contagious distribution of zooplankton; the latter may be common under natural conditions (Colebrook, 1960; George and Edwards, 1976; Cook, 1979). Cook (1979) gives estimates of the sampling error associated with a similar system of sampling lake zooplankton.

2.3 Laboratory work and methods of analysis

Rudd, roach, bream, crucian carp and pike scales were brushed clean in hot water then mounted between two microscope slides for examination. Perch and tench scales were not routinely examined because of reported difficulties in their interpretation (Le Cren, 1947; Gee, 1976) and age determinations for these species were made from opercular bones which had been cleaned in water and allowed to dry.

The scale preparations were examined at x 35 magnification on a microfische projector and only checks that were visible all around the scale were accepted as annual checks. Total scale radii and radii to annual checks, required for the back-calculation of lengths-at-age, were measured (in mm) in the posterior field of the scale (Hofstede, 1974) on the projected scale image.

Opercular bones were examined with a binocular stereo-microscope, using combinations of incident and transmitted light, with and without polarisation. The distance from the apex of the main face of the opercular bone to the free edge (opercular height) and to each annual check was measured (in mm) with the aid of an eyepiece micrometer. All scale and opercular measurements were recorded onto computer coding sheets together with fork lengths and assessed age.

Functional regressions (Ricker, 1973, 1975) were computed for fork length/posterior scale radius using Log_{10} transformed data (Hile, 1970). Restricted ($X = Y = 0$) functional regressions were computed for fork length/opercular height (Ricker, 1973) on similarly transformed data.

Back-calculations of length-at-age were computed by substituting measurements of scale radii or opercular distances to annual checks, into appropriate fork length/scale or opercular regressions. Programmes for these and other computations were written in Fortran and run on an ICL 1900 series computer. Other data were analysed with the aid of a Texas T1-59 programmable calculator.

Length/frequency histograms were inspected to check whether age determinations and back-calculated lengths were reasonable. Generally, the interpretation of roach, rudd, bream and pike scales and perch operculae was not difficult and to demonstrate the annual pattern of scale growth, the amount of scale growth beyond the last check on rudd scales was plotted against time (Fig. 6); rudd were chosen because data were relatively few for the other species.

It was quite difficult to determine the age of tench from their opercular bones and a Walford plot (Walford, 1946; Hellawell, 1974) was made (Fig. 18) in an effort to assess the validity of ageing and back-calculated lengths-at-age. The length of tench at a given age (L_t) was plotted against length one year later (L_{t+1}) and a regression line fitted to the points; the intercept with the L_{t+1} axis estimates length at the end of year 1, which should roughly correspond with back-calculated lengths for that age if the fish have been aged correctly. The Walford plot technique utilises the Von Bertalanffy growth model (Von Bertalanffy, 1938):

$$L_t = L\ (1 - e^{-K(t-t_0)})$$

where L = ultimate theoretical length, estimated on the plot as the value given to the point where the fitted line meets the line of equality; K = constant determining the rate of change of length increments.

Year-class growth was calculated as the mean of each back-calculated lenth-at-age for all individuals of that year class. Composite growth was calculated as the mean of all back-calculated lengths-at-age for each species, irrespective of year-classes. Means and associated statistics were calculated assuming Normal distributions of lengths-at-age (see Appendix 1).

Comparisons of mean back-calculated lengths-at-age for year 1 roach, rudd and bream of various year classes were made by a number of t-tests in a manner similar to that described by Gee (1976). The type of t-test employed was designed to accommodate samples of unequal size and variance (Snedecor and Cochran, 1967; section 4.14) and was used on most other occasions for the straightforward comparison of means. The mean lengths of various year-classes of rudd at year 2 were also compared but for older fish and other species the data were too few to justify statistical analysis; however, composite mean lengths-at-age for roach in lakes A and B were compared by t-tests.

Functional length/weight regressions (Ricker, 1973) were computed, using Log_{10} transformed data (Chapter 1 equation 1), monthly for various groups of fish e.g. male tench with mouth damage, male tench without mouth damage etc. Regressions were also computed to cover longer periods of time for comparison or where data were sparse. The majority of paired length/weight observations were from fish caught during the census but others were from fish caught by seine during population estimates.

The significance of deviations of the slopes of length/weight regressions from 3 were tested (i.e. null hypothesis: slope = 3) at

$p = 0.05$, by comparing observed values of 't' ($n < 30$, $n - 2$ d.f.; $n > 30$ obs. 't' taken as 1.96) with calculated values of 't' (Snedecor and Cochran, 1967; section 6.10), the 95% confidence intervals for the slopes were found at the same time. Where the value of the slope was relatively stable, the condition of individual fish was calculated from:

$$K = \frac{W_o 10^5}{l^3}$$

where W_o = observed wet weight in grams
l = fork length in mm

after Van Den Avyle and Carlander (1977). Values for relative condition (K_n) of individual fish (Chapter 1, equation 3) were also calculated for inspection. Mean values of K were compared for various groups of fish (e.g. rudd with and without mouth damage) using t-tests as previously described.

It was a natural extension of the analysis to compare the length/weight regressions of rudd and tench with and without mouth damage. For this purpose analyses of covariance were made according to the method described by Snedecor and Cochran (1967) (section 14.6) whenever the data appeared adequate (i.e. $n > 10$).

Population estimates were obtained from mark-recapture data (Appendix 2a) by the application of the following methods:

(i)	Lincoln index (Petersen method) single census; Bailey (1951) modification	(5)
(ii)	Schnabel (1938) multiple census	(7)
(iii)	Bailey's (1951) triple-catch	(8)
(iv)	Bell's (1974) method	(6)

The numbers in parentheses refer to the formulae given in Chapter 1. In an attempt to assess the catchability of marked fish values of μ (Gee, 1976; see Chapter 1.2 equation 10) were calculated where suitable data were available.

Confidence limits for estimates from (i) and (ii) (above) were found by treating the number of marked recaptures as a Poisson variable, utilising tables provided by Ricker (1975); the upper and lower limits were then substituted in equation 5 or 7. Bailey's triple catch estimates were rarely determined and confidence limits were not calculated.

Population estimates were obtained for specific year-classes where possible otherwise for groups of year-classes; year-classes were identified by reference to age/length data and length/frequency histograms.

In the absence of marked recaptures, estimates were made by solving Bell's (1974) expression, by iteration, for p = 0.50, alternatively estimates were made by proportion relative to a year class or size group for which mark-recapture estimates were available. Usually estimates depended on capture and recapture by seine, however, some estimates relied on capture by seine and recapture by angling or vice versa, while others were dependant on angling for capture and recapture.

'Best' estimates were arrived at after inspection of the range of estimates available, taking account of factors likely to have affected a particular estimate. If an estimate was less than the number of fish known to be present, the latter was taken as the 'best' estimate.

Instantaneous mortality rates (Z) were estimated from the difference between two population estimates (Ricker, 1971) as follows:

$$Z = \frac{\ln N_t - \ln N_{t+1}}{\Delta t}$$

where N_t = number of fish at the start of the time interval

N_{t+1} = number of fish at the end of the interval

t = time interval (years); as an approximation $\Delta t = 1$

Z was also found as the slope of regressions fitted to plots of ln % number against age, using the mean % number of fish in age groups given in Tables 12, 16 and 28 (Mann, 1973, 1976; Ricker, 1975). Survival rates (S) were found using:

$$S = \frac{N_{t+1}}{N_t}$$

where N_t = the % number at t years and N_{t+1} = the % number 1 year later, both calculated from the ln % number/age regressions. During the production of Tables 12, 16, 20 and 28 numbers of fish in age groups were allocated after inspection of age/length data (Appendix 1) and length/frequency histograms. The relative strength of year classes were derived from tabulated % age data (Tables 12, 16, 20 and 28) as described by Mann (1973), essentially:

$$\text{Relative year class strength} = \frac{\text{sum of \% occurrence of a year class through all years of capture}}{\text{sum of mean \% occurrence of age groups carrying the year class}} \times 100$$

The biomass of single or grouped year classes of a species was estimated by substituting the length corresponding to the mid-point of a 5 mm interval on the length/frequency histogram (seine capture) into an appropriate length/weight regression then multiplying the determined weight by the number of fish of the interval present in the population (calculated by proportion relative to a population estimate); this gave the biomass of the interval. The process was repeated for each interval and finally the biomass for the year class or group was found by summation.

Population densities for the fish in lake A were calculated in terms of numbers and biomass per unit area (i.e. No. m^{-2} and g m^{-2}), assuming lake areas of 17367 m^2 for August 1974 to April 1976 (inclusive) and 16829 m^2 for October, 1976 to September, 1977 (inclusive). The same areas were assumed for the calculation of production (below).

Although it was not a primary aim of the study, the data supported the estimation of production; of course the populations of fish were not subjected to regular (i.e. monthly) estimates of abundance necessary (Chapman, 1971) for a precise assessment. Nevertheless, the estimates of production given in this thesis are probably as reliable as those given elsewhere (Gee, 1976) for gravel-pit lakes.

Production was estimated using:

$\hat{P} = G\bar{B}$ (Chapman, 1971)

where G = instantaneous growth rate and $\bar{B}$ = mean biomass. $\hat{P}$ was calculated for $\sim$ 1 year intervals i.e. g m^{-2} yr^{-1}. G was obtained from the formula:

$$G = b\,(\ln l_2 - \ln l_1) \quad \text{(Tesch, 1971)}$$

where b = slope of an appropriate length/weight regression and l_1 and l_2 are interval estimates of mean length. In the absence of other information, a linear change in biomass was assumed and mean biomass was estimated by:

$$\bar{B} = \frac{B_1 + B_2}{2} \quad \text{(Chapman, 1971)}$$

where B_1 and B_2 are interval estimates of biomass.

To determine that anglers' baits really were a component of the diet of lake A fish a few (<40) formalin preserved fish of each species, caught by angling and seine net, were dissected for gut analyses; at the same time their body cavities were searched for parasites, especially *Ligula sp* which has been shown (Sweeting, 1976) to have a high incidence in young cyprinids from gravel-pit lakes. In order to make full use of the limited material, the whole gut was removed from all specimens (Cook, 1979) and the contents examined with a binocular stereomicroscope; food items were identified and counted where possible and the percentage of the total number of a species containing a particular food was recorded.

In order to explain the onset of vulnerability to angling, it became necessary to examine the relationship between mouth gape and length for the species at Barham. The mouth gape of formalin-preserved fish was found by a method similar to that used by Shirota (1970) and Cook (1979). With the aid of a binocular stereomicroscope, the length of the upper and lower jaws were found, while they were held apart approximately 90°; the mouth gape was then calculated using Pythagoras' theorem. This method was used because the upper and lower jaws were not necessarily the same length. Functional regressions (restricted, $X = Y = 0$) were then computed for mouth gape/fork length.

Information collected during the routine census, special and ordinary matches (e.g. details of fish caught, angling effort, pegs used etc.) were used to create computer files which were then sorted and simply analysed by means of a number of specifically written programmes.

Catch rates were calculated by dividing the number of fish caught (as species, size groups or overall; see below) by the unit of angling effort required to catch them (as rod hours). Catch rates were also calculated for periods longer than a census day, e.g. weekly catch rates. Unless otherwise stated, overall catch or catch rate means the catch or catch rate for all species of all sizes. Total angling effort on lake A was estimated for each month of the summer by the following formula:

$$\hat{E} = ab\left(\sum_{i=1}^{n} Ti\right) + \left(\sum_{j=1}^{n} Tmj\right) + \left(abc\left(\sum_{i=1}^{n} Ti\right)\right)$$

where $\hat{E}$ = estimated total angling effort (rod hours)

a = 1 + 0.33 (compensates for hours not covered by census)

$b = 1 + \dfrac{\text{number of pegs in unsampled sector of lake}}{\text{total pegs on lake}}$

$c = \dfrac{\text{number of unsampled days}}{\text{number of sampled days *}}$

* including match days

and $\sum_{i=1}^{n} Ti = T_1 + T_2 \ldots T_n$ T_1 = angling effort on day 1 of census.

$\sum_{j=1}^{n} Tmj = Tm_1 + Tm_2 \ldots Tm_n$ Tm_1 = angling effort during first match.

Approximate 95% confidence limits were calculated to accompany each monthly estimate of total effort, based on the observed data and assuming a Normal distribution (if $n > 5$) or Poisson distribition (if $n < 5$). Values for $\hat{E}$ are probably conservative approximations but some attempt to calculate them was considered necessary to allow estimation of total catch, and for comparison with angling effort on other waters.

Fish examined during the census and matches were recorded on 'angling' (A) length/frequency histograms, however, the numbers stated on the histograms were occasionally less than the numbers caught (and used in catch rate determinations) because some anglers returned fish to the water before they could be measured and marked.

Further analysis of angling data was by standard statistical methods e.g. correlation and Chi^2 (see Snedecor and Cochran, 1967). Functional regressions (see previously) were used to describe catch/effort and catch rate/population density relationships.

Multiple regressions were calculated to predict the effect of environmental variables on angling success (as catch rates). The analyses were performed on computer using a programme developed by the Statistics Department, Levington Research Station (Fisons Ltd.) Ipswich. Variates were selected for retention in the regressions by a 'step-down' method (see next chapter and Snedecor and Cochran, 1967, section 13.13).

The preserved, pooled zooplankton samples were adjusted to 50 cm^3 and detergent added; the samples were stirred before and during the removal of 2.5 cm^3 sub-samples with a wide bore (4.5 mm) calibrated glass tube and pipette pump. Sub-samples were placed into a circular perspex counting trough and observed with a binocular stereomicroscope at X 32 magnification.

Zooplankton were counted and measured as seven groups: calanoid copepods, cyclopoid copepods, daphnids (including Daphnia and related genera), chydorids (except Eurycercus Lamellatus which was recorded separately), Bosmina sp. and Asplanchna sp. The keys of Scourfield and Harding (1966) and Harding and Smith (1974) were used for identification of zooplankton.

Counts of three groups of organisms in replicate sub-samples (Table 6b below) suggested that the method of sub-sampling was unbiased; i.e. random.

Table 6b Counts on replicate sub-samples taken from a single water core zooplankton sample and a Chi^2 test for agreement with a Poisson series.

Replicate		Counts per 2.5 cm^3		
		Calanoids	Cyclopoids	Daphnids
1		36	9	3
2		44	16	0
3		29	8	1
4		40	13	2
	$\bar{x}$	27.25	11.5	1.5
	s^2	40.8	13.6	1.6
	Chi^2 *	3.3	3.6	3.2

$Chi^2 = 3.2 - 3.6$ $p > 0.25$ d.f. = 3, agreement with Poisson series at 95% level (see Elliott, 1971; Fig. 8)

* Variance to mean ratio = $\frac{S^2(n-1)}{\bar{x}}$ (when $n < 31$)

Zooplankters were measured with the aid of an eyepiece micrometer: cladocerans from the top of the head (excluding crest) to the posterior edge of the carapace; copepods from the anterior margin to the base of the furcal ramus. Measurements were to the nearest 0.025 mm. Each measurement record represented a single organism so the total measurements for an aliquot of the sample served as a count. Where possible, up to 100 organisms from each group were measured to reduce sub-sampling error to approximately ±20% (Lund, Kipling and Le Cren, 1958).

The above data were analysed using a programme supplied by Cook, which estimated the numerical abundance of each group (as no. m^{-3}) and gave a reasonable representation of each group's size distribution.

CHAPTER 3

RESULTS

3.1 The fish populations

Lakes A and B at Barham were clearly dominated by cyprinids (Tables 5, 7 and 8) but because of its connections with the River Gipping, lake B contained species normally associated with flowing waters e.g. chub.

Samples of fish were regularly taken from lake A (Table 8) by seine netting for the purpose of population estimation but only on two occasions from lake B. Fish were caught from both lakes by angling but the majority of those examined were taken from lake A, reflecting the emphasis of the census effort.

In this section (3.1) the general biology of each species of fish is treated separately, followed by a sub-section on biomass and production (3.2). In section 3.3 the success of angling and its impact on the fish is considered. Raw mark-recapture, age, growth, catch rates and other data are to be found in Appendices 1 to 18.

(i) Rudd

Rudd were numerically the most important species in the angling catches made on lake A: 1310 were examined during the census and 2077 during seining operations (Tables 7 and 8).

Key scales were collected from 207 lake A rudd; they were easy to interpret with clear annual check marks, but care was needed to distinguish the first check on scales from fish > 5 years old. A few (10) rudd displayed scale growth patterns that were obviously different to the majority examined and they were assumed to be stock fish; their scale data and those from two rudd which appeared to have 'false' annual checks (see Introduction) were excluded from further analyses. Pooled scale measurement data for the 1971 to 1976 year classes of rudd showed

Table 7 Numbers of fish examined during the angling census (routine census + matches) Lake A, 1974 to 1977

	1974			1975					1976					1977		Total
	A	S	O	J-My	J	J	A	S	J	J	A	S	O-D	J-Mr	A-J	
Rudd	274	16	2	1	212	118	70	60	181	279	61	18	3	0	15	1310
Roach	83	7	6	0	1	2	9	2	81	24	11	0	3	1	5	235
Bream	11	3	1	0	19	43	5	6	37	36	69	4	13	8	22	277
Tench	29	9	0	21	63	140	47	5	154	133	34	4	5	0	84	728
Perch	6	6	6	0	1	49	2	11	18	12	5	1	2	1	8	122
Crucian carp	11	2	0	1	8	21	5	0	13	8	1	0	0	0	1	71
Common carp	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	18
Total	423	52	9	23	304	373	138	84	484	492	181	27	26	10	135	2761

Note: J-My = Jan. to May (inc.); O-D = Oct. to Dec. (inc.); J-Mr = Jan. to Mar. (inc.); A-J = Apr. to Jun. (inc)
1 pike was caught, 1.5.77 < 250 mm.

Table 8 Numbers of fish caught by seine netting. Lake A, 1974 to 1977

Date	Rudd	Roach	Tench ♂	Tench ♀	Tench un	Bream	Perch	Crucian carp	Common carp	Pike	Total	Seining effort (days)
1974 Aug.	55	621 (21)	32 (1)	20	14	289 (7)	14	69 (8)	0	13 (1)	1127	2
1975 Feb.	174 (2)	178 (4)	3	4	2	74 (4)	8	14	0	6	463	3
Jun. to Jul.	37	39 (1)	73 (14)	71 (14)	56	47 (1)	7	7	0	6	343	2
1976 Apr.	373 (21)	296 (6)	38 (3)	18 (2)	2	105	149 (7)	3	0	13 (3)	997	3
Oct.	1393 (253)	1027	4	5	0	1019 (10)	375 (15)	0	0	7	3830	3
1977 Sep.	354 (19)	639 (3)	30	25	2	1073 (2)	58 (1)	0	1	15 (2)	2197	2
Total	2386	2800	180	143	76	2607	611	93	1	60	8957	

Note: un. = sex not determined.
Numbers of marked recaptures in parentheses.

(Fig. 6) that annual scale checks formed between April and May.

The following length/scale relationship was derived from lake A rudd data and used in the back-calculation of length-at-age:

$$\text{Log}_{10}\ \text{FL} = 0.3412 + 0.8591\ \text{Log}_{10}\ \text{Sr} \qquad r = 0.9781,\ n = 195$$

where FL = Fork length (mm) and Sr = Scale radius (mm) on X 35 image.

Back-calculated lengths-at-age were found for individual year classes and combined for each age group to provide composite growth data (Fig. 7 and Appendix 1).

Growth was slow, with fish being only 100 mm after 4 years. However, measurements of 0+ rudd (Appendix 1) at the end of the main growing season confirmed that back-calculated lengths at year 1 were approximately correct. Scales from 16 lake B rudd caught between September 1974 and February 1975 included 12 1+ fish (1973 year class) that ranged from 60 to 84 mm (Fig. 10).

Most of the rudd examined from lake A were < 5 years and it has been assumed that those from the 1974 to 1977 year classes were indigenous with the majority of rudd from earlier year classes probably being stock fish. The oldest rudd examined from the lake was 10 years old.

Comparison of the mean lengths of one year old rudd from the 1971 to 1976 year class (Table 9a,d) revealed the 1975 year class to be the fastest growing; the largest increment from year 1 to year 2 was also produced in 1975 (by the 1974 year class). The apparently poor growth of rudd from the 1972 and older year classes during their second and subsequent years may have been due to Lee's phenomenon (Tesch, 1971; see Introduction), with size-selective mortality probably accounting for the low estimates of length-at-age, alternatively the fish comprising the older year classes may have been (see above) stunted stock fish.

Length/weight regressions were calculated for lake A rudd, pooled

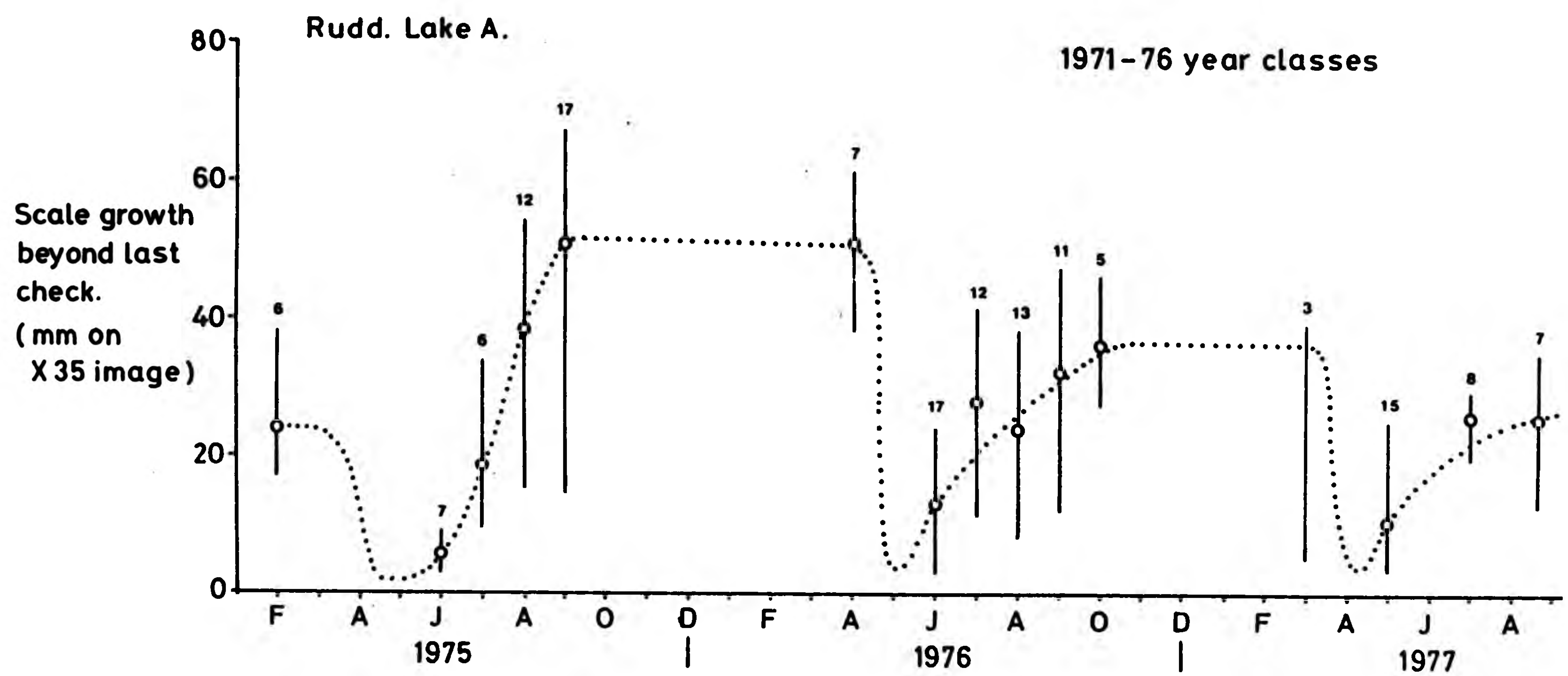


Fig. 6 Mean scale growth beyond the outermost check for lake A rudd from the 1971 to 1976 year classes. Range shown by vertical bar; trend line fitted by eye.

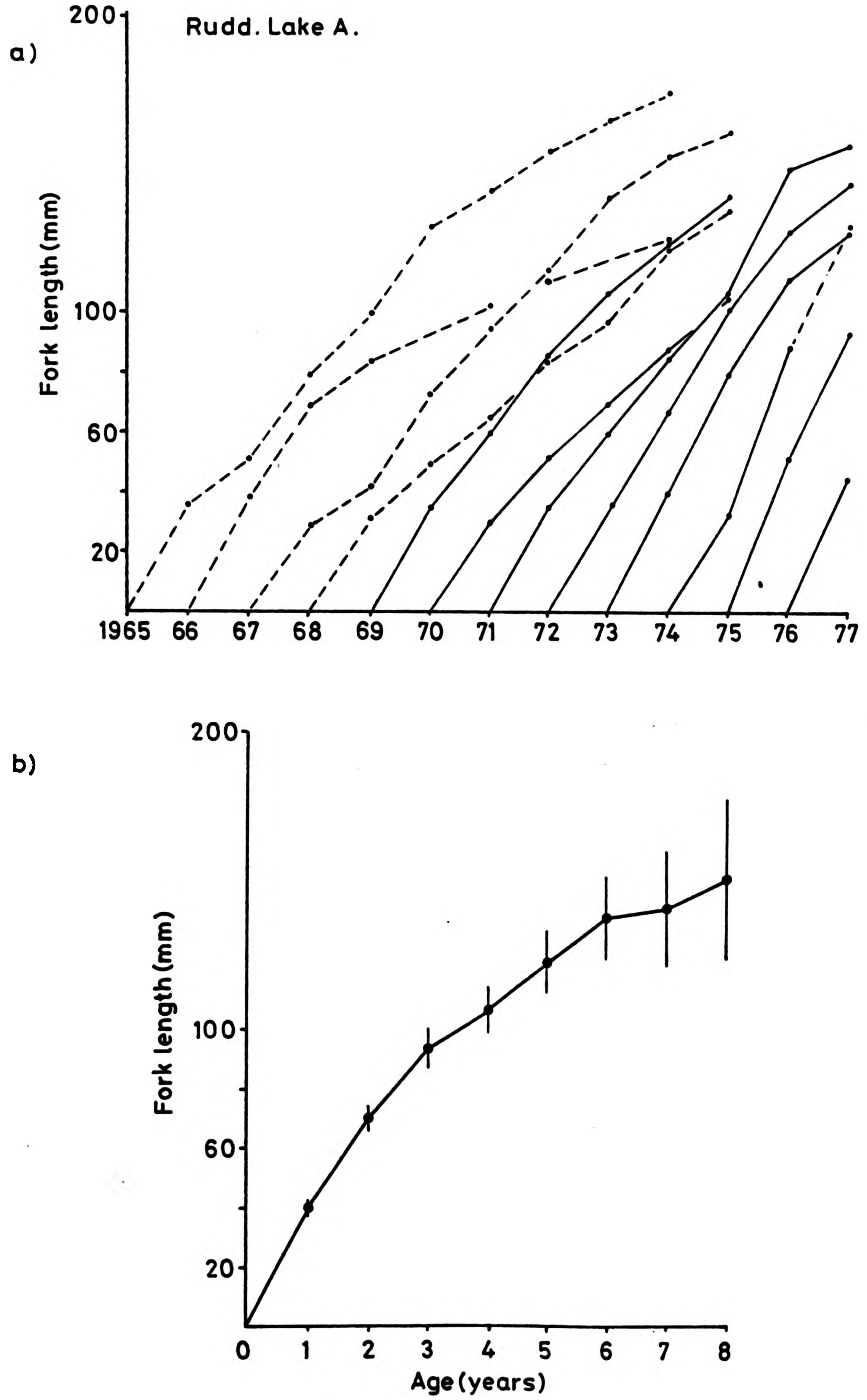
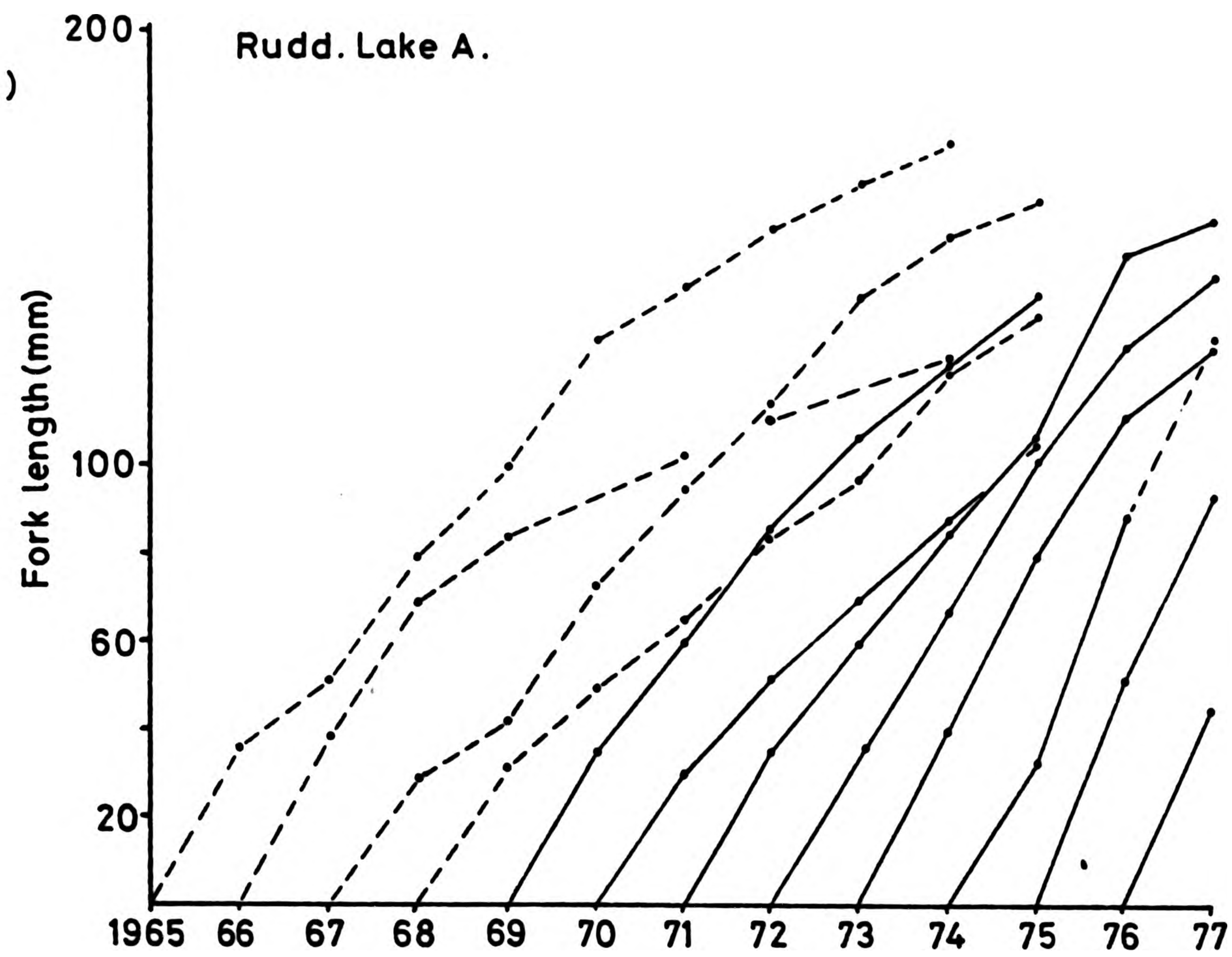


Fig. 7 (a) Mean back-calculated lengths-at-age for lake A rudd, 1969 to 1975 year classes.

(b) Composite mean back-calculated lengths-at-age for lake A rudd, with 95% confidence limits (vertical bar).

a)



b)

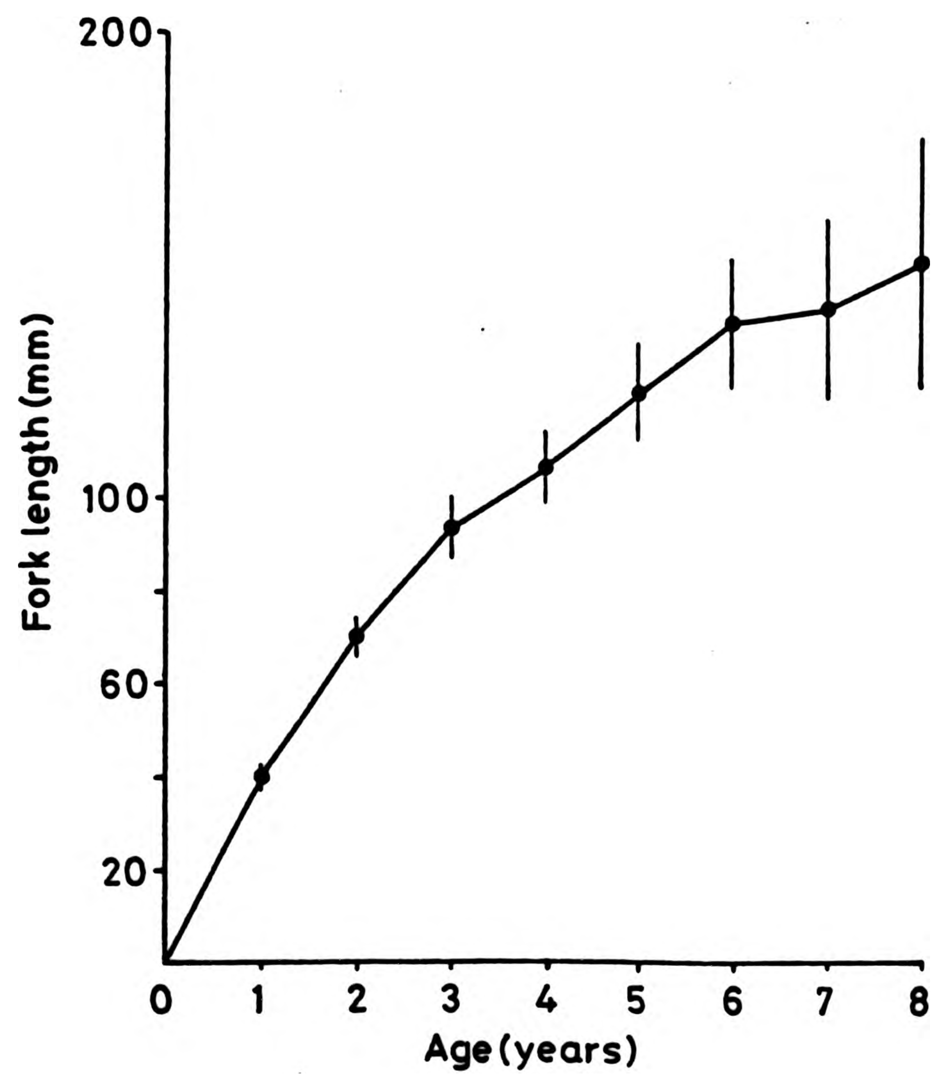


Fig. 7 (a) Mean back-calculated lengths-at-age for lake A rudd, 1969 to 1975 year classes.
(b) Composite mean back-calculated lengths-at-age for lake A rudd, with 95% confidence limits (vertical bar).

(i.e. immature + mature males and females) each month from June to September inclusive for 1975 and 1976 and from April to June for 1977 (Appendix 8). The length of the rudd weighed ranged from 65 to 222 mm and were from several year classes, however, length/weight regressions were not found for the separate year classes because data were limited.

The slope of the monthly length/weight regression for June 1975 was not significantly (i.e. $p \leqslant 0.05$) different from 3 but in July, August and September 1975, the value of the slope was significantly > 3. During June, July and August 1976 the slopes did not deviate significantly from 3 but in September 1976 the slope was significantly > 3. A preponderance of relatively large and plump rudd in the small samples taken may have caused the observed departures from isometric growth. Monthly regressions for the period April to June 1977 were not computed because sample sizes were low.

Pooled length/weight regressions were also computed for the period June to September inclusive (summer season) in 1975 and 1976 and for April to June inclusive (close season), 1977 (see Table 10). The slopes for the pooled summer and close season regressions were all >3.

Table 10 Pooled length/weight regression parameters. Rudd, lake A.

Year	Log_{10} intercept	Slope	95% confidence limits for slope	r	n
1975[1]	-5.2392	3.2225*	3.1425 - 3.3025	0.892	136
1976[1]	-5.6912	3.4810*	3.2126 - 3.7484	0.9308	89
1977[2]	-5.7635	3.4423*	3.2746 - 3.6100	0.9938	22

* significantly >3 ($p \leqslant 0.05$)
1. Summer season; 2. close season (see text)

The slope of the pooled length/weight regression for 1975 was within the 95% confidence limits of the slopes of all the monthly regressions (June to September) in 1975. In 1976, the slope of the pooled length/weight

Table 9 Observed and calculated values of 't' for comparisons of mean fork length of year one rudd, roach and bream followed by year two rudd; 1971 to 1976 year classes. Lake A.

Year one

a) Rudd

	1971	1972	1973	1974	1975	1976
1971		0.31 2.14	1.75 2.13	0.73 2.15	6.01* 2.14↑	3.55* 2.16↑
1972			0.44 2.07	1.41 2.08	7.14* 2.07↑	4.04* 2.12↑
1973				4.43* 2.03↓	6.91* 2.02↑	2.91* 2.09↑
1974					12.50* 2.03↑	7.99* 2.13↑
1975						4.21* 2.10↓

b) Roach

	1971	1972	1973	1974	1975	1976
1971		0.39 2.65	1.14 2.72	- -	4.38* 2.79↑	0.72 2.75
1972			2.58* 2.24↑	- -	8.25* 2.37↑	0.48 2.30
1973				- -	9.07* 2.47↑	4.71* 2.29↓
1974					- -	- -
1975						15.07* 2.70↓

c) Bream

	1971	1972	1973	1974	1975	1976
1971		1.34 2.34	1.35 2.28	3.56* 2.30↓	2.12 2.24	5.28* 2.46↓
1972			0.01 2.27	3.39* 2.28↓	0.47 2.24	4.50* 2.32↓
1973				3.39* 2.23↓	0.47 2.20	4.52* 2.24↓
1974					4.25* 2.19↑	0.38 2.25
1975						5.95* 2.18↓

d) Year two rudd

	1971	1972	1973	1974	1975
1971		1.38 2.13	4.81* 2.13↑	4.21* 2.37↑	7.24* 3.04↑
1972			3.15* 2.08↑	3.20* 2.35↑	5.78* 3.01↑
1973				1.45 2.40	3.84* 3.57↑
1974					0.76 2.83

The upper value in each cell of the table is the observed value of 't', the lower value is calculated 't' for p = 0.05.

* = mean lengths significantly different at 5% level, ↓ indicates that the mean length (in the year across) is the greater, ↑ that it is the smaller.

See Appendix 1 for the mean lengths of fish from the various year classes.

Table 9 Observed and calculated values of 't' for comparisons of mean fork length of year one rudd, roach and bream followed by year two rudd; 1971 to 1976 year classes. Lake A.

Year one

a) Rudd

	1971	1972	1973	1974	1975	1976
1971		0.31	1.75	0.73	6.01*	3.55*
		2.14	2.13	2.15	2.14↑	2.16↑
1972			0.44	1.41	7.14*	4.04*
			2.07	2.08	2.07↑	2.12↑
1973				4.43*	6.91*	2.91*
				2.03↓	2.02↑	2.09↑
1974					12.50*	7.99*
					2.03↑	2.13↑
1975						4.21*
						2.10↓

b) Roach

	1971	1972	1973	1974	1975	1976
1971		0.39	1.14	-	4.38*	0.72
		2.65	2.72	-	2.79↑	2.75
1972			2.58*	-	8.25*	0.48
			2.24↑	-	2.37↑	2.30
1973				-	9.07*	4.71*
				-	2.47↑	2.29↓
1974					-	-
					-	-
1975						15.07*
						2.70↓

c) Bream

	1971	1972	1973	1974	1975	1976
1971		1.34	1.35	3.56*	2.12	5.28*
		2.34	2.28	2.30↓	2.24	2.46↓
1972			0.01	3.39*	0.47	4.50*
			2.27	2.28↓	2.24	2.32↓
1973				3.39*	0.47	4.52*
				2.23↓	2.20	2.24↓
1974					4.25*	0.38
					2.19↑	2.25
1975						5.95*
						2.18↓

d) Year two rudd

	1971	1972	1973	1974	1975
1971		1.38	4.81*	4.21*	7.24*
		2.13	2.13↑	2.37↑	3.04↑
1972			3.15*	3.20*	5.78*
			2.08↑	2.35↑	3.01↑
1973				1.45	3.84*
				2.40	3.57↑
1974					0.76
					2.83

The upper value in each cell of the table is the observed value of 't', the lower value is calculated 't' for $p = 0.05$.

* = mean lengths significantly different at 5% level, ↓ indicates that the mean length (in the year across) is the greater, ↑ that it is the smaller.

See Appendix 1 for the mean lengths of fish from the various year classes.

regression was within the 95% confidence limits of the slopes of the length/weight regressions for July and August but exceeded the upper 95% confidence limits of the slopes of the length/weight regressions for June and September.

The relative stability of the slope value for the rudd length/weight regressions suggested that an examination of condition (as K; see 2.3, equation) would be meaningful. The mean condition (K) of rudd (Fig. 8) without mouth damage declined from June to September 1975; mean K in September 1975 was significantly less than mean K for June of the same year (t-test; $p < 0.05$). In 1976 there was not an obvious decline in mean K and mean K for June and September 1976 were not significantly different.

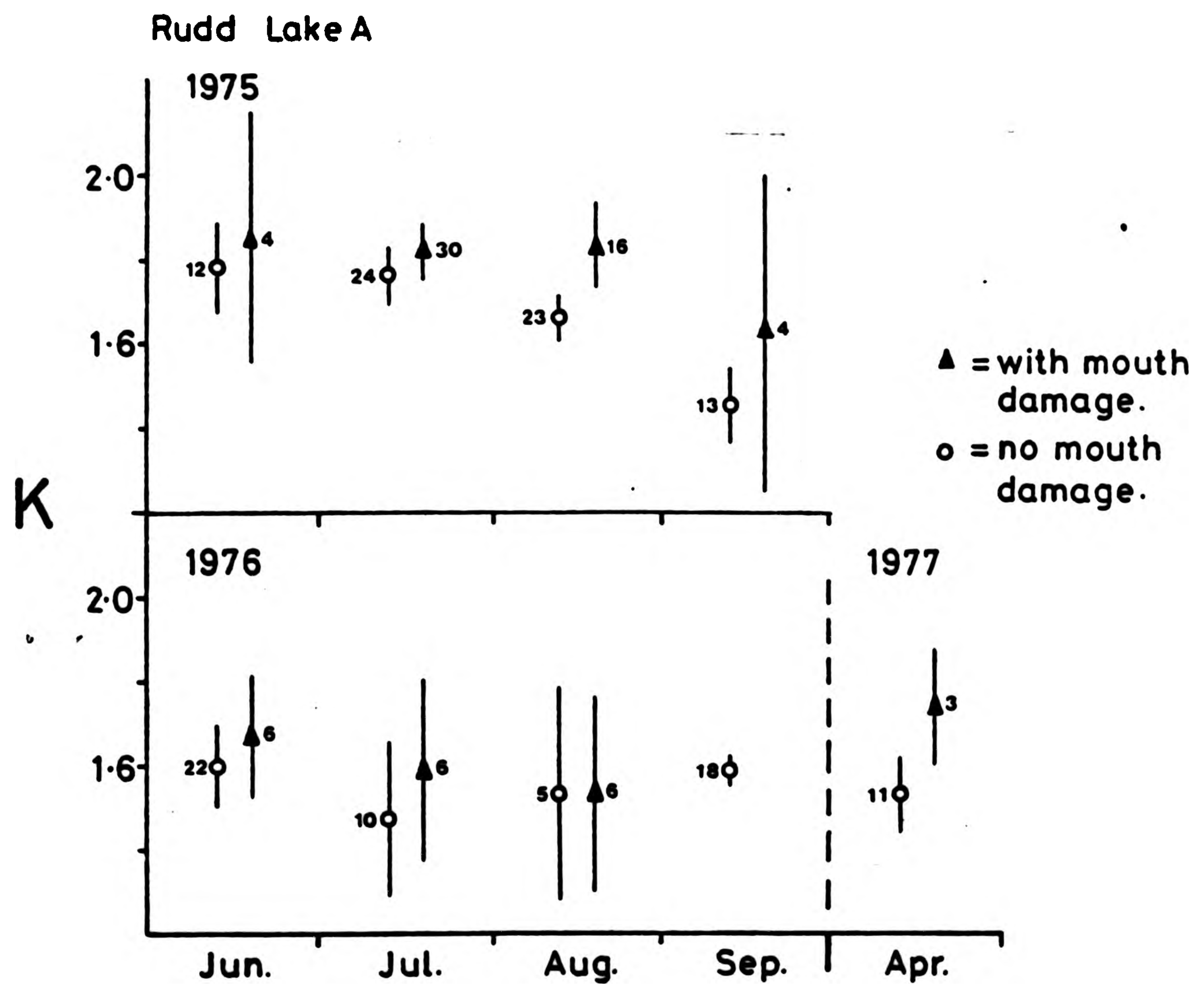


Fig. 8 Mean condition (K) of lake A rudd with (▲) and without (o) mouth damage (1975 to 1977). Sample sizes are stated with 95% confidence limits (vertical bar).

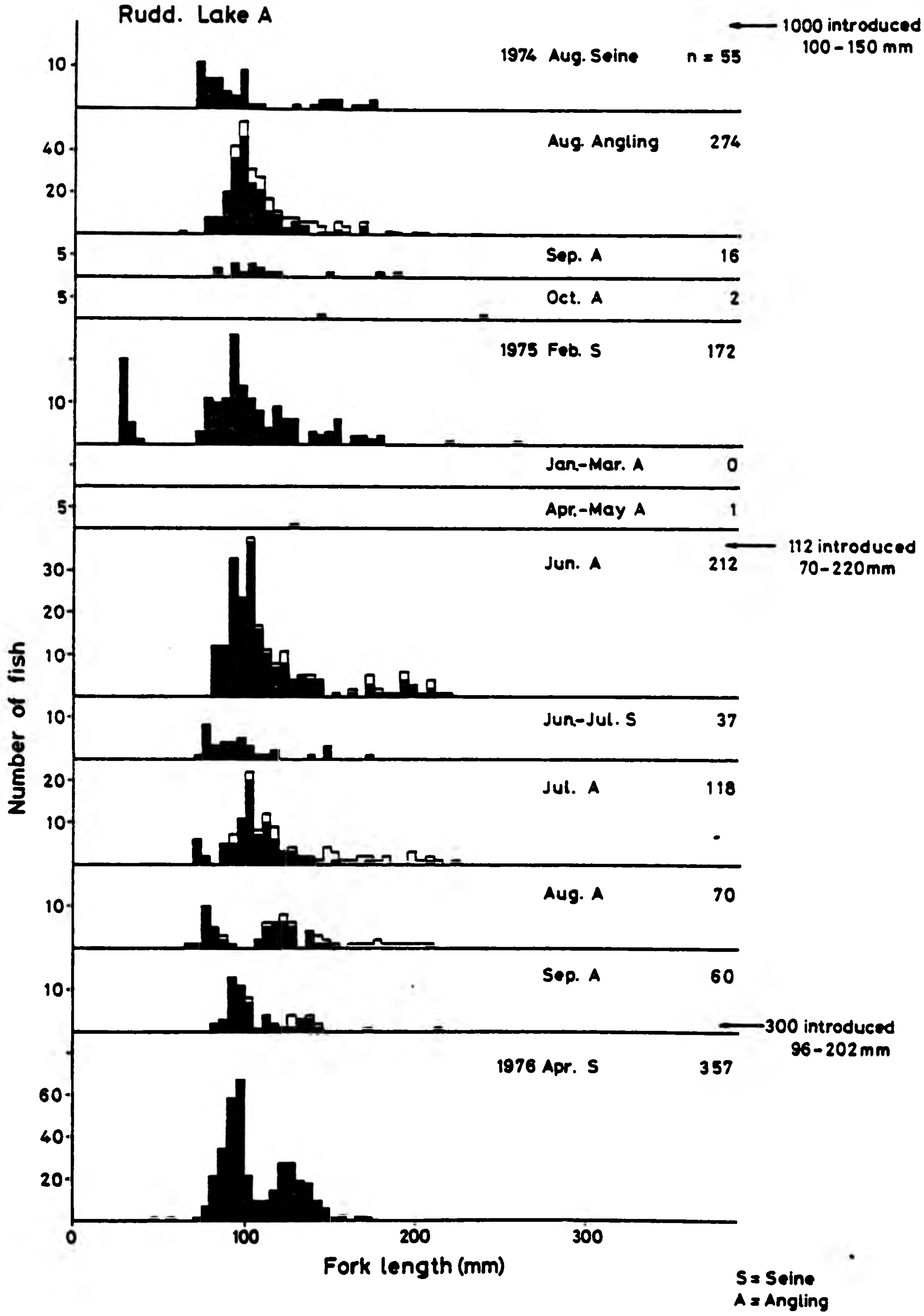


Fig. 9 Length/frequency histograms for lake A rudd caught by seine (S) and angling (A), 1974 to 1977. Unshaded blocks represent fish with mouth damage (see also over page).

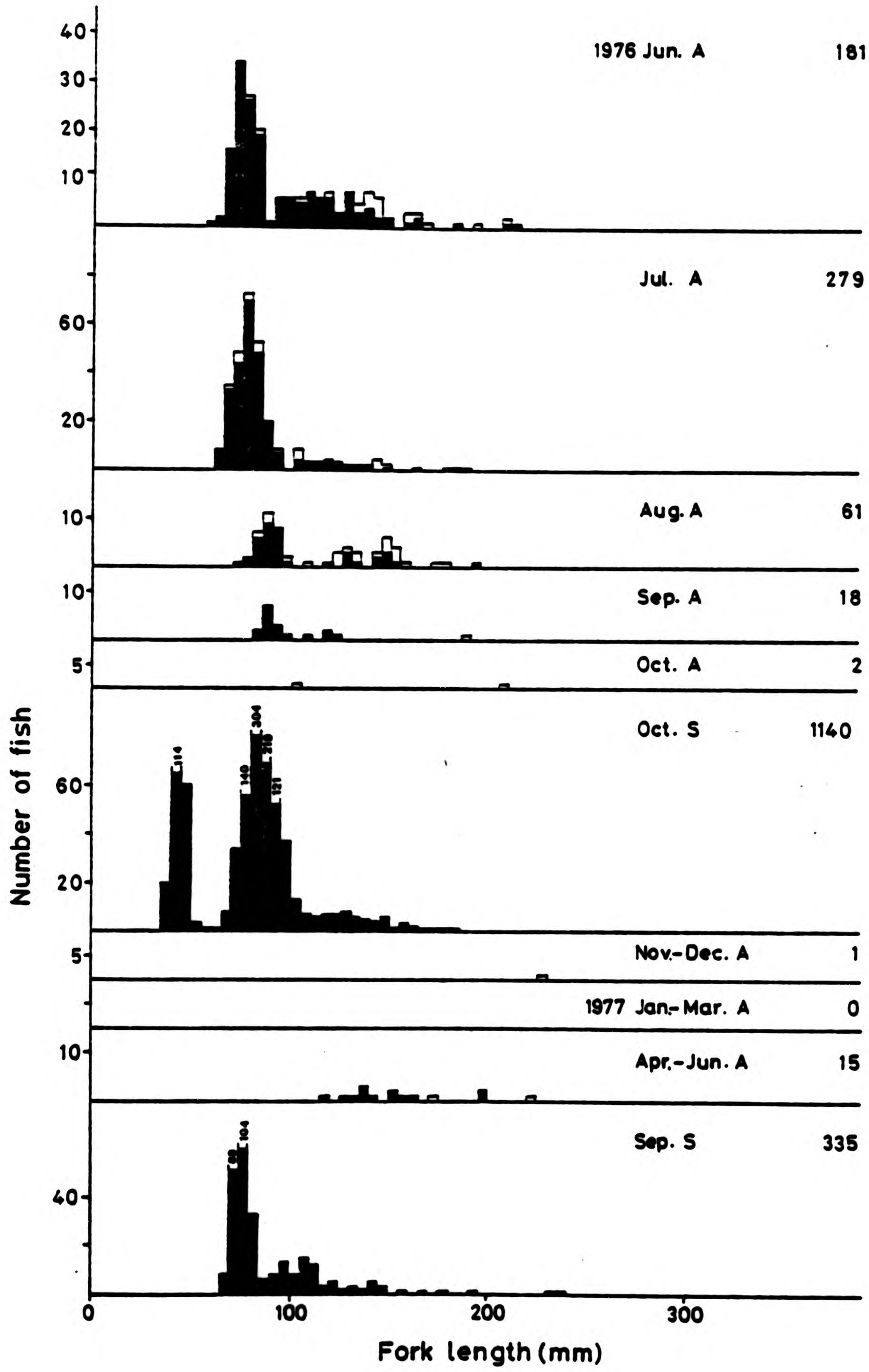


Fig. 9 Continued.

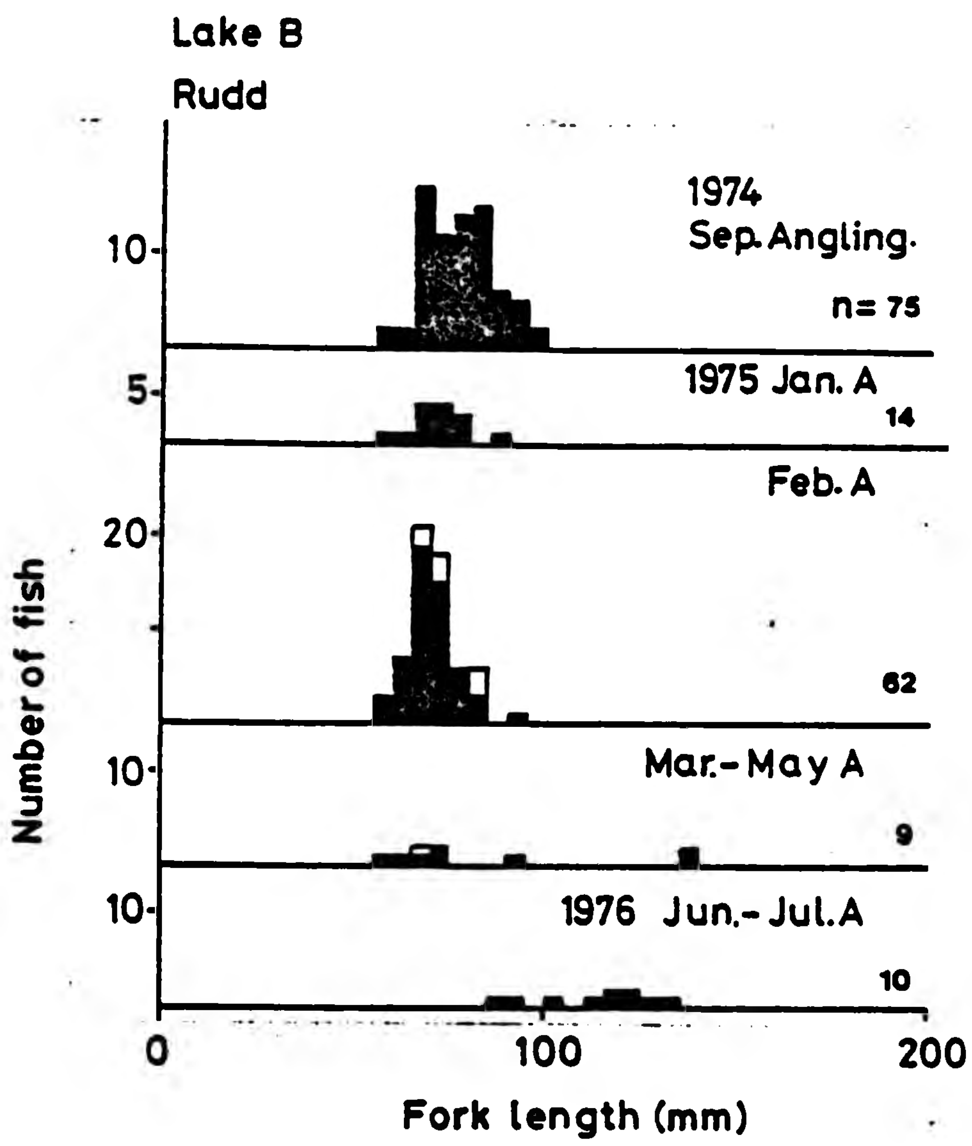


Fig. 10 Length/frequency histograms for lake B rudd caught by angling, 1974 to 1976. Unshaded blocks represent fish with mouth damage.

During June, July and August 1975, mean K of rudd without mouth damage was higher than in the same months of 1976 although the difference in means was only statistically significant (t-test; $p \leq 0.05$) for July. In September 1975 however mean K was significantly lower than in the same month of 1976.

The mean condition of rudd with damaged mouths is considered separately, see 3.2(iv) where the length/weight regressions for rudd and tench with and without mouth damage are compared.

Rudd length/frequency histograms (Figs. 9 and 10) and Table 12 show that the population structures for both lakes were biased towards young (0+ to 2+) fish. The histograms also show that 0+ rudd were only sampled towards the end of the growing season. The progress of the 1974, 1975 and 1976 year classes may be easily followed on the lake A histograms; the 1974 year class was weak compared with other year classes particularly those of 1971 and 1972, which may have been strengthened by stocking.

Estimates of instantaneous mortality (Z) and survival (S) were calculated using Table 12 data for the periods 1974 to 1977 (Z_1,S_1), 1976 to 1977 (Z_2,S_2) and in the case of the 1975 year class (Z_3,S_3) by using population estimates (Table 11):

$Z_1 = 0.80$ $S_1 = 0.30$

$Z_2 = 1.20$ $S_2 = 0.80$

$Z_3 = 2.61$ $S_3 = 0.07$

High mortality/low survival of a specific year class during early life may occur frequently in cyprinid populations.

The number of rudd $\geq$ 1+ years in lake A remained similar throughout the study (Table 11; Fig. 28a) however, during 1975 successive weekly Schnabel estimates utilising angling for capture and recapture, increased markedly from June to August (Appendix 2b) presumably because of recruitment of the 1974 year class. Recaptures were too few to repeat the analysis for 1976.

* The interpretation is suspect: reference to Fig.7 would indicate that rudd >100mm length are older than suggested.

Table 11 Rudd; estimated population, densities and biomass. Lake A, 1974 to 1977.

Date size (mm)	Age group	Petersen (Bailey modification)	Bell (1974)	Triple (Bailey or Schnabel)	'Best' estimate	Density No. m^{-2}	$\hat{B}$ g m^{-2}
Aug. 1974							
70-109	1+	420	630	-	1550[1]	0.089	0.89
125-174	>1+	35	70		70	0.004	0.27
Feb. 1975							
25- 40	0+				> 250	0.014	0.004
70-107	1+	1066 (390-2665)			863	0.050	0.62
* 108-130	2+				207	0.012	0.35
* 135-155	3+		150	-	127[3]	0.007	0.41
* 160-180	4+				63[3]	0.004	0.33
>180	>4+				20[3]	0.001	0.25
Jun.Jul. 1975							
70-175	1-4+	-	455	-	500	0.029	0.57
Apr. 1976							
70-109	2	476 (292-821)	-	-	500	0.029	0.39
110-174	3	283 (147-595)	-		300	0.017	0.67
Oct. 1976							
35- 59	0+				>800	0.048	0.06
60-110	1+	1347 (1181-1567)		1458 (1292-1659)	1500	0.089	0.87
111-184	>1+	224 (91-560)		158 (82-332) 661[2]	400	0.024	0.96
Sep. 1977							
65- 90	1+	839 (476-1618)		—	840	0.050	0.32
95-120	2+	106 (59-213)			110	0.007	0.12
130-240	>2+		170		170	0.010	0.73

1 Includes stock fish.

2 Bailey triple catch.

3 By proportion to 1972 and 1973 year classes.

Approximate 95% confidence limits in parentheses.

Table 12 Rudd; numbers in age groups caught by seine and angling. Lake A, 1974 to 1977.

Year of capture		No. and % in age groups					Total (100%) 1 to 4+
		1+	2+	3+	4+	5+ and over	
1974-5	n	155	194	77	45	(22)	471
	%	32.9	41.2	16.3	9.6		
1975-6	n	111	247	77	27	(35)	462
	%	24.0	53.5	16.7	5.8		
1976-7	n	1264	335	201	24	(15)	1824
	%	69.3	18.4	11.0	1.3		
1977-	n	241	62	26	6	(14)	335
	%	71.9	18.5	7.8	1.8		
1974-7 mean	%	49.5	32.9	13.0	4.6		
1976-7 mean	%	70.6	18.4	9.4	1.6		

Relative year class strengths derived from data in Table 12 were:

Year class	Relative strength
1971	200.9
1972	201.4
1973	99.2
1974	52.6
1975	106.6
1976	145.3

See 2.3 for method of calculation.

Table 13 Gut contents of Lake A fish, 1975 to 1977.

Species	n	Size range mm	Capture Method	Gut contents (% occurrence)								
				'Maggots'		Crustacean zooplankton				Benthos[3]	Algae/ plant material	Detritus/ other
				Larvae	Pupae	Daphnids	Bosmina	Calanoids	Cyclopoids			
Rudd	15	53-111	Seine	0	0	33	0	0	7	20	13	47
	10	59-140	Angling	60	30	0	0	0	0	30	40	30
Roach	6	78-108	Seine	0	0	83	0	0	0	0	0	33
	3	115-171	Angling	100	0	0	0	0	0	33	0	33
Bream	15	50-201	Seine	0	0	33	27	7	60	27	27	33
	1	96	Angling	100	0	100	0	0	0	100	0	100
Perch	20	54-96	Seine	0	0	45	5	60	55	15	0	0
	3	61-63	Angling[2]	66	0	0	0	0	0	100	0	0
Tench	11	33-93	Seine	0	0	18	0	46	27	36	0	0
	20	57-232	Angling	60	35	5	0	30	10	45	0	10

1. Samples collected April to Oct. 1975 to 1977.
2. Lake B samples.
3. The following groups of organisms were identified and classified as benthos: Trichoptera larvae; Chironomid larvae; Ostracoda; Gastropoda; Lamellibranchs; Zygoptera nymphs and Chaoborus sp.

Estimates of lake A rudd biomass (Table 11; Fig. 28b) displayed gentle seasonal fluctuations, with the 1+ group the most important, contributing 32 and 46% of rudd biomass in February 1975 and October 1976 respectively.

The contribution of rudd to the community biomass and production of lake A is considered at the end of this section with similar data for the other species.

The gut contents of 25 lake A rudd (Table 13) were examined; the guts of rudd caught by angling contained maggots, benthic organisms and plant material but those taken by seine had been feeding on crustacean zooplankton (especially daphnids and cyclopoids) benthos and plants.

Ripe male and female rudd (Kesteven, 1960) were caught by anglers from lake A during June 1975 and 1976. The ripe fish ranged from 105 - 188 mm (males) to 105 - 175 mm (females), corresponding to fish > 3 years. Running males were caught from June to July 1976 and in 1977 ripe males and females were caught by anglers fishing in May i.e. during the statutory close season. The above evidence suggests that the spawning of rudd was prolonged over a period May to July, but a range of fry sizes consistent with an extended spawning period was not detected.

(ii) <u>Roach</u>

Previous to 1975 roach were common in lake A but during 1975 catches of roach by seine and angling declined sharply, however, they became common in catches again during 1976 and 1977 after stocking (see Table 33).

Roach scales examined were mainly from young fish (0+ to 5+, lake A; 0+ to 7+, lake B) and annual checks were easily discerned. The pattern of scale growth pointed to annual checks being formed between March and May but data were insufficient to justify the production of a scale growth plot similar to Fig. 6.

Back-calculations of length-at-age were made using the following length/scale relationships derived from measurement data from lake A and B roach:

Lake A: $\text{Log}_{10}\ \text{FL} = 0.4551 + 0.8098\ \text{Log}_{10}\ \text{Sr}$ $r = 0.9875$, $n = 61$

Lake B: $\text{Log}_{10}\ \text{FL} = 0.3185 + 0.8815\ \text{Log}_{10}\ \text{Sr}$ $r = 0.9836$, $n = 50$

The slope for the lake B regression was significantly greater than that for lake A (t-test, $p < 0.05$).

There was good agreement between observed and calculated lengths for year one lake A roach (Appendix 1) but data were too few to assess the value of back-calculation for lake B roach.

First year growth of lake A roach was rapid (Fig. 11) and significantly greater than lake B fish until year three (see Table 14). Comparisons of lengths of lake A roach at year one for the 1971 to 1976 year classes (Table 9b; Fig. 12) show that growth was best in 1975; growth of the 1973 year class of lake B roach was also good during 1975 especially between June and July where mean fork lengths increased from 97 to 115 mm (see Fig. 14).

Table 14 Values of 't' for comparisons of composite mean lengths of roach[1] in lakes A and B.

Age group	Observed value of 't'	Calculated value of $t_{0.05}$
1	8.9817	2.0149*
2	5.9031	2.0823*
3	1.6179	2.2276
4	0.7906	2.5943

* mean lengths significantly different at $p \leq 0.05$

1 See Appendix 1.

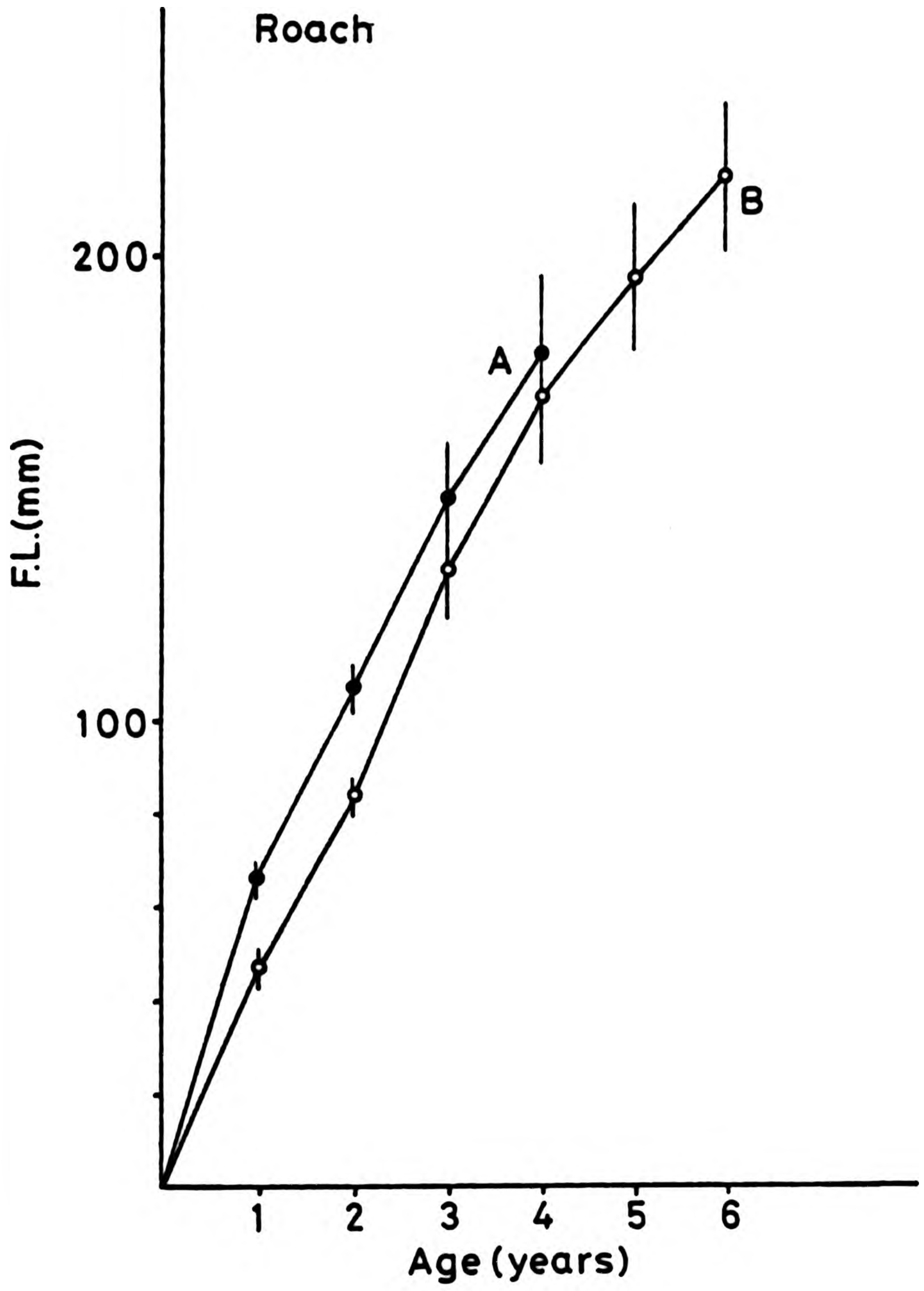


Fig. 1·1 Plot of composite mean lengths-at-age for lake A (•) and lake B (o) roach, with 95% confidence limits (vertical bar).

Few roach were both weighed and measured, therefore only pooled (summer season) length/weight regressions were calculated for 1975 and 1976 (Appendix 8), in both cases the slope was ≏ 3. Condition analysis was not attempted because of insufficient data but it was noted that during August and September 1974 roach with an ulcerative disease were common in catches from lake A. In 1975 and 1976 several large roach (> 150 mm) were caught from the same lake in an emaciated state, often with sub-cutaneous haemorrhages and fin damage; it was not possible to confirm that the latter were stock fish.

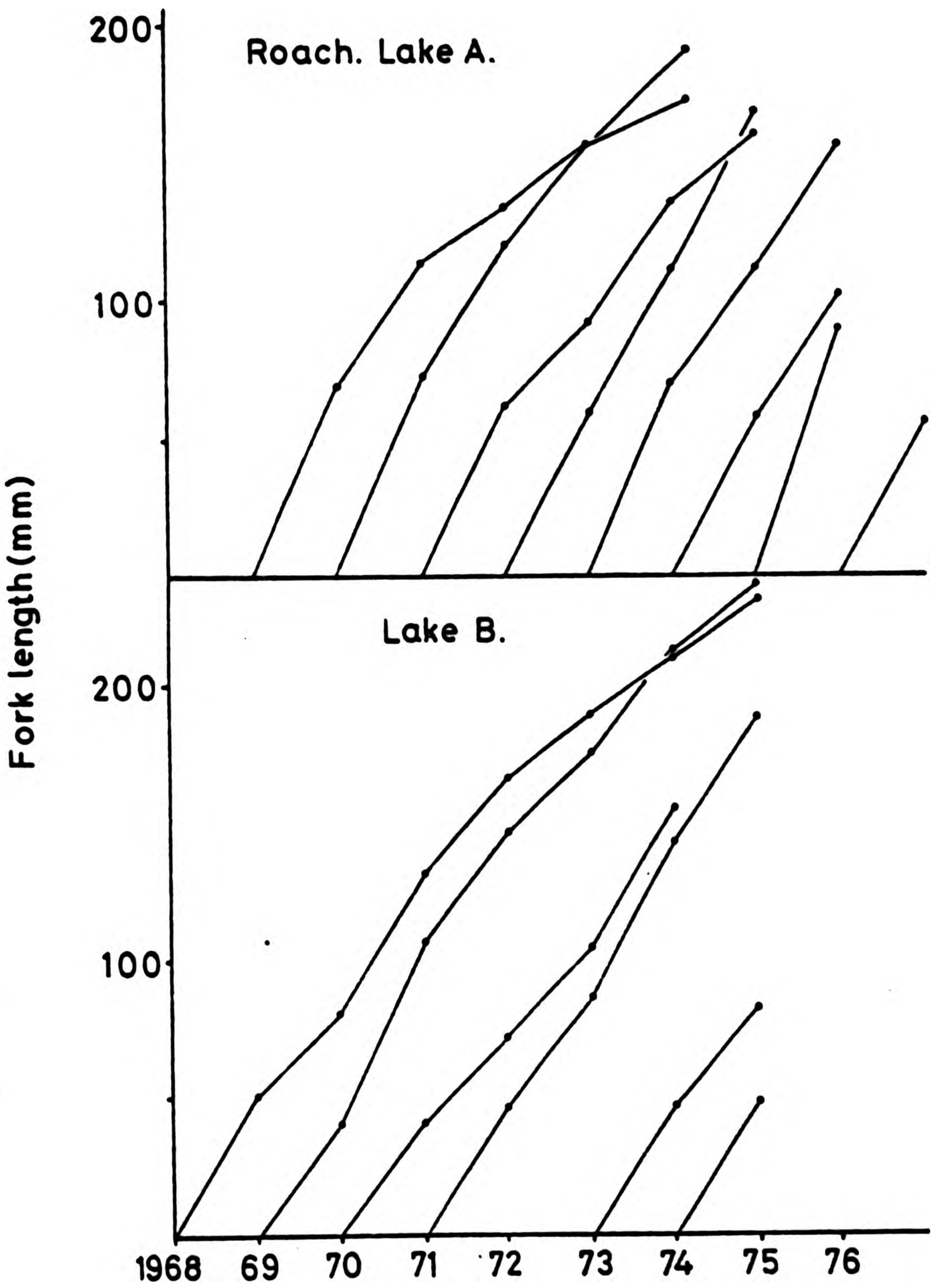


Fig. 12 Mean back-calculated lengths-at-age for lake A and B roach, 1968 to 1975 year classes.

The population structure of lake A roach appeared to be balanced in late summer 1974, with 1+, 2+, 3+ and older fish represented in samples (Fig. 13). By February 1975 however, 1+ fish were less common and during the following summer all age groups of roach were scarce. The decline and recovery of the roach population in lake A was partially obscured by stocking (Fig. 13 and Table 16) but clearly sufficient numbers of mature roach were present to produce the 1975 year class.

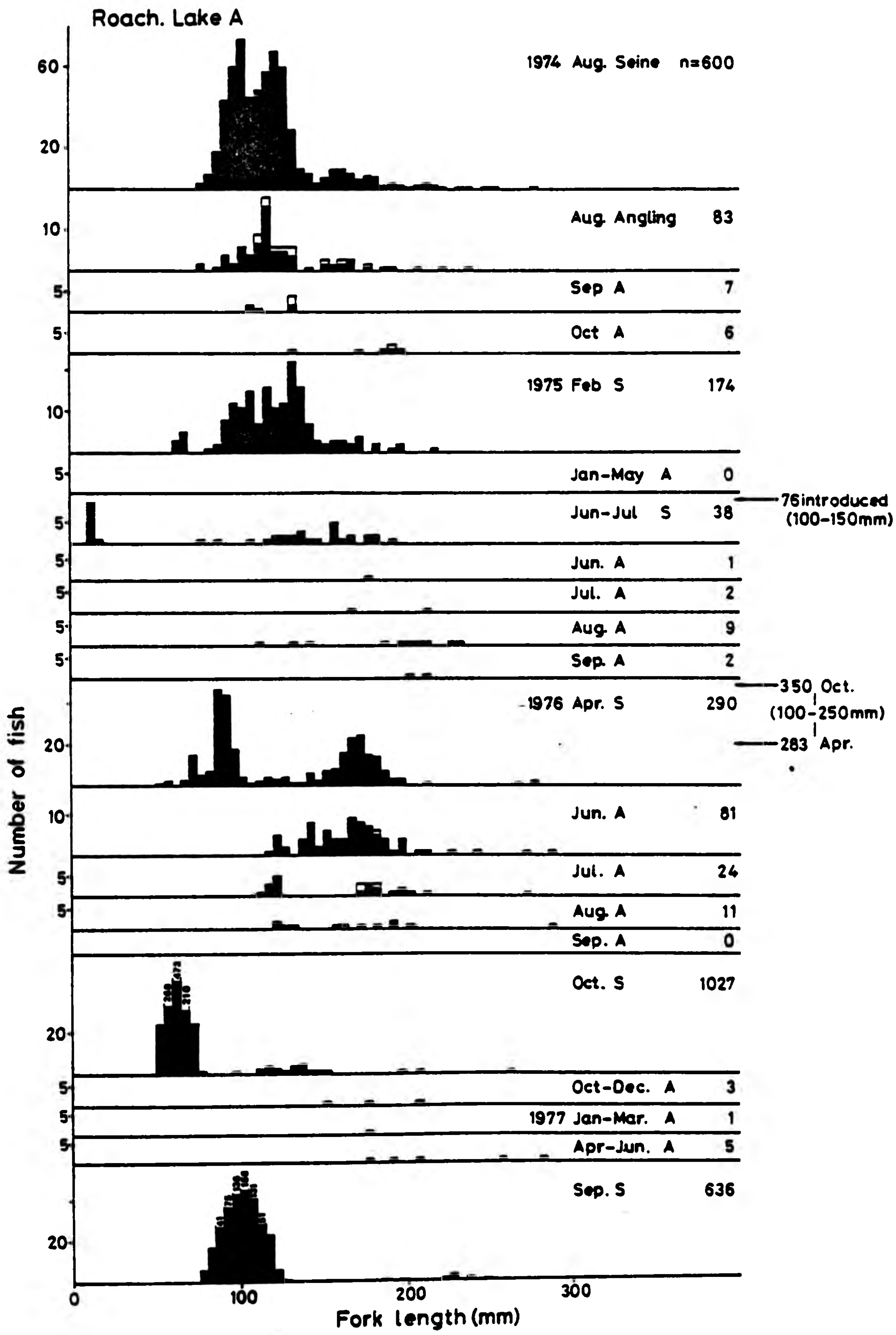


Fig. 13 Length/frequency histograms for lake A roach caught by seine (S) and angling (A), 1974 to 1977. Unshaded blocks represent fish with mouth damage.

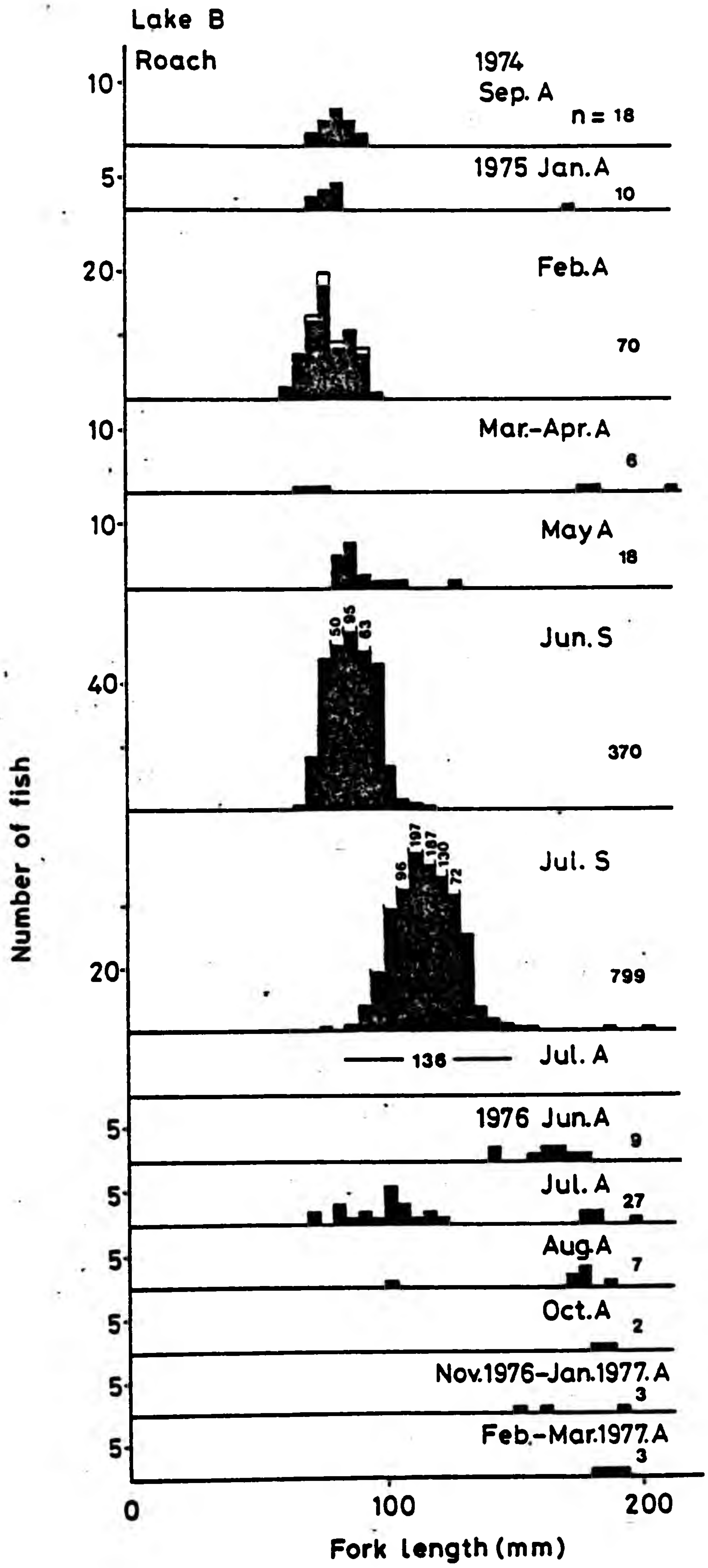


Fig. 14 Length/frequency histograms for lake B roach caught by seine (S) and angling (A), 1974 to 1977. Unshaded blocks represent fish with mouth damage.

From the autumn of 1976 the roach population of lake A was dominated by the strong 1976 year class; the irregularities of population structure between 1975 and 1977 are shown in Table 16 and by population estimates (Table 15).

The only estimate available for lake B roach (32080 ± 19772) was subject to gross error; the mortality of marked fish on the first day of sampling was high, primarily due to hot weather conditions. The 0+ roach in lake A were also considered to be under-estimated in October 1976.

Mortality (Z) and survival (S) were calculated for combined age groups (1 to 3+) of lake A roach from the population estimates for August 1974 and June/July 1975 (i.e. 11 months):

$Z = 3.95 \qquad S = 0.02$

Calculation of mortality and survival over a 6-month period (August 1974 to February 1975) using population estimates but for separate age groups indicated very low survival of the 1+ group (1973 year class) during the population decline:

1+	Z = 2.27	2+	Z = 1.11	3+	Z = 0.73
	S = 0.10		S = 0.33		S = 0.48

Using a mean percentage number of lake A roach in successive age groups (Table 16) estimated overall mortality and survival was different from the above, i.e.

$Z = 0.55 \qquad S = 0.58$

this was probably because of stocking and 'dilution' of 'within year' effects.

Lake A roach biomass (Tables 15 and 31; Fig. 28b) declined from 8.57 g m^{-2} in August 1974 to only 0.23 g m^{-2} in June 1975 (97.3% reduction), but was restored (by stocking?) to August 1974 levels by late spring 1976. Most stock fish had disappeared by September 1976 (see Fig. 13) leaving the 1976 year class as the major contributor to roach biomass in the lake.

Information on the feeding habits of roach from lake A is scarce (Table 13) but sufficient to show that they consumed crustacean zooplankton, benthic organisms and maggots.

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Information on the feeding habits of roach from lake A is scarce (Table 13) but sufficient to show that they consumed crustacean zooplankton, benthic organisms and maggots.

Table 15 Roach; estimated populations, densities and biomass. Lake A, 1974 to 1977.

Date Size (mm)	Age group	Petersen (Bailey modification)	Bell (1974)	Triple (Bailey or Schnabel)	'Best' estimate	Density No. m^{-2}	$\hat{B}$ g m^{-2}
Aug. 1974							
75-109	1+	3113 (1331-9730)	-	-	3100	0.178	3.51
110-144	2+	1400	-	-	1400	0.081	2.97
145-175	3+	300 (122-750)	-	-	150	0.008	0.70
>176	>3+				150	0.008	1.39
All sizes		4360 (2905-6849)	-	-	4800	0.280	8.57
Feb. 1975							
60- 70	0+				>50	0.003	>0.02
80-120	1+	320 (117-800)	-	-	320	0.018	0.40
120-150	2+	464 (170-1160)	-	-	460	0.027	1.17
151-175	3+				72[1]	0.004	0.35
>175	>3+				31[1]	0.002	0.25
Jun-Jul.1975							
75-170	1-3+	88 (27-160)			90	0.005	0.23
Apr. 1976							
65-109	1	1353 (410-2460)	2400	1634 (557-8170)	1700	0.098	1.13
110-214	>2	1010 (306-1683)		955 (408-2984)	1000	0.058	4.86
Oct. 1976							
50-80	0+		70		>1000	>0.059	>0.24
>95	>1	-	70		>25	>0.001	>0.08
Sep. 1977							
75-130	1+	20089 (8200-50224)	-	-	10000	0.594	10.50
185-250	>2	-	45		50	0.003	0.57

1. By proportion to 1972-3 year classes.

Approximate 95% confidence limits in parentheses.

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>175	>3+				31[1]	0.002	0.25
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Table 16 Roach; numbers in age groups caught by seine and angling. Lake A, 1974 to 1977.

Year of capture		No. and % in age groups					Total (100%) 1 to 4+
		1+	2+	3+	4+	5+	
1974-5	n	295	447	68	34	(18)	844
	%	35.0	53.0	8.1	4.0		
1975-6	n	3	15	9	7	(7)	34
	%	8.8	44.1	26.5	20.6		
1976-7	n	177	62	142	42	(14)	423
	%	41.8	14.7	33.6	9.9		
1977-	n	629	0	1	4	(9)	634
	%	99.2	0.0	0.2	0.6		
Mean	%	46.2	27.9	17.1	8.8		

Relative year class strengths:

Year class	Relative strength
1971	110.8
1972	166.2
1973	113.3
1974	25.9
1975	56.4
1976	214.7

(iii) Bream

Bream were first stocked into lake A during 1970 (Table 32) but there were several subsequent stockings. Many of the larger bream examined during the census were these introduced fish.

Bream scales displayed well-defined annual check marks and age determination was easy with the aid of length/frequency histograms (Fig 15).

Lengths-at-age were found by back-calculation using the following equation derived from lake A bream data:

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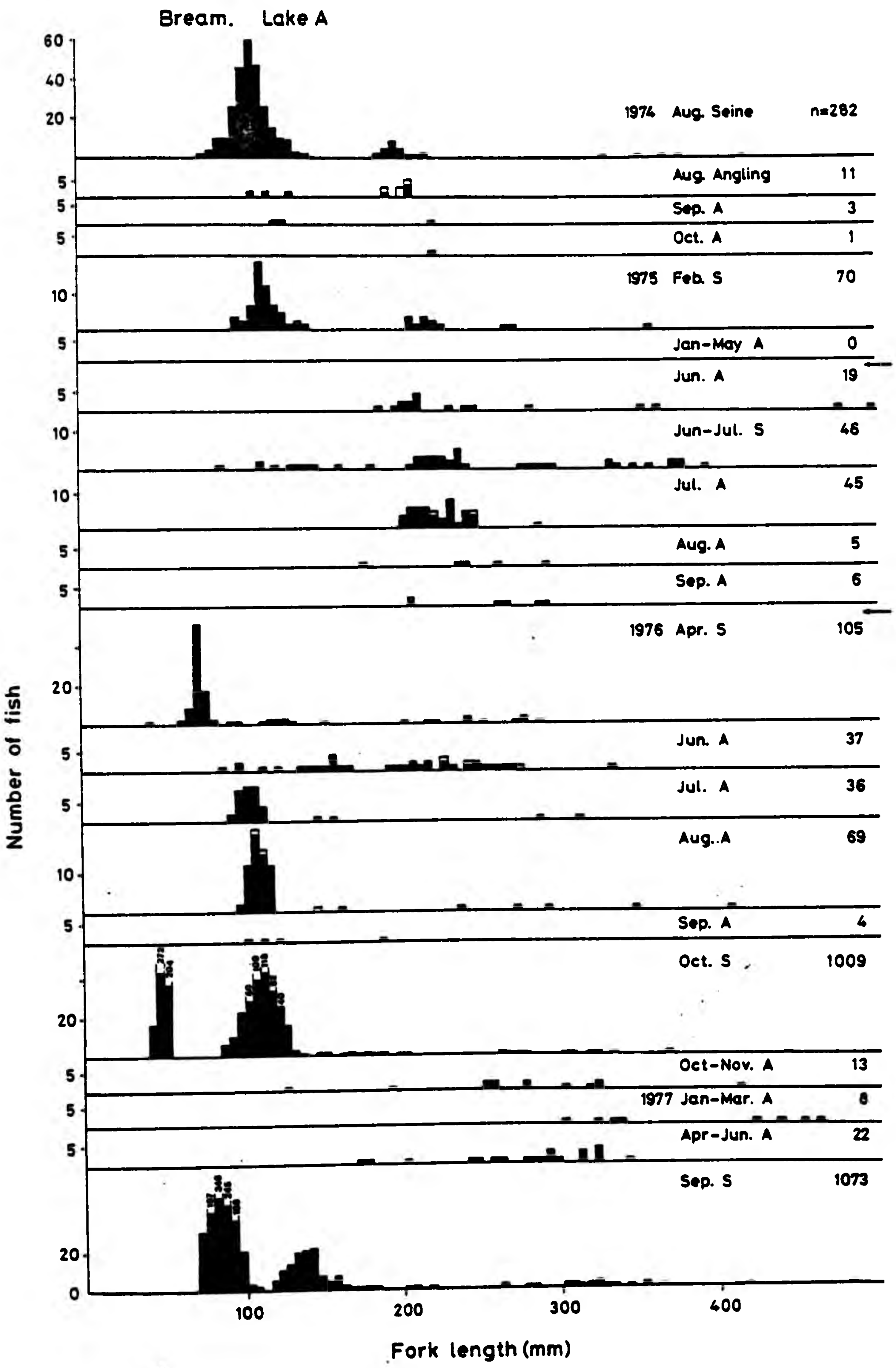


Fig. 15 Length/frequency histograms for lake A bream caught by seine (S) and angling (A), 1974 to 1977. Unshaded blocks represent fish with mouth damage.

$$\text{Log}_{10}\,FL = 0.4082 + 0.9410\ \text{Log}_{10}\,Sr \qquad r = 0.9865,\ n = 79$$

There was no obvious tendency for back-calculation to over- or under-estimate the lengths-at-age of bream from the 1971 to 1976 year classes.

The growth of individual year classes and composite growth for lake A bream are shown in Fig.16 a,b. Growth of the 1974 and 1976 year classes during year 1 was poor compared with that of the 1975 year class (Table 9c).

First year growth was moderate but during the second and subsequent growing seasons it was good (Appendix 1, composite). Scales from two bream > 400 mm were examined, both were 8+ years. Only 4 bream from lake B were examined (range 110-230 mm).

Length/weight regressions were calculated each month for lake A bream during the summer and autumn (Appendix 8), but sample sizes were small and included many age groups. Slope values were, with the exception of September, significantly > 3 ($p \leq 0.05$) through 1976 but not significantly different from 3 in 1975; in 1977 between April and June slope was again significantly > 3. Pooled (all observations) length/weight regressions were also calculated for lake A (Table 17 below).

Table 17 Pooled length/weight regression parameters. Lake A bream, 1975 to 1977.

Year	Log_{10} intercept	Slope	95% confidence limits for slope	r	n
1975	-5.7428	3.4275	2.9602 - 3.8948	0.8623	55
1976	-5.4795	3.3048*	3.2549 - 3.3547	0.9981	66
1977	-5.5817	3.3570	3.0776 - 3.6364	0.9772	27

* Slope significantly > 3 ($p \leq 0.05$)

The slope of the 1975 pooled length/weight regression was not significantly > 3 but exceeded the upper confidence limits for the regressions for June and July 1975. In 1976 the slope for the pooled

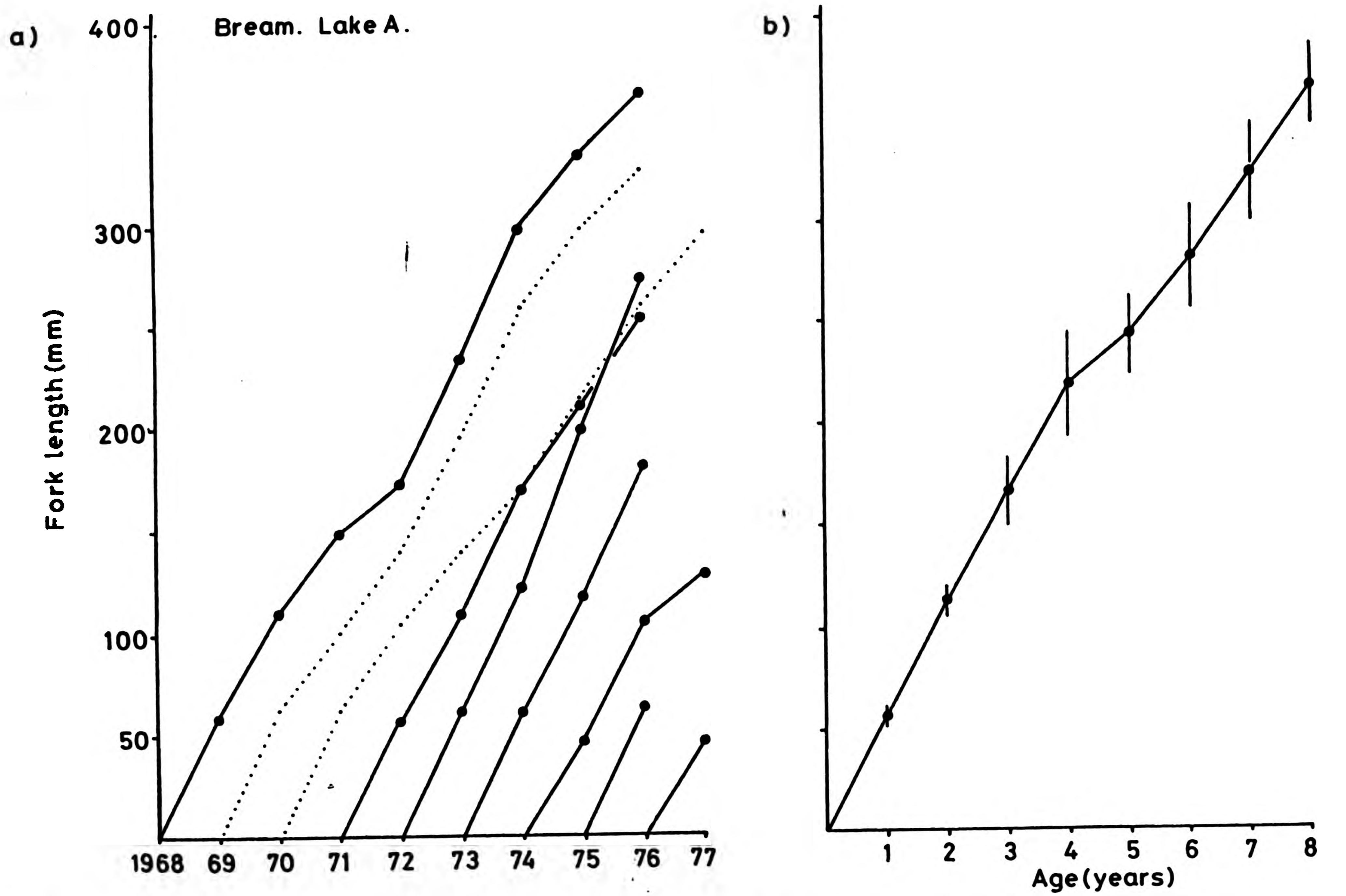


Fig. 16 (a) Mean back-calculated lengths-at-age for lake A bream, 1968 to 1976 year classes:
(b) composite mean back-calculated lengths-at-age for lake A bream with 95% confidence limits (vertical bar).

regression fell approximately within the confidence limits for each monthly regression.

Because the length/weight relationship was relatively stable, condition (K) was calculated but only for a few months each year where data appeared adequate (Table 18).

Table 18 Condition (K) of bream > 120 mm. Lake A

Year/month	Size range, mm	Mean K ± 95% conf. limits	n
1975 Jun.	185 - 495	1.893 ± 0.177	9
Jul.	204 - 289	1.934 ± 0.032	38
Aug.	175 - 294	1.913 ± 0.144	5
1976 Jun.	145 - 333	1.848 ± 0.064	15
Aug.	160 - 408	1.760 ± 0.201	6
Oct. to Dec. (inclusive)	129 - 410	1.862 ± 0.071	13
1977 Feb. to Mar. (inclusive)	303 - 460	1.965 ± 0.127	6
May	171 - 340	1.887 ± 0.081	17
Jun.	245 - 310	1.827 ± 0.259	4

The data of Table 18 suggests that the bream had an annual cycle of condition including loss of condition at spawning with recovery in the post-spawning period, i.e. July and August. Bream < 120 mm were excluded from analysis because they would almost certainly have been immature and their inclusion may have masked any condition change.

The bream population of lake A was dominated by the strong 1973 year class during the late summer of 1974 with the year class composing 88% of the estimated population (Table 20). By the summer of 1975 however, the 1973 year class was less evident (Fig. 15) and the structure of the population was changed by stocking.

The 1975 year class dominated the bream catch to anglers through the summer of 1976 but in the autumn a strong 1976 year class was detected by seine netting and was clearly dominant in September 1977.

Numbers of bream (> 400 mm) were also present in lake A and caught throughout the study; they were often observed shoaling near the surface during the hot summer of 1976.

Mortality and survival were estimated from % mean number data (Table 20) for 1976 and 1977 (1 to 3+ age groups) as:

$$Z = 2.195 \qquad S = 0{\cdot}151$$

For the 1975 year class only using population estimates for autumn 1976 and 1977:

$$Z = 0.069 \qquad S = 0.50$$

Bream biomass estimates (Tables 19 and 31; Fig. 27b) increased almost ten-fold from 1974 to 1977, 1+ and 2+ fish making the major contribution.

Crustacean zooplankton and other food organisms, excluding maggots, were recovered from the guts of small bream caught by seine (Table 13) but the gut of a single fish examined after capture by angling contained only 2 maggots. The presence of Caryophyllaeus sp. in another bream shows (Kennedy, 1969) that it had fed on tubificid worms at some time.

Seven bream (257 - 323 mm) caught by angling from lake A on 8 May 1977 had tubercles present on the head but they were not ripe, however, on 22 May 1977 a ripe female bream was caught. Bream were observed shoaling in the shallows of lake A through May 1977 when the water temperature was between 12 and 16°C - presumably their shoaling was a preliminary to spawning. A single ripe male bream (280 mm) had been caught on 20 June 1975. It appears therefore that the bream in lake A spawned during late May to early June.

Table 19 Bream; estimated populations, densities and biomass. Lake A, 1974 to 1977.

Date Size (mm)	Age Group	Petersen (Bailey modification)	Bell (1974)	Triple (Bailey or Schnabel)	'Best' estimate	Density No. m^{-2}	$\hat{B}$ g m^{-2}
Aug. 1974							
75-144	1+	2430 (1206-5316)	-	-	2430	0.140	3.48
185-219	2+	64 (19-116)	-	-	60	0.003	0.56
>220	>2+				>20	0.001	0.29
Feb. 1975							
95-144	1+	87 (26-158)	-	218 (98-546) 1175[2]	800	0.046	1.17
210-235	2+	-	-	-	30[1]	0.002	0.30
>250	>3+	-	-	-	>3	<0.001	0.09
Jun-Jul. 1975							
85-245	>1+	-	>60	-	>250[1]	0.014	2.82
280-394	>5+	33 (10-60)		-	50	0.003	1.86
Apr. 1976							
60- 99	0+/1	-	-	-	>6000	0.346	2.18
>100	>1+	-	20	-	~400	0.023	4.67
Oct. 1976							
40- 55	0+	-	-	-	>5500	0.327	0.53
85-139	1+	5805 (3110-11874)	-	6100 (3459-11772) 9603[2]	6000	0.357	7.72
>140	>2+	-	-	-	300[1]	0.018	5.76
Sep. 1977							
70-110	1+	64736 (19617-117701)	-	-	>5000	0.297	2.65
110-159	2+	-	3300	-	3000	0.178	7.38
160-220	3-4	-	35	-	~40	0.002	0.25
260-	>5+	20 (6-35)	-	-	>50	0.003	2.07

1. estimates based on proportional calculation relative to bream mark-recapture estimate made at the same time.
2. Bailey triple catch.

Approximate 95% confidence limits in parentheses.

Table 20 Bream; numbers in age groups caught by seine and angling. Lake A, 1974 to 1977

Year of capture		No. and % in age groups				Total (100%) 1 to 3+
		1+	2+	3+	4+ and over	
1974-5	n	317	42	2	(6)	361
	%	87.9	11.5	0.6		
1975-6	n	11	60	26	(24)	97
	%	11.3	61.9	26.8		
1976-7	n	587	28	15	(51)	630
	%	93.2	4.4	2.4		
1977-	n	940	110	4	(49)	1054
	%	89.2	10.4	0.4		
Mean	%	70.3	22.2	7.5		

Relative year class strengths:

Year Class	Relative strength
1972	129.3
1973	152.6
1974	15.6
1975	112.0
1976	126.9

(iv) Tench

Both lakes at Barham were stocked with tench (all > 0.5 kg) during the spring of 1970 (see Table 32).

The scales of small and large tench were difficult to interpret and it was necessary to examine opercular bones to assess age and growth. However, anglers were reluctant to kill tench and this restricted the number available for autopsy. Scales and opercular bones were taken from 53 small tench (< 250 mm) and 5 large fish that were found dead in littoral zone of lake A during 1975, 1976 and 1977 (see Table 21).

Table 21 Length and age of tench corpses recovered from lake A, 1975 to 1977.

Date found	Sex	Fork length mm	Number of checks on operculum	Probable age (years)
22.2.75	F	428	11	12
8.3.75	M	365	10	11
24.7.76	M	401	10	11
2.3.77	M	385	13	14
22.5.77	M	332	6	6-7

M = Male; F = Female

A body length/operculum relationship was established for small lake A tench (Fig. 17) but data for the 5 tench (Table 21) were plotted on the same figure. Back-calculations of length-at-age were made using the equation shown on Fig. 17 (see Appendix 1).

Mean back-calculated lengths at year 1 ranged from 37 mm (1974 year class) to 53 mm (1971 year class). A Walford plot (Walford, 1946) suggested (see Fig. 18) that mean length of lake A tench at the time of first annual check formation would be 28 mm, reasonably close to the lowest back-calculated value (above). The validity of age determinations for young tench received further support from two chance observations: (i) the remains of 3 tench (each approximately 30 mm long) were recovered from the gut of a lake B pike caught in October 1976 (i.e. at the end of the main growing season); (ii) two tench (35, 37 mm) were taken from the nearby River Gipping in a macrophyte sampler during September 1978.

The composite growth curve of lake A tench is shown in Fig. 19b while Fig. 19a emphasises the variation in growth between year classes.

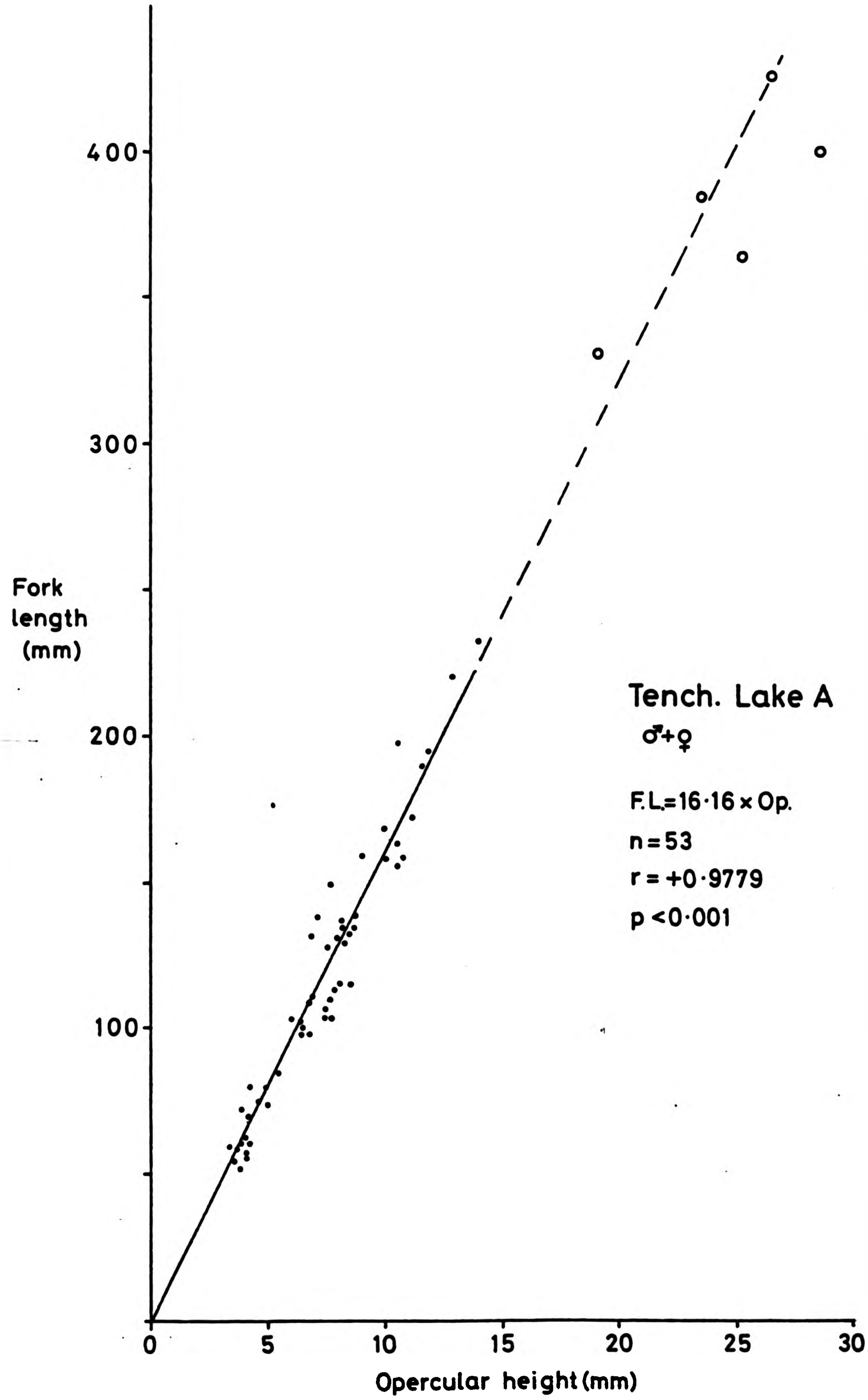


Fig. 17 Fork length/operculum relationship for lake A tench (males + females) < 250 mm. Data for larger tench (o) were not used during the calculation of the regression.

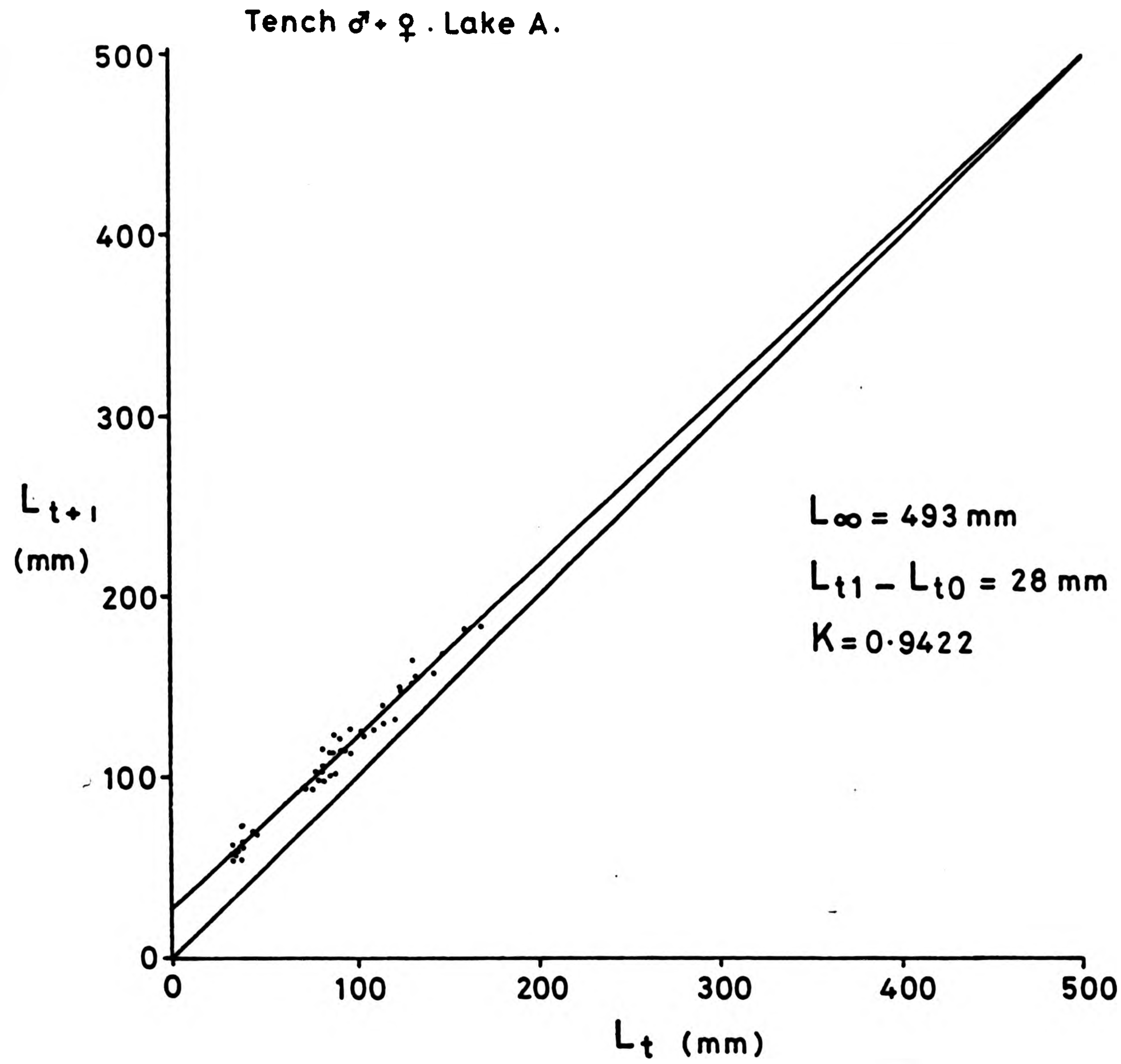


Fig. 18 Walford plot of lake A tench back-calculated lengths-at-age.

Length/weight regressions were calculated separately for male and female tench with and without mouth damage for each month where data were sufficient (Appendix 8). Pooled length/weight regressions (Table 22) were computed for 1975, 1976 and 1977 using data for tench caught by angling during May to September 1975; June to September 1976 and April to June 1977; dates inclusive.

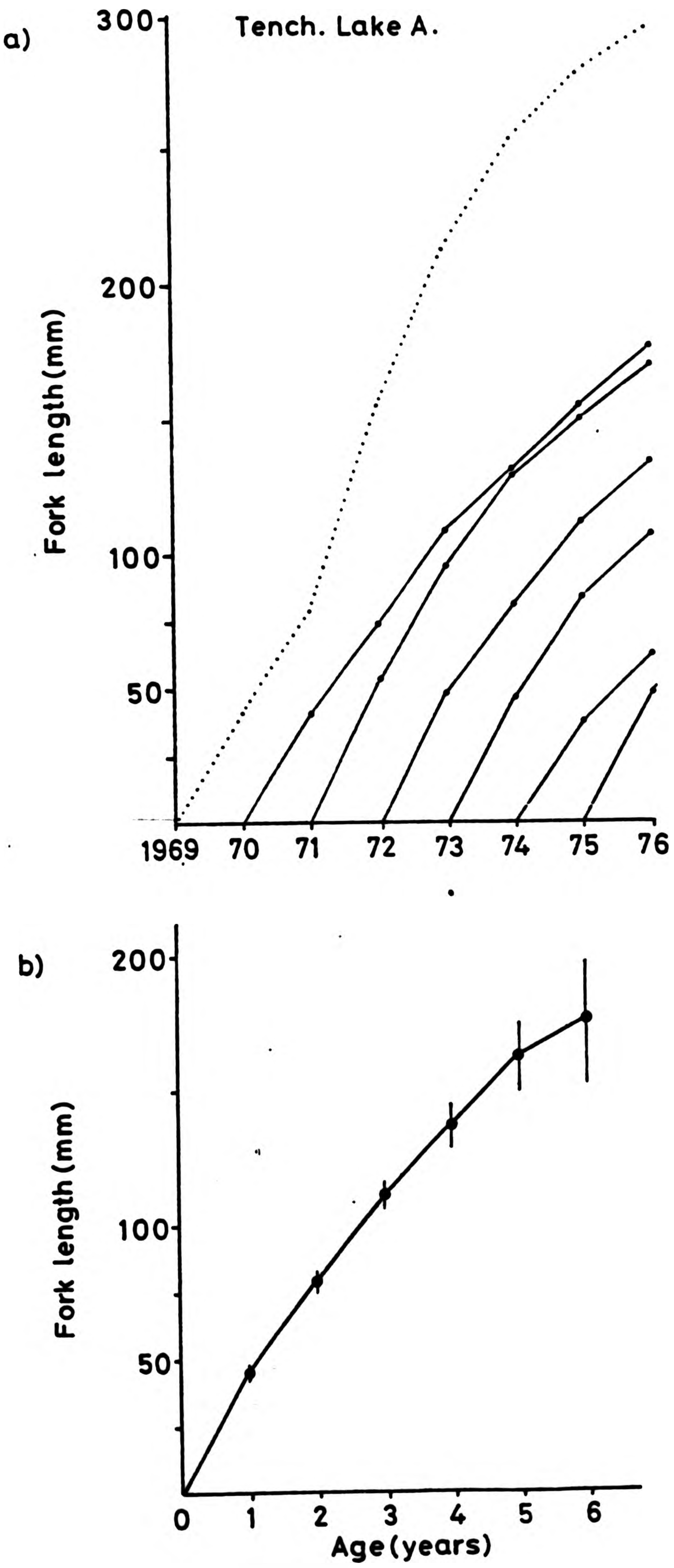


Fig. 19 (a) Mean back-calculated lengths-at-age for lake A tench, 1969 to 1975 year classes; (b) composite mean back-calculated lengths-at-age for lake A tench, with 95% confidence limits (vertical bar).

Table 22 Pooled length/weight regressions for male and female tench lake A, 1975 to 1977

Year	Sex	Log_{10} intercept	Slope	95% confidence limits for slope	r	n
1975	M	-3.9502	2.6848*	2.5768 - 2.7929	0.9751	119
	F	-4.2209	2.7746*	2.7269 - 2.8695	0.9916	101
1976	M	-4.5770	2.9290	2.8303 - 3.0279	0.9906	65
	F	-4.3547	2.8106*	2.7472 - 2.9284	0.9904	74
1977	M	-4.5196	2.9020	2.6643 - 3.1397	0.9535	54
	F	-4.1838	2.7853	2.4761 - 3.0945	0.9233	48

* significantly < 3 at $p \leq 0.05$.

Although there were some significant departures from isometric growth (Table 22; Appendix 8) condition factor (K) was calculated for lake A male and female tench > 200 mm for the period between April 1976 and June 1977 (inclusive), see Fig. 20. K values were also computed for all male and female tench (fish with and without mouth damage combined) for June to August (inclusive) 1975 (see Appendix 9).

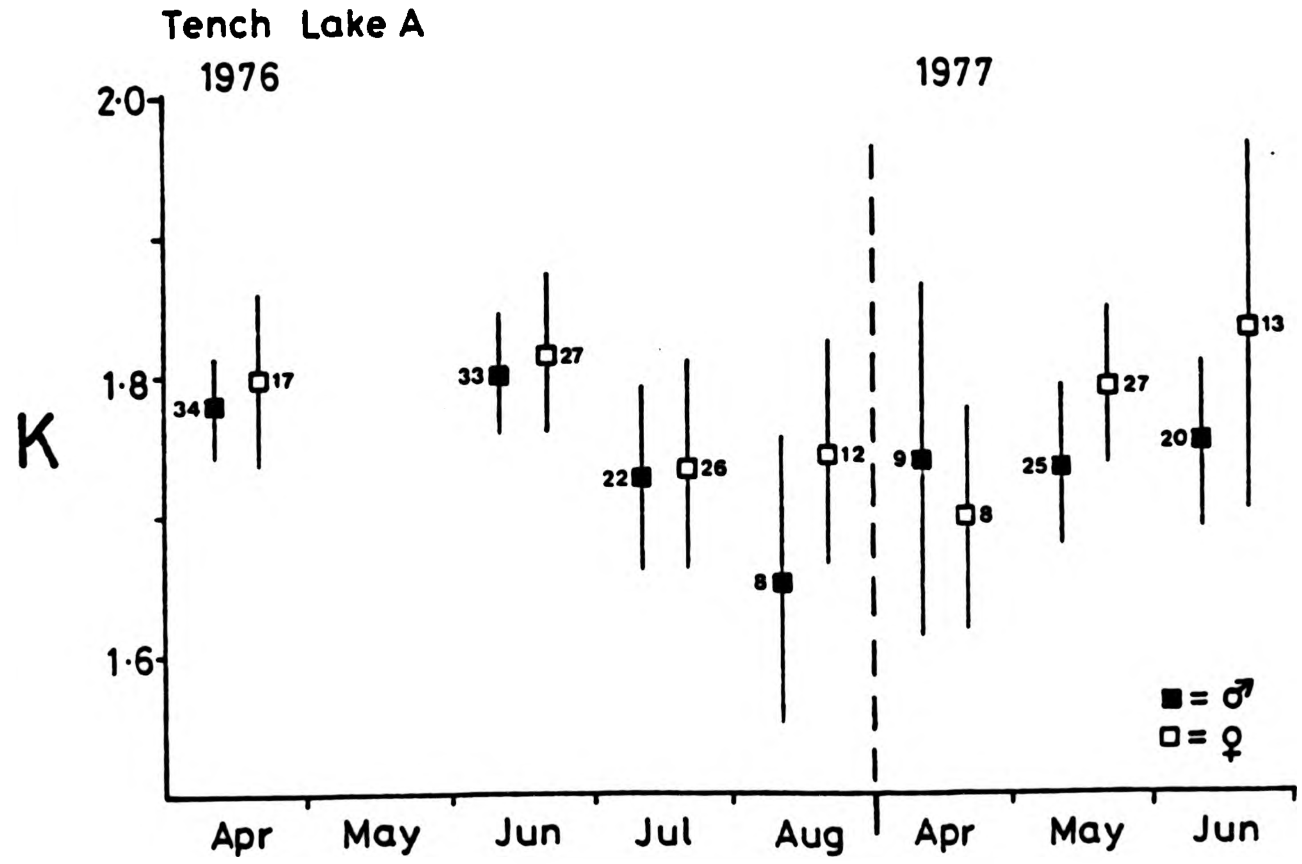


Fig. 20 Mean condition (K) of lake A male (■) and female (□) tench > 200 mm during part of 1976 and 1977. Sample sizes are stated with 95% confidence limits (vertical bar).

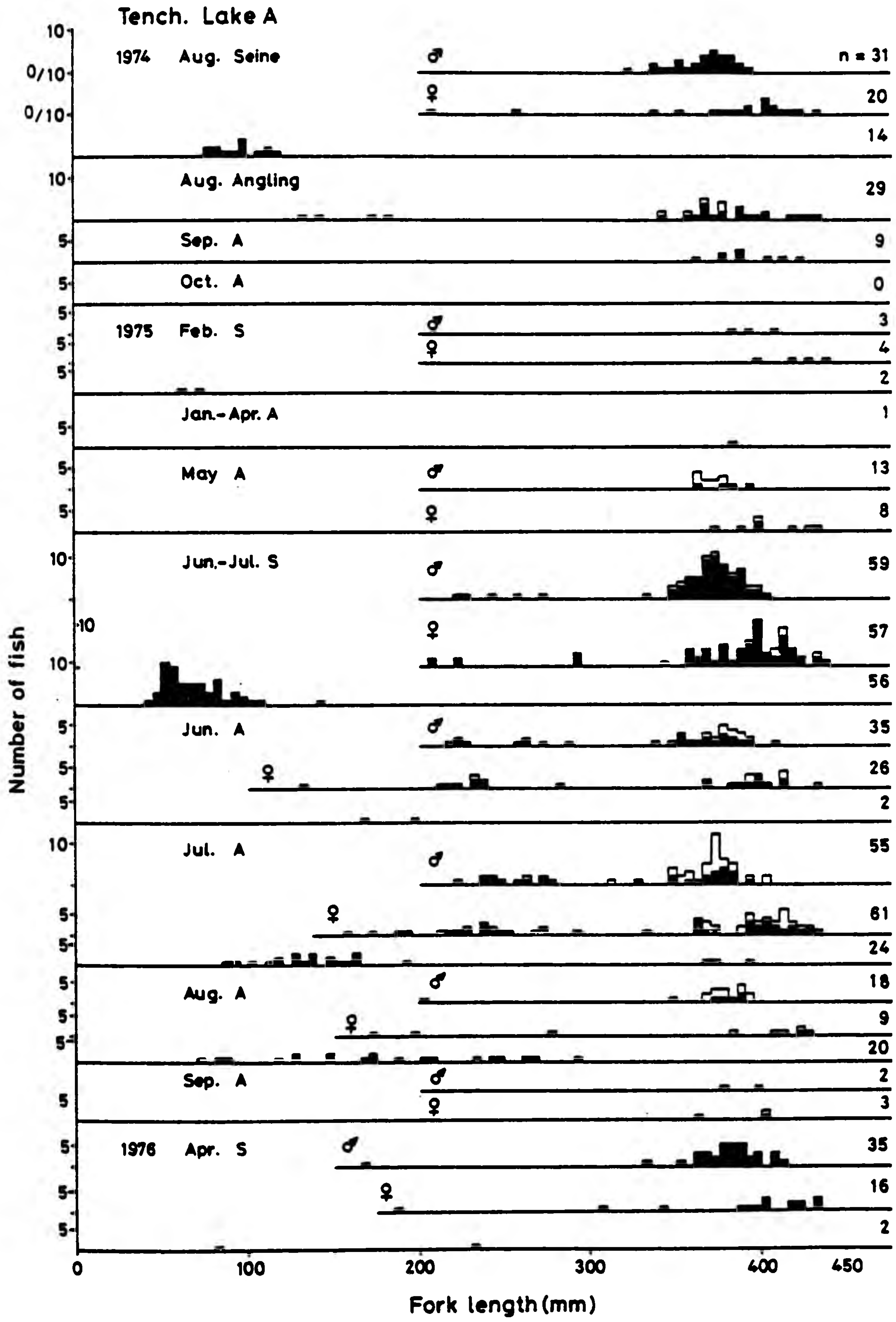


Fig. 21 Length/frequency histograms for lake A tench caught by seine (S) and angling (A), 1974 to 1977. Unshaded blocks represent fish with mouth damage (see also over page).

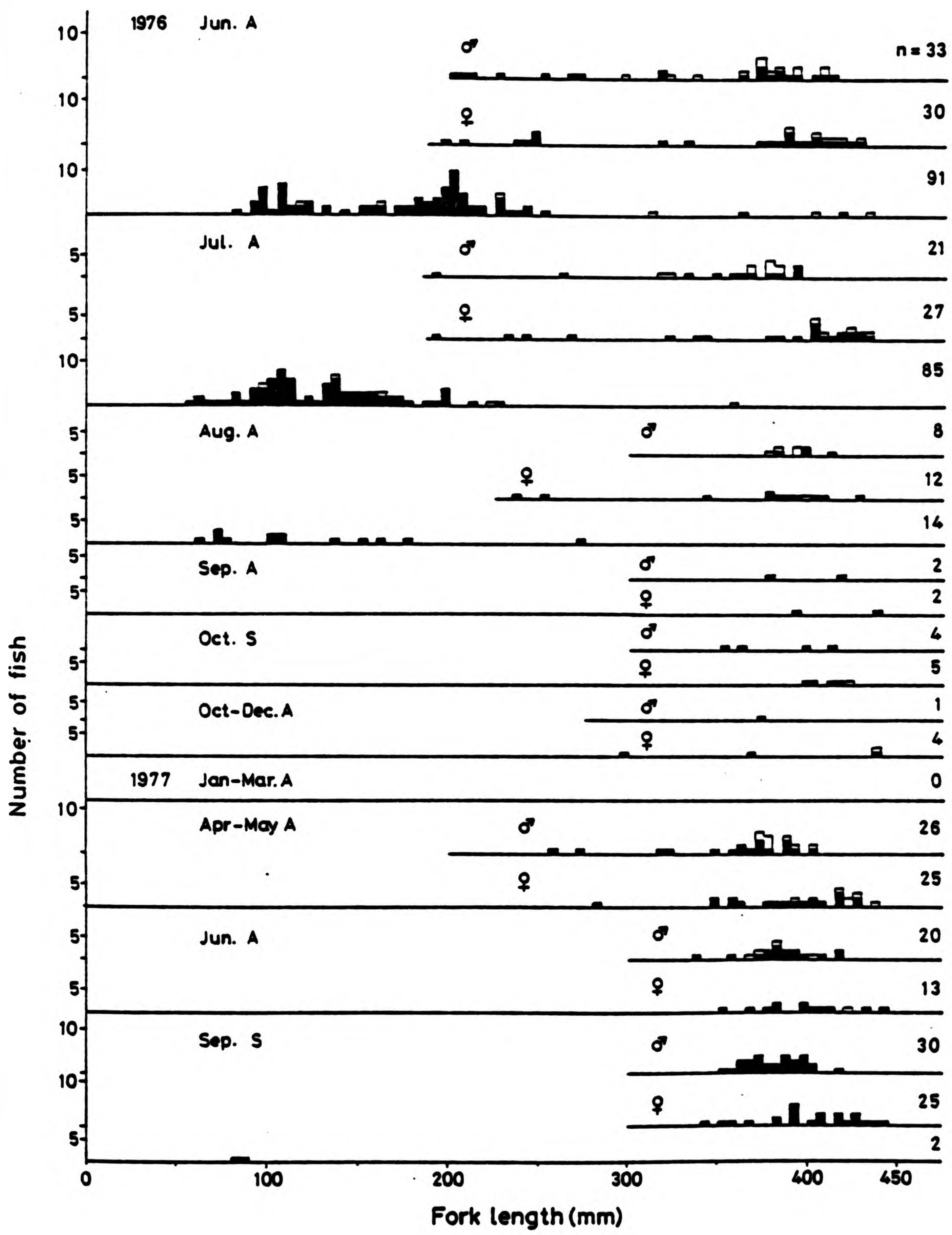


Fig. 21 Continued.

The mean K for male tench was significantly less (t-test; $p \leq 0.05$) than the mean K for females in July and August 1975. In June 1975 and in June, July and August 1976 the difference between the mean K for males and females was not significant (see also Fig. 38). The condition (mean K) of male tench in June, July and August 1975 was not significantly different from their condition during the same months in 1976. In the case of female tench, however, mean K during July and August 1975 was significantly higher (t-test; $p \leq 0.05$) than during the same months 1976.

The condition (K) of tench with and without mouth damage is considered later (see 3.3(iv) and Fig. 38).

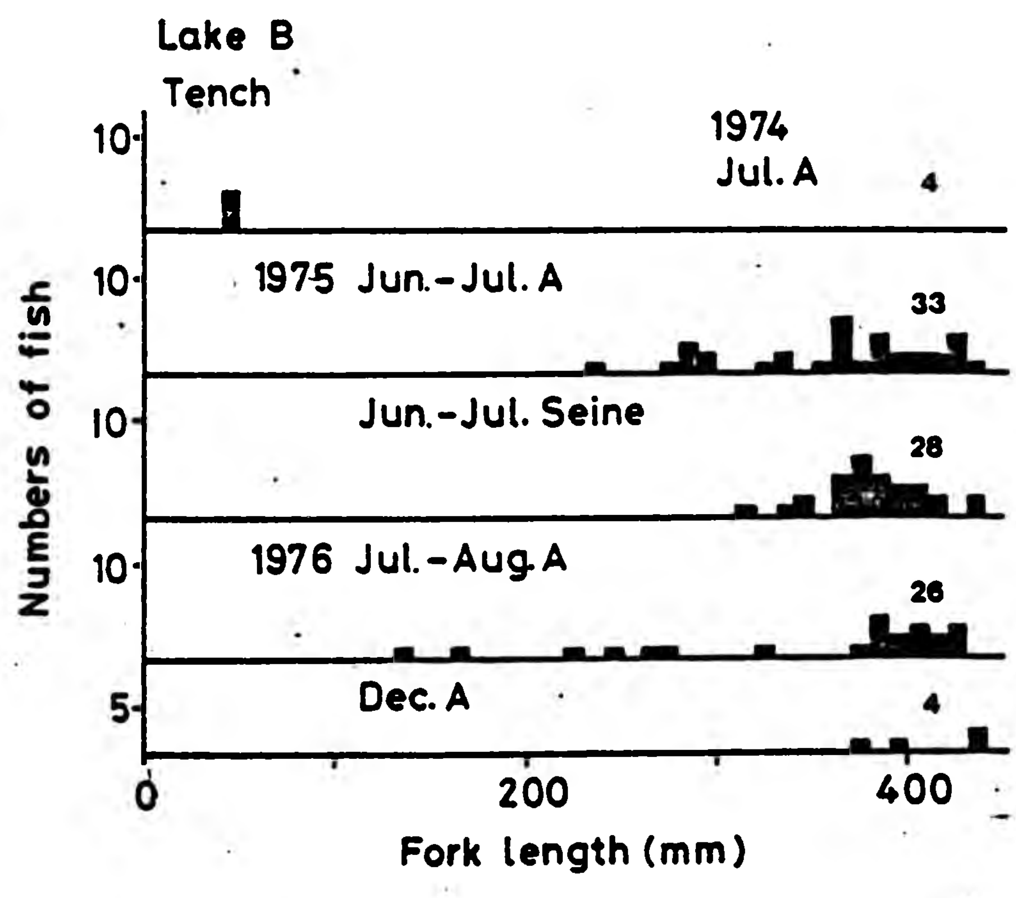


Fig. 22 Length/frequency histograms for lake B tench caught by seine (S) and angling (A), 1974 to 1976.

It was difficult to assess changes in the structure of the lake A tench population because only a few peaks corresponding to specific age groups were present on the length/frequency histograms (Fig. 21) viz: June to July, Seine (S) 1975 (1+ and 2+ groups); June, Angling (A) 1976 (6+ group) and July, Angling (A) 1976 (3+ and 4+ groups). Large tench were well represented on most of the histograms; they were mainly stock fish and it was clear that they had spawned successfully each year following their introduction.

Population estimates are not available for small tench because they were not caught consistently in sufficient numbers. However, it was possible to obtain estimates for large tench which, with due allowance for mortality, corresponded with the numbers stocked. Estimates for male and female tench when angling was used for capture and recapture were similar to those obtained using seine for capture and recapture (Table 23). Too few tench were caught in February 1975 and October 1976 to allow estimation of population size (see Appendix 2a); the estimates for female tench for April 1976 were judged to be too low (Table 23).

There was evidence of recruitment into the sexually mature group of tench during 1976 when Schnabel (1938) estimates increased through the angling season (Appendix 2b).

Large tench stocked in 1970 appeared to dominate the lake B tench population; they were estimated at 308 ± 194 (Schnabel estimate) in June/July 1975, by utilising data from samples obtained by angling and seining (Appendix 2a). The presence of a 1973 year class of tench in lake B (Fig. 22, 1974 histogram) indicated that the stock fish had reproduced.

Sexual dimorphism was obvious in tench ≥ 250 mm and the sex ratio for these large fish in lake A was approximately 1:1.

Mortality and survival were estimated for large lake A tench over 3 intervals (Table 24).

Table 23 Tench; estimated populations, densities and biomass. Lake A, 1974 to 1977.

Date, size (mm) sex and age	Petersen (Bailey modification)	Bell (1974)	Triple (Bailey or Schnabel)	'Best' estimate	Density No. m^{-2}	$\hat{B}$ g. m^{-2}
Aug. 1974						
74-119 1+/2+				400	0.023	0.323
320-394 ♂	130 (39-236)			130	0.007	6.633
335-434 ♀		120		100	0.006	6.017
Overall	540 (164-981)					
Feb. 1975						
Jun-Jul. 1975						
45-110 1+/2+				>50	0.003	0.021
230-405 ♂	73 (54-131)		77[1] (54-133)	90	0.005	4.268
200-430 ♀	66 (54-114)		76 (54-131)	85	0.005	5.068
Apr. 1976						
330-414 ♂	42 (17-105)		100 (41-249)	85	0.005	4.629
340-440 ♀	25 (8-45)		28 (15-47)	75	0.004	4.804
Oct. 1976	-	-	-	-	-	
Sep. 1977[2]						
350-410 ♂	68 (31-184)	130		80	0.005	4.245
340-440 ♀	74 (33-184)	120		70	0.004	4.472

1. Schnabel estimates.

2. Estimates based on angling recaptures (Appendix 2a).

Approximate 95% confidence limits in parentheses.

Table 24 Instantaneous mortality (Z) and survival (S) for lake A tench (> 280 mm), 1974 to 1977.

	Z		S	
	Male	Female	Male	Female
1974 to 1975	0.37	0.16	0.69	0.85
1975 to 1976	0.06	0.13	0.94	0.88
1976 to 1977	0.06	0.07	0.94	0.93

The data in Table 24 when combined with the loss of only 100 large tench between 1970 and 1974 emphasises the high survival potential of these fish in angling waters.

The gut contents of 31 small lake A tench (Table 13) were examined and all, irrespective of capture method, contained crustacean zooplankton and benthic organisms. Despite being caught during the angling season, the guts of tench taken by seine net did not contain either maggots or pupae (casters).

Gravid (Kesteven, 1960) tench were caught by anglers from lake A in June 1975 and one spawning female was caught on 15 July (water temperature 21°C). In the same year, large tench were observed shoaling and swimming nose to tail along a fixed circuit over a sward of Ceratophyllum sp. in lake B during late June (water temperature also 21°C). Finally, in 1976, 1 female and 4 male tench in spawning condition were caught by anglers from lake A between 18 and 22 June (water temperature 23 to 24°C).

(v) Crucian carp

Crucian carp were introduced to lake A several times between 1970 and 1974; the stock fish were generally >200 mm and probably sexually mature (Wheeler and De Heaume, 1969). Inspection of the scales from 6 crucian carp of varying size suggested that the carp reached approximately 50 mm by year 1 and 120 to 150 mm at 3 years; one carp of 200 mm was assessed as 5+ years.

Length/weight regressions were calculated for June, July and August 1975 and for June and July 1976 (Appendix 8).

Sufficient numbers of marked crucian carp were recaptured in August 1974 to allow for a reasonable estimate of the population, but subsequent estimates (Table 25) must be regarded as very approximate. Catches (by seine and angling) of crucian carp were much higher in 1974 than in 1975: 73 crucian carp were caught during the late summer, 1974 but only 41 during the whole summer season of 1975. There was however some spawning success in 1974 because 0+ carp were caught (Fig. 23) in February 1975.

Table 25 Crucian carp; estimated populations, densities and biomass. Lake A, 1974 to 1977.

Date size (mm)	Age group	Petersen (Bailey modification)	'Best' estimate	Density No. m^{-2}	$\hat{B}$ g m^{-2}
Aug. 1974					
115-164	3+	51 (19-127)	60	0.003	0.23
185-254		30 (12-75)	35	0.002	0.56
270-329		28 (11-70)	30	<0.002	1.09
Feb. 1975					
40- 70	1+	-	~50[1]	0.003	-[2]
>100		-	~85[1]	0.005	"
Jun-Jul.1975					
50- 60	1+/2	-	~50[1]	0.003	"
>100		-	~65[1]	0.004	"
Apr. 1976					
>100		-	~50[1]	0.003	"
Oct. 1976					
>100		-	~40[1]	0.002	"
Sept. 1977					
>100		-	~30[1]	<0.002	"

1. Estimates suggested from catch data.
2. Insufficient data.

Approximate 95% confidence limits in parentheses.

Spawning male crucian carp were caught by anglers from lake A between June and August (1975 and 1976).

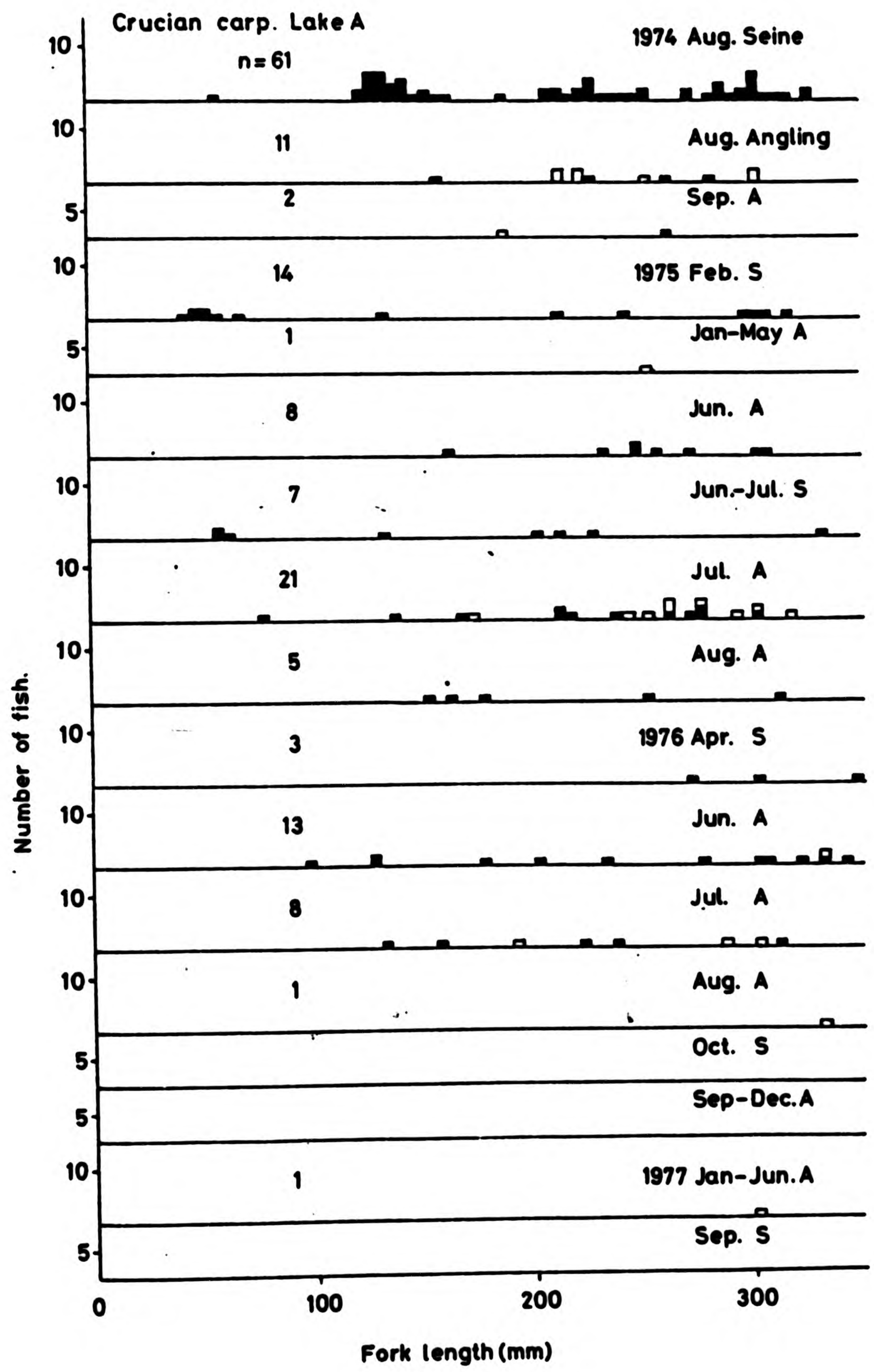


Fig. 23 Length/frequency histograms for lake A crucian carp caught by seine (S) and angling (A), 1974 to 1977. Unshaded blocks represent fish with mouth damage.

Spawning male crucian carp were caught by anglers from lake A between June and August (1975 and 1976).

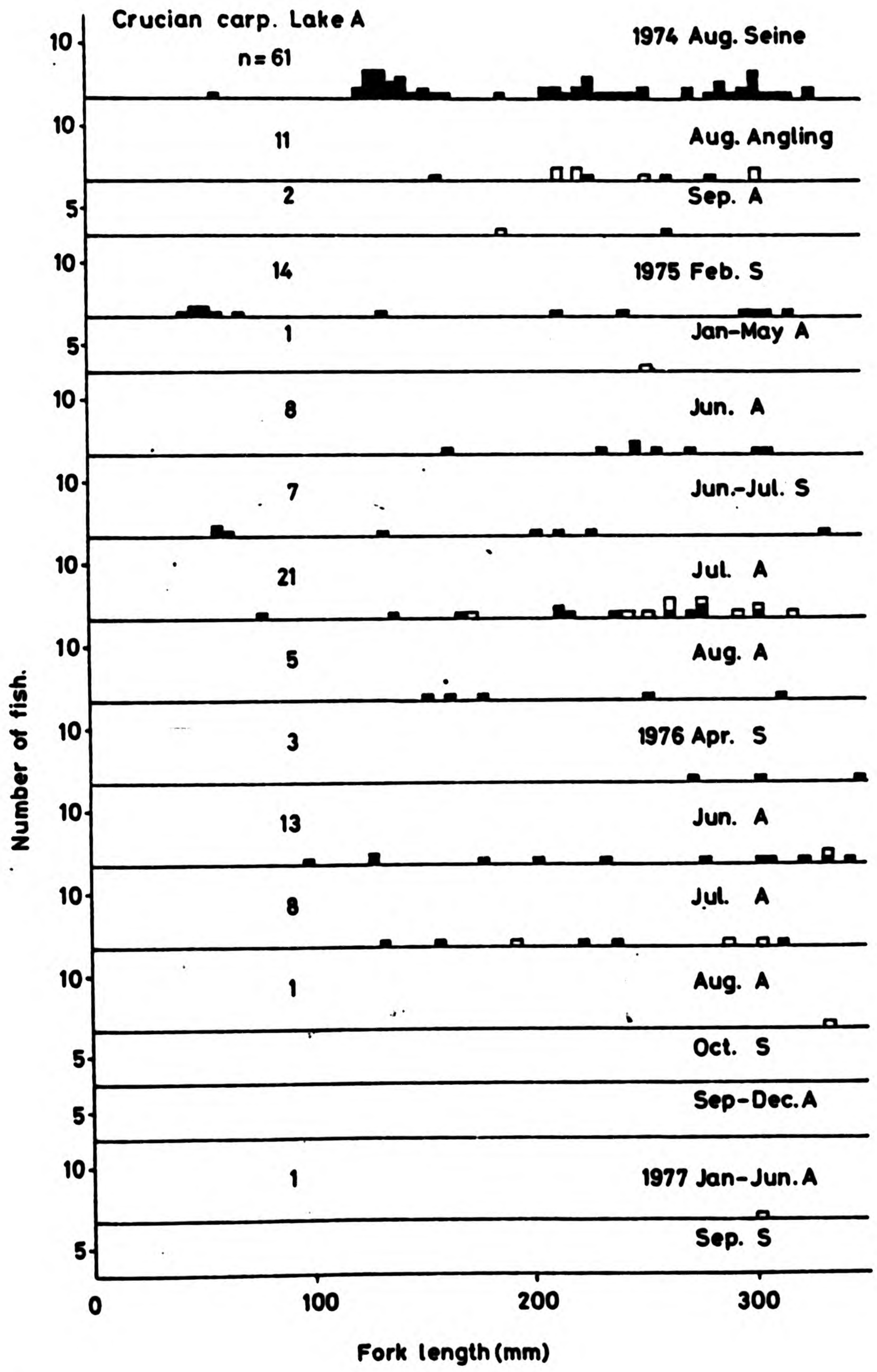


Fig. 23 Length/frequency histograms for lake A crucian carp caught by seine (S) and angling (A), 1974 to 1977. Unshaded blocks represent fish with mouth damage.

(vi) Common carp

Common carp were stocked into both lakes at Barham (Table 32; Fig. 24) but only 15 carp were caught from lake A during this study and there was no evidence of reproduction. Lake B received many more stock carp and immediately after their introduction a number were captured by angling (Fig. 24); interestingly, after their introduction the water clarity of lake B was markedly reduced.

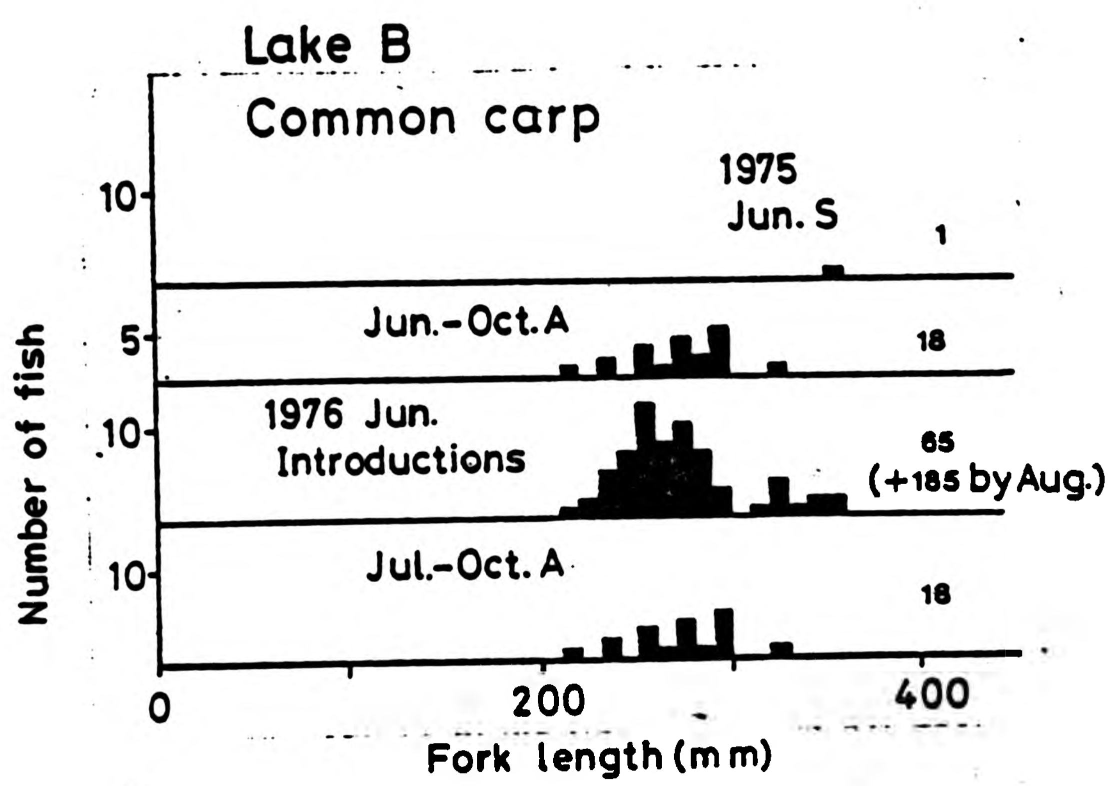


Fig. 24 Length/frequency histograms for lake B common carp caught by seine (S) and angling (A) and stock carp, 1975 to 1976.

(vii) Perch

Perch were relatively uncommon in the lakes between 1974 and 1977 although, according to angling society records, they had previously been abundant.

Opercular bones and scales, principally the former, were used to assess the age of perch. The following simple body length/operculum relationship was derived from data for lake A perch:

FL (mm) = 1.8166 Op   r = 0.9852 n = 22

where Op = opercular height (mm).

The above relationship was employed during the back-calculation of lengths at year 1 for the 1974, 1975 and 1976 year classes (Table 26).

Table 26 Mean back-calculated lengths of lake A perch at year 1

Year Class	Mean FL (mm) at year 1	s	n
1974	69	10.3	2
1975	79	10.0	6
1976	65	15.1	3

s = standard deviation

By the end of their second summer (see Fig. 25) lake A perch had a mean fork length of 102 mm (n = 37). Data were too few to justify the production of a growth curve. Lake B perch from the 1974 to 1976 year classes grew similarly (Fig. 26).

Length/weight regressions were calculated for lake A perch (Appendix 8).

Perch stocked into lake A in October 1975 had virtually disappeared from catches by the following autumn, but a strong 1976 year class was produced and it was still evident in September 1977. Perch populations in both lakes were strongly biased towards young (0+ to 2+) fish (Table 28; Figs 25 and 26).

Mortality and survival for the 1976 year class of lake A perch between October 1976 and September 1977 was as follows:

Z = 1.93   S = 0.14

More general estimates from Table 28 data for 1+ to 2+ perch were of the same order:

Z = 1.82   S = 0.16

Table 27 Perch; estimated populations, densities and biomass. Lake A, 1974 to 1977.

Date Size (mm)	Age group	Petersen (Bailey modification)	Bell (1974)	Triple (Bailey or Schnabel)	'Best' estimate	Density No. m^{-2}	$\hat{B}$ g m^{-2}
Aug. 1974							
60- 94	0+	-	30	-	125[1a]	0.006	0.055
95-220	>1				25[1b]	0.001	0.163
Feb. 1975							
65- 90	0+		25		100[1c]	0.006	0.045
Jun-Jul.1975							
85-130	1+	-	-	-	100[1d]	0.006	0.137
Apr. 1976							
75-109	1	255 (93-638)		521 (271-1097)	500	0.029	0.311
120-199	2		250		200	0.012	0.886
75-199	1-2	335 (122-839)		787 (409-1656)	700	0.040	
Oct. 1976							
50- 94	0+	2656 (1380-5592)		2656 (1647-4520) 896[2]	1800	0.107	0.356
95-150	1+				100	0.006	0.075
Sep. 1977							
50-85	0+	-	-	-	200[1e]	0.008	0.033
90-115	1+	257 (78-466)			260	0.015	0.189
120-135	2+				35		0.058

1. Estimates largely based on proportional calculation:

   a: with roach 75-109 mm;
   b: with roach 75-279 mm;
   c: with rudd 70-130 mm;
   d: with rudd;
   e: with 1+ perch

2. Bailey triple catch.

Table 28 Perch; numbers caught in age groups by seine and angling. Lake A, 1974 to 1977.

Year of capture		No. and % in age groups				Total (100%)
		0+	1+	2+	3+ and over	0 to 2+
1974-5	n	18	5	4	(7)	27
	%	66.7	18.5	14.8		
1975-6	n	0	63	5	(2)	68
	%	0	92.6	7.4		
1976-7	n	302	121	10	(57)	433
	%	69.7	27.9	2.3		
1977-	n	15	37	5	(9)	57
	%	26.3	64.9	8.8		
Mean %		40.7	51.0	8.3		

Relative year class strengths:

Year class	Relative strength
1973	43.7
1974	161.6
1975	36.7
1976	146.8

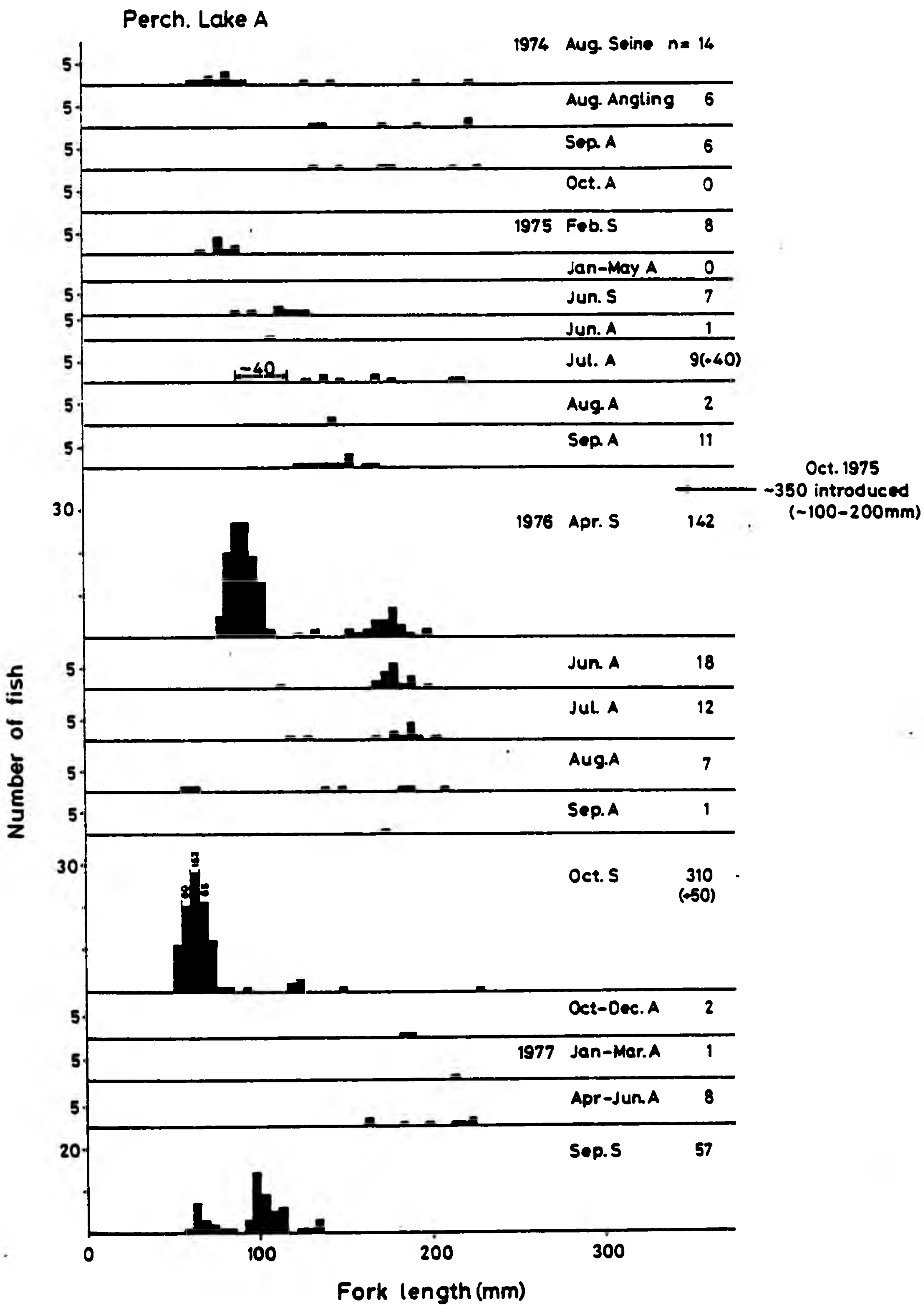


Fig. 25 Length/frequency histograms for lake A perch caught by seine (S) and angling (A), 1974 to 1977. Unshaded blocks represent fish with mouth damage.

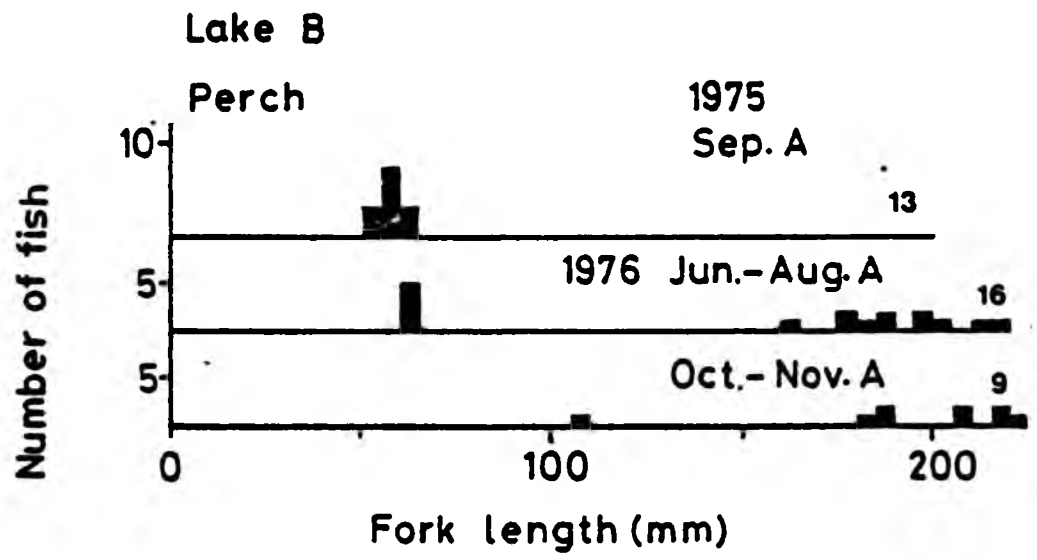


Fig. 26 Length/frequency histograms for lake B perch caught by angling, 1975 and 1976.

Many young perch caught from lake A between 1974 and 1977 had skin ulcers (lesions) while numbers of older fish had diseased fins.

Chironomid larvae and crustacean zooplankton were the principal gut contents of the perch examined (Table 13).

(viii) Pike

Only one pike was taken from lake A by angling during the census, but a number (54) were caught by seine (Fig. 27). Examination of their scales indicated that most were <4 years. The following body/length/scale relationship was derived from lake A pike data:

$$\mathrm{Log}_{10}\,\mathrm{FL\ (mm)} = 1.986 + 0.6502\ \mathrm{Log}_{10}\,\mathrm{Sr} \qquad r = 0.9681,\ n = 9$$

and used to back-calculate lengths-at-age for the first three years of life (Table 29).

Table 29 Back-calculated mean lengths-at-age for lake A pike. (Composite)

Age (years)	Mean FL (mm)	s	n
1	158	36.5	7
2	251	36.7	5
3	359	25.6	5

Several large pike were caught from lake A: in 1975 a pike of 1010 mm (7+) was taken by seine, then in 1977 another (the same pike?) of 1070 mm was caught by the same method and aged at 9+ years. During April 1976 two different pike (both >1000 mm) were seined on the same day from lake A, one at least may have been introduced earlier in the month. A very large pike (13 kg) was caught by an angler fishing lake A at night during September 1978.

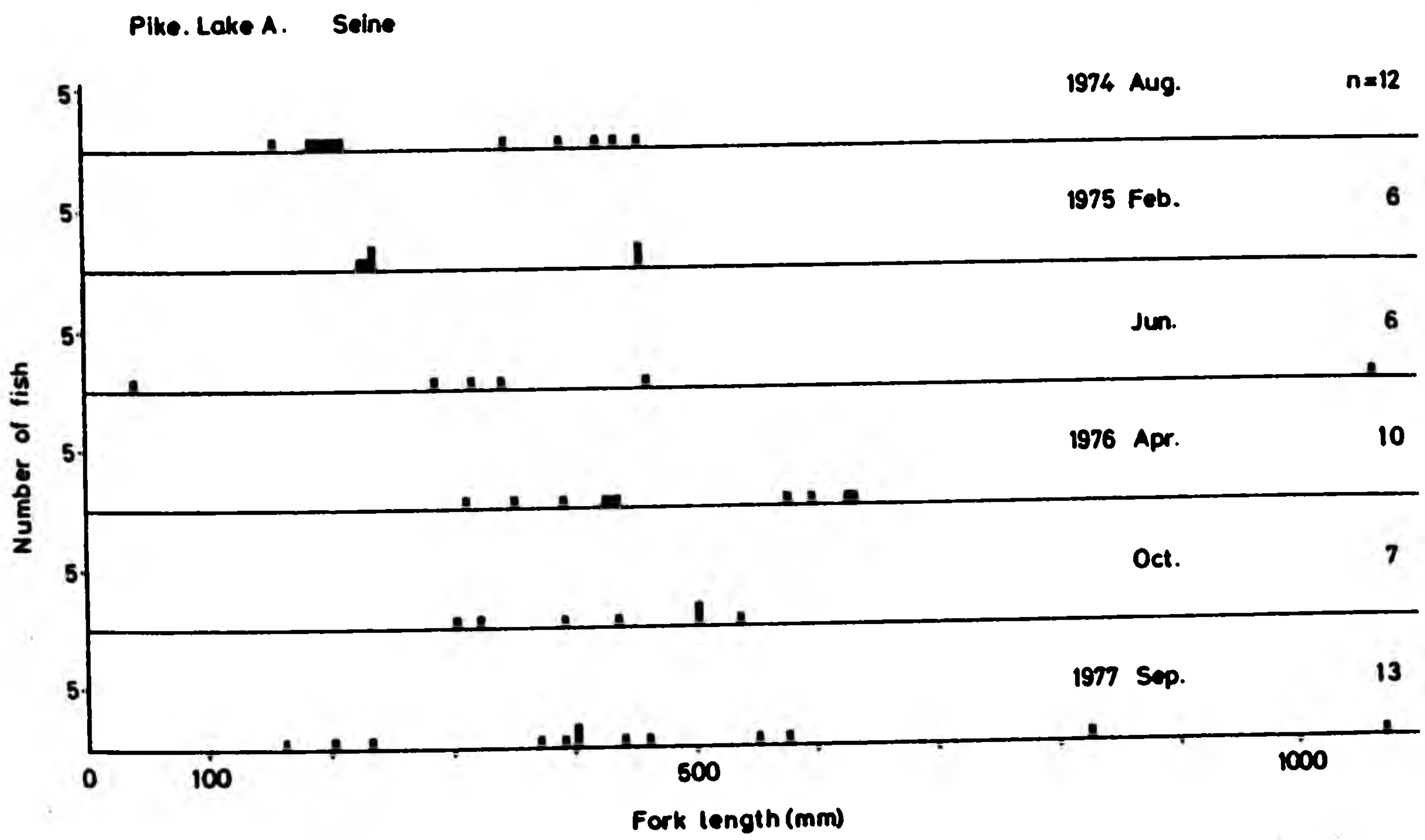


Fig. 27 Length/frequency histograms for lake A pike caught by seine, 1974 to 1977.

Table 30 Capture/recapture of tagged pike by angling. Lake A 1972 to 1977.

256 Date	FL	304 Date	FL	258 Date	FL	315 Date	FL	306 Date	FL
12.72	635	12.73	755	12.72	545	1.76	785	1.74	915
11.73	620	12.74	810	11.73	635	10.77	785	10.74	990
12.73	620	12.75	810[1]	12.73	635			6.75	1010[2]
12.75	695	12.75	810[1]	11.74	723				
12.75	695	9.77	825[2]	1.75	735				

FL = Fork length (mm)

1. caught twice on same day
2. taken by seine net.

A pike angler who fished the lakes regularly during the autumn and winter jaw-tagged the pike that he caught and some of his data are given in Table 30; despite the presence of a tag some of the pike grew considerably.

A length/weight regression was calculated (see below) from lake A data for pike < 575 mm, and used during the estimation of biomass (Table 31).

$$\text{Log}_{10}\, w = -5.8651 + 3.2889\ \text{Log}_{10}\, FL \qquad r = 0.9908,\ n = 18$$

where w = weight, g
and FL = fork length (mm).

The population estimates obtained for lake A pike were considered to be unrealistic, therefore, biomass estimates were based on the number caught by seine (Fig. 27) plus those reported by an angler (Table 30), excluding recaptures, with an allowance of one 10 kg pike for each estimation point, if one was not actually caught.

Two pike (one approximately 1000 mm with a swollen abdomen - female (?), the other approximately 700 mm - male (?)) were seen alongside each other in the shallows of lake A amongst dead *Typha* stems on 5 April 1975; the water temperature was 5.2°C, they were probably about to spawn.

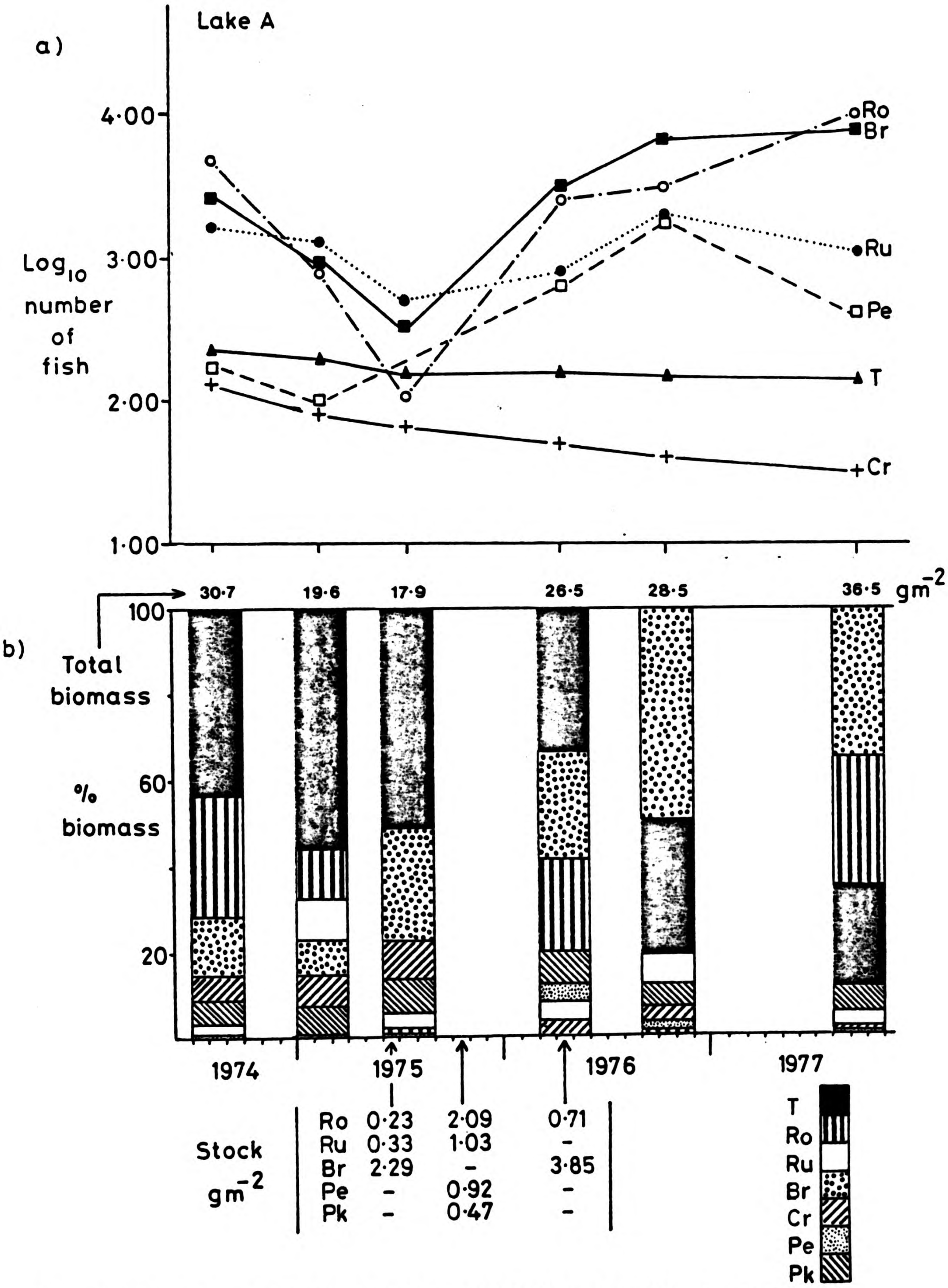


Fig. 28 a) Log_{10} estimated numbers of fish vulnerable to angling in lake A, 1974 to 1977; b) estimated total biomass, % contribution of species to total fish community biomass and biomass of stock fish; lake A, 1974 to 1977.

3.2 Biomass and production

Estimates of biomass ($\hat{B}$) or standing crop for the main elements of the lake A fish community are given below (Table 31). The data is reproduced in Fig. 28b with principal stock introductions and changes in population number (Fig. 28a).

Table 31 Fish community biomass estimates (gm^{-2}). Lake A.

Date		Rudd	Roach	Bream	Tench	Cru. carp	Perch	Pike[2]	Total
1974. Aug.	$\hat{B}$	1.16	8.57	4.33	12.97	1.88	0.22	1.61	30.74
	%	3.8	27.9	14.1	42.2	6.1	0.7	5.3	
1975 Feb.	$\hat{B}$	1.96	2.19	1.56	(11.00)	(1.50)	0.05	1.34	19.60
	%	10.0	11.2	8.0	56.1	7.7	0.3	6.8	
1975 Jul.	$\hat{B}$	0.57	0.23	4.68	9.36	(1.50)	0.14	1.44	17.92
	%	3.2	1.3	26.1	52.2	8.4	0.8	8.0	
1976 Apr.	$\hat{B}$	1.06	5.99	6.85	9.43	(1.00)	1.20	2.09	26.53
	%	3.8	21.7	24.8	34.1	3.6	4.3	7.6	
1976 Oct.	$\hat{B}$	1.89	0.32[1]	14.01	(9.00)	(1.00)	0.54	1.69	28.45
	%	6.6	1.1	49.3	31.6	3.5	1.9	5.9	
1977 Sept.	$\hat{B}$	1.17	11.07	12.35	8.72	(0.70)	0.28	2.23	36.52
	%	3.2	30.3	33.8	23.9	1.9	0.8	6.1	

Note: 1. October 1976 roach estimate unrealistically low.
2. Minimal estimates based on numbers caught (see 3.1 (viii))

The numbers in parentheses are interpolations and acknowledge an existing population.

Conversion: $1.0\ g\,m^{-2} \equiv 10\ kg\ ha^{-1}$

Tench, as relatively small numbers of large old fish (see 3.1 (iv)), supplied the major part of community biomass until 1976 and 1977 when young bream and roach became dominant. Rudd, crucian carp, perch and pike were minor contributors to community biomass.

Changes in community biomass appeared to occur as a result of stocking undertaken by the angling society between 1969 and 1976.

Unfortunately, the records of stock introductions for the period 1969 to 1974 were approximate (see Table 32), however, from 1975 on introductions were carefully documented (Table 33) and many of the stock fish were marked before release into the lakes. The numbers of fish stocked from 1975 on and their approximate size ranges are also shown on the length/frequency histograms.

Table 32 Numbers of fish stocked into lake A, 1969 to 1974

Species and size range		1969	1970	1971	1972	1973	1974
Rudd	100 - 150 mm	8000	700	250	-	-	100
	100 - 200 mm	-	1000	-	-	-	-
Roach	100 - 150 mm	-	50	-	-	-	-
	100 - 200 mm	-	-	7500	-	-	-
Crucian carp	100 - 150 mm	-	-	-	-	-	-
	150 - 250 mm	-	355	30	-	-	-
Tench	0.7 - 1.5 kg	-	310	-	-	10	-
Bream	0.5 - 1.0 kg	-	100	-	-	-	-
	up to 0.3 kg	-	-	-	-	1200	-
Common carp		-	-	-	1(4 kg)	-	-
	up to 0.7 kg	-	-	-	-	-	50

In terms of biomass some of the early stockings were heavy, e.g.

Tench (1970) 17.2 g m^{-2}

Bream (1970, 1973) 2.9 and 6.9 g m^{-2}

Crucian carp (1970) 9.0 g m^{-2}

The above are only rough estimates of the biomass stocked.

In 10 months covering part of 1975 and 1976 105 kg of bream were stocked into lake A (Table 33 and Figs. 28 and 29), this was the heaviest reliably recorded stocking (i.e. 6.1 g m^{-2}) for the lake. Common carp were stocked into lake B during the summer 1976 (Fig. 24) at approximately the same level (i.e. 6.2 g m^{-2}; 250 carp at mean weight 570 g). The effect of stock fish on angling success is considered later (section 3.3).

Table 33 Fish stocked. Lake A, 1975 to 1976.

	Bream		Roach			Rudd		Perch	C. carp
	1975 Jun.	1976 Apr.	1975 Jun.	1975 Oct.	1976 Apr.	1975 Jun.	1975 Oct.	1975 Oct.	1976 Aug.
Number stocked	207	1017	76	350	283	112	300	∿350	50
Size range (mm)	100-250	50-270	80-185	162+	100-204	70-220	96-202	100-175	210-360
Stock fish biomass (kg)	39.8	64.7	4.0	36.3	12.4	5.7	18.0	∿16	∿29
Stocking density									
(a) g m^{-2}	2.29	3.85	0.23	2.09	0.71	0.33	1.03	∿0.92	∿1.7
(b) no. m^{-2}	0.0121	0.0605	0.0044	0.0201	0.0163	0.0064	0.0172	∿0.0201	0.0030
$\hat{B}$ before stocking g m^{-2}	<u>1.56</u>	2.17-3.00	low	<u>0.23</u>	2.3-5.3	0.23-<u>0.57</u>	<u>0.57</u>	∿<u>0.14</u>	0.5-1.0
$\hat{B}$ after stocking g m^{-2}	3.85-<u>4.68</u>	6.02-6.85	<u>0.23</u>	2.32	3.0-<u>6.0</u>	0.9	1.60	1.06-1.20	∿3.5

1. Numbers underlined are $\hat{B}$ derived from mark-recapture population estimates.

Table 33 Fish stocked. Lake A, 1975 to 1976.

	Bream		Roach			Rudd		Perch	C. carp
	1975 Jun.	1976 Apr.	1975 Jun.	1975 Oct.	1976 Apr.	1975 Jun.	1975 Oct.	1975 Oct.	1976 Aug.
Number stocked	207	1017	76	350	283	112	300	~350	50
Size range (mm)	100-250	50-270	80-185	162+	100-204	70-220	96-202	100-175	210-360
Stock fish biomass (kg)	39.8	64.7	4.0	36.3	12.4	5.7	18.0	~16	~29
Stocking density									
(a) $g\ m^{-2}$	2.29	3.85	0.23	2.09	0.71	0.33	1.03	~0.92	~1.7
(b) no. m^{-2}	0.0121	0.0605	0.0044	0.0201	0.0163	0.0064	0.0172	~0.0201	0.0030
$\hat{B}$ before stocking $g\ m^{-2}$	<u>1.56</u>	2.17-3.00	low	<u>0.23</u>	2.3-5.3	0.23-<u>0.57</u>	<u>0.57</u>	~<u>0.14</u>	0.5-1.0
$\hat{B}$ after stocking $g\ m^{-2}$	3.85-<u>4.68</u>	6.02-6.85	<u>0.23</u>	2.32	3.0-<u>6.0</u>	0.9	1.60	1.06-1.20	~3.5

1. Numbers underlined are $\hat{B}$ derived from mark-recapture population estimates.

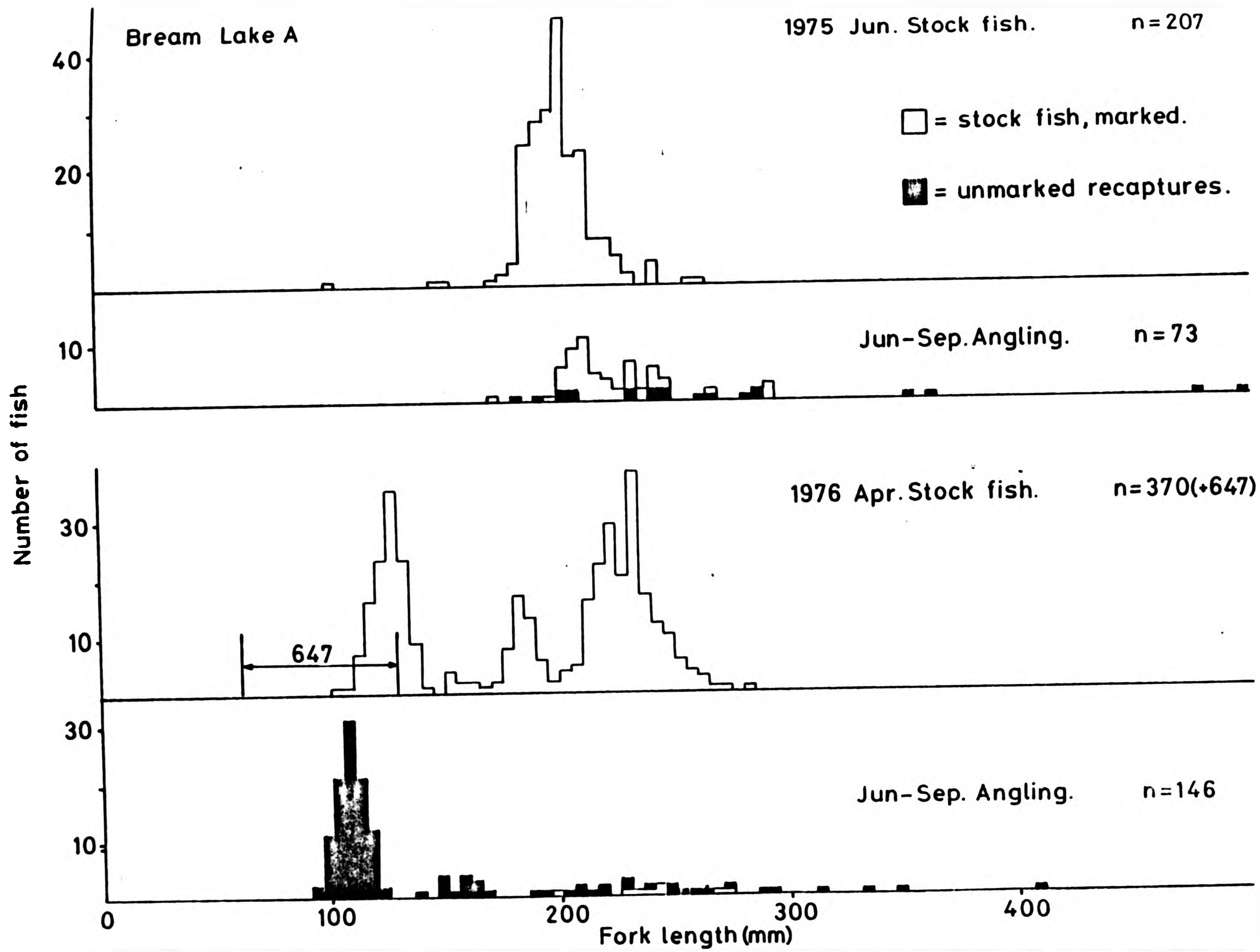


Fig 29 Length/frequency histogram of bream stocked into lake A and caught by angling, 1975 and 1976. Number of bream stated in parentheses were not individually measured.

Production for several species present in lake A was estimated ($\hat{P}$) in terms of biomass produced per unit area of lake surface (Table 34).

Table 34 Growth, estimated mean biomass and production. Lake A.

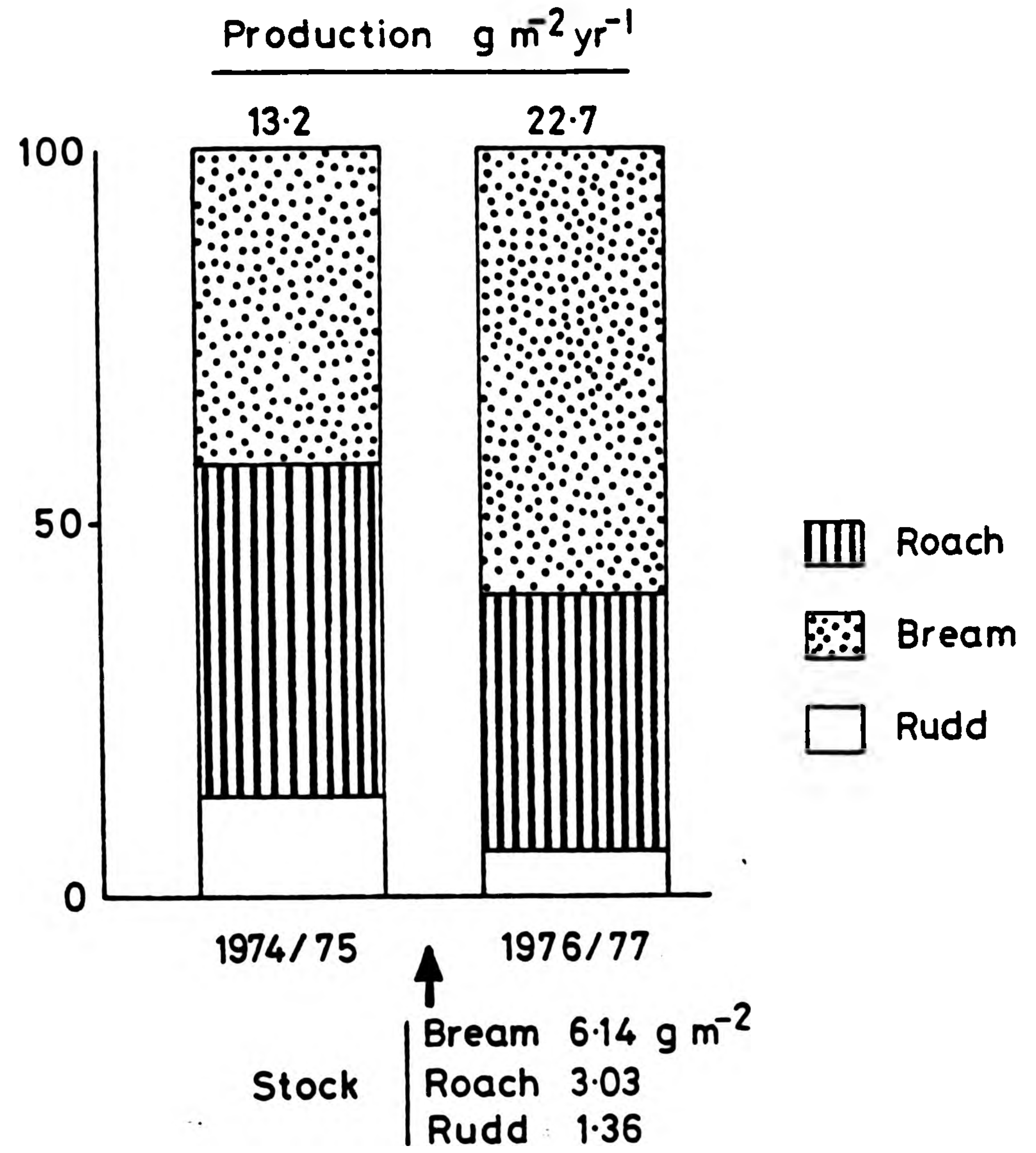
Species	Interval	Age group	G	$\bar{B}$ g m^{-2}	$\hat{P}$ g m^{-2}
Rudd	8/74 - 2/75	1+	2.29	0.76	1.73
	10/76 - 9/77	0-1+	1.72	0.19	0.33
	" "	1-2	1.90	0.50	0.94
Roach	8/74 - 2/75	1+	1.39	1.96	2.72
	" "	2+	1.22	2.07	2.53
	" "	3+	0.49	0.53	0.26
	" "	>3+	~0.43	0.82	0.35
	10/76 - 9/77	0-1+	1.45	5.37	7.78
Bream	8/74 - 2/75	1+	2.11	2.33	4.91
	" "	2+	1.57	0.43	0.67
	10/76 - 9/77	0-1+	2.74	1.59	4.36
	" "	1-2+	1.23	7.55	9.29
Tench					
Males	6/75 - 4/76	>7+	0.08	4.45	0.35
Females	" "	+	0.09	4.94	0.45
(>290 mm)					
Perch	8/74 - 6/75	0-1+	0.72	0.10	0.07
	10/76 - 9/77	0-1+	1.82	0.27	0.50

Note: $\bar{B}$ and P given in terms of fresh (wet) weight.

Best estimates of annual production for roach, rudd and bream were obtained by addition from data in Table 34 and used in the production of Fig. 30a. Production from 1974 to 1975 was probably underestimated but the relative contribution of the three species probably remains valid.

Annual production by the old tench stock and the 0+ to 1+ perch was low and the bulk of production was clearly attributable to the young (but >1 year) cyprinids.

a)



b)

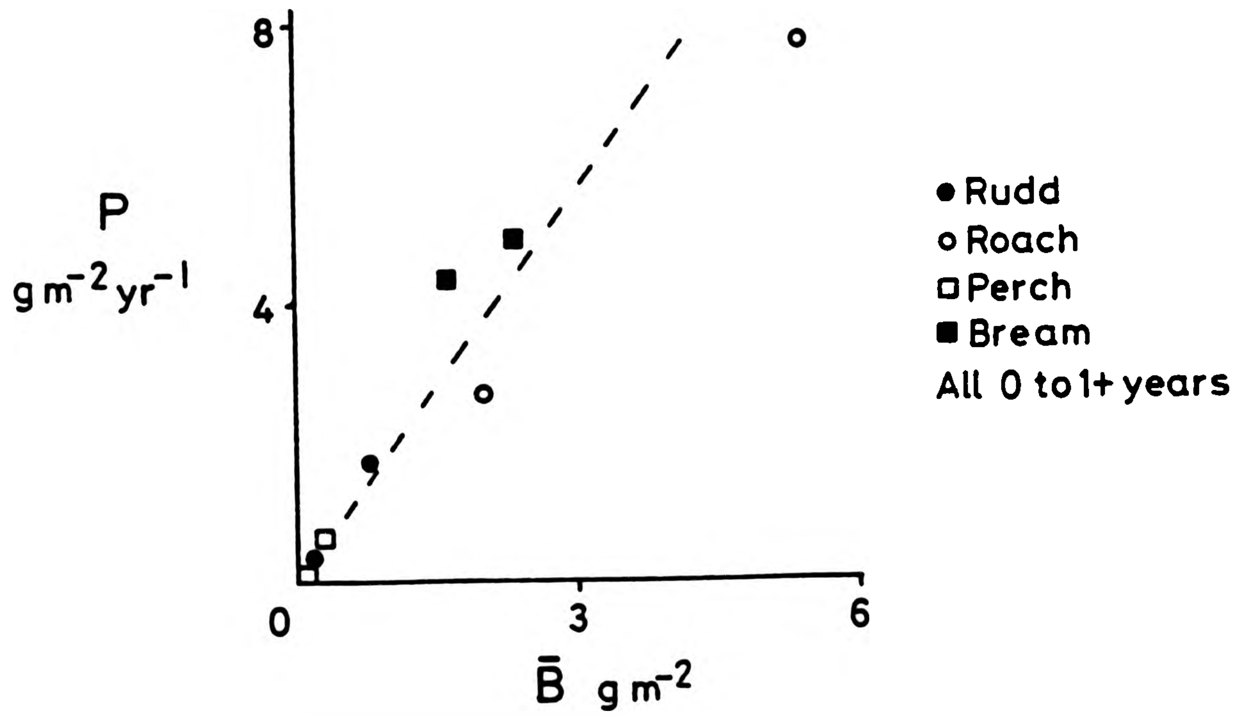


Fig. 30 a) Production by the dominant cyprinids (bream, roach and rudd) 1974 to 1975 and 1976 to 1977; lake A.
b) Production/biomass plot for 0 to 1+ cyprinids and perch (see Table 34) 1974 to 1977, lake A. Trend line fitted by eye.

Increased production after stocking (Fig. 30a) indicated a tendency for production to increase with biomass which was also demonstrated in the results for 0 to 1+ fish plotted as Fig. 30 b. The effect of stocking over production and the relationship between production and biomass is considered specifically in the next chapter.

3.3 Angling and the Fish

(i) Angling effort and catch

Anglers visited the lakes throughout the angling season but were only subjected to census on pre-selected days and match days (Table 35). Angling effort was concentrated on the summer months, with the number of visits by anglers, total observed and estimated angling effort at a maximum during July (Table 36), but only the last 15 days of June were 'open' for angling, therefore simple comparisons of effort for June with other months were not possible. On an effort per day basis angling was most intense during June (Table 37).

Table 37 Effort/day during the routine census. Lake A, 1975 and 1976.

	Effort/day (h)	
	1975	1976
Jun.	64.6	69.9
Jul.	46.0	40.3
Aug.	34.5	21.3
Sep.	20.3	17.8

Note: Data from Tables 35 and 36

The number of individual anglers encountered during the routine census of lake A in 1975 and 1976 totalled 341 and they made 404 recorded visits in 1975 and 285 in 1976 (June to September inclusive; see Table 36). The duration of an angling visit ranged from 2.2 to 5.2 hours in

Table 35 Census dates ; 1974 to 1977.

Year	Month	Dates	Total census days
1974	Aug.	12 14 16 18 20 24 25 26 31	9
	Sep.	1 3 5 7 8 12 13 14 15 17 19 21 22 29	14
	Oct.	5 6	2
1975	Jan.	18 25	2
	Feb.	1 8 15 22	4
	Mar.	1 8 22	3
	Apr.	5 19	2
	May	4 17 31	3
	Jun.	16 18 20 21 22 23 25 27 29	9
	Jul.	1 2 5 6 8 9 11 12 13 15 17 20 21 23 25 26 28 30	18
	Aug.	1 2 11 13 15 17 19 20 22 26 28 31	12
	Sep.	2 5 13 21 28	5
1976	Jun.	16 17 18 20 22 23 25 27 29 30	10
	Jul.	2 6 7 11 13 14 18 20 22 24 27 29	12
	Aug.	9 11 13 15 19 20 24 29	8
	Sep.	5 12 19	3
	Oct.	3 10 23	3
	Nov.	7 20	2
	Dec.	4 18	2
1977	Jan.	22	1
	Feb.	6 19	2
	Mar.	5 12	2
	Apr.	23	1
	May	1 8 22	3
	Jun.	5	1
		Total	133

1. Unboxed dates refer to census on both lakes.
2. ○ dates refer to Lake A census only.
3. ◌ dates refer to Lake B census.
4. ▣ dates of matches held on both lakes simultaneously.
5. □ match on Lake A; ⬚ match on Lake B.

Table 36 Summary census statistics with observed and estimated total angling effort. Lake A, 1975 and 1976.

	No. census days	No. angler visits	Mean visit time ± 95% CL (h)	Mean daily catch rate[1] ± 95% CL (catch h^{-1})	Observed angler effort in routine census (h)	Total[2] observed angling effort (h)	Total estimated angling effort ± 95% CL (h ha^{-1})
1975 Jun.	7	112	4.04 ± 0.34	0.5900 ± 0.5364	452.3	917.3	1087.9 ± 152.2
Jul.	12	166	3.34 ± 0.31	0.3590 ± 0.1532	552.5	1610.5	1646.8 ± 216.4
Aug.	10	108	3.22 ± 0.30	0.3790 ± 0.1432	344.8	398.8	1093.9 ± 254.3
Sep.	3	18	3.39 ± 0.84	0.9633 ± 0.8519	61.0	307.0	541.4 ± 102.4
	32	404		0.4725 ± 0.1348[3]	1410.6	3233.6	
1976 Jun.	8	148	3.85 ± 0.33	0.8400 ± 0.3617	558.8	733.8	1053.1 ± 212.8
Jul.	8	90	3.58 ± 0.34	1.0890 ± 0.4154	322.3	557.3	1271.0 ± 262.9
Aug.	5	39	3.35 ± 1.32	0.9660 ± 0.6504	106.5	206.5	590.0 ± 255.1
Sep.	2	8	4.49 ± 2.29	0.1500 -	35.5	119.5	451.8 ± 134.7
	23	285		0.8939 + 0.2182[3]	1023.1	1617.1	

Note: 1. Routine census only, excludes matches.
2. Includes match effort.
3. Applies to June to September inclusive.

Table 36 Summary census statistics with observed and estimated total angling effort. Lake A, 1975 and 1976.

	No. census days	No. angler visits	Mean visit time ± 95% CL (h)	Mean daily catch rate[1] ± 95% CL (catch h^{-1})	Observed angler effort in routine census (h)	Total[2] observed angling effort (h)	Total estimated angling effort ± 95% CL (h ha^{-1})
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	32	404		0.4725 ± 0.1348[3]	1410.6	3233.6	
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Note: 1. Routine census only, excludes matches.
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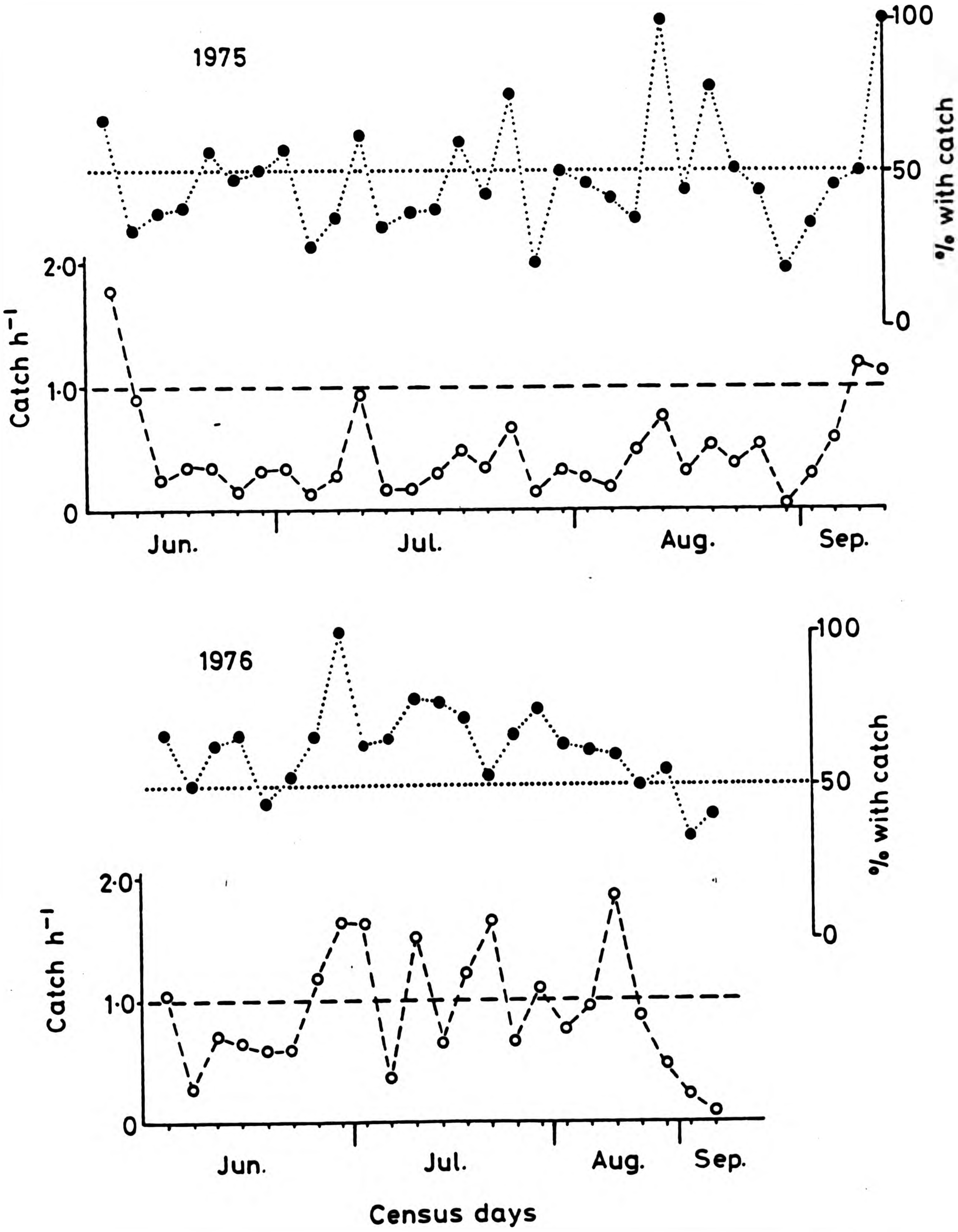

Fig. 31 Percentage of anglers with catch and overall catch rates for each day of the routine census; lake A, 1975 and 1976.

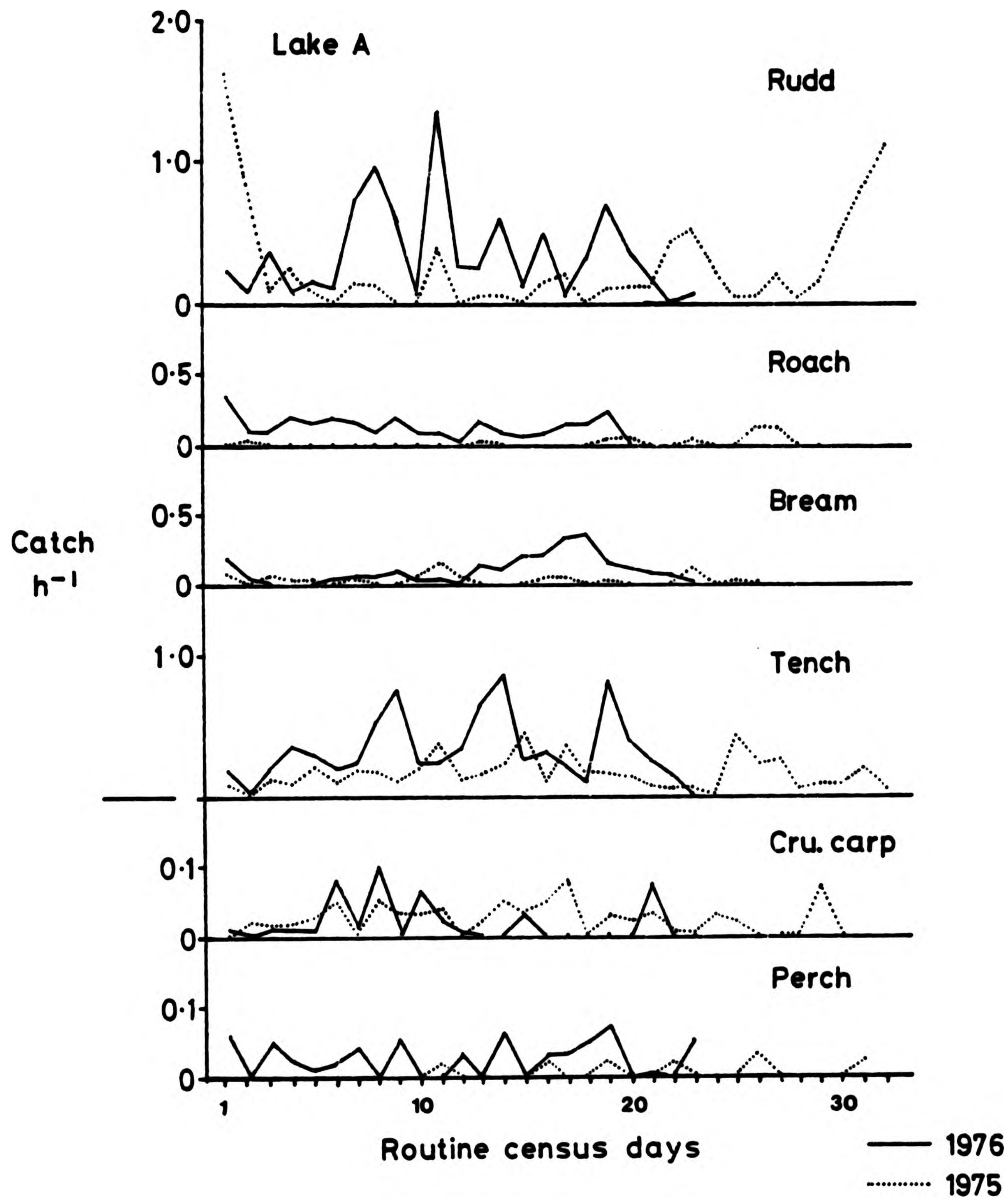

Fig. 32 Catch rates for the cyprinids and perch on each day of the routine census; lake A, 1975 and 1976

Table 38 Summary match angling statistics. Lake A, 1975 and 1976.

	No. anglers	Total effort h	Total catch	Catch rates. Catch h^{-1}						
				Ov.	TRu	TRo	TBr	TTe	TPe	TCr
1975										
Jun.22 A	44	220	30	0.14	0.08	0.00	0.01	0.04	0.00	0.01
" 29 A	49	245	11	0.04	~0.01	0.00	0.01	0.02	0.00	0.00
Jul. 5 A	42	168	18	0.11	0.07	0.00	0.01	0.02	0.01	0.00
" 6 A	39	195	8	0.04	0.01	0.00	0.005	0.02	0.00	0.005
" 12 A_2	20	80	5	0.06	0.00	0.00	0.01	0.04	0.00	0.01
" 13 A	44	220	41	0.11	0.03	0.00	0.04	0.04	0.00	0.00
" 20 A	40	200	70	0.35	0.21	0.005	0.05	0.08	0.01	0.005
" 26 A	39	195	26	0.03	0.09	0.00	0.02	0.02	0.005	0.00
Aug. 2 A_2	12	54	25	0.46	0.39	0.02	0.00	0.06	0.00	0.00
Sep.21 A	30	150	28	0.09	0.13	0.00	0.02	0.01	0.03	0.00
" 28 A_2	16	96	23	0.24	0.08	0.03	0.03	0.03	0.06	0.00
1976										
Jun.20 A_2	21	105	32	0.30	0.05	0.03	0.02	0.19	0.01	0.00
" 27 A_2	14	70	47	0.67	0.40	0.02	0.11	0.12	0.01	0.01
Jul.11 A_2	23	115	137	1.19	1.02	0.01	0.01	0.10	0.04	0.01
" 24 A_2	24	120	80	0.68	0.39	0.02	0.09	0.14	0.02	0.02
Aug.15 A_2	20	100	122	1.22	0.43	0.06	0.53	0.17	0.03	0.00
Sep.12 A_2	21	84	23	0.27	0.21	0.00	0.04	0.02	0.00	0.00

A_2 = Sector 2, Lake A

Key: Ov = Overall catch rate; TRu, Total rudd; TRo, Total roach, etc.

1975 and 2.2 to 7.8 hours in 1976 (June to September inclusive; see also Table 36 for further data.

Catch rates achieved by anglers are presented in Tables 36, 38, 39 and 40 and Figs. 31 and 32 in terms of catch per rod hour (catch h^{-1}). All the data presented indicates that angling was more successful in 1976 than in 1975. Factors affecting angling success are examined in Section 3.3 (iii).

Table 38 emphasises the intensity of angling effort on match days, when catch (and catch rates) were extremely variable.

The number of fish caught through the summer of 1975 and 1976 was generally related to effort (Fig. 33) but the correlation between catch and match effort was not statistically significant; catch/effort regressions (Table 41) were calculated and show that for the routine census, catch for effort was greater in 1976 than in 1975, supporting the evidence (see Fig. 28a) for a larger vulnerable fish population in 1976.

Table 39 Total reported catch/total observed effort. Lake A, summer 1975 and 1976.

	Routine census only catch h^{-1}		Routine census + matches catch h^{-1}		Matches only catch h^{-1}	
	1975	1976	1975	1976	1975	1976
Jun.	0.6279	0.7927	0.3510	0.7127	0.0817	0.4571
Jul.	0.4380	1.1139	0.2620	1.0336	0.1701	0.9234
Aug.	0.3799	0.8638	0.3862	1.0363	0.4259	1.2200
Sep.	0.7377	1.1408	0.3160	0.2343	0.2114	0.2738
Jun.Sep.*	0.4977	0.8787	0.3043	0.8268	0.1547	0.7374

Note: (i) Numbers of fish caught are recorded in Appendix 6.
(ii) Effort and number of census days from Tables 36 and 38.
* Inclusive.

Table 40 Summary test angler data. Lakes A and B, 1975 and 1976.

	Lake	Month	No. anglers	No. visits	Total effort (h)	Total catch	Overall catch h^{-1}
1975	A	Jun.	18	30	153.25	84	0.55
		Jul.	19	49	232.25	126	0.54
		Aug.	7	11	62.00	170	2.74
	B	Jun.	14	19	78.75	41	0.52
		Jul.	5	9	37.50	55	1.47
		Aug.	2	4	16.50	20	1.21
1976	A	Jun.	18	33	180.25	316	1.75
		Jul.	10	18	84.25	109	1.29
		Aug.	2	2	6.75	17	2.52
	B	Jun.	7	8	43.00	37	0.86
		Jul.	14	36	168.00	408	2.43
		Aug.	7	21	95.00	125	1.32

See Appendix 13 for details.

Table 41 Catch/effort regressions (restricted, X = Y = 0). Lake A 1975 and 1976.

	Slope	n	r	p
Routine census				
1975	0.4587	32	0.4659	<0.05
1976	0.8640	23	0.6359	<0.005
Matches				
1975	0.1688	11	0.2541	NS
1976	0.7441	6	0.5513	NS

NS = correlation not significant at $p < 0.05$

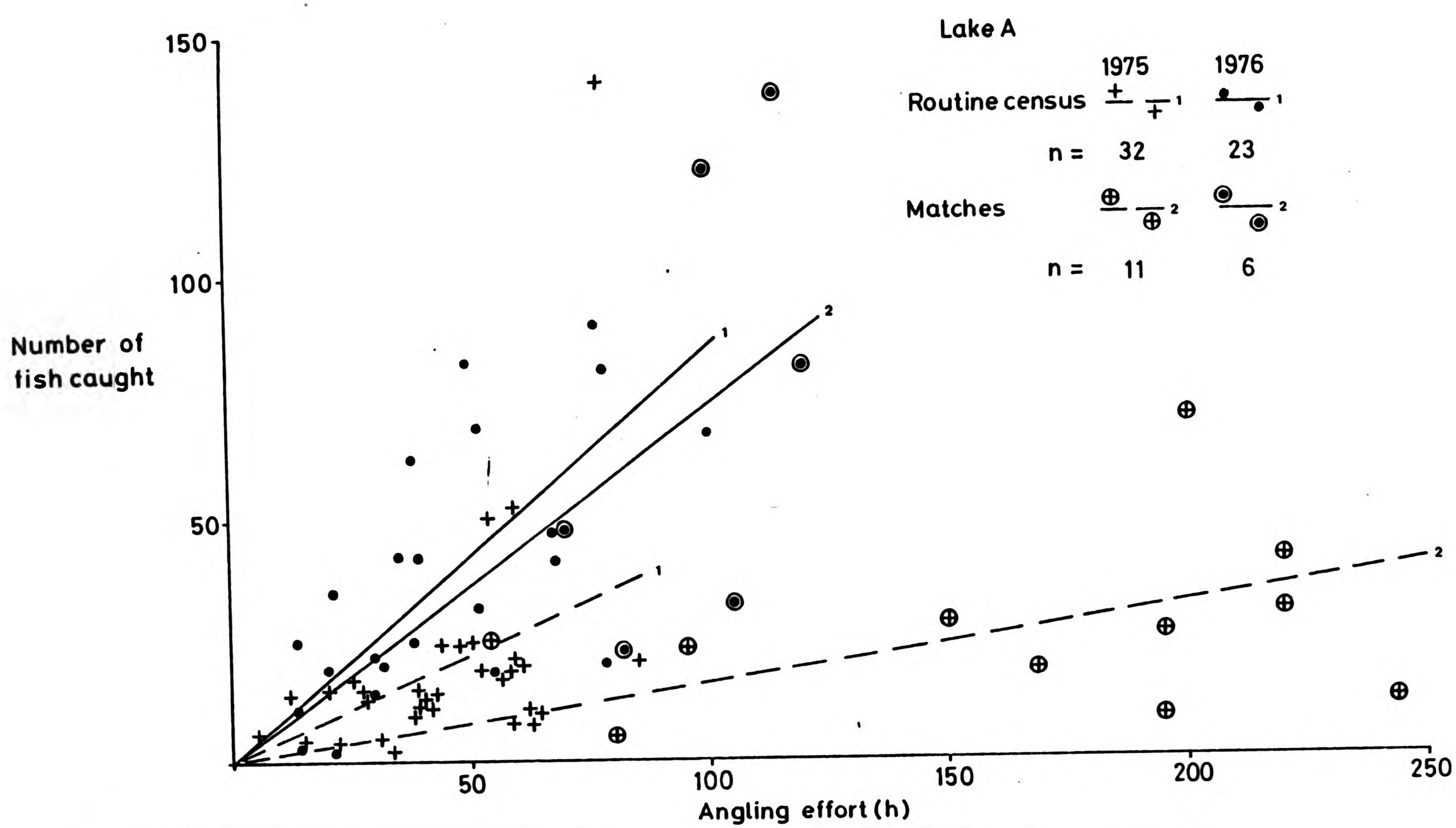

Fig. 33 Catch/effort relationships for the routine census and matches, 1975 and 1976.

In 1975, 42 anglers enlisted as Test anglers and only 4 failed to make a return, but in 1975 15 out of 47 defaulted. Test anglers returned 125 (34.2%) of the forms issued in 1975 and 118 (27.7%) in 1976. Effort was concentrated on the first two months of the angling season (Table 42) and Lake A was most popular with Test anglers in 1975 but not in 1976. Forms indicating that no fish were caught on a visit (i.e. blank returns) were included in the returns and indicated that at least some of the test anglers were prepared to record 'failures' as well as 'successes'.

Table 42 Test angler returns. Lake A and B, 1975 and 1976.

	Lake	Jun.	Jul.	Aug.	Sep.	Total	Blanks
1975	A	30 (32.3)	49 (52.7)	11 (11.8)	3 (3.2)	93 (74.4)	22
	B	19 (59.4)	9 (28.1)	4 (12.5)	0 (0)	32 (25.6)	9
Total		49 (39.2)	58 (46.4)	15 (12.0)	3 (2.4)	125 (100.0)	31
1976	A	33 (62.3)	18 (33.9)	2 (3.8)	-	53 (44.9)	5
	B	8 (12.3)	36 (55.4)	21 (32.3)	-	65 (55.1)	4
Total		41 (34.7)	54 (45.8)	23 (1-.5)	-	118 (100.0)	9

% in parentheses.

(ii) Angling techniques

The majority of anglers used rods of 3 to 4 m constructed from tubular glassfibre sections, with fixed-spool reels loaded with 0.5 to 1.5 kg breaking-strain nylon monofilament line. Almost all (99%) of anglers used terminal tackle that included some kind of streamlined float to indicate movements of the bait. The tackle was used to present baits on or close to the substrate in the littoral zone, but the baits passed through the mid-water zone where fish were often hooked.

Barbed hooks size 8 to 20 (Table 43) were used, but small hooks (size 14-18) were favoured by most anglers (Table 44). The effect of hook size over angling success is considered later.

Table 43 Hook sizes.

Hook size (Redditch scale)	External gape (mm)	Hook type
14	3.6; 4.0	Mustad RB; VMC C
16	3.1; 3.1	" "
18	2.8; 2.8	" "
20	2.2; 2.2	" "

Mustad RB = Mustad round-bend, straight eye.

VMC C = Viellard-Migeon crystal-bend, spade end.

Table 44 Hook sizes used by anglers. Lake A. 1975 and 1976.

		Hook sizes (Redditch scale)							Total number of observations
		8	10	12	14	16	18	20	
1975 Jun.	No.	2	2	3	22	38	24	5	96
	%	2.1	2.1	3.1	22.9	39.6	25.0	5.2	
Jul.	No.	1	5	18	43	78	21	2	168
	%	0.6	3.0	10.7	25.6	46.4	12.5	1.2	
Aug.	No.	2	7	9	29	43	11	0	101
	%	2.0	6.9	8.9	28.7	42.6	10.9	0.0	
Total		5	14	30	94	159	56	7	365
	%	1.4	3.8	8.2	25.8	43.6	15.3	1.9	
1976 Jun.	No.	5	5	14	25	54	30	7	140
	%	3.6	3.6	10.0	17.9	38.6	21.4	5.0	
Jul.	No.	1	3	8	21	41	7	2	83
	%	1.2	3.6	9.6	25.3	49.4	8.4	2.4	
Aug.	No.	1	2	4	6	12	8	4	37
	%	2.7	5.4	10.8	16.2	32.4	21.6	10.8	
Total		7	10	26	52	107	45	13	260
	%	2.7	3.8	10.0	20.0	41.2	17.3	5.0	

Table 45 Use of hook baits, ground baiting and terminal tackles during the routine census. Lake A, 1975 and 1976.

		Hook baits															Ground bait				Tackle			
		M	B	C	W	MC	BM	CW	CB	MW	BW	WBM	WMC	BMC	MW BC	Co.	0	1	2	3	F	L	F/L	n*
1975 Jun.	No.	35	3	2	0	13	23	1	1	3	1	12	3	6	6	0	1	62	46	0	106	2	1	109
	%	32.1	2.8	1.8	0	11.3	21.1	0.9	0.9	2.8	0.9	11.0	2.8	5.5	5.5	0	0.9	56.9	42.2	0	97.2	1.8	0.9	
Jul.	No.	56	37	4	5	8	33	0	1	2	3	3	0	3	2	0	24	81	51	1	155	0	2	157
	%	35.7	23.6	2.5	3.2	5.1	21.0	0	0.6	1.3	1.9	1.9	0	1.9	1.3	0	15.3	51.6	32.5	0.6	98.7	0	1.3	
Aug.	No.	25	34	1	4	5	21	0	1	5	2	4	0	1	0	0	22	52	25	2	95	8	0	103
	%	24.3	33.0	1.0	3.9	4.9	20.4	0	1.0	4.9	1.9	3.9	0	1.0	0	0	21.8	51.5	24.8	1.9	92.2	7.8	0	
Total	No.	116	74	7	9	26	77	1	3	10	6	19	3	10	8	0	47	195	122	3	356	10	3	369
	%	31.4	20.1	1.9	2.4	7.0	20.9	0.3	0.8	2.7	1.6	5.1	0.8	2.7	2.2	0	12.8	53.1	33.2	0.8	96.5	2.7	0.8	
1976 Jun.	No.	79	16	2	2	7	25	0	0	5	2	1	0	4	1	0	9	101	30	3	139	5	0	144
	%	54.9	11.1	1.4	1.4	4.9	17.4	0	0	3.5	1.4	0.7	0	2.8	0.7	0	6.3	70.6	20.9	2.1	96.5	3.5	0	
Jul.	No.	36	16	1	4	3	18	0	1	0	0	1	0	1	0	4	9	42	34	0	83	1	1	85
	%	42.4	18.8	1.2	4.7	3.5	21.2	0	1.2	0	0	1.2	0	1.2	0	4.7	10.6	49.4	40.0	0	97.6	1.2	1.2	
Aug.	No.	26	8	0	0	0	1	0	0	0	0	0	0	2	2	0	5	15	17	2	38	0	1	39
	%	66.7	20.5	0	0	0	2.6	0	0	0	0	0	0	5.1	5.1	0	12.8	38.5	43.6	5.1	97.4	0	2.6	
Total	No.	141	40	3	6	10	44	0	1	5	2	2	0	7	3	4	23	158	81	5	260	6	2	268
	%	52.6	14.9	1.1	2.2	3.7	16.4	0	0.4	1.9	0.7	0.7	0	2.6	1.1	1.5	8.6	59.2	30.3	1.9	97.0	2.2	0.7	

Baits: M = maggots
B = bread
C = caster(chrysalis)
W = worm

Co. = corn(maize)
MC, BM etc = combinations of baits used on a visit

Ground bait: 0 = not used
1 = light
2 = medium
3 = heavy

Tackle: F = float
L = ledger

n* = total anglers interviewed.

A range of baits were used: maggots/casters (respectively larvae and pupae of various Muscidae), bread (as crumb, crust or paste), earthworms and cooked maize fruits; however, maggots were used more than any other bait despite a tendency for anglers to use bread baits as the season progressed (Table 45). It was not practical to assess the quantity of ground bait introduced, but >70% of anglers admitted the use of ground baiting methods.

(iii) Fish caught by angling

All the species of fish known to be present in the lakes were caught by angling at some time (but see below for catchability characteristics of various species). The numbers of fish caught during the routine census, in matches and by Test anglers are tabulated (Tables 7, 38, 40 and Appendix 6). Most fish were caught early in the angling season (Table 46 below) when angling effort was at its height.

Table 46 % total number of fish caught during June and July. Routine census. Lake A.

	Rudd	Roach	Bream	Tench	Perch	Cru. carp
1975	72	21	84	80	79	85
1976	85	91	50	88	83	95

The size distributions of fish caught by angling are recorded as length/frequency histograms (see 3.1). Small fish were often caught (Table 47); perch became vulnerable during their first year (0+), roach, bream, rudd and tench during their second year (1+). Crucian carp were apparently not included in anglers' catches i.e. recruited into the fishery, until their third year (2+).

Table 47 Size and age of fish vulnerable to capture by angling. Lake A, 1974 to 1977.

	Fork length (mm)	Age (years)
Rudd	>55	1+
Roach	>75	1+
Bream	>85	1+
Tench	>55	1+
Perch	>50	0+
Cru. carp	>75	1+/2+

Interestingly, 1+ rudd were only partially recruited into the fishery by June 1975, but by June 1976 1+ rudd were fully recruited, emphasising the role of growth rate in determining the timing of recruitment.

The relationship between mouth gape and fork length was apparently linear and the regression parameters are given in Table 48; they suggest that for a given length the mouth size of young perch was approximately twice that of roach and bream (Fig. 34). Rudd appeared to have slightly larger mouths size for size than roach or bream.

Table 48 Mouth gape (mm)/fork length (mm) regressions (restricted, i.e. $X = Y = 0$) for 0+/1+ fish

Species	Slope	n	r
Rudd	0.0611	17	0.9750*
Roach	0.0501	13	0.9880*
Bream	0.0462	17	0.9450*
Perch	0.0995	17	0.9845*

* correlation significant at $p \leq 0.05$

See Appendix 11 for mouth and fork length measurements.

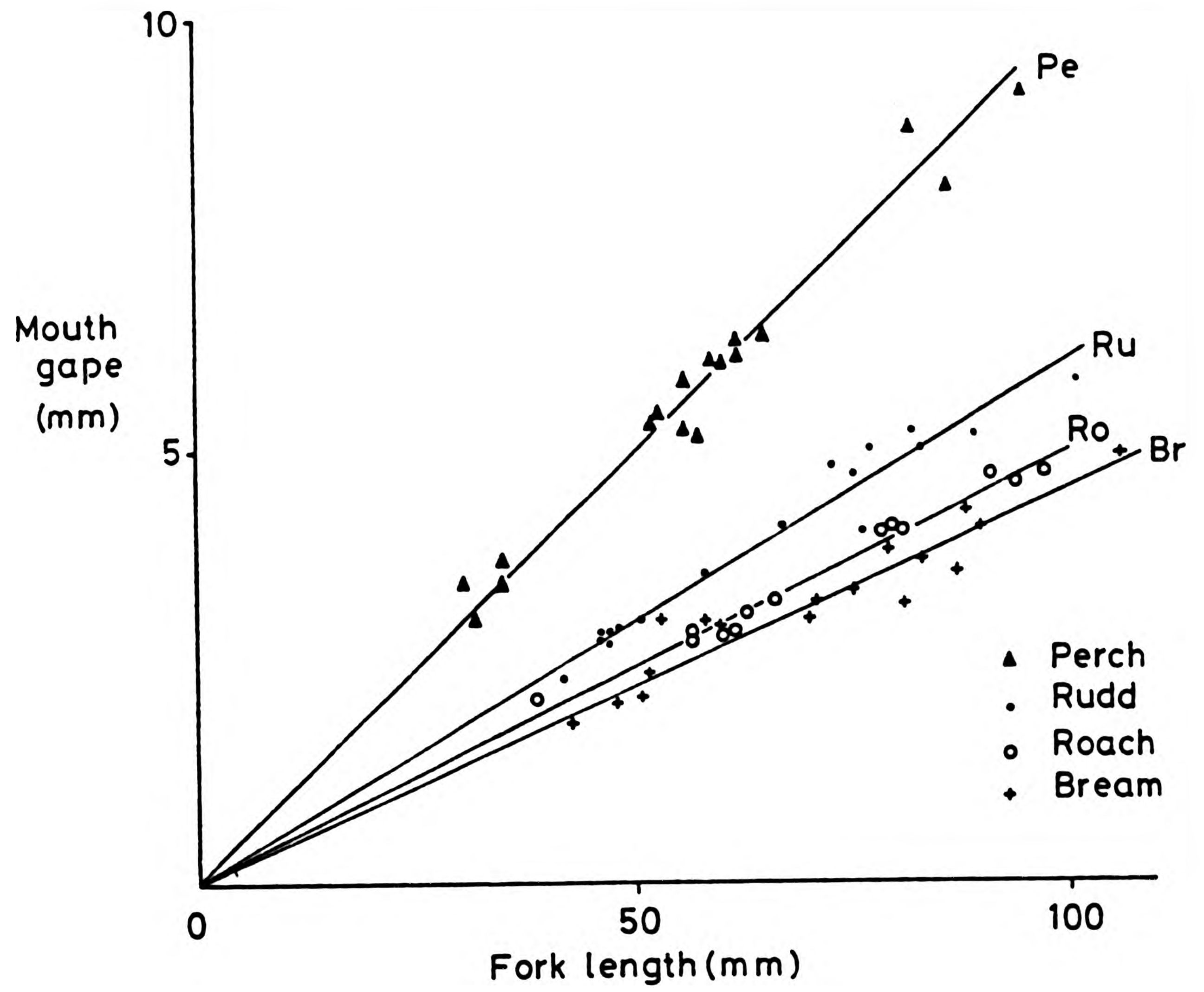

Fig. 34 Mouth gape/fork length relationship with fitted regression lines for perch, rudd, roach and bream.

Small hooks were generally used by anglers (Table 44) and substitution of the external gape of a size 16 hook (Table 43) into the mouth gape/fork length regressions (Table 48) suggested that the species concerned would become vulnerable to angling at the following lengths:

Rudd	∿ 51 mm
Roach	∿ 63 mm
Bream	∿ 67 mm
Perch	∿ 35 mm

The predicted length for recruitment therefore corresponded closely with the observed length for rudd (Table 47) but roach and bream were larger than expected at recruitment (see Discussion).

The mouth gape of 0+ cyprinids was not > 3 mm (the ∿ gape of a size 16 hook or diameter of a maggot bait) until late summer (Appendix 11) but 0+ perch had mouths of comparable size much earlier in the year (late spring).

Fig. 35 compares the size distribution of fish caught by test anglers with those caught by anglers fishing during the routine census and in matches. The comparison was only for two consecutive months in 1976 when data were most extensive, but the distributions were similar regardless of sampling method particularly for rudd. The capture of small roach and bream may have been more common during matches but mumbers were too small for valid comparison.

Fifty-two stock bream (Fig. 29) were caught during the routine census in 1975 from June to September inclusive, and comprised 71% of the total bream catch for the period. Test anglers also reported the capture of marked stock bream from lake A in 1975: 14 in June, 15 in July and 5 in August. Stocking is considered further later.

Comparison of the size of fish caught by seine net and angling suggested that the two methods were differentially selective. Plots of % catch against fork length (Fig. 36) show that angling was more effective than seine for the capture of large rudd, but oscillations in the size range 50-150 mm imply equal efficiency. However, rudd < 50 mm were only caught by seine. Roach up to 180 mm were caught most effectively by seine but angling appeared to be as effective for the capture of larger roach. Small bream and perch were only regularly caught by seine, but there was little difference between seine and angling for the capture of tench and crucian carp (Figs. 21 and 23).

In addition, the observed mean fork lengths of rudd caught by seine and angling (85 mm and 96 mm respectively), in August 1974 were compared and found to be significantly different ($d = 6.576$; $n = 186$, Angling; $n = 42$, Seine; $p < 0.001$) suggesting that angling selects the larger fish from the small size groups. However, with 1+ roach (August, 1974) the opposite effect i.e. angling selecting the smaller fish was observed but the data was poor ($t_{0.05} = 2.04$, $t' = 4.06$ significantly different at p 0.05; $n = 225$ Seine; $n = 17$, Angling).

The species composition of catches (excluding common carp and pike)

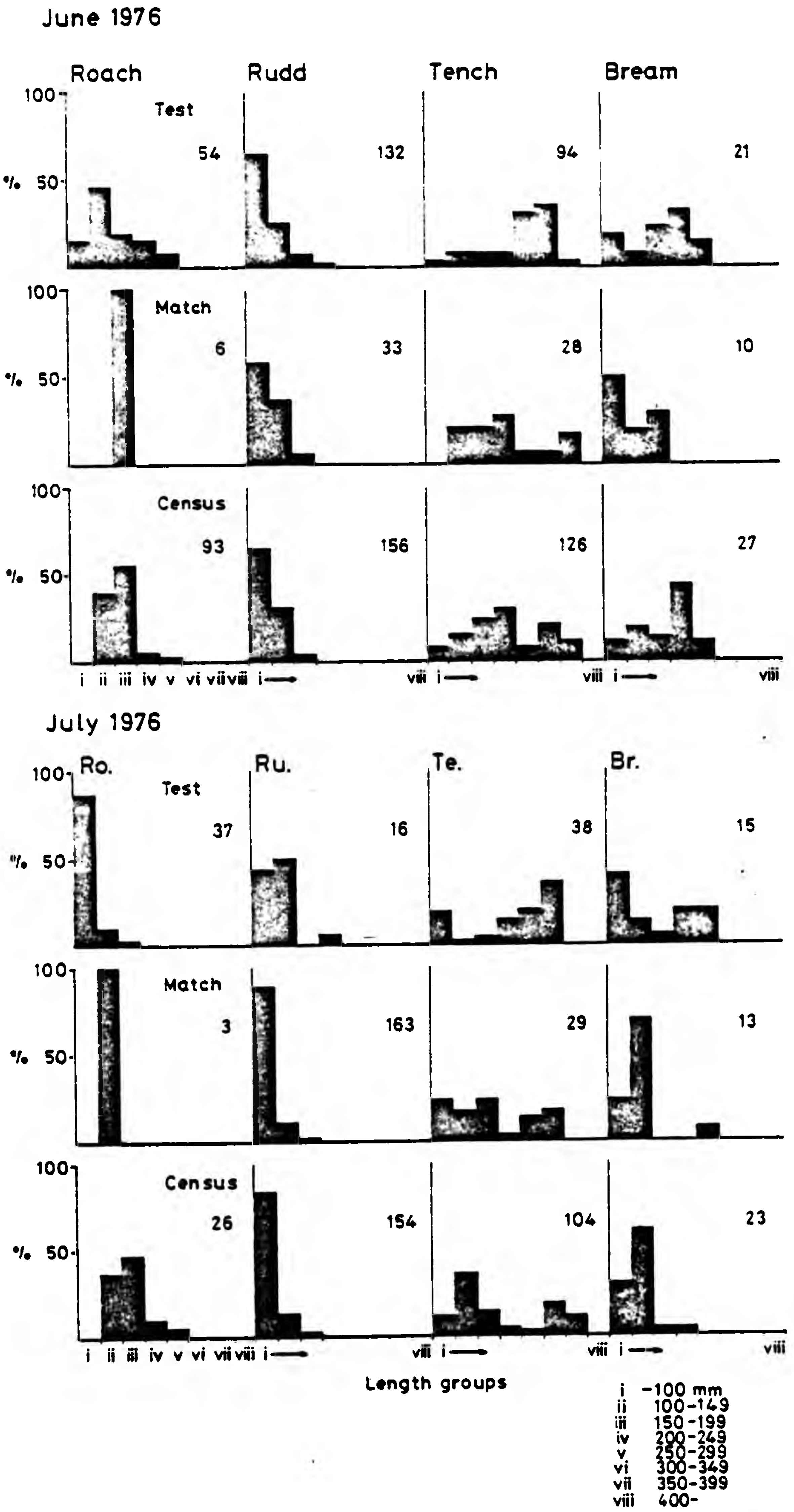

Fig. 35 Percentage length distributions; catches reported by test anglers and recorded for anglers fishing during the census and matches. Lake A, June and July, 1976.

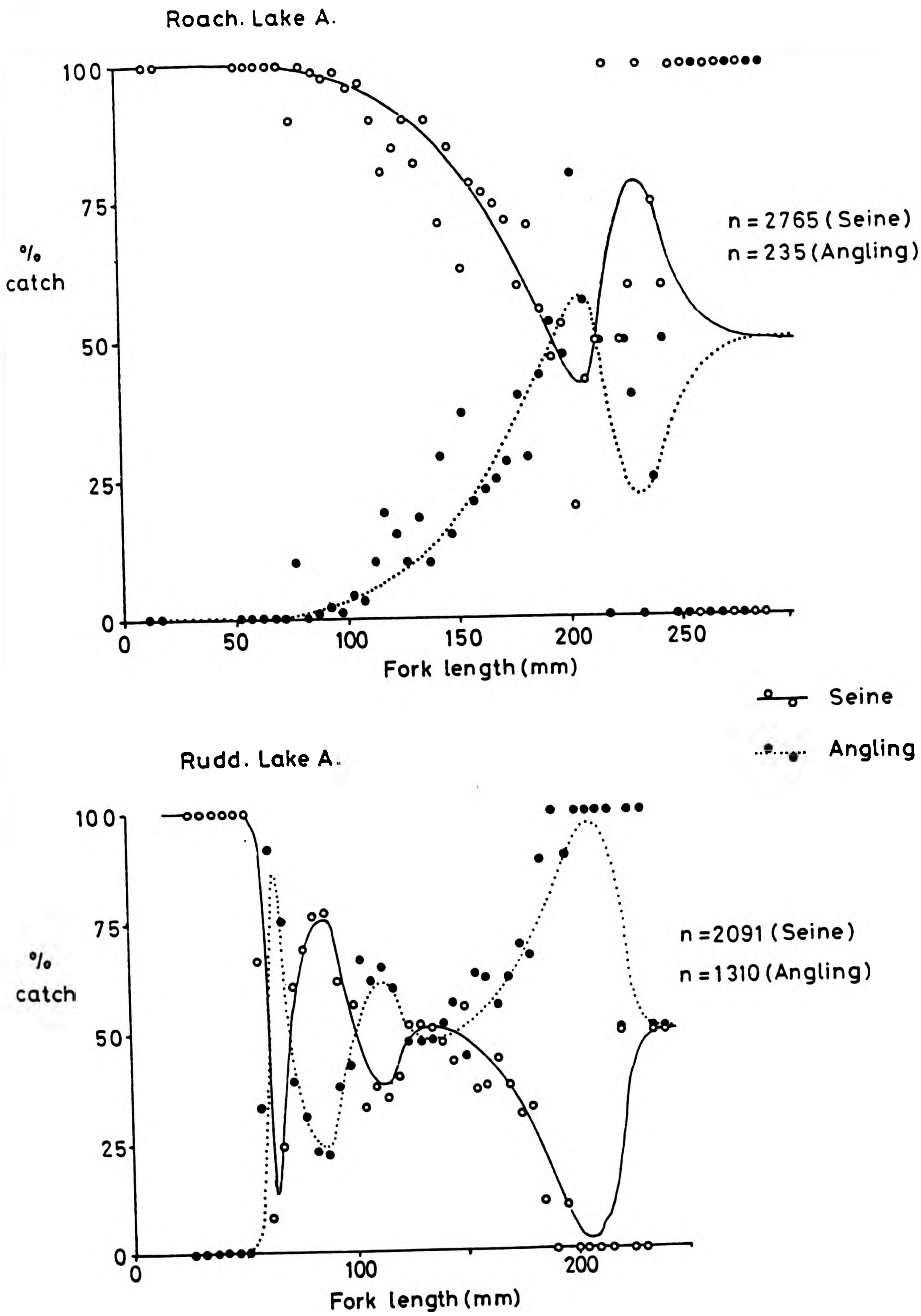

Fig. 36 Size (length) selectivity of methods of capture (seine and angling) for roach and rudd; lake A, 1974 to 1977.

made by angling and seine were compared by Chi^2 analysis (H_o = species composition of catch independent of capture method) for two occasions, August 1974 and June to September 1975, when sampling by angling and seine coincided. Observed Chi^2 = 875.05 (1974); 276.90 (1975) therefore the null hypothesis was rejected in both cases at $p < 0.001$ (5 df). Rudd were most frequently caught by angling and roach by seine on both occasions; bream were more prone to capture by seine in 1974 but in 1975 the difference was small. Tench, perch and crucian carp were not captured selectively consistently by either method.

Male and female tench (>280 mm) appeared to be equally vulnerable to capture by seine, except in April 1976, and angling (i.e. H_o = equal numbers of male and female tench in catch - was generally accepted at $p \leqslant 0.05$), see Table 49.

Table 49 Numbers of male and female tench (>280 mm) caught by seine and angling. Lake A, 1975 and 1976.

	Date	Number of tench		Observed Chi^2
		Male	Female	
Seine	1974 Aug	31	18	3.45
	1975 Feb.	3	4	0.14
	1975 Jun.	67	67	0.00
	1976 Apr.	35	15	8.00
	1976 Oct.	5	4	0.11
	1977 Sep.	30	25	0.46
Angling	1975 (Jun.-Sep.)	110	99	0.58
	1976 (Jun.-Sep.)	64	71	0.36

Actual Chi^2 = 3.84 at p = 0.05, 1 df.

The species composition of anglers' catches from lake A for June to September (inclusive) in 1975 was significantly different from that in the same period in 1976 (Observed Chi^2 = 86.6; Actual Chi^2 = 11.07 at p = 0.05, 5 df). The null hypothesis of no difference in the numbers or roach, rudd, bream, tench, perch and crucian carp caught in the two

Table 50 Monthly variation in species composition of anglers catches. Lake A, 1975 and 1976.

1975	Roach	Rudd	Bream	Tench	Perch	Cru. carp	Total
Jun.	1(4.7)	212(155.6)	19(24.7)	63(86.2)	1(21.3)	8(11.5)	304
Jul.	2(5.8)	118(190.9)	43(30.3)	140(105.8)	49(26.1)	21(14.1)	373
Aug.	9(2.2)	70(70.6)	5(11.2)	47(39.1)	2(9.7)	5(5.2)	138
Sep.	2(1.3)	60(43.0)	6(6.8)	5(23.8)	11(5.9)	0(3.2)	84
Total	14	460	73	255	63	34	899

Observed Chi^2 = 184.1

1976	Roach	Rudd	Bream	Tench	Perch	Cru. carp	Total
Jun.	81(47.4)	181(220.3)	37(59.7)	154(132.9)	18(14.7)	13(9.0)	484
Jul.	24(48.2)	279(224.0)	36(60.7)	133(135.1)	12(15.0)	8(9.1)	492
Aug.	11(17.7)	61(82.4)	69(22.3)	34(49.7)	5(5.5)	1(3.4)	181
Sep.	0(2.6)	18(12.3)	4(3.3)	4(7.4)	1(0.8)	0(0.5)	27
Total	116	539	146	325	36	22	1184

Observed Chi^2 = 201.7 Chi^2 = 25.0 at p 0.05 (15 d.f.)

Expected values in parentheses.

Table 51 Chi^2 analysis of the sex composition of anglers tench catches. Lake A, 1975 and 1976.

1975	May	Jun.	Jul.	Aug.	Sep.	Total
Males	13(11.2)	35(32.6)	55(62.0)	18(14.4)	2(2.7)	123
Females	8(9.8)	26(28.4)	61(54.0)	9(12.6)	3(2.3)	107
Total	21	61	116	27	5	230

Observed Chi^2 = 4.94 Chi^2 = 9.49 at p 0.05 (4 d.f.).

1976	Jun.	Jul.	Aug.	Sep.	Total
Males	33(29.9)	21(22.8)	8(9.5)	2(1.9)	64
Females	30(33.1)	27(25.2)	12(10.5)	2(2.1)	71
Total	63	48	20	4	135

Observed Chi^2 = 1.33 Chi^2 = 7.81 at p 0.05 (3 d.f.).

Expected values in parentheses.

years was however accepted for crucian carp. Catches of the other species were greater in 1976 than in 1975 except for the perch catch which was lower. The species composition of anglers' catches was also dependent on month during the period June to September in 1975 and 1976 (Table 50) with rudd and tench tending to be caught in greatest numbers in June and July (both years). The majority of roach caught in 1976 were also taken in June and July. The sex composition of the tench catch was independent of month (Table 51).

Catch rates for the species in lake A (Fig. 32, Tables 38, 40) suggests unequal catchability. Catch rates for rudd were consistently high through the study during the summer (June to September inclusive) and catch rates for other species e.g. bream and tench, increased towards the end of the study. Because catch rates can be influenced by many factors, a realistic assessment of catchability requires that catch over a period of time be related to population size. With these in mind, catchability indices were calculated for the main species in lake A (Table 52, Fig. 37) where

$$\text{Catchability Index (CI)} = \frac{\text{Catch}}{\text{Population}} \times 100.$$

Table 52 Catch[1] to anglers and population estimates[2] during three summers. Lake A, 1974 to 1976

		Rudd	Roach	Bream	Tench[3]	Perch	Cru. carp
1974 (Aug. to Oct inclusive)	Catch	292	96	14	49	12	13
	Population	1620	4800	2500	230	50	130
	CI (%)	18.0	2.0	0.6	21.3	24.0	10.0
1975 (Jun. to Jul. inclusive)	Catch	330	3	59	132	50	29
	Population	500	90	300	175	100	65
	CI (%)	66.0	3.3	19.7	75.4	50	44.6
1976 (Jun. to Oct inclusive)	Catch	539	116	146	113	36	22
	Population	1900	3000	6300	155	200	40
	CI (%)	28.4	3.9	2.3	72.9	18.0	55.0

CI = Catchability Index.
1. Catch during routine census - season recaptures excluded.
2. From appropriate 'Best' population estimates of vulnerable fish.
3. Tench >280 mm.

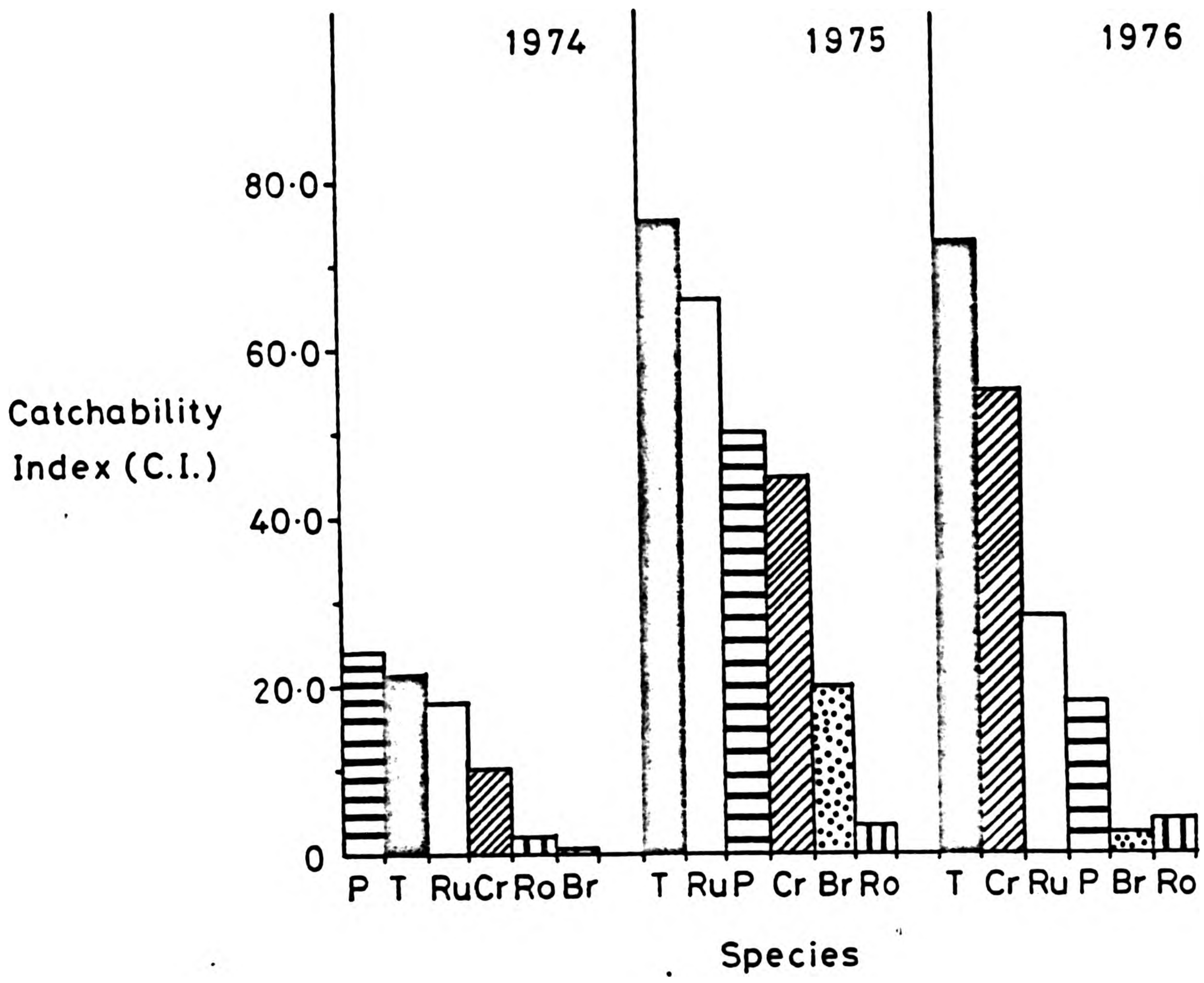

Fig. 37 Catchability indices for rudd, roach, bream, tench, crucian carp and perch. Lake A, 1974, 1975 and 1976.

(iv) Effect of angling on the fish

The capture of fish by any method causes stress or physical damage. Fish caught by angling are damaged by hooking, handling and storage (i.e. while held in keep-nets). The damage inflicted may be sub-lethal, and the incidence of damaged fish may be expected to increase through the angling season for a year-class undergoing recruitment.

The incidence of mouth damage is shown on the length-frequency histograms (see 3.1) as unshaded blocks, and was recorded only for fish caught by angling.

Rudd, even small fish (1+), were able to survive severe mouth damage (e.g. jaw distortion) caused by clumsy unhooking techniques; it was observed that the incidence of mouth damage increased steadily among

Table 53 Percentage of rudd in age groups with mouth damage. Caught by angling. Lake A, 1974 to 1976.

		Age group				Rudd examined *
		1+	2+	3+	4+	
1974	Aug.	13.8	32.0	69.6	15.4	274 (60)
1975	Jun.	0.0	2.5	13.2	32.1	212 (18)
	Jul.	0.0	14.5	42.1	82.4	118 (32)
	Aug.	4.8	14.3	40.0	90.9	70 (19)
	Sep.	2.7	0.3	22.2	50.0	60 (7)
1976	Jun.	2.0	5.3	30.0	50.0	181 (19)
	Jul.	5.8	38.0	58.3	50.0	279 (31)
	Aug.	12.9	58.3	57.1	66.7	61 (21)
	Sep.	0.0	0.0	-	100.0	2 (2)

* Number of rudd with mouth damage in parentheses.

Table 54 Chi^2 analysis of the incidence of rudd (1+ to 2+ age groups) with and without mouth damage. Caught by angling. Lake A, summer 1975 and 1976.

1975	Jun.	Jul.	Aug.	Sep.	Total
Mouth damaged	3(9.9)	10(5.5)	5(3.3)	4(3.3)	22
No mouth damage	144(137.1)	72(76.5)	44(45.7)	45(45.7)	305
Total	147	82	49	49	327

Observed $Chi^2 = 10.15$

1976	Jun.	Jul.	Aug.	Sep.	Total
Mouth damaged	4(9.9)	18(18.8)	11(3.1)	0(1.2)	33
No mouth damage	134(128.1)	245(244.2)	33(40.9)	17(15.8)	429
Total	138	263	44	17	462

Observed $Chi^2 = 26.20$ $Chi^2 = 7.81$ at p 0.05 (3 d.f.)

Expected values in parentheses.

Table 53 Percentage of rudd in age groups with mouth damage. Caught by angling. Lake A, 1974 to 1976.

		Age group				Rudd examined *
		1+	2+	3+	4+	
1974	Aug.	13.8	32.0	69.6	15.4	274 (60)
1975	Jun.	0.0	2.5	13.2	32.1	212 (18)
	Jul.	0.0	14.5	42.1	82.4	118 (32)
	Aug.	4.8	14.3	40.0	90.9	70 (19)
	Sep.	2.7	0.3	22.2	50.0	60 (7)
1976	Jun.	2.0	5.3	30.0	50.0	181 (19)
	Jul.	5.8	38.0	58.3	50.0	279 (31)
	Aug.	12.9	58.3	57.1	66.7	61 (21)
	Sep.	0.0	0.0	-	100.0	2 (2)

* Number of rudd with mouth damage in parentheses.

Table 54 Chi^2 analysis of the incidence of rudd (1+ to 2+ age groups) with and without mouth damage. Caught by angling. Lake A, summer 1975 and 1976.

1975	Jun.	Jul.	Aug.	Sep.	Total
Mouth damaged	3(9.9)	10(5.5)	5(3.3)	4(3.3)	22
No mouth damage	144(137.1)	72(76.5)	44(45.7)	45(45.7)	305
Total	147	82	49	49	327

Observed Chi^2 = 10.15

1976	Jun.	Jul.	Aug.	Sep.	Total
Mouth damaged	4(9.9)	18(18.8)	11(3.1)	0(1.2)	33
No mouth damage	134(128.1)	245(244.2)	33(40.9)	17(15.8)	429
Total	138	263	44	17	462

Observed Chi^2 = 26.20 Chi^2 = 7.81 at p 0.05 (3 d.f.)

Expected values in parentheses.

Table 55 Chi^2 analysis of the incidence of tench with and without mouth damage in anglers' catches during the summer seasons of 1975 and 1976.

Male tench

1975	May	Jun.	Jul.	Aug.	Sep.	Total
Mouth damaged	8(6.4)	12(17.1)	29(26.8)	10(8.8)	1(1.0)	60
No mouth damage	5(6.7)	23(17.9)	26(28.2)	8(9.2)	1(1.0)	63
Total	13	35	55	18	2	123

Observed $Chi^2 = 4.46$

1976	Jun.	Jul.	Aug.	Sep.	Total
Mouth damaged	12(12.9)	9(8.2)	4(3.1)	0(0.8)	25
No mouth damage	21(20.1)	12(12.8)	4(4.9)	2(1.2)	39
Total	33	21	8	2	64

Observed $Chi^2 = 1.91$

Female tench

1975	May	Jun.	Jul.	Aug.	Sep.	Total
Mouth damaged	4(2.8)	6(9.2)	22(21.7)	5(3.2)	1(1.1)	38
No mouth damage	4(5.2)	20(16.8)	39(39.3)	4(5.8)	2(1.9)	69
Total	8	26	61	9	3	107

Observed $Chi^2 = 4.08$

1976	Jun.	Jul.	Aug.	Sep.	Total
Mouth damaged	6(4.6)	4(4.2)	1(1.9)	0(0.3)	11
No mouth damage	24(25.4)	23(22.8)	11(10.1)	2(1.7)	60
Total	30	27	12	2	71

Observed $Chi^2 = 1.31$

* $Chi^2 = 7.81$ at p 0.05 (3 d.f.) and 9.49 (4 d.f.)

Expected values in parentheses.

the recruiting year-class (1975) of rudd in 1976 (Table 53). The null hypothesis that the incidence of mouth damage in 1 to 2+ rudd was independent of month during the summer of 1975 and 1976 was rejected (Table 54). Rudd >4+ years had >50% incidence of mouth damage.

Many of the large tench in lake A had damaged mouths, but there was no significant change in the incidence of mouth damage during the summer (Table 55). The condition of the mouth (i.e. damaged or undamaged) in tench was independent of sex (Chi^2 analysis, $p < 0.05$) for all periods examined (1975: June, July and August; 1976 June - August pooled. Observed Chi^2 values respectively 0.90, 3.26 <0.01, 0.57; Actual $Chi^2 = 3.84$ at $p = 0.05$, 1 df). Mouth damage was common among the large crucian carp.

Relatively few bream (13) and roach (22) caught had damaged mouths, an observation that may support the evidence for low catchability (see above). Alternatively poor survival of bream and roach after capture may account for the observation. Only 3 perch caught by angling had mouth damage.

The condition (K) of rudd with and without mouth damage was examined (Fig. 8) and the mean K for mouth damaged rudd was consistently higher than that for rudd without mouth damage, however, the difference between the mean K for the two groups of rudd was only significant (t-test; $p \leq 0.05$) during August, 1975.

Length/weight regressions were calculated separately for male and female tench (>300 mm) with and without mouth damage (Appendix 8) but the slopes of the regressions rarely deviated significantly (i.e. at p 0.05) from 3 in any category. The condition (K) of male and female tench caught by angling, with and without damaged mouths, was also examined (Fig. 38) for the months June, July and August, when the numbers of tench caught were sufficient to warrant analysis. The mean K for mouth damaged male tench was significantly (t-test; $p < 0.05$) less than the mean K for male tench without mouth damage on one occasion,

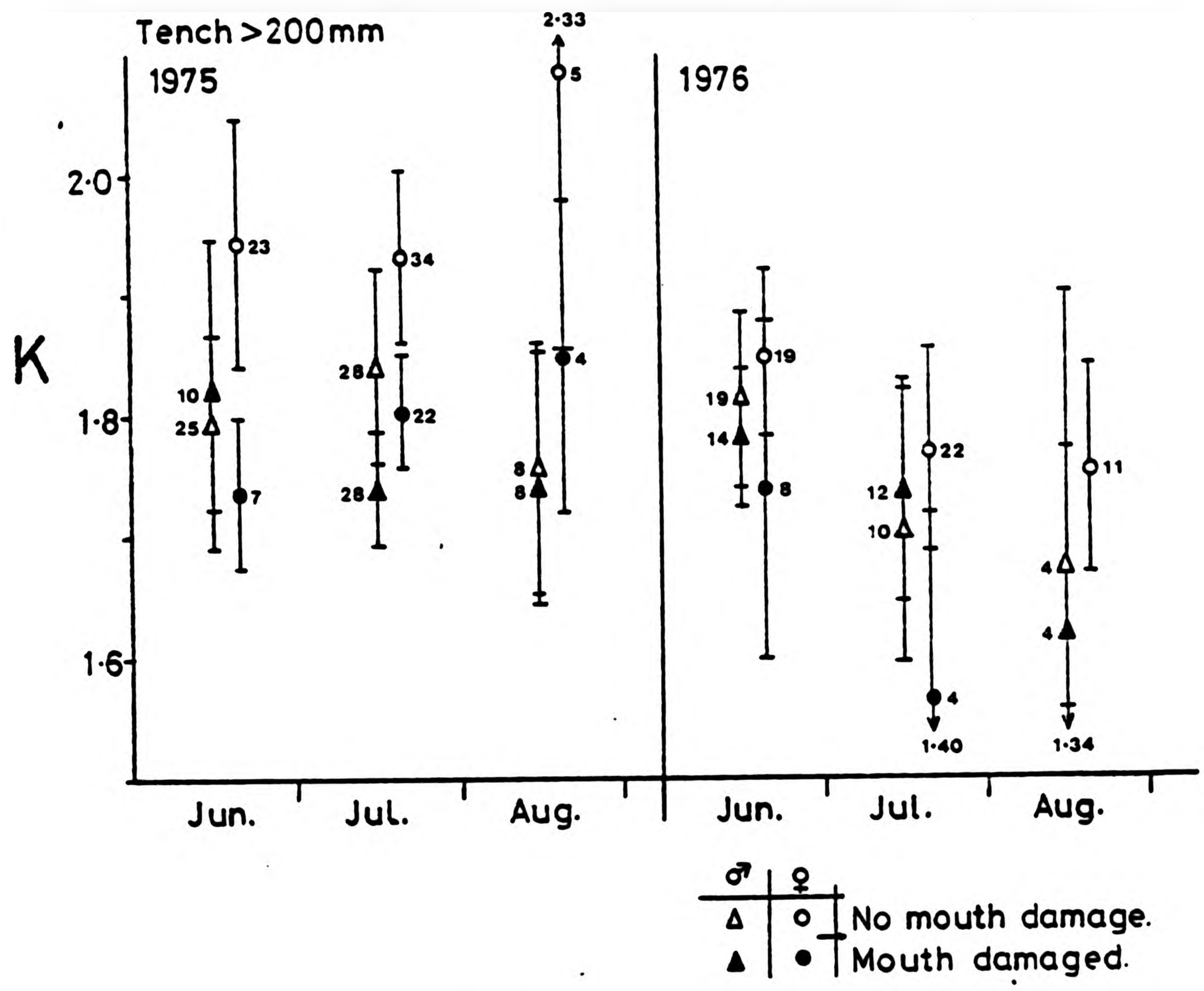

Fig. 38 Mean condition (K) of lake A male and female tench with and without mouth damage for June, July and August 1975 and 1976. Sample sizes are stated with 95% confidence limits (vertical bar).

i.e. July 1975. In the case of female tench, the mean K of those with mouth damage was significantly (t-test; $p \leq 0.05$) less than those without mouth damage on three occasions i.e. June and July 1975 and July 1976. Mean K, particularly for female tench without mouth damage, appeared to be higher in 1975 than in 1976 (Fig. 38 and see 3.1), however, the data are difficult to interpret because of their variability.

Analysis of covariance was used to assess the significance of differences in the slopes of length/weight regressions for rudd, with and without mouth damage and for tench (all sizes, male and female separately) with and without mouth damage. The rudd length/weight data applied to lake A, June to September inclusive, 1975 and the tench data for July only (lake A, 1975). The data were selected because the number of observations were relatively large with about equal numbers in the with and without damage groups. The slopes of the rudd and male tench regressions for the groups with and without mouth damage were not significantly different (at $p \leq 0.05$) but in the case of female tench they were (at $p < 0.01$). The last result was spurious because the regressions compared were not based on samples of tench with similar length distributions (see Appendix 10 for an outline of the above analysis).

Fin damage was common among tench, crucian carp and rudd; pectoral, dorsal and caudal fins were often found with splits or tears; eroded and incompletely regenerated caudal fins were particularly common on large tench and rudd. Apart from the fin damage in some, the general condition of the rudd caught from lake A between 1974 and 1977, was good whether they had mouth damage or not, and much better than that of the roach caught over the same period.

The parasites *Piscicola* sp and *Argulus* sp were recorded from all species of fish in lake A at some time (1974 to 1977) but only one roach was identified as being infected with *Ligula* sp.

The numbers of tench, rudd and crucian carp recaptured by angling 1, 2, 3 ... weeks after initial capture (by angling) are shown in Fig. 39. Many rudd and tench were recaptured within one week of their initial recorded capture, some were marked and recaptured on > two occasions during a summer angling season. One perch was recaptured three times within 4 weeks during August to October, 1974. The recapture of marked fish was relatively rare, particularly for roach, bream and perch, presumably because the numbers of fish marked during the census was low, some of the marks faded or mortality of marked fish was higher than for unmarked individuals.

Fig. 40a shows the catch rate for medium to large tench on successive days of the routine census; there was no trend towards a catch rate reduction as the season progressed in 1975, but in 1976, when there was a general increase in the abundance of other cyprinids (see Fig. 28a) the catch rate of tench appeared to decline towards the end of the summer.

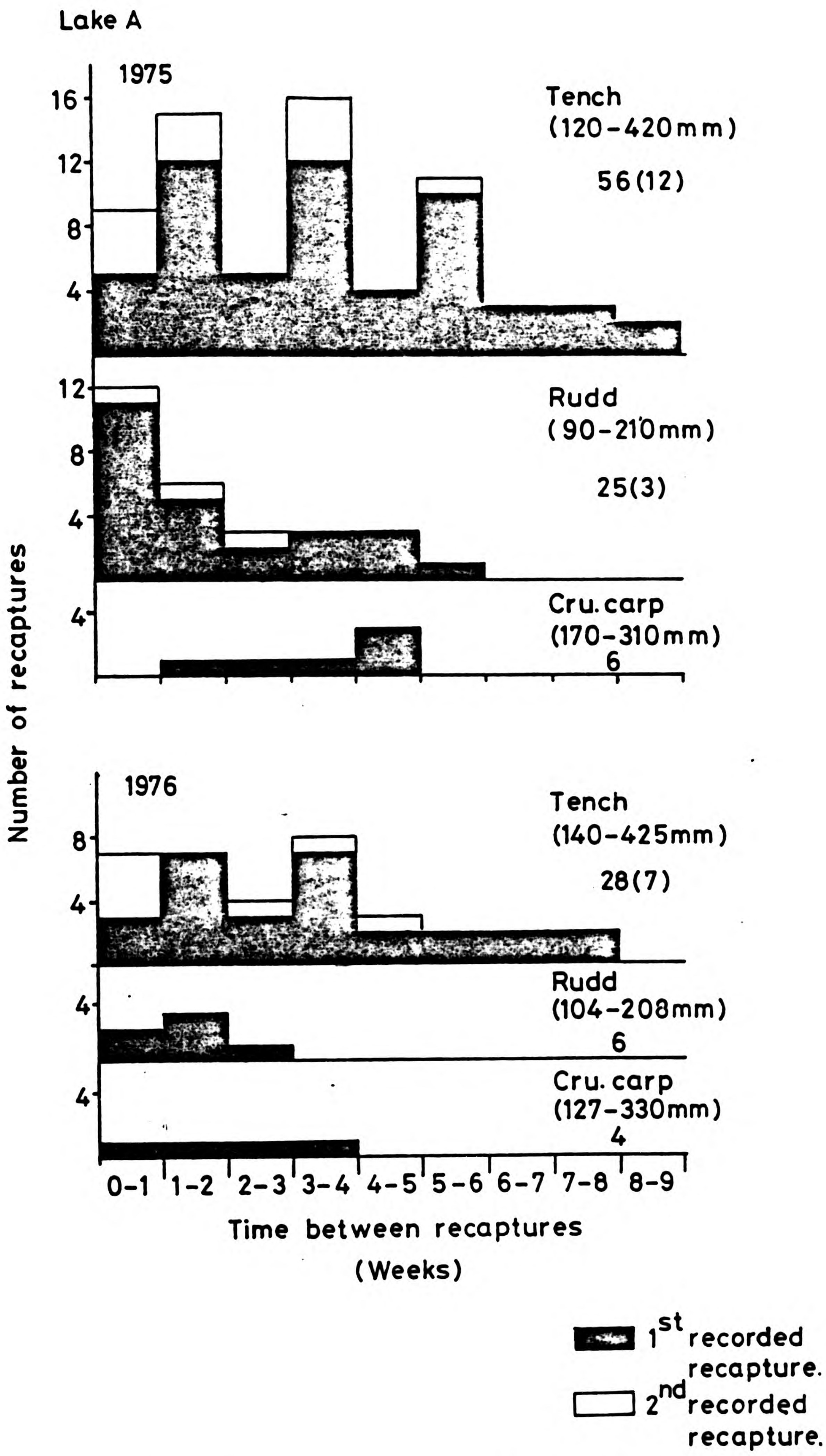

Fig. 39 First and second recaptures recorded for tench, rudd and crucian carp through time after initial recorded capture by angling. Lake A, June to September (inclusive), 1975 and 1976.

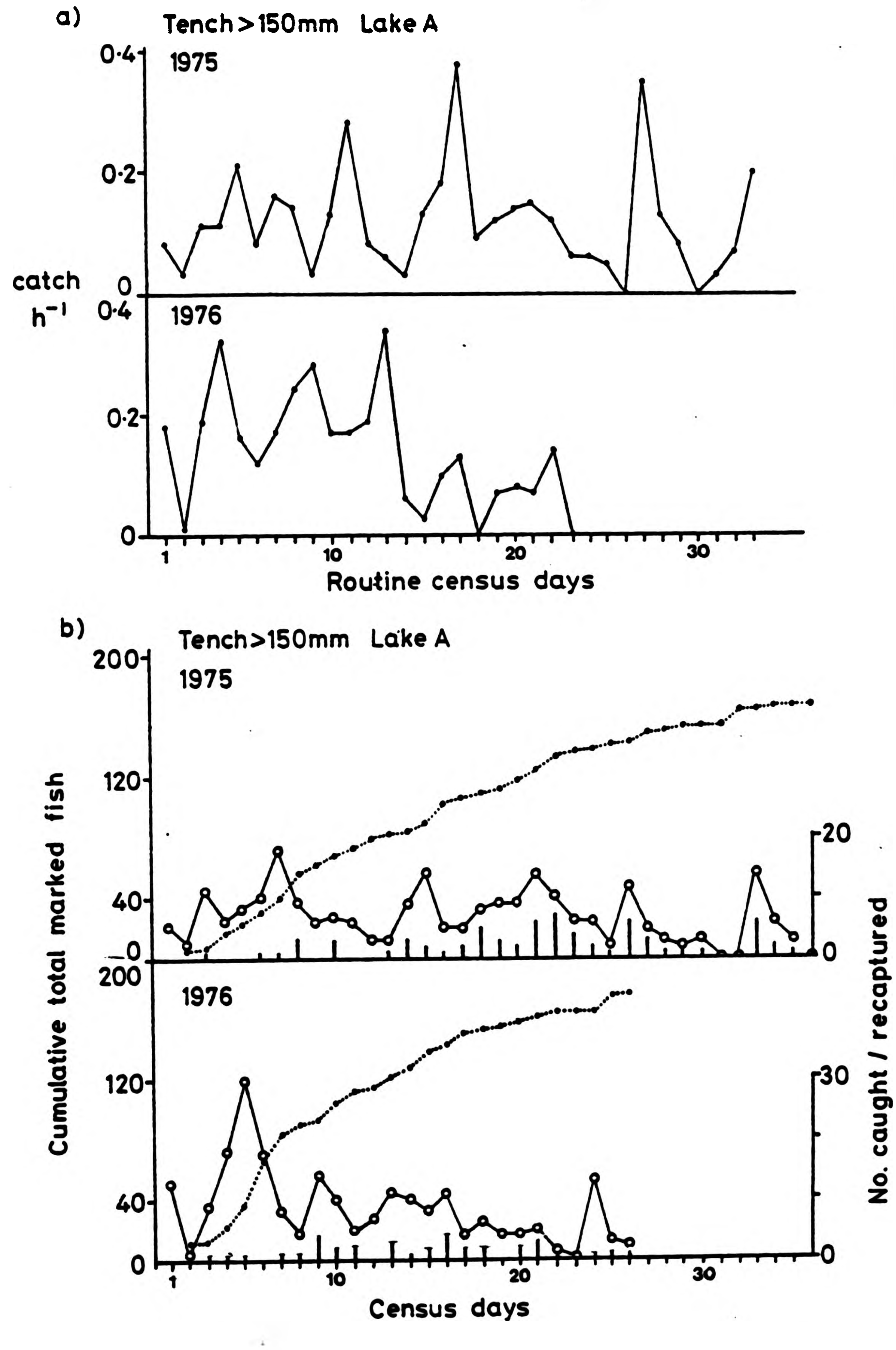

Figure 40 a) Catch rates for tench >150 mm on successive census days; lake A, 1975 and 1976.
b) Numbers of tench >150 mm captured (o) and recaptured (vertical bar) by angling, with cumulative totals (•) of tench marked during the census. Lake A, 1975 and 1976.

Figure 40b shows the numbers of tench caught on successive census days and the cumulative total of marked tench, the latter increased until a large proportion of the tench population were marked. The proportion of marked tench in the catch also increased through the census, suggesting that the majority of marks remained visible over the three-month period (mid-June to mid-September).

Further analysis related to the recapture of marked fish was not attempted because of sparse data and because it was not possible to identify individual fish. This part of the study was made difficult by the opposition of anglers to the attachment of numbered tags to the tench and other large fish.

Small roach, rudd, bream and perch were occasionally found dead in anglers' keep-nets during the census but tench and crucian carp were never included among those killed. Fish kills attributable to angling appeared to be more common during matches, for example, in lake B matches the following mortalities were observed:

24 September 1974	75 rudd caught (15 killed) = 20% mortality (55 - 99 mm)
	18 roach caught (1 killed) = 5.5% mortality (70 - 95 mm)
13 July 1975	136 roach caught (59 killed) = 43% mortality (90 - 130 mm)

Mortalities on the above scale were generally avoided in lake A because small fish were not often caught in large numbers. However, out of 30 medium-size carp stocked into lake A during 1974, 5 were killed by angling (deep hooking/mishandling) within two months of their introduction (i.e. 17% angling mortality).

(v) Effect of various factors on angling success

Figure 31 in the previous section shows the variability of angling success (as overall catch rate) on lake A through two summer seasons (see also Appendix 12 for weekly and other catch rates). Clearly angling was more successful in 1976; in 1975 the percentage of anglers

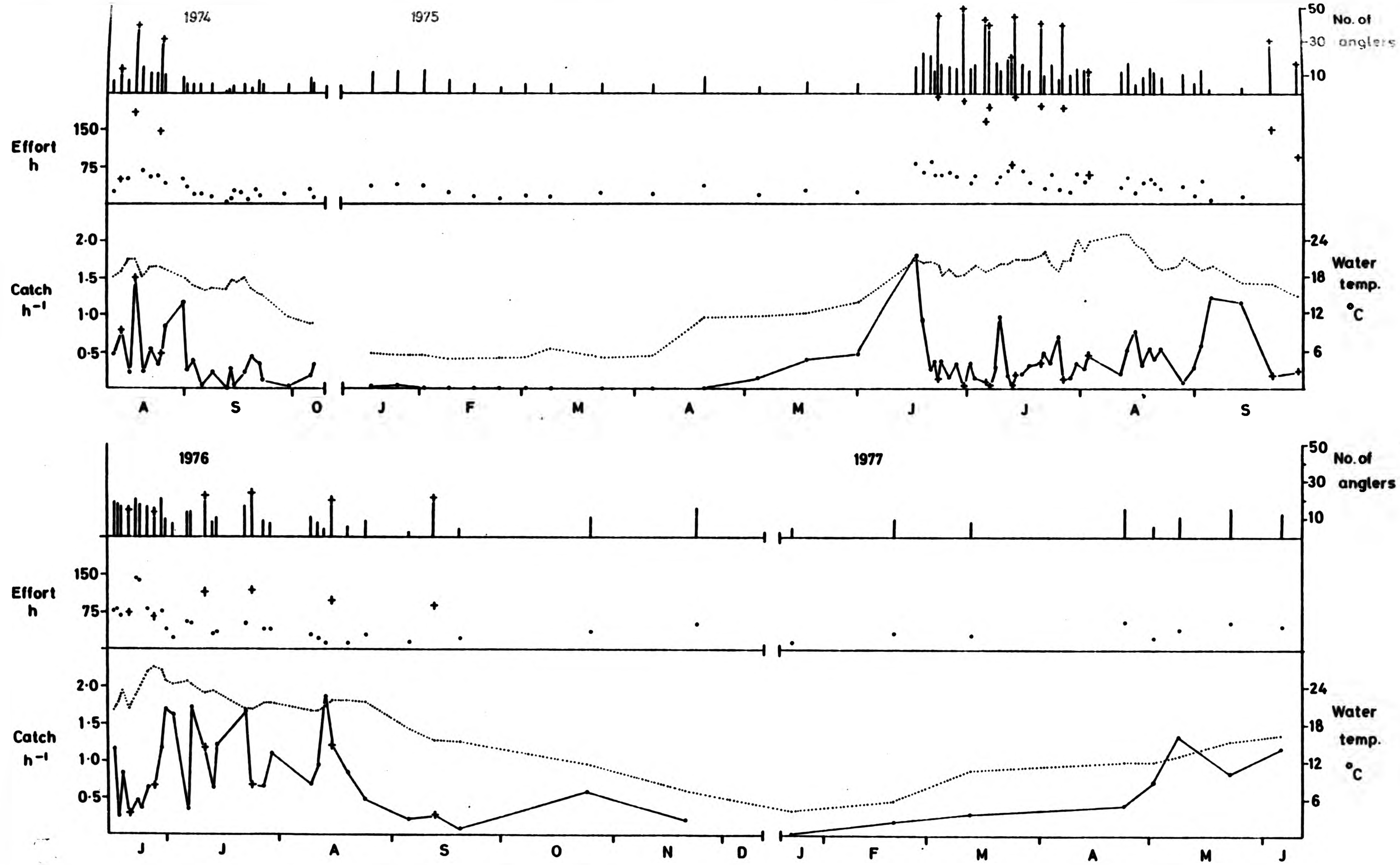

Fig. 41 Numbers of anglers, angling effort, overall catch rates and water temperature for each census visit (match data marked +). Lake A, 1974 to 1977.

with catch only exceeded 50% on 9 out of 32 census days (28%) but in 1976 the 50% level was exceeded on 18 out of 23 census days (78%). If an overall catch rate of 1.0 fish rod h^{-1} is taken as an acceptable standard, angling was poor in 1975, the overall catch rate was only ≥1.0 fish rod h^{-1} on 3 census days but in 1976 it was ≥1.0 on 9 census days. Catch rates of the various species in lake A (Fig. 32) were also generally better in 1976 except for crucian carp whose catch rates were broadly similar in both years.

Catch rates have been taken as the criteria for the assessment of angling success in the following section; obviously a number of factors may affect angling success and they are examined under two broad headings:

(a) Abiotic factors

The overall catch rates in lake A tended to rise to a peak during the summer and fall to a minimum during winter (Fig. 41). In lake B however roach and rudd were caught through the winter of 1975 (see Appendix 14) with overall catch rates of 2.53 and 4.59 fish rod h^{-1} during two consecutive weeks in February (water temperature approximately 5°C). Obviously water temperature was an important factor influencing catch rates; Table 56 shows the maximum and minimum temperatures at which various species were caught. Lake B was fished on one occasion when the water temperature was 3.3°C but no fish were caught.

Table 56 Water temperature (°C) at the time of the observed capture of species by angling. Lake A and B, 1974 to 1977.

Species	Minimum temperature	Maximum temperature
Rudd	10.3 (4.9)	27.0 (25.0)
Roach	7.5 (4.9)	27.0 (25.0)
Bream	5.9 (20.0)	27.0 (25.0)
Tench	5.3 (9.5)	27.0 (22.0)
Crucian carp	5.3 (-)	27.0 (-)
Common carp	14.8 (16.5)	21.0 (22.0)
Perch	7.5 (9.5)	27.0 (22.0)

Lake B observations in parentheses.

The importance of water temperature and other variables (Table 57) in the determination of catch rates were examined by exploratory multiple regression analyses. An example of the print-out from a typical multiple regression and correlation is provided in Appendix 5.

Preliminary analysis indicated that dissolved oxygen (DISO, variable 13) was strongly correlated with air temperature and it was excluded from some variable sets along with wind run (WIRN, 8). The computer programme rejected variables for inclusion in the multiple regression if they failed to reach specific levels of significance (see 2.3 and Appendix 5). The multiple regression equations and associated data are given in Table 58.

A total of 121 data points were available for the multiple regression analysis, representing information collected during the routine census and autumn, winter and close season special matches held from 1975 to 1977. Unfortunately only 50 data points incorporated measurements of water clarity (SECI, 12).

The significant single correlations between catch rates and listed variables are presented in Table 59. The positive and negative correlations between catch rates and the generated variables COSD and SIND are complementary, values for the two variables decrease and increase repectively as DAYN rises, implying a rise in catch rate as DAYN increases. Time (YEAR) and angling effort (EFFT) were retained in the multiple regressions, however, EFFT was not included in the list of single significant correlates (Table 59).

Fig. 40 shows the ability of the multiple regression CATR to model the observed catch rate of rudd.

Multiple regressions accounted for between 25% and 41% of catch rate variance (d and c respectively, Table 58) but some important variables were not compatible with the others included (see(b), Biotic factors, below).

Table 57 Variables used in multiple regression analyses

Variable name	Code No.	Identification
CATH	1	Catch rate - all species. Catch h^{-1}
CATR	16	Catch rate - rudd "
CATB	15	Catch rate - bream "
CATT	17	Catch rate - tench "
DAYN	2	Day; January 1st = 1
YEAR	3	Year
MAXT	4	Maximum day air temperature. °C
MINT	5	Minimum day air temperature. °C
RAIN	6	Rainfall. mm day^{-1}
WIDR	7	Wind direction. Scale: 1-8 **
WIRN	8	Wind run. Km day^{-1}
RADN	9	Solar radiation. Langleys
EFFT	10	Angling effort. rod hours
WTEM	11	Water temperature. °C ***
SECI	12	Secchi disc visibility depth cm.
DISO	13	Dissolved oxygen. mg l^{-1} ***
YRDU	14	Year dummy (1 for 1974 - 4 for 1977)
AVAT	19* 22	Average air temperature. ½(MAXT + MINT)
COSD	17* 18	$\text{Cos}\left(\frac{2\pi}{365}\right)\cdot$ DAYN
SIND	18* 19	$\text{Sin}\left(\frac{2\pi}{365}\right)\cdot$ DAYN
SIWD	21	$\text{Sin}\left(\frac{2\pi}{8}\right)\cdot$ WIDR
COWD	20	$\text{Cos}\left(\frac{2\pi}{8}\right)\cdot$ WIDR

* Variable numbers used during runs with overall catch rate as Y variable.

** 1 = N, 2 = S, 3 = E, 4 = W, 5 = NE, 6 = NW, 7 = SE, 8 = SW

*** Mean of single samples from 3 stations.

Langley = gram calories cm^{-2} min^{-1}.

Table 58 Multiple regression equations[1], and associate statistics. Lake A data 1975 to 1977.

a) CATH[2] = 0.189(YEAR)+0.019(RAIN)-0.002(EFFT)+0.076(WTEM)-0.047(AVAT)-14.394

ANOVA

	d.f.	SS	MS	F
Regression	5	9.5780	1.9156	14.40**
Deviations	115	15.3030	0.1331	
Total	120	24.8810	0.2073	

S = 0.3648 Variance "explained" by regression = 1 - 0.6420 = 0.3579

R = 0.6204 R^2 = 0.3849

b) CATH[3] = 0.226(YEAR)+0.036(WTEM)-0.007(SECI)-16.761

ANOVA

	d.f.	SS	MS	F
Regression	3	3.6502	1.2167	6.98**
Deviations	46	8.0136	0.1742	
Total	49	11.6638	0.2380	

S = 0.4174 Variance "explained" by regression = 1 - 0.7319 = 0.2681

R = 0.5594 R^2 = 0.3129

c) CATR[4] = 0.279(YEAR)+0.026(RAIN)+0.063(WTEM)-0.048(DISO)+0.471(COSD)+0.161 (COWD)+0.149(SIWD)-21.39

ANOVA

	d.f.	SS	MS	F
Regression	7	2.4131	0.3447	5.84**
Deviations	42	2.4791	0.0590	
Total	49	4.8922	0.0998	

S = 0.2429 Variance "explained" by regression = 1 - 0.5912 = 0.4088

R = 0.7023 R^2 = 0.4933

d) CATB = 0.149(YEAR)-0.143(SIND)-11.25

ANOVA

	d.f.	SS	MS	F
Regression	2	0.1753	0.0877	9.51**
Deviations	47	0.4332	0.0092	
Total	49	0.6085	0.0124	

S = 0.0960 Variance "explained" by regression = 1 - 0.7419 = 0.2580

R = 0.5367 R^2 = 0.4072

e) CATT = 0.172(YEAR)-0.002(EFFT)-0.278(COSD)-12.88

ANOVA

	d.f.	SS	MS	F
Regression	3	1.0894	0.3631	10.53**
Deviations	46	1.5861	0.0345	
Total	49	2.6755	0.0546	

S = 0.1857 Variance "explained" by regression = 1 - 0.6319 = 0.3681

R = 0.6381 R^2 = 0.4072

Note: 1. Predictive multiple regressions at 95% level. See Appendix 5 for an example

2. 121 data points; YEAR, RAIN, RADN, EFFT, WTEM, COSD, SIND and AVAT screened. WIRN, DISO and SECI excluded.

3. 50 data points. YEAR, RAIN, RADN, EFFT, WTEM, SECI and AVAT screened.

4. CATR, CATB and CATT all on 50 data points DAYN, YEAR, RAIN, WIRN, RADN, EFFT, WTEM, SECI, DISO, COSD, SIND, COWD, SIWD and AVAT screened.

** F > tabulated F at $p < 0.01$:. Ho regression coeffs. equal 0 rejected at 1% level.

S = Deviation (residual) standard error.

R = Multiple correlation coefficient.

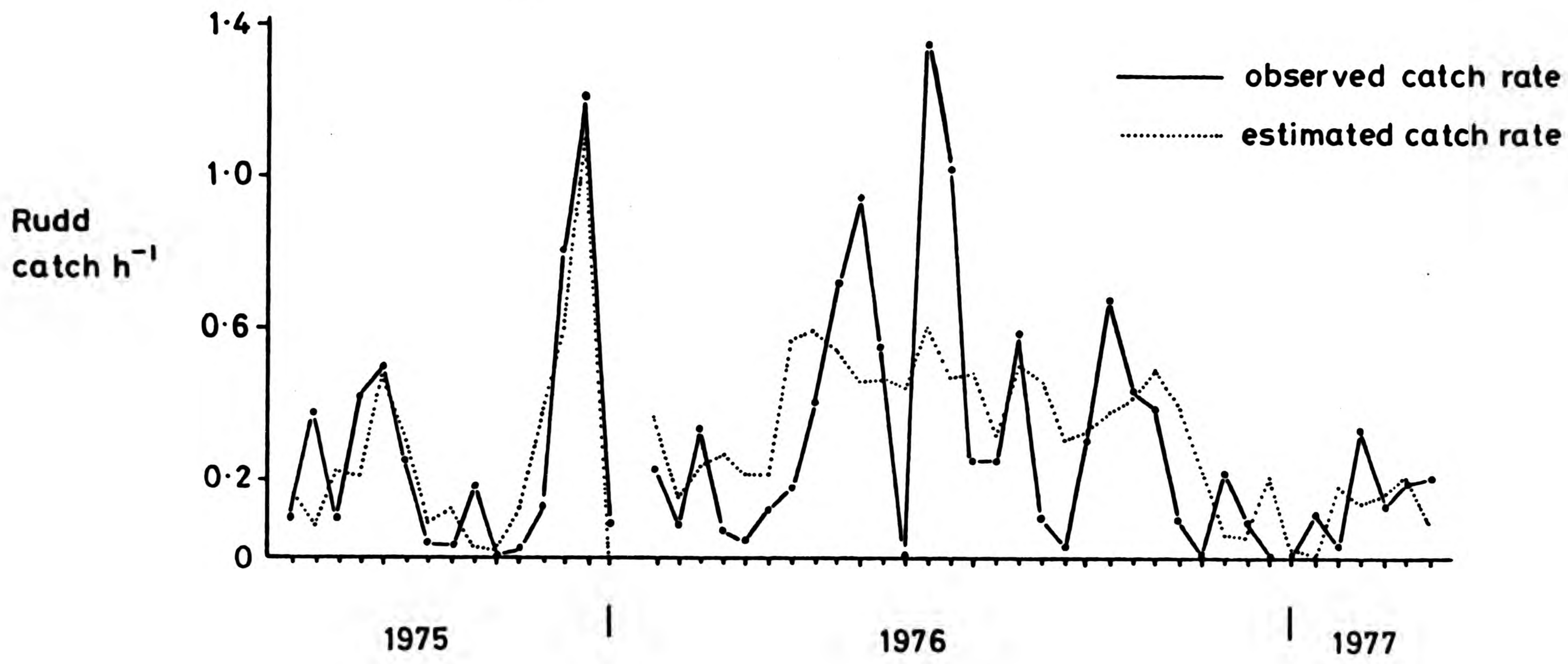

Fig. 42 Observed catch rates for rudd with estimated (predicted) catch rates from the multiple regression, CATR. Lake A, 1975 to 1977.

Table 59 Catch rates X environmental variables: significant single correlations.

Catch rates				
Overall[1]	Overall[2]	Rudd[3]	Bream[3]	Tench[3]
WTEM + 0.4347	RADN + 0.3543	RADN + 0.4013	SIWD + 0.3715	YEAR + 0.3670
RADN + 0.4137	SECI - 0.4462	RAIN + 0.3436	YEAR + 0.3075	SIND + 0.2783
YEAR + 0.3495		WTEM + 0.3385	DISO + 0.3048	SECI - 0.3515
COSD - 0.3963		SIWD + 0.3204	SECI - 0.2868	COSD - 0.3592
		COSD - 0.2774		
n = 121	n = 50	n = 50	n = 50	n = 50

Significance levels for r n = 50 r ≥ 0.273 (5% level), r ≥ 0.354 (1% level)
n = 121 r ≥ 0.174 (5% level), r ≥ 0.228 (1% level)

1 All data, excluding WIRN, DISO, SECI; 8 variables screened.

2 Data with associated SECI record; 8 variables screened

3 Data with associated SECI record; 14 variables screened.

(see Appendix 5 for example of correlation and multiple regression analysis)

Angling was continued through the statutory close season (15 March to 15 June inclusive) during 1975 and 1977 in an attempt to assess angling success in this period normally closed to angling. Catch and effort data for close season angling are given in Appendix 15. Roach and rudd were caught from lake B in the close season of 1975, but only tench from lake A. In the close season of 1977 however, all species present in lake A were caught except pike.

The validity of comparing angling success in periods where the frequency of sampling and the type of angling effort varies may be questioned, but catch rates were better in the close season than in the immediate pre-close season (Table 60). In 1975 post-close season angling was better than in the close season itself; unfortunately catch rates for the 1977 post-close season were not available.

The fishing places (pegs) selected by anglers appeared to influence angling success. Figure 43 shows data from the routine census of 1975 and 1976 for the pegs located in sector 2 of lake A (see Fig. 4). Catch,

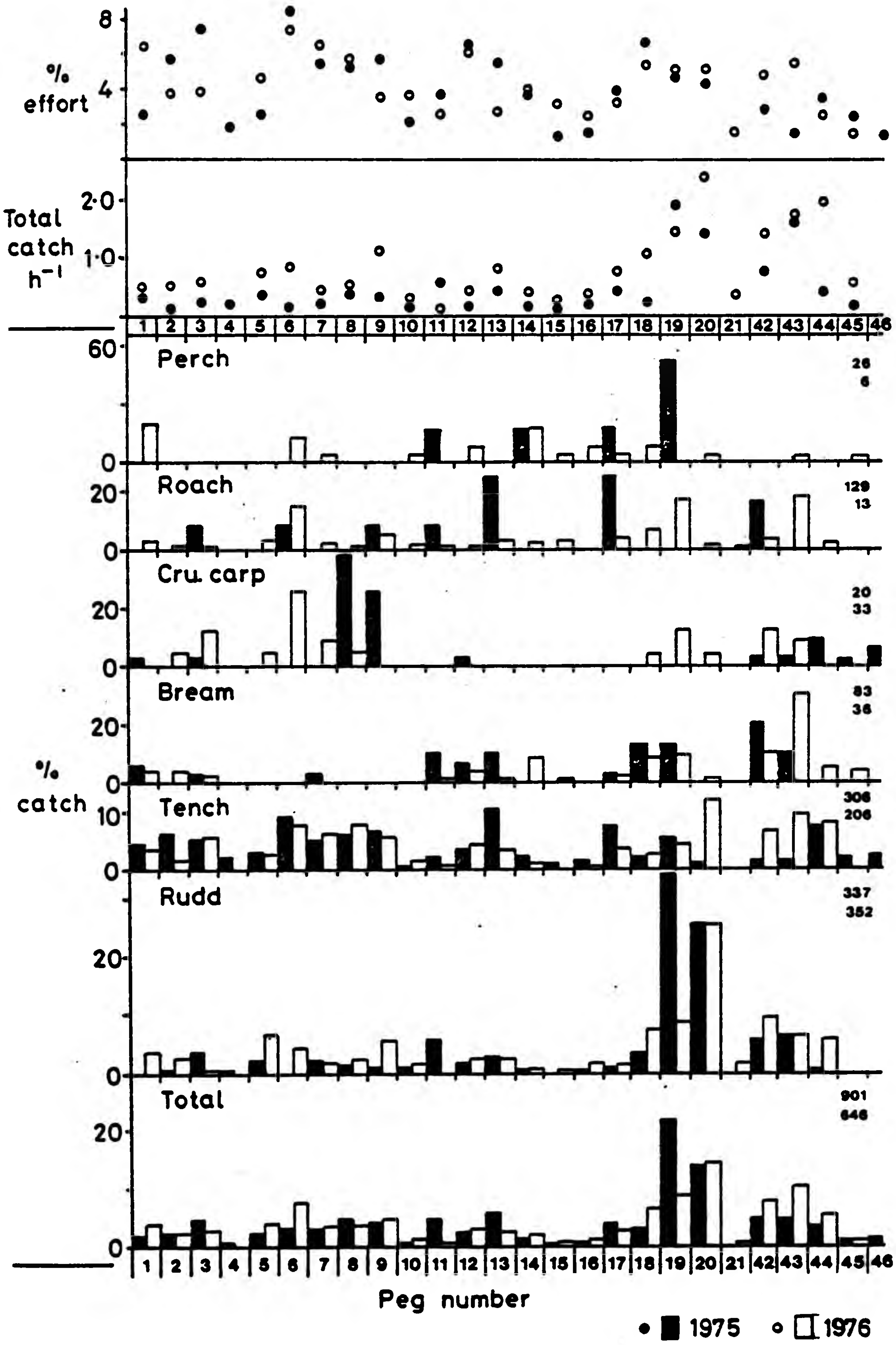

Fig. 43 Percentage of recorded catch taken at each peg during the routine census with overall catch rate and effort. Lake A, 1975 and 1976 (numbers of species caught stated, upper number refers to 1976 in each case).

Table 60 Catch rates in the close season and proximate periods. Lake A, 1975 and 1977.

Period[1]		No. sampling occasions	Catch No. fish	Effort (h)	Catch[2] h^{-1}
1975					
Pre-close season	18.1.75 - 8.3.75	8	2	176.5	0.01
Close season	22.3.75 - 31.5.75	6	21	132.6	0.16
Post-close season	16.6.75 - 13.9.75	32	991	3233.6	0.31
1977					
Pre-close season	22.1.77 - 12.3.77	3	14	75.1	0.19
Close season	23.4.77 - 6.6.77	5	183	209.5	0.87

Notes 1 See Table 35 for dates of census days.
2 Total observed catch/total observed effort.

effort and to a lesser extent, total catch rate varied according to peg location. The highest catch and catch rates were observed at pegs 19 and 20 where rudd particularly were readily caught. Catches of crucian carp were concentrated in the two shallow bays of lake A, pegs 5 to 9 and 42 to 46.

(b) Biotic factors

Biotic factors that may affect catch rate variance are angler ability, angling techniques, benthos/zooplankton (size of particles and abundance) and the density of vulnerable fish stocks (i.e. fish > 55 mm).

The nature of the census prevented a meaningful examination of individual angler ability, it was rare for the same group of anglers to fish on the same day and lake at the same time. Some anglers certainly achieved high catch rates whereas others did not. Certain anglers appeared more adept at catching large (>300 mm) tench, about 40% and 35% of the latter were caught by 4% and 3% of the anglers participating in the census on lake A during 1975 and 1976 respectively.

The influence of bait selection over catch rate was confused by the use of several baits during an angling visit. In 1976 bait combinations that included maggots accounted for 84 to 97% of the fish caught in lake A and comparisons of catch and catch rates on single baits during that year are given in Table 61. 1976 was chosen because catch rates were generally more satisfactory during that year. Unfortunately baits other than maggot were only used occasionally, reducing the value of the comparison but while tench catch rates were not obviously dependent on bait type, rudd, roach and perch catch rates were highest when maggots and casters (fly pupae) were used. The interpretation of results was further complicated by hook size-bait relationships, large hooks were generally used with large bread or worm baits whereas small hooks were used with small particle baits, e.g. maggots and casters. Not surprisingly a simple comparison of catch and catch rates to anglers using large and small hooks (Table 62) suggested that catch and catch rates were highest with small hooks (catch included all species in all size groups) but large hook tackles captured bream, roach and crucian carp in the largest size groups, however, small tench were caught on large hooks. The majority of anglers clearly favoured the use of small hooks (see Table 44).

The changes in fish population size between 1974 and 1977 provided an opportunity to examine the relationship between the density of vulnerable fish (Appendix 16) and catch rates to anglers. Catch rates were calculated (i.e. total catch/total observed effort) for six periods covering the duration of the study (Appendix 12) but only those for 1974, 1975 and October 1976 covered periods when population estimates were likely to be valid, restricting the analysis to four data points. Catch rate/population density regressions were calculated (Table 63) and the results plotted (Fig. 44).

Table 61 Bait, catch and catch rates. Lake A, 1976.

Bait	Month	Effort (h)	Catch h^{-1} (catch) *					
			Rudd	Roach	Bream	Tench	Cru. carp	Perch
Maggot	Jun.	301.2	0.35 (104)	0.14 (44)	0.05 (16)	0.30 (91)	0.03 (10)	0.03 (10)
	Jul.	138.5	0.74 (102)	0.12 (17)	0.12 (17)	0.64 (899	0.01 (1)	0.04 (5)
	Aug.	78.3	0.31 (24)	0.13 (10)	0.14 (11)	0.38 (30)	0.03 (2)	0.04 (3)
Caster	Jun.	13.5	0.15 (2)	0.15 (2)	0.07 (1)	0.37 (5)	0.0 (0)	0.07 (1)
	Jul	1.5	6.67 (10)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
	Aug.	0.0	-	-	-	-	-	-
Bread	Jun.	53.6	0.09 (5)	0.0 (0)	0.0 (0)	0.13 (7)	0.04 (2)	0.0 (0)
	Jul.	58.5	0.07 (4)	0.0 (0)	0.0 (0)	0.31 (18)	0.03 (2)	0.0 (0)
	Aug.	20.2	0.0 (0)	0.0 (0)	0.50 (10)	0.05 (1)	0.0 (0)	0.0 (0)
Worm	Jun.	5.4	0.0 (0)	0.0 (0)	0.20 (1)	0.40 (2)	0.0 (0)	0.0 (0)
	Jul.	12.4	0.0 (0)	0.0 (0)	0.0 (0)	0.8 (1)	0.0 (0)	0.0 (0)
	Aug.	0.0	-	-	-	-	-	-

* Numbers caught on a given bait recorded in parentheses.

Table 62 A comparison of catch and catch rates to anglers using large and small hooks. Lake A, 1975 & 1976.

	Hook size *							
	6-10				20			
	Effort h	Catch	Catch h^{-1}	No. anglers	Effort h	Catch	Catch h^{-1}	No. anglers
1975								
Jun.	21.5	0	0.00	4	18.0	2	0.11	5
Jul.	17.0	2	0.12	5	9.0	5	0.56	2
Aug.	30.7	8	0.26	9	-	-	-	-
	T,Ro.				T,Cr,Br,Ro.			
1976								
Jun.	33.9	10	0.29	9	29.4	34	1.16	7
Jul.	20.0	7	0.35	5	6.0	29	4.83	2
Aug.	8.0	0	0.00	3	12.5	16	1.28	4
	T,Br,Cr.				T,Br,Ro,Pe,Ru.			

* Redditch scale; hooks drawn actual size.
T=Tench; Ro=Roach etc.

Table 63 Catch rate (Y)/Population density (X) regressions (restricted, X = Y = 0) for lake A, 1974 to 1976

Species	Slope	(n)	r
Rudd	1.8414	4	0.4326
Bream	0.2449	4	0.9137
Roach	0.4206	4	0.9778*
Perch >100 mm	2.8182	4	0.7753
Perch >50 mm	0.4769	4	0.4662
All species[1]	1.1216	4	0.8805

* significant at $p < 0.05$
1 Includes perch >100 mm.

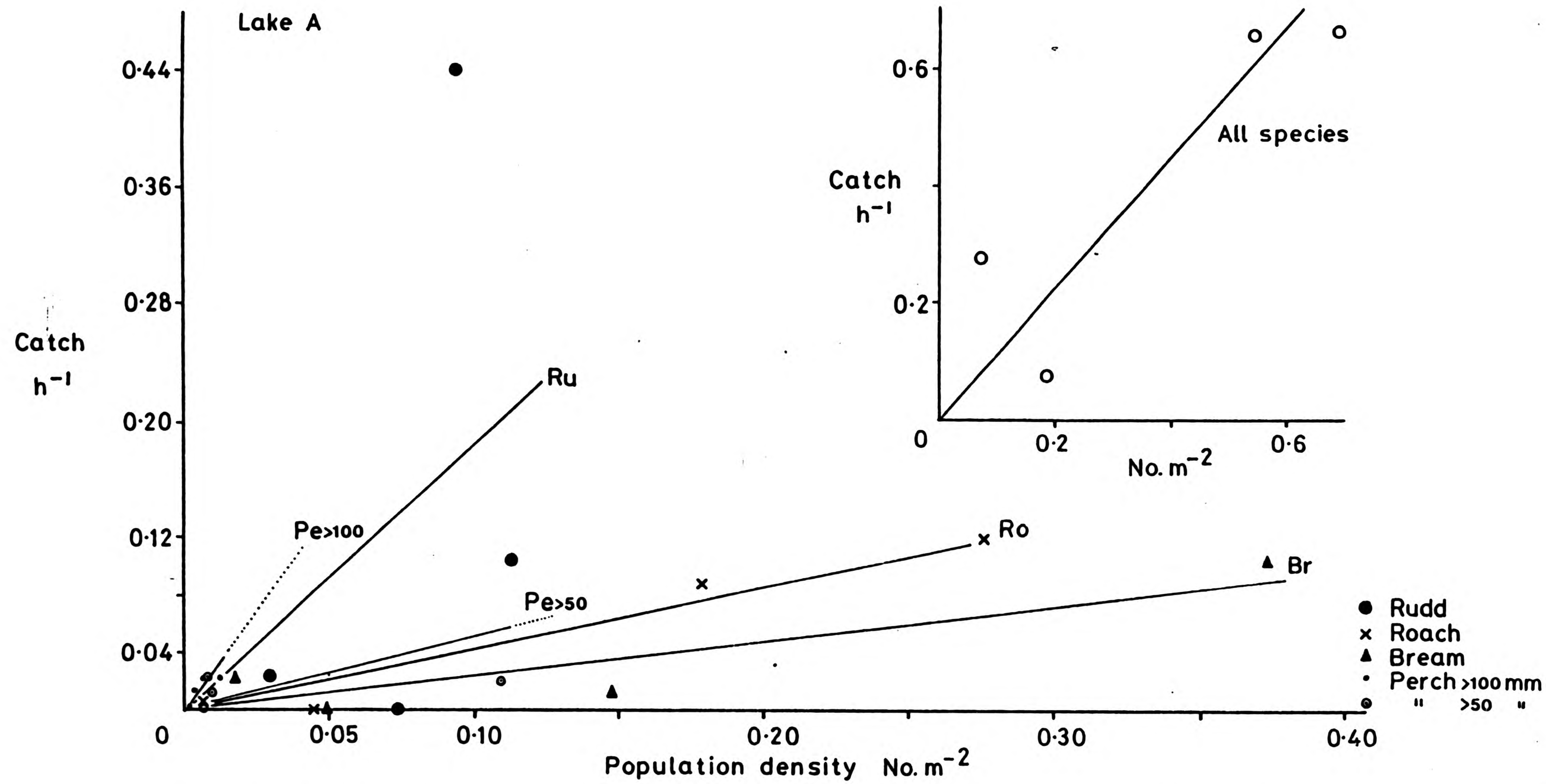

Fig. 44 Catch rate/population density relationships for rudd, roach, bream, perch and all species with fitted regression lines. Lake A, 1974 to 1976.

Catch rate and population density were positively correlated but only significantly in the case of roach. The population size of large tench remained similar throughout the study and there was no sensible relationship with catch rate. The slopes of the regressions emphasised the catchability differences that had been noted previously (see 3.3(iii)). For perch >50 mm the slope of the catch rate/density regression was less than that for perch >100 mm, suggesting that in spite of their vulnerability to angling (Table 47) the catchability of the former was relatively lower.

Stocking (Table 33; Fig. 29) increased the density of several species populations in Barham. For example, bream density was increased by about 24.2% in June 1975; in the following angling season 52 out of the 73 bream caught (71%) were marked stock fish and stocking appeared to be responsible for a greater than three-fold increase in bream catch rates through the season i.e. $^{21}/3233 = 0.006$ compared with $^{73}/3233 = 0.023$ (Table 64). Marked bream stocked in 1975 were not recognised in catches during 1976, but the alcian blue marks may have faded. The effect of the 1976 bream stocking over catch rates was not clear because the indian ink marks applied appeared to fade rapidly and many of the smaller bream were not marked.

Table 64 Bream catch rates and recapture of stock fish. Lake A, 1975

	Angling effort (h)	No. bream caught and examined	No. marked bream in catch	catch h^{-1} marked	catch h^{-1} unmarked
Jun.	917	19	11 (58%)	0.012	0.009
Jul.	1610	43	35 (81%)	0.022	0.005
Aug.	399	5	3 (60%)	0.008	0.005
Sep.	307	6	3 (50%)	0.009	0.009
Total	3233	73	52		

Roach stocked in October 1975 (Table 33) were not marked and those introduced in April 1976 were marked with indian ink (see comments above) however their introduction appeared to improve catch and catch rates of the species in the summer of 1976 compared with 1975 i.e. 144 roach caught in 1976 (June to September inclusive) but only 19 in the same period in 1975; catch rates were also higher in 1976 (see Fig. 32).

The crustacean zooplankton in lake A were sampled frequently (i.e. each week) from June to September in 1976 therefore correlations between zooplankton (abundance, No. m^{-3} and size) and catch rates were only attempted for that year.

None of the correlations (Table 65) between zooplankton densities in 1976 (Appendix 18) and weekly catch rates (Appendix 12) were statistically significant ($p \leq 0.05$). However, catch rates for rudd and perch were significantly correlated ($p \leq 0.05$) with the mean length of daphnids (Table 66a). Variation in the mean length of sampled cyclopoid copepods was slight and correlations with catch rates were not calculated. Correlations between numbers of crustacean zooplankton particles in certain length categories (i.e. number of particles >1 mm, 1 - 0.6 mm, 0.6 - 0.4 mm and <0.4 mm) and catch rates for rudd and perch were calculated; for this analysis crustacean zooplankton particles were considered as three groups: total crustacean zooplankton, copepods and daphnids. Table 66b shows that none of the correlations were significant.

Figure 45 suggests that rudd catch rates might decrease as the proportion of large crustacean zooplankton increases (but see above) however, it equally suggests that catch rates are depressed in the presence of zooplankton populations dominated by small zooplankters.

Bosmina sp was not present in the 1975 zooplankton samples but appeared during late July, 1976 (Appendix 18).

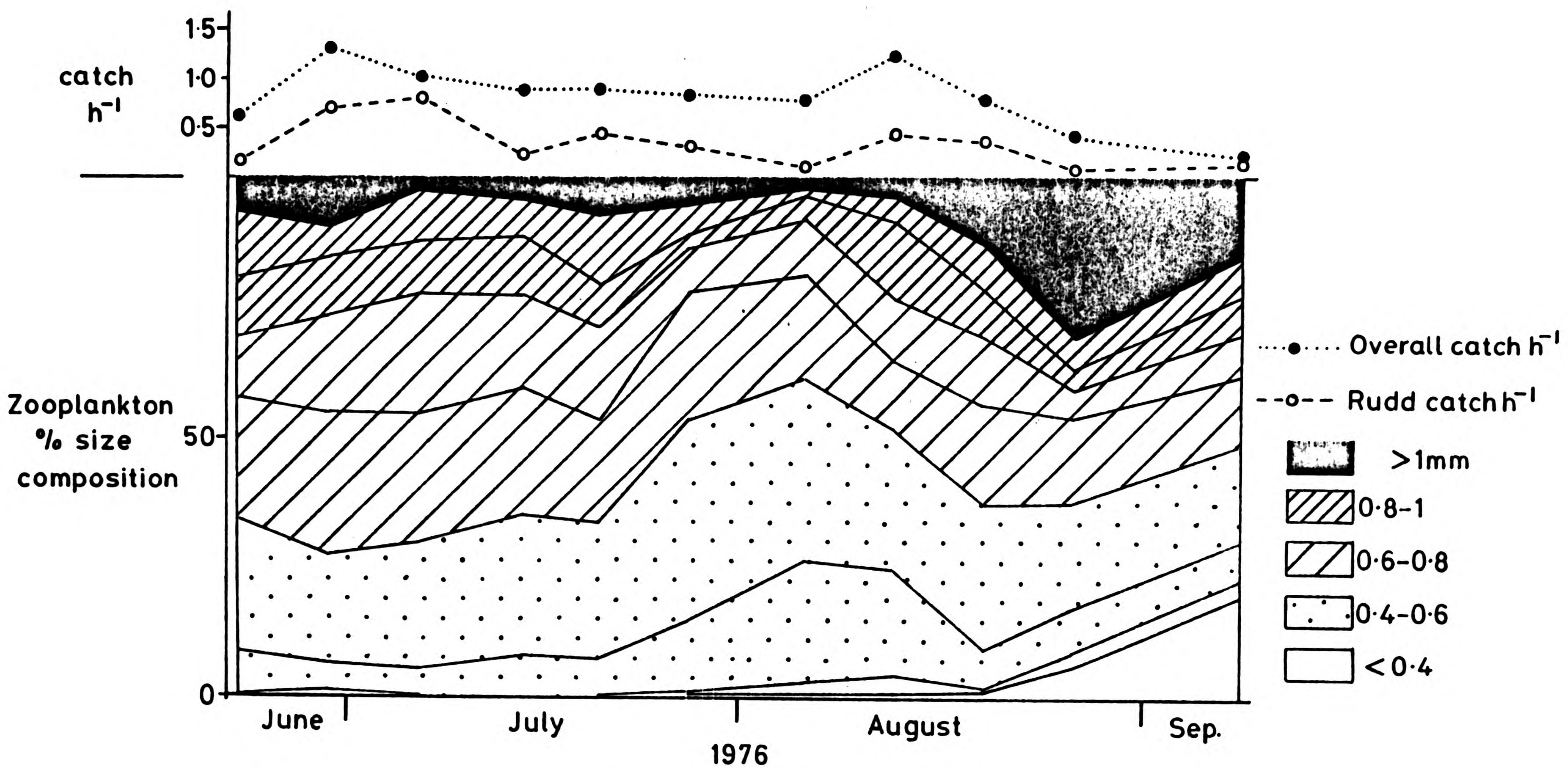

Figure 45 Zooplankton % size composition changes in lake A during the routine census 1976, with overall and rudd catch rates.

Table 65 Zooplankton densities[1.] X weekly catch rates to anglers[2.]; correlation coefficients. Lake A , 1976.

Species	Zooplankton					n
	All crustacean zooplankton	Daphnids	Calanoid copepods	Cyclopoid copepods	Bosmina	
Rudd	-0.1096	-0.1439	+0.3207	-0.0591	-0.3636	12
Rudd <100mm	-0.0352	-0.1145	+0.3535	-0.0098	-0.2854	12
Bream	-0.1195	-0.2197	-0.3969	-0.1969	+0.1421	12
Roach	+0.0493	+0.3786	+0.2237	+0.0501	-0.1047	12
Perch	-0.4010	-0.3556	-0.2123	-0.3637	-0.3772	12
All species	-0.2933	-0.2315	+0.0352	-0.2448	-0.4013	12

For p 0.05, r = 0.576 @ 10 d.f.

1. As numbers m^{-3}. See Appendix 18

2. See Appendix 18

Table 66 a Zooplankton mean lengths (mm)[1.] X weekly catch rates[2.] to anglers; correlation coefficients. Lake A, June to October, 1976.

Species	Daphnids (a)	Calanoid copepods (b)	n (a)	n (b)
All species	+0.5987	-0.0546	9	12
Rudd	+0.6813*	+0.0013	9	12
Rudd < 100mm	+0.6600	+0.0488	9	12
Bream	+0.0208	-0.3487	9	12
Roach	+0.2017	-0.5557	9	12
Perch	+0.6979*	-0.1465	9	12

Table 66 b Numbers of zooplankton[1.] particles in length groups X weekly catch rates[2.] for rudd < 100mm and perch; correlation coefficients. Lake A, June to October, 1976.

Zooplankton particles; Length groups. (mm)	All crustacean zooplankton		Copepods		Daphnia	
	Rudd	Perch	Rudd	Perch	Rudd	Perch
< 0.4	-0.2879	-0.3776	-0.2749	-0.0590	-0.2360	-0.4288
0.4 - 0.6	-0.0377	-0.3126	-0.0235	-0.3067	-0.2323	-0.3350
0.6 - 1.0	+0.4765	-0.1416	+0.4833	-0.1399	+0.1636	-0.1824
> 1.0	-0.1774	-0.3565	-0.1785	-0.3559	+0.0714	-0.0682

n = 12 in each case.

Note: 1. See Appendix 18
2. See Appendix 12
For p = 0.05 , r = 0.666 @ 7 d.f. and r = 0.576 @ 10 d.f.
* significant @ p 0.05 .

Table 66 a Zooplankton mean lengths (mm)[1.] X weekly catch rates[2.] to anglers; correlation coefficients. Lake A, June to October, 1976.

Species	Daphnids (a)	Calanoid copepods (b)	n (a)	n (b)
All species	+0.5987	-0.0546	9	12
Rudd	+0.6813*	+0.0013	9	12
Rudd <100mm	+0.6600	+0.0488	9	12
Bream	+0.0208	-0.3487	9	12
Roach	+0.2017	-0.5557	9	12
Perch	+0.6979*	-0.1465	9	12

Table 66 b Numbers of zooplankton[1.] particles in length groups X weekly catch rates[2.] for rudd <100mm and perch; correlation coefficients. Lake A, June to October, 1976.

Zooplankton particles; Length groups. (mm)	All crustacean zooplankton		Copepods		Daphnia	
	Rudd	Perch	Rudd	Perch	Rudd	Perch
< 0.4	-0.2879	-0.3776	-0.2749	-0.0590	-0.2360	-0.4288
0.4 - 0.6	-0.0377	-0.3126	-0.0235	-0.3067	-0.2323	-0.3350
0.6 - 1.0	+0.4765	-0.1416	+0.4833	-0.1399	+0.1636	-0.1824
> 1.0	-0.1774	-0.3565	-0.1785	-0.3559	+0.0714	-0.0682

n = 12 in each case.

Note: 1. See Appendix 18

2. See Appendix 12

For p = 0.05 , r = 0.666 @ 7 d.f. and r = 0.576 @ 10 d.f.

* significant @ p 0.05 .

CHAPTER 4

DISCUSSION

The Barham gravel-pit lakes that are the subject of this study are part of a complex of recently excavated lakes that extends along the valley of the River Gipping from Ipswich to Needham Market. They have been used as recreational coarse fisheries since 1969 and it is the intention of Suffolk County Council (Swain, Way and Horstead, 1977) that they will continue to be used in the same way. Apart from their location (see Fig. 1), the lakes at Barham are of similar age, surface area and average depth to those already studied by the City of London Polytechnic gravel pit study group. The same range of species were present (see Gee, 1976; Barber, 1976) with roach and bream the dominant cyprinids but with tench common. Growth of cyprinids, perch and pike varied considerably between pits (Gee, 1976) and from year to year (Gee, 1976; this study) and population sizes tended to fluctuate.

Gravel-pit lakes are undoubtedly important additions to the freshwater resources of the United Kingdom but they require appropriate management to achieve their full recreational and conservation potential. The aims of this investigation were to observe angling success under the rare circumstances of knowing the structure and abundance of the fish populations and to study the catchability and vulnerability of the fish species present, with a view to suggesting general and specific management practices applicable to small standing-water coarse fisheries, in particular gravel-pit lakes.

4.1 Fish growth, populations and production

Lakes A and B at Barham contained similar fish species (Table 5) although lake B held dace, chub and eels which were apparently absent from lake A despite the connection that had once existed between it and

and the River Gipping. Gudgeon were not caught in either lake but they were present in the river.

Rudd, roach, bream, tench, crucian and common carp, perch and pike had all been stocked sporadically from 1969 (Table 32) and it was often hard to distinguish indigenous fish from stocked ones. For this reason, growth estimates may not be fully representative of the gravel-pit environment, but the majority of fish caught at Barham were young (0 to 3+ years) and had probably been spawned in the lakes.

(i) Growth and populations

The greater part of the literature on the growth of coarse fish in the standing waters of the British Isles applies to long-established environments such as the Cheshire Meres, Norfolk Broads and Windermere (e.g. Banks, 1970; Goldspink 1978a and b; Hartley, 1947; Le Cren, 1947, 1951, 1958; Frost, 1954) with little published data available (Gee, 1976, 1978; Barber, 1976; Cook, 1979) for gravel-pit lakes which are of relatively recent origin.

To assist the assessment of the growth of coarse fish, growth standards have been proposed against which growth in specific waters can be compared. Kempe (1962) for example suggested that roach should achieve a standard of 40 mm in 'natural' Swedish lakes by the end of year 1, but Hickley and Dexter (1979) have advanced 50 mm as the standard for year 1 roach and bream in British waters. Hickley and Dexter's standards are listed (Appendix 17) and in the following discussion, when mean lengths at age for Barham fish are stated, they are followed (in parentheses) by a % relationship with an appropriate standard from the list.

There was statistically significant variation in the mean length of lake A year 1 roach, rudd and bream of the 1970 to 1976 year classes (Table 9; Appendix 1). The mean length for lake A roach at year 1 ranged from 57 mm (114%) to 92 mm (184%) for the 1976 and 1975 year classes. In lake B growth was poorer, with roach at year 1 ranging from 41 mm (82%) 1970 year class, to 49 mm (98%) 1974 year class. The differences in the composite mean lengths of roach in lakes A and B were not statistically significant after year 3 (see later).

Gee (1976) found that the length of year 1 roach taken from a number of gravel-pit lakes during a single year varied, from 35 to 95 mm. He was unable to correlate growth with any measured lake characteristic, but the variation of growth between pits and years is well established (Gee, 1976; Cook, 1979). Gravel-pit roach rarely grow as slowly as those in a Scottish reservoir (Mills, 1969) which were 25 mm at year 1.

In their second and third years lake A roach continued to grow well, with composite mean lengths (Appendix 1) reaching 107 mm (116%) and 148 mm (117%) respectively. However, the roach in Tatton Mere (Goldspink, 1978) were 175 mm by year 3, and those retained in an effluent treatment lagoon at Rye Meads (White, 1975) had the fastest growth of any recorded in the British Isles, i.e. 189 mm at year 3 and 283 mm at year 6. Previously, the fastest growth rate for roach was claimed for Chew Valley lake by Wilson (1971), but is now regarded as being in error (Gee, 1978).

The growth of roach and other fish may be stunted under certain conditions (see later) and Linfield (1974) refers to roach in Grey-Mist Mere that only reached ∿120 mm after eight years.

In common with roach and rudd the growth of the 1975 year class of lake A bream was good during year 1, i.e. 63 mm (126%) compared with 47 mm (94%) and 46 mm (92%) in 1974 and 1976. At 7 years the mean length of lake A bream was 322 mm (108%), almost reaching the average for Irish bream i.e. 330 mm given by Kennedy and Fitzmaurice (1968), but only corresponding to a medium growth rate according to Backiel and Zawisza (1968). Individual bream may grow rapidly in gravel-pit lakes however, e.g. 505 mm at 10 years (Gee, 1978); 450 mm (124%) and 435 mm (119%) at 8+/9 years (Lake A, Barham; this study).

Rudd in lake A were 40 mm at year 1 and 70 mm at year 2 (Appendix 1 composite) and their growth was average for gravel-pit lakes (see below). As with roach and bream, however, the growth of the 1975 year class of rudd was good in the first and second years (52 and 94 mm respectively). The rudd in Gee's (1976) gravel-pit lakes ranged from 31 to 47 mm at year 1 and 80 to 88 mm at year 2; in subsequent years their growth compared favourably with that achieved in ponds of the Elbe region, Czechoslovakia (Frank, 1962). Growth of rudd in the Norfolk broads (Hartley, 1947) was similar to that achieved in Gee's lakes and at Barham. Rudd may grow more rapidly; for example, Steinmetz (1974) has reported rudd reaching ∿210 mm after 4 years in a stock pond in Holland.

The growth of tench and crucian carp was more difficult to assess; Weatherley (1959) reported that the interpretation of tench scales was straightforward and Kennedy and Fitzmaurice (1970) claim that they were able to readily resolve the annuli on tench scales, so long as they were examined wet and under high magnification. However, it was not easy to determine the age of lake A tench by scale reading and Gee (1976) experienced similar problems ageing gravel-pit tench. In both situations (this study; Gee, 1976) age was determined from opercular bones, where annuli were clearly visible. Because of the importance of tench in angling waters (see later), it is essential that methods of age determination that do not require fish to be killed are thoroughly investigated.

The growth of lake A tench during their first year was good i.e. at year 1 they ranged from 37 to 53 mm exceeding the size range (25 to 31 mm) for tench of the same age for Kuybyshev Reservoir (Kutznetsov, 1975). Until year 5 the growth of lake A tench broadly corresponded with the growth of those in College Lake, Ireland (Kennedy and Fitzmaurice, 1970) but beyond that age the growth of Irish tench was superior. Examination of Gee's (1978) tench data, applying the assumption that the first two annuli were missed at ageing because of the thickening of the opercular bone, suggests that tench from gravel-pit lakes may grow to 210 to 250 mm by year 5, equalling growth in many Irish lakes (Kennedy and Fitzmaurice, 1970).

The large (>350 mm) tench caught in lake A were estimated to be >10 years old and had probably been stocked during 1969 (Table 32). Kennedy and Fitzmaurice (1970) found that female tench grew faster than males; in lake A the largest tench caught were females (Fig. 20).

The data for crucian carp were sparse but growth appeared to be as good as generally reported (Muus and Dahlstrøm, 1978) for mainland Europe.

Most of the perch caught at Barham were 0+ to 2+ years, and were growing well compared with perch in Rostherne mere (Banks, 1970) and other gravel-pit lakes (Gee, 1978), but not as fast as in Windermere (Le Cren, 1958).

The growth of pike during their first three years in lake A was also poor compared with growth in Windermere (Frost and Kipling, 1959) and Rostherne mere (Banks, 1970), but fast-growing pike were present: in 1975 a pike of 1010 mm (7+ years) was caught in lake A and during 1977 a pike, possibly the same fish, of 1070 mm was caught and aged at 9+ years, such rapid growth is equivalent to that reported (Healy, 1956) for Lough Glore, Ireland.

In comparison with other similar standing waters the growth of cyprinids, perch and pike in lakes A and B at Barham was generally good, providing adequate numbers of fish vulnerable to angling. The rapid growth rates of some of the species e.g. roach and bream, in their early years of life, may be attributed to the maintenance of low population densities by predation, disease or angling or to other factors such as the domination of crustacean zooplankton populations by small (<1 mm) forms. This type of zooplankton fauna may develop because of size selective predation of the zooplankton by fish (e.g. Brooks and Dodson, 1965; Stenson, 1972; Nilsson, 1978; Cook, 1979) and once established improve the growth and survival of young (0+ to 1+) cyprinids. The results show (Fig. 45; Appendix 18) that in lake A the crustacean zooplankton was dominated by small animals, particularly during 1976 when the populations of young cyprinids appeared to be increasing (Fig. 28a).

Backiel and Le Cren (1978) have suggested that cyprinids held in small impoundments will naturally tend to form dense, slow-growing populations, and it is possible that the good growth rates observed in gravel-pit lakes so far (Barber, 1976; Gee, 1976; Cook, 1979 and this study) may merely represent an early phase in population development.

There was evidence for the growth of cyprinids in lake A being density dependent: in 1975 when population densities were low (Fig. 28a; Appendix 16) the growth of roach, rudd, bream and tench of the 1975 year class was rapid. In 1974 and 1976 population densities were higher and the growth of 0+ cyprinids was poorer in both years relative to 1975 (Table 9). Burrough and Kennedy (1979) observed an increase in the growth of roach in Slapton Ley during 1976, following extensive roach mortalities in 1975. It should be remembered however that reductions in population density have failed to precipitate increased growth (Van Oosten and Hile, 1949) and changes in food supply or climate (see below) may be as important.

The structure of roach, rudd, bream and perch (see above) populations in lake A were biased towards young fish (i.e. <4 years) although 8 year classes were identified for roach and bream and 12 for rudd by 1976 (the older year classes were considered to include many introduced fish). Large old fish were more scarce than expected in the gravel-pit lakes studied by Gee (1976) and a similar situation has emerged in recent studies on the Norfolk Broads (Wortley; pers. comm.) suggesting that recruitment into older age groups has been partially impaired in recent years. However, in view of the sparse data on coarse fish populations it is difficult to decide on the 'normality' of population structures particularly if sampling has been infrequent or based on selective capture methods.

In 1973, 1975 and 1976 rudd and bream in lake A formed strong year classes whereas roach formed strong year classes in 1973 (also in lake B) and 1976 but not in 1975. The 1974 year classes were weak despite the presence of adequate numbers of mature roach, rudd and bream to ensure spawning and further suggesting that recruitment is not simply related to mature stock.

Growth rates of 0+ roach, rudd and bream were good in 1975 (see above) but only average in 1976 and the latter suggests that density dependent effects masked the stimulation of growth observed by others (Broughton and Jones, 1978; Cook, 1979) during the fine summer of 1976. Interestingly, roach and bream formed strong year classes in several waters in 1973 (Cook, 1979; Goldspink, 1978a), but as in lake A, the 1974 year class of roach was weak in Rostherne and Tatton Meres (Goldspink, 1978a). Such coincident reports emphasise the importance of climate as a factor controlling spawning and early survival of coarse fish and ultimately year class strength. Climate probably operates mainly by affecting water temperatures; the direct and indirect (i.e. acting through the fish food supply) effect of water temperature on growth, reproduction and survival has been thoroughly discussed, e.g. Broughton and Jones, 1978; Le Cren, 1955 and 1958.

Because population estimates are central to a study of this kind it is appropriate to briefly discuss their reliability. While it is not claimed that the estimates for the Barham fish populations are precise, they may be regarded as approximately accurate in view of the number of indirect checks that were made:

(i) estimates of the number of large tench present in lake A were, after allowing for some mortality, compatible with the numbers stocked in 1970 (Table 32);

(ii) changes in catch rates to anglers were positively correlated with changes in estimated population sizes;

(iii) seine net capture/recapture and angler capture/recapture estimates were often similar;

(iv) population estimates generally increased after stocking;

(v) Schnabel estimates of the rudd population tended to increase through the summer indicating sensitivity to recruitment (Lagler and Ricker, 1943).

There was also some evidence (Chapter 3.1) from the calculation of μ values (Gee, 1976) that marked fish were either more or less catchable than unmarked fish and there were occasions, when the mortality of marked fish was clearly very high; both findings suggest that there were times when the fundamental principle of mark/recapture i.e. equal catchability was not upheld. In particular, the estimates for roach in lake A during October 1976 and September 1977 (Table 15) were considered unreasonable, as were those for lake B roach in June to July, 1975 and consequently adjustments were made in the production of 'best' estimates. Because of the wide variation in sample sizes Bailey's Triple Catch estimates were also suspect (Gee, 1975; Cook, 1979) and were not therefore accorded much weight in the determination of 'best' estimates.

The population density of rudd in lake A remained relatively low throughout the study period but was subject to modest fluctuation (Table 11; Fig. 28a); from 1974 to 1975 the population was reduced by approximately two-thirds but increased five-fold by 1976 only to be halved in 1977. Interaction with other species (Burrough, Bregazzi and Kennedy, 1979) and anglers may have limited rudd population expansion. Bream populations (Table 19) in lake A showed a steady increase from 1974 however and the heavy stocking during 1975 and 1976 obviously assisted this development.

In contrast the size of the roach population in lake A changed drastically between 1974 and 1977: the density of roach greater than 1 year old was reduced more than fifty-fold between 1974 and 1975 but had increased to 119 times the 1975 population size by the autumn of 1977. The decline of the roach population between 1974 and 1975 appeared to be relatively gradual but comparable with previously-observed roach population reductions (Sweeting, 1976; Burrough and Kennedy, 1979) caused by epidemics of the parasite Ligula sp. In lake A however, Ligula sp. was not responsible. The decline was probably precipitated by an unidentified ulcerative disease of a kind previously implicated with roach losses (e.g. Ayton, 1974; Bottomley and Woodiwiss, 1969), coupled with selective predation by cormorants and pike (see below).

Cormorants were often seen at Barham, particularly during the autumn and winter of 1975 and 1976. Five cormorants were shot in the winter of 1975 while at roost not more than 400 m from lake A and the contents of their oesophageal pouches and stomachs examined (Table 67).

Table 67 Length of fish found in the guts of five cormorants and the occurrence of other contents.

Species	Mean length and range (mm)	n	Scales %	Pharyngeal bones %
Roach	157 (55 - 270)	7	80	60
Perch	126 (55 - 250)	3	20	-
Rudd	42 (40 - 45)	2	-	-
Bream*	-	-	20	-

* Some scales from Blicca bjoerkna (L.) (Wheeler; pers. comm.)

Three of the cormorants were adult, two juveniles. The gut of one adult bird was empty, but the other adults contained 165 and 7 g wet weight of fish respectively, the juveniles 170 and 290 g.

Several large (>200 mm) roach and rudd were caught from Barham in the winter of 1975 bearing wounds that may have been inflicted by cormorants. Correlation between wound structure on one large female roach and the dimensions of the lower bill from an adult cormorant was highly significant ($r = 0.9968$, $n = 14$; $p < 0.001$). Surprisingly a common carp (~300 mm) was found alive on the bank of lake A in February 1975, with fresh wounds similar to those found on roach and rudd.

The above data, although sparse, imply that cormorants were feeding on the fish in Barham during 1975, particularly on roach. McIntosh (1978) has suggested that slow-moving shoaling fish such as roach, that swim in mid-water, are most likely to be taken by cormorants; diseased roach may be expected to be even more susceptible and Van Dobben (1952) has reported selective predation of ligulosed fish by cormorants. Pike may also prey selectively on diseased fish (see later).

The population of large tench in lake A decreased slowly throughout the study and the relatively slow growth of young tench affected recruitment into the large size group. The large tench were an important part of the fish community in lake A, but small tench did not appear to be so abundant as small roach, bream or rudd. Kennedy and Fitzmaurice (1970) reported that a water temperature of 20°C or more was necessary for spawning of tench, and they observed that tench failed to spawn in some years in certain waters. Spawning tench were observed in lake A and B in 1975 and 1976 and the presence in 1976 of 6 year classes (1970 to 1975) in lake A, exclusive of the large stock tench, indicated that spawning had occurred each year following the introduction of the species in spring 1970; however, spawning may have been suboptimal in some of those years and in addition, the survival of young tench could have been adversely affected by interaction with other species. Kennedy and Fitzmaurice (1970) observed the cryptic behaviour of juvenile tench in aquaria and found that they were unable to obtain sufficient food when placed in an 'open water' situation with juvenile roach and rudd. If their observations are applicable to natural waters, the survival and growth of young tench may depend partially on the presence of stands of submerged macrophytes. The restriction of the latter to a narrow band round the margin of lake A (Fig. 4) could have been a factor governing the success of tench and other species e.g. rudd. Habitat partitioning of the kind alluded to above may be common in freshwater fish communities (Werner, Hall, Laughlin, Wagner, Wilsmann and Funk, 1977); further evidence for habitat partitioning in lake A is discussed later.

The number of large crucian carp in lake A appeared to decline steadily between 1974 and 1977; damage and stress caused by multiple capture may have contributed to the decline, but no dead fish were observed. Very few young crucian carp were caught and reproductive success was poor.

The perch population in lake A was small (<700 fish) and composed of mainly young fish, except during 1976 when older stock perch (Fig. 25) were common. Perch ulcer disease (Bucke, et al. 1979; Goldspink and Goodwin, 1979; Pickering and Willoughby, 1977), reduced feeding success (see below) and other subtle effects of eutrophication (e.g. Leech, Johnson, Kelso, Hartmann, Numann and Entz, 1977) may have prevented the development of a more 'typical' population structure i.e. a population with large numbers of young small fish with gradually falling numbers of fish in the successively older age groups.

Pike were the main piscivorous fish in the lakes at Barham; they were not abundant in lake A, but several year classes were represented in the samples (Fig. 27). The dependence of pike and possibly perch on visual search hunting (Frost and Kipling, 1967; Nilsson, 1978) may have resulted in their feeding being adversely affected by the turbid conditions in lake A. Large pike were present however, and the conditions may have caused them to feed more extensively on diseased, damaged and juvenile prey (see later). Sweeting (1976) noted that pike selectively removed ligulosed roach from a population held in a turbid lake (Sweeting, pers. comm.) and it appears that pike, and presumably perch, are able to locate their prey using olfactory and acoustic senses - diseased or damaged fish probably behave in a manner that makes them easy to find under conditions of low visibility. It is intriguing to consider the possibility of pike-cormorant interaction in so far as fish that escape cormorant attack in a damaged state (see above) may be more vulnerable to predation by pike.

Mortality among young immature i.e. 1+ roach and rudd was high -

i.e. $Z = 2.27$ and 2.61 respectively for 1975 year classes; but relatively low i.e. $Z = 0.69$ for 1+ bream of the same year class.

Survival rates for lake A adult roach ($S = 0.58$; $S = 0.48$, 3+ group) were lower than rates reported for River Stour fish; $S = 0.64$ (Mann, 1973) and for Rostherne mere (Goldspink, 1978a) where $S = 0.80$ to 0.92 (females) and 0.57 to 0.74 (males).

Survival of large tench in lake A was good ($S = 0.69$ to 0.94) but there was a 46% reduction in the numbers of large crucian carp caught in 1975 compared with 1974 (see Chapter 3).

Sampling of the fish populations was not designed to obtain an analysis of condition, but some changes in condition (K) were observed for rudd, tench and bream in lake A. Rudd and tench appeared to have a simple cycle of condition with a single peak about the time of spawning (Figs. 8 and 20). The cycle of condition for bream appeared to be more complex, with a suggestion (Table 18) of two peaks, one at spawning and another in summer. Weatherley (1959) found that tench in Tasmania also had a simple annual cycle of condition and this may be typical for summer spawners e.g. tench, rudd and crucian carp in the temperate zone. Perch (Le Cren, 1951) and roach (Mann, 1973) which spawn in the spring however have time to reach a second peak of condition after spawning, and bream probably fall into this category.

The condition (K) of rudd and tench from lake A was generally higher during June to August 1975 than in the same period of 1976 (Figs. 8 and 38; Appendix 9) suggesting a growth response to a general reduction in fish population density during 1975 (see above). Alternatively, late spawning/spawn reabsorption may have been responsible for the maintenance of high condition (K) during the summer of 1975 (see 4.2(ii) for further comments regarding condition).

Small cyprinids and perch from lake A were certainly planktophagous, an observation that agrees with the findings of more detailed investigations by Barber (1976), Cook (1979) and other authors. Cook (1979) for example found that 1+ roach fed selectively on cladocerans, selecting Daphnia and in particular the larger individuals, but switched to feeding on Bosmina when Daphnia were scarce. He noted that roach consumed very few copepods, which also appeared to be the case in lake A. Daphnia are important in the diet of larger (67 to 143 mm) gravel-pit roach (Barber, 1976), but they are often eaten along with a variety of benthic organisms. Stenson (1972) also regarded adult roach as being facultatively planktophagous and White (1975) found that they consumed large numbers of crustacean zooplankton; under certain conditions, however, molluscs, chironomid and trichopteran larvae may constitute the bulk of their diet (Mann, 1973; Hartley, 1947).

Hartley (1947) observed that plant material comprised the main food for rudd taken from the Norfolk Broads, but in addition to plants, lake A rudd fed on daphnids and benthic invertebrates. A range of planktonic crustaceans and filamentous algae were found in the guts of lake A bream <80 mm. Adzhimuradov (1978) found that juvenile bream relied heavily on crustacean zooplankton, but according to the references below, larger fish eat chironomid larvae, trichopteran larvae, molluscs, tubificid worms and crustaceans e.g. Gammarus (Hartley, 1947; Kennedy and Fitzmaurice, 1968).

Weatherley (1959) and Kennedy and Fitzmaurice (1970) found that juvenile tench consumed much the same food as bream of similar age; the crustacean zooplankton recovered from the guts of small lake A tench were essentially similar to those found in the guts of small Irish tench (Kennedy and Fitzmaurice, 1970). The guts of lake A tench >232 mm were not examined but Kennedy and Fitzmaurice (1970) report that the chief foods of large tench were molluscs,trichopteran and chironomid larvae, ephemeropteran nymphs and crustaceans; tubificid worms were rarely found in the guts of Irish tench, but were a major item in the diet of tench from a Tasmanian farm dam, as were Odonata nymphs (Weatherley, 1959).

Perch of >1 year feed on benthic invertebrates and fish (Alm, 1946;

Smyly, 1952; Healy, 1954; Banks, 1970; Barber, 1976; Guma'a, 1978) but this does not mean that adult perch ignore zooplankton; Thorpe (1974b) and White (1975) have shown that adult perch may feed heavily on crustacean zooplankton. Crustacean zooplankton, particularly copepods, were common in the diet of small perch in lake A, and other workers (Smyly, 1952; Guma'a, 1978 and Cook, 1979) have found that fast-moving copepods are more attractive to 0+ perch than slower-moving cladocerans. Cook (1979) found that 0+ perch and roach in a gravel-pit lake operated their different feeding strategies simultaneously i.e. roach feeding on cladocera and perch on copepods, and he advanced his findings as strong evidence for food resource partitioning. Until further work is completed it may be unwise to extend the concept to fish >1 or 2 years or to different species, and Burrough et al (1979) have suggested that the co-existence of perch with rudd and roach may depend on perch being dependent on zooplankton for a much shorter period than either cyprinid, reducing the effect of competition for a resource.

Examination of the guts of fish captured by rod and line revealed that maggots were present in the guts of all species (Table 13), one tench(128 mm) examined had 12 maggots in its gut and this compared with reports by Moore (1973) of smaller roach and bleak containing 15 to 20 maggots. Furthermore, fish caught by angling more frequently contained benthic organisms and detritus compared with seined fish. Macan, McCormack and Maudsley (1967) observed a small qualitative difference between the stomach contents of trout caught in gill nets and those caught by rod and line, but the numbers of fish examined from lake A were too small to confidently state that fish caught by angling were predominantly feeding on benthos or zooplankton.

Maggots and other hook baits are normally thrown into the water as 'ground bait' by anglers, and maggots at least have probably achieved the status of 'natural' food items in many coarse fisheries. This may account for the lack of measurable hook avoidance behaviour (see later) in several fish species studied so far, and explain the continued success of maggots and other baits that are used in a similar fashion.

Although the gut contents of pike from lake A were not examined, the diet of standing-water pike has been studied on several occasions e.g. Hartley, 1947; Frost, 1954; Healy, 1956 and Banks, 1970. In view of their importance as predators and the presence of several large pike in lake A, some speculation on their feeding is appropriate. It is generally recognised that large pike can consume large prey fish and Banks (1970) has proposed that a few such fish comprise the bulk of nutrition of large pike. However, he conceded, along with other workers (see references above), that large pike may take many small (20 to 80 mm) fish. It is possible that the nutritional importance of small cyprinids and perch in the pike's diet is underestimated because of their rapid digestion compared with larger prey (Popova, 1978). If sufficient numbers of small prey are eaten, any extra effort expended in their capture may be compensated by increased digestive efficiency.

It is therefore reasonable to suggest that the pike in lake A, while they possibly consumed prey of all sizes, concentrated their feeding on young i.e. 0+ and 1+ fish (cyprinids and perch) regulating the population sizes of the latter and indirectly increasing their growth rates. This is discussed further (this chapter, section 4.4).

(ii) Biomass and production

Biomass estimates for several gravel-pit lakes are given in Table 68, with a number of roach biomass estimates for other temperate standing waters and rivers. The range of total biomass for lake A was within the limits previously reported for gravel-pit lakes, but in general terms it appears that the fish biomasses in small- to medium-sized gravel pits may be about half those in lowland rivers (see below) and intensively managed ponds.

Williams (1967) estimated the biomass of roach, perch, bleak and dace in the River Thames at Reading as 47.6 g m^{-2} but Mann (1965) put the figure higher to 65.9 g m^{-2} by including all fish species and allowing for size groups not vulnerable to the net, Hrbácek, Dvoráková, Korínek and Procházková (1961) have estimated the biomass of a mixed species population of small cyprinids in a backwater of the River Elbe as 110 g m^{-2} but because of the situation, this may be more in line with the true biomass in nutrient-rich lowland lakes. Undoubtedly the biomass estimates for gravel pits could be increased if allowances were made for all fish present; for example, Cook (1979) considered that the highest total biomass estimate for Darenth 39 could be increased up to three times by the inclusion of common carp biomass.

Mann (1965) reported that roach contributed ~32% (21.2 g m^{-2}) of total biomass in the River Thames at Reading, but Hart (1971) found that they dominated (50 g m^{-2}) certain reaches of the River Nene. Roach comprised 70.1% and 96.0% of total biomass respectively in two gravel-pit lakes, Darenth 40 and Twyford 32, studied by Gee (1976) and in Farnborough and Yately between 1975 and 1976 the decline of roach was responsible for a steady decrease in fish biomass (Cook, 1979). In lake A the roach biomass was reduced by 97.3% between August 1974 and June 1975, with important effects on the fishery (see 4.1(i) and 4.2). Roach biomass was exceptionally high in Humbie Reservoir but Mills (1969) neglected to record whether other species were present.

Small numbers of large tench made up 43 to 77% of fish biomass in Farnborough 18a and Yateley 7 (Gee, 1976; Cook, 1979) and they comprised 23.9% of fish biomass in lake A until bream dominated the community in 1977 (Table 31). Cook (1979) detected a steady increase in bream biomass in Darenth and in one of Gee's lakes (Larkfield 41) bream contributed 96.4% of total biomass, but few other species were present. With the exception of tench and common carp, the bulk of fish biomass in the gravel gravel pits studied so far has been in the form of young 1 to

Table 68 Biomass and production estimates for coarse fisheries in still waters and rivers of the British Isles.

Water	Area ha	Total B $g\ m^{-2}$	Roach B $g\ m^{-2}$	P $g\ m^{-2}yr^{-1}$	Total P/B	Source
Gravel-pit lakes						
Yateley 7	0.46	6.3 - 38.8	1.03 -12.06	-		Barber, 1976
" "	"	26.4 - 40.2	0.82 -14.18	-		Cook, 1979
Darenth 39	4.95	1.76[1.]	0.83	7.54	1.9	Gee, 1976
" "	5.69	3.9 - 14.8	0.14 - 3.32	-	-	Cook, 1979
Darenth 40	0.16	16.43	11.51	49.8	1.3	Gee, 1976
Farnborough 18a	1.17	26.74	7.12	51.4	1.4	" "
" "	1.09	25.7 - 48.8	4.15 -15.84	-	-	Cook, 1979
Twyford 32	6.83	0.59	0.56	1.96	2.8	Gee, 1976
Larkfield 41	2.74	38.57	1.39	35.7	1.3	" "
Barham A	1.71	17.9 - 36.5	0.23 -11.07	23(30)[2.]	1.5,2.1[3.]	This study.
Other standing waters						
Humbie Reservoir	2.9	-	41.6[4.]	-	-	Mills, 1969
Tatton Mere	31.7	-	3.86	-	-	Goldspink, 1978
Rostherne Mere	47.8	-	3.62	-	-	" "
Rye Meads Effluent Lagoon		18.2 - 37.7				White, 1975
Reservoir Intake Lagoon	0.30	-	10.5,2.1[5.]	14.6,8.6	1.2,1.9	Hickley and Bailey, 1977
Rivers						
R.Tarrant	-	-	-	57.8[6.]	-	Mann, 1967
R.Thames	-	65.6		197[7.]		Mann, 1965

Note: 1. Estimates exclude common carp biomass assessed as an additional 9 to 44 $g\ m^{-2}$ (Cook, 1979).

2. See Chapter 3.

3. 1974 to 1975 values followed by 1976 to 1977; restricted to roach, rudd, bream and perch.

4. Roach > 120mm

5. 1972 followed by 1973 values - cropping between 1972 and 1973.

6. Includes trout production but bullheads accounted for 41.6 g

7. 185g produced by young roach, gudgeon, bleak and dace.

3+ roach and bream.

As expected, pike formed a relatively small part, 5.3 to 8.0%, of total fish community biomass in lake A (Table 31); in Darenth pike biomass was similar i.e. 4.4 to 20.3% of total fish biomass, with actual biomass also similar at 0.22 to 1.97 g m^{-2} (Cook, 1979).

Perch population and biomass was low (i.e. 0.3 to 4.3% of total biomass) in lake A compared with Yateley 7 and Farnborough 18a, where they represented 18.4 and 18.8% of total biomass respectively (Cook, 1979). However, when Gee (1976) studied the same pits, perch did not exceed 4% of the total fish biomass. Changes in the fish populations of this kind and magnitude may be commonplace (see section 4.1(i) for comment).

The role of stocking in biomass changes is important generally. Lake A was stocked regularly over a number of years (Tables 32 and 33) in the hope that catch rates to anglers would be continually improved. Some of the stockings were heavy: existing estimated biomass was increased by 2.85 g m^{-2} (14.5%) by the combined stocking of June 1975 and by 6.51 g m^{-2} (36.3%) between the autumn of 1975 and late spring 1976. The biomass of bream stocked exceeded that of all other species (Table 33), but stocking with roach was second in importance. The two bream stockings were large, and in each case greater than the 1975 biomass estimates for the entire bream populations of Darenth or Farnborough reported by Cook (1979), and probably increased the pre-existing bream biomass of lake A by 147% in 1975 and between 202 and 377% in 1976. The latter stocking also increased the numbers of bream fourfold; however, increases in the numbers of other species by stocking were more modest.

The increase in bream biomass in lake A resulting from the stocking in June 1975 was not sustained until the introduction of stock in April 1976. After April 1976 however, the increase in biomass was not only maintained, but almost doubled by October 1976 and continued at a high level to September 1977. Roach biomass increases due to stocking always appeared to be sustained, but this does not necessarily imply that the survival of the stock fish themselves was good. In general, the biomass introduced by stocking appeared to be maintained; as a further example a total of 8.60 g m^{-2} of rudd, roach, bream and perch were stocked (Table 33) between September 1975 and the end of April, 1976. Before the stocking the best estimate of pre-existing biomass was that of June/ July 1975 at 17.92 g m^{-2} (Table 33), afterwards, in April 1976, the biomass was estimated at 26.53 g m^{-2} (i.e. sum of 8.60 and 17.92) increasing by up to 38% by September 1977. Unfortunately it was not possible to distinguish endogenous from exogenously produced biomass.

In spite of the effects of stocking, the standing crop in lake A did not exceed the highest estimates (Table 68) for other gravel-pit lakes, but it would be interesting to observe the effects of stocking on a water where the pre-existing biomass was judged to be close to maximum. The effects of stocking on standing crop and production are discussed further (see section 4.4).

The short-term (2 to 3 months) survival of bream stocked into lake A during June 1975 was good (Figs. 15 and 29), but their long-term survival was unknown. Their catchability appeared to be high and Timmermans (1967) noted that for some time after their introduction stock roach were more common in anglers' catches than roach from the indigenous population. Increased catchability of stock fish may depend on search behaviour being elevated in a new environment, resulting in more encounters with anglers' baits.

In contrast with bream it appears (see below) that roach are not so easy to stock. The survival of small roach stocked into lake A during 1975 was uncertain, none were caught during the routine census, and in 1976 marked stocked roach were not caught although this may have been due to marks fading or poor survival. However, anglers did catch more roach in 1976 (see Table 7 and Fig. 13) and some of them must have been level to September 1977. Roach biomass increases due to stocking always appeared to be sustained, but this does not necessarily imply that the survival of the stock fish themselves was good. In general, the biomass introduced by stocking appeared to be maintained; as a further example a total of 8.60 g m^{-2} of rudd, roach, bream and perch were stocked (Table 33) between September 1975 and the end of April, 1976. Before the stocking the best estimate of pre-existing biomass was that of June/July 1975 at 17.92 g m^{-2} (Table 33), afterwards, in April 1976, the biomass was estimated at 26.53 g m^{-2} (i.e. sum of 8.60 and 17.92) increasing by up to 38% by September 1977. Unfortunately it was not possible to distinguish endogenous from exogenously produced biomass.

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In the year following their introduction to a Belgian canal (Timmermans, 1967) recaptures of stock roach decreased steadily and although roach stocked into the River Nidd (Axford, 1974b) appeared in anglers' catches immediately after stocking, they made up an insignificant portion of the catch five months later. Ayton (1976) introduced 3183 perch >90 mm into a midland canal, but only 4 were known to have been caught. In all three cases cited, dispersion probably accounted for the apparent disappearance of stock fish, but in some instances they may die from injuries received during capture and transportation (Bennett, 1970).

Barber (1976) found that the survival and growth of roach stocked into a gravel pit containing other species, was equal to that of native fish, but the pit that he studied was not used for angling. Compared with Ayton's (1976) stocking of perch (above), the introduction of perch into lake A during October 1975 was successful, they over-wintered in sufficient numbers to feature in anglers' catches in 1976, an observation that supports Timmermanns' (1967) opinion that stocking would only be justified for small understocked enclosed waters where the stock could be caught before its removal by natural mortality.

The more direct effect of stocking on angling success is considered in section 4.2(i) and in the final section (4.4).

Some stocking of lake A occurred in 1975 at a time of population decline when the first year growth of rudd, roach and bream was good, stocking between September 1975 and April 1976 however was particularly heavy (Table 33) and first year growth of rudd, roach and bream in the 1976 growing season was reduced to 86%, 62% and 73% respectively of 1975 mean lengths at year one (see section 4.1(i) for comparison with Hickley and Dexter's (1979) standards). Interestingly the mean year 2 to year 3 growth increment for the 1974 year class of bream in 1976 was only 23 mm compared with 63 mm in 1975 (1973 year class), 77 mm in 1974 (1972 year class) and 60 mm in 1973 (1971) year class). However, in view of earlier comments about year-to-year variation in growth it would be unwise to suggest increased stock density as the only cause of growth suppression in lake A during 1976.

The introduction of so many relatively large roach and bream into lake A probably conferred an advantage on these species by increasing reproduction and/or modifying the environment to favour growth and survival of their young, allowing them to finally dominate the fish community by the autumn of 1977.

Estimates of production (Table 34) for lake A were approximate, (estimates of 2+ to 4+ fish were judged to be low) but valuable as production data for mixed coarse fish populations is scarce. Annual production of roach, rudd and bream in lake A during 1976 to 1977 was conservatively estimated as 23 g m^{-2} yr^{-1}. Tench, crucian and common carp may have collectively produced about 2 g m^{-2} yr^{-1} and the pike 4.5 g m^{-2} yr^{-1} (i.e. using $P \doteq 2B$ from Chapman, 1978) giving a total annual production of approximatly 29.5 g m^{-2}, which compares slightly unfavourably with production of 35.7 to 51.4 g m^{-2} yr^{-1} (Table 68) in other similar size gravel-pit lakes (Gee, 1976). For further comparison production in intensively-managed ponds in the temperate zone may be about 45 g m^{-2} yr^{-1} (Macan and Worthington, 1968) but many temperate standing-waters only produce up to 15 g m^{-2} yr^{-1} (Chapman, 1978).

Staples (1975) found that production in the small part of Spectacles Lake (max. depth ~4 m; area 0.58 ha) New Zealand by the only species present, the upland bully (Philypnodon breviceps. Stokell), reached 40 g m^{-2} yr^{-1}, supporting Le Cren's (1972) observation that small fish are capable of very high production. It was clear that young bream and roach (Table 34) made the greatest contribution to production in lake A even though their biomass was initially less than that of the tench; Gee (1976) found a similar situation in his lakes that contained tench.

The contribution of parts of a fish's life cycle to production has not been widely studied; in the first month or so after hatching, cyprinids and other coarse fish are abundant and growing fast. However, their contribution to annual production is probably negligible during this phase because maximum mortality occurs in the first few weeks after hatching, and individuals that die then will contribute little to production. With older but still young fish i.e. late 0 to 1+, the situation is quite different: Goldspink (1979) has reported that roach fry contribute 41.1% of total roach production (9.5 g m^{-2} yr^{-1}) in Tjeukemeer, Holland and young fish were responsible for the bulk of production in several gravel-pit lakes (see above). Total roach production in lake A was similar to that in Tjeukemeer which Goldspink (1979) felt was poor, due primarily to competition with other species and the scarcity of zoobenthos.

Compared with standing-waters, fish production in running waters (rivers, streams) may be extremely high (see Table 68). High production is not however a characteristic of all parts of a river system and Hynes (1970) found for example that invertebrate production in an upland stream in Wales was only 3 g m^{-2} yr^{-1}.

One important reason for the high productivity of rivers compared with standing waters at the same latitude is the relatively high amounts of allochthonous material entering the former. The River Thames at Reading for example carries 16.5 g dry weight m^{-3} of suspended material of which 40% is organic (Burgis and Dunn, 1978) and represents a high energy input relative to the input from primary producers within the ecosystem. The particulate organic material is used as food by filter-feeding Cladocera (which live in the shelter of macrophytes in the main river) and chironomids which serve as food for the cyprinids. Adult roach, dace and gudgeon may feed directly on the organic detritus. Energy is lost when organic detritus is converted to invertebrate biomass, but most fish production is due to species that feed on invertebrates and/or fish.

Soluble organic material also encourages the growth of micro-organisms which are subsequently grazed by invertebrates (Warren, Wales, Davis and Doudorof, 1964) and therefore indirectly increase fish production.

It would be interesting to examine the productivity of shallow gravel-pits with a ratio of water area to shore i.e. shoreline development similar to that displayed by productive lowland rivers; a comparison of production in morphometrically similar gravel-pit lakes having high and low allochthonous inputs i.e. pits surrounded with trees compared with those set in open grassland, would also lead to a better understanding of the factors controlling production.

Anglers' baits and leaves which constituted the major allochthonous input to lake A were consumed by the fish (Table 13) and therefore contributed to the maintenance of production.

The fish and invertebrates present in a water play a central role in the determination of its productivity. If fish are removed the biomass of benthic invertebrates increases, but their rate of production falls (Hayne and Ball, 1956); conversely heavy predation by dense fish stocks may increase invertebrate production (Backiel and Le Cren, 1978). Experiments with lake enclosures (e.g. Andersson, Berggren, Cronberg and Gelin, 1978) indicate that the turnover of essential nutrients accelerates when dense fish populations are present, and primary production increases, ultimately stimulating secondary production.

Gee (1976) found that total fish community production in five gravel-pit lakes was related to fish density (expressed as biomass m^{-2}) by $P = 2.4\bar{B}^{0.82}$ and he proposed that growth was generally inversely proportional to biomass: $\bar{G} = 2.4\bar{B}^{-0.18}$. He also suggested that gravel pit lake communities might be regarded as relatively 'less complex' because of their domination by 2 to 3 species of fish, and could under those circumstances, be expected to show an inverse relationship between growth rate and density; in lake A the first year growth of some cyprinids improved when density declined (see 4.1(i)).

Chapman (1978) has shown that production may be proportional to biomass 'up to a point', beyond which it may be reduced. He too has suggested that growth (G) and biomass are negatively correlated, citing an inverse relationship between $^{P}/\bar{B}$ and biomass (Hunt, 1966) as evidence.

There was evidence that the production of young fish in lake A increased with biomass (Fig. 30b) and the few data available suggested that $^{P}/\bar{B}$, after peaking at low biomass, eventually falls as mean biomass increases, implying a fall in G with increasing biomass.

$^{P}/\bar{B}$ values for 0+ to 2+ lake A fish ranged from 0.72 to 2.74 but as expected (Mathews, 1971), were consistently lower for older fish, implying that most of the energy flow in the fish community was within the young relatively fast-growing cyprinid group. Bream (0+ to 1+) in 1976 to 1977 had the highest recorded $^{P}/\bar{B}$ value (2.74) in lake A (Fig. 30b) which demonstrates their effective utilisation of all energy sources from organic detritus, to zooplankton and zoobenthos. Goldspink (1978) concluded that a major flow of energy to bream was through zooplankton, but he was dealing with slow-growing bream in Tjeukemeer where the zoobenthos was scarce. Total $^{P}/\bar{B}$ for lake A was comparable with other waters (Table 68) but higher in 1976/77 than in 1974/75 presumably because of the increased abundance of young fish and introduced stock.

The heavy stocking previously discussed probably played a part in increasing production in 1976 to 1977 compared with 1974 to 1975. Bream contributed approximately 60% of production in 1976 to 1977 compared with approximately 40% in 1974 to 1975 (Fig. 30a). Roach production also increased over the same period, but their % share of total estimated production was reduced; rudd % contribution to production also declined.

Large piscivorous fish were rare in the gravel-pit lakes studied by Gee (1976) and he felt that while cyprinids would produce high biomass and therefore support high production, their populations would inevitably be composed of large numbers of small slow-growing fish. In lake A the growth of juvenile fish (0+ to 2+) was generally good and large fast-growing fish (bream) were present, but there was a slowing of growth for most fish beyond the juvenile stage. Biomass and production in lake A were respectively average and relatively low but a portion of annual production was obviously removed by pike and cormorant predation which probably helped to maintain the good growth rates observed for some species. Assuming an annual ration of 350% pike body weight (Popova, 1978) for fish >100 mm, the pike in lake A probably consumed a minimum of 7.81 g m^{-2} yr^{-1} or 34% of annual cyprinid production in 1976 to 1977. Consumption of up to 30% of total fish production is regarded as normal in the standing waters of the USSR (Popova, 1978) therefore, the estimate for lake A was not extraordinarily high. Throughout the study large cyprinids e.g. tench, were present in lake A in sufficient numbers to provide regular catches for anglers and it was therefore unlikely that pike, including the largest fish, obtained their annual ration by feeding solely on large fish (see previous comment, 4.1(i)).

4.2 Angling and the fish

(i) Angling and catch

The anglers co-operating with the routine census represented a broad spectrum of abilities. The anglers present on a particular day were neither all novices nor experts; as a result, catch rates and similar data derived from the routine census were considered relatively unbiased. On the other hand, match and test anglers comprised special groups incorporating a high proportion of anglers with above average enthusiasm, experience and ability; they therefore provided data that was biased compared with that from the routine census.

Not surprisingly Crisp and Mann (1977a) found that of a group of anglers that regularly fished a reservoir for trout, a small sub-group of 'key-anglers' caught 40 to 50% of the total catch; Lagler and de Roth (1953) and Bennett (1970) refer to creel records which show that >80% of fish are caught by <50% of anglers. Analysis of lake A angler data suggests that (Section 3.2(iii)) a few anglers caught a considerable proportion of the large tench.

Simple estimates of total angling effort for lake A were 4627 rod h ha^{-1} in 1975 and 3526 rod h ha^{-1} in 1976 (Table 36 and taking into account test angler effort, Table 40; allowance for autumn and winter angling not included). The observed angling effort was intense from mid-June to late September. Angling effort was low during autumn and winter, probably amounting to 5 to 10% of summertime effort. Moore (1971) found that most of the catch from the River Nene was taken before November each season, and suggested that unpleasant weather prevented anglers from fishing during the winter.

Angling effort was particularly high on match days, when it was normal for all the pegs on lake A and B to be occupied for ~5 hours.

Bennett, Adkins and Childers (1969) reported 222 to 791 rod h ha^{-1} and Elrod (1971) 934 to 1509 rod h ha^{-1} for single seasons on largemouth bass/bluegill fisheries. Trout fisheries near to large centres of human population e.g. Ardleigh reservoir, Essex, may experience ~ 1000 rod h ha^{-1} (Rogers and Cane, 1979; assuming mean visit time of 6.5 h from Crisp and Mann, 1977b). The angling pressure on lake A was therefore high compared with the fisheries cited above but probably similar to that on other small coarse fisheries easily accessible to anglers.

Test anglers devoted most of their effort to fishing lake A during 1975, possibly because lake B supported a heavy growth of hornwort (Ceratophyllum sp.), in 1976 however the hornwort was much reduced and test angler effort was spread more evenly between the lakes (Table 40). After July more effort was directed to lake B when it became known that further carp had been introduced to that lake (Fig. 24).

The total catch during the routine census and matches on lake A increased with effort (Fig. 33) but was density dependent, as indicated by the different relationships between catch and effort for 1975 (low total population density) and 1976 (high total population density). Changes in species composition, population density, climate and other factors probably affected the observed catch/effort relationship, which therefore only applies to the time stated.

Numbers of fish caught per unit effort (catch rates) are discussed later (this section).

Anglers visiting lakes A and B used similar tackles and were slow to adopt the tackle, baits and techniques described in Burr and Winstanley (1970) and similar publications which might have significantly increased catches. Those anglers in search of large fish who might have applied some of the special angling techniques explained by Walker (1975) avoided fishing lake A.

As far as possible results were presented to allow some comparison of bait effectiveness which is discussed in Section 4.2(ii). However, maggots either alone or in combination with other baits (Table 45) accounted for 72.9% of total bait use in 1975 and 79.1% in 1976. Parry (1974) and Moore (1971) implied that maggots were the most common bait on the fisheries they surveyed, but they did not record the incidence of their use. The popularity of maggots as a bait probably stems as much from their easy availability (at most tackle shops) as from their fish catching success.

Ground baiting with maggots and other baits (introduction of 'free hook baits') was undertaken by 87 to 91% of anglers encountered during the routine census and by a similar % of match anglers. The quantity of food introduced to lake A was therefore large although heavy ground-baiting with cereal bait mixes was rare. The importance of ground bait as a nutrient resource has already been discussed (4.1(ii)) and the effects of ground-baiting on fish behaviour are discussed later.

Anglers' catch included all species found in the lakes (Table 5) but catchability was variable and some species were caught more readily than others (see later). The age and size at which fish became vulnerable to angling at Barham was species dependent (Table 47) and the same probably holds true on other waters where similar angling methods are employed. For example, roach from lake A and the River Nene (Moore, 1973) became vulnerable during their second year (1+) at 75 mm and 80 mm respectively, however, smaller roach (∿ 60 to 65 mm) were caught in lake B during February 1975 (Fig. 14) when they were 0+. Perch were also caught during their first year but rudd, bream and tench were not normally caught until their second year.

Growth affected the timing and size of fish at recruitment i.e. entry into the size group vulnerable to angling: the relatively slow growth of rudd meant that 1+ fish were only ∿ 50 mm and they only became vulnerable at the start of the angling season (16 June) whereas roach and bream were 70 to 80 mm at the same-time. If close season angling were allowed roach and bream would no doubt recruit at 60 to 70 mm (see above, 1975 lake B observation). The mouth sizes of some 0+ roach, bream and rudd were probably sufficiently large to accommodate anglers' baits by the autumn, but sampling was much reduced then and the early capture of 0+ cyprinids may have been missed. The mouths of rudd were larger than the mouths of roach and bream (Fig. 34) of comparable length, which suggests that rudd will generally recruit at a smaller size.

It is prudent to recall that while mouth gapes were found with the upper and lower jaws held open at 90° to each other, angles of 45 to 70° are usual when fish are feeding (Shirota, 1970) with 60° the consistent angle for juvenile Atlantic salmon (Thorpe and Wankowski, 1978).

The effect of restricted mouth opening would be to increase the observed size at recruitment beyond that predicted by substitution of bait and hook sizes into the mouth gape/length regressions, and may explain discrepancies between observed and predicted lengths at recruitment (Table 47 and 3.3(iii)).

Cook (1979) found mouth gape/length relationships for roach and perch similar to those reported here and remarked that the mouth gape of 0+ perch was approximately twice that of 0+ roach on any date. In view of their large mouths, it was surprising that perch of <50 mm were not taken by angling in lakes A and B; on fisheries with large perch populations however catches of such small fish might be expected.

Vulnerability to angling is likely to depend on factors in addition to mouth size; the capture of juvenile and adult fish may be affected by behavioural traits such as feeding on zooplankton (Cook, 1979), shoaling close to the surface or by the development of hierarchies (Bakiel and Le Cren, 1978).

The capture of 0+ rudd, roach, bream and perch could become commonplace with the regular use of hooks $\leq$ size 20, but only if baits smaller than 'normal' maggots e.g. chironomid larvae were employed. The maximum diameter of a bait is likely to be more important than hook gape in determining the minimum size of fish caught; baits are 'solid' but hooks are 'open' and constructed from wire $\sim$ 0.5 mm diameter in the case of the smaller sizes. A small bait with a medium size hook may catch fish with mouths too small to accommodate the hook gape and their capture probably depends on their manipulation or approach to the baited hook; unfortunately this type of fish feeding behaviour is poorly understood.

The size distributions of fish caught by test, match and routine census anglers in lake A were similar (Fig. 35) with the exception of roach (very few roach were caught during matches). A more detailed comparison was not attempted because of wide variations in sample size and the lack of individual fish measurements in the test angler data.

When Moore (1973) compared the size distribution of seine- and angling-caught fish he found that the mean length of roach caught by angling was significantly greater than the mean length taken by seine during July and August, by September however the difference was no longer significant, which suggests that the annual recruitment of roach into the fishery was complete by then. In lake A, angling appeared to select the largest rudd from the combined 1 to 2+ group during 1974 and at other times e.g. June and July 1975; September and October 1976 (Fig. 9). Fig. 36a suggests that more large rudd i.e. >150 mm were caught by angling but seining was generally more effective than angling for the capture of roach (see also Fig. 36b).

Ayton (1974) and Moore (1973) reported that gudgeon and bronze bream were more susceptible than other species to capture by angling and suggested that it was their habit of feeding on benthos which accounted for their relatively high catchability. The species composition of angler and seine catches for lake A indicated that the opposite was true i.e. a higher proportion of bream and roach were caught by seine; rudd however were more likely to be taken by angling. The angling catchability differences for bream, roach and rudd are discussed further (see later, this section). The low seine catchability of rudd is difficult to explain but may be associated with a localised distribution of rudd shoals.

Moore (1973) found that over two years, the ratio of silver bream to roach caught by netting and angling changed significantly and he proposed that angling would give a better indication of species status than a few test nettings. This may be so if netting operations are carried out incorrectly; analyses of angling and seine net catches for lake A (see 3.3(i)) show that while there were proportional differences in the catches of species by the two methods, both provided comparable information on the changes occurring in the fish community over the period 1974 to 1977.

Angling success may be quantified in a number of ways (see introduction) but overall catch per rod hour (catch h^{-1}) has been widely used (e.g. Eschmeyer, 1942; Bennett, 1970; Parry, 1974; Ayton, 1974; Buckley and Stott, 1977) as an indicator of success on game and coarse fisheries in Europe and the United States. North (1980) however considers % of anglers with catch to be superior to catch rate as an indicator of angling quality, arguing that the former statistic is more likely to be independent of angling skill i.e. an angler winning a competition is of equal importance to an angler catching the smallest weight. North found through an examination of the effects of water temperature on angling success that there was a wider variation of results around fitted lines for catch rate/temperature regressions than for regressions using % with catch as the dependent variable, and he advanced this as evidence in favour of using % anglers with catch data. Ayton (1974) also felt that % of anglers with catch would give the best indication of the suitability of a fishery for anglers of wide-ranging abilities, but during the routine census on lake A in 1975 and 1976 % anglers with catch and overall catch per rod hour (Fig. 31) were closely correlated (1975, $r = 0.5669$, 30 df, $p < 0.001$; 1976, $r = 0.5468$, 21 df, $p < 0.01$) which suggests that either statistic is equally useful in fishery evaluation.

Overall catch rate or % anglers with catch, if taken in isolation, may disguise important changes in a fishery, and the numbers of fish of each species caught together with estimates of their size are required for a full assessment. Ayton (1974) claimed that anglers preferred information on catch rates to be in terms of biomass per unit effort, but this will only give information on the quality of fish if considered in the light of numbers caught.

Overall catch rates during the routine census on lake A ranged from 0.06 to 1.79 fish per rod hour (rod h^{-1}) in 1975, and 0.09 to 1.85 fish rod h^{-1} in 1976 (Appendix 12; Fig. 31). Total catch divided by total observed effort gave 0.31 fish rod h^{-1} in 1975 and 0.83 fish rod h^{-1} in 1976 - June to September inclusive for both years.

Easton and Morgan (1974) recorded a catch rate of 0.76 fish rod h^{-1} from a small Staffordshire lake in the summer (June to October inclusive) of 1973, but Buckley and Stott (1977) reported unusually high catch rates for a Yorkshire pond: 3.61 fish rod h^{-1} (1973) and 6.89 fish rod h^{-1} (1974), however, their results may have been over-estimates because of non-reporting of zero returns by anglers. Ayton (1974) observed an overall maximum catch rate of 11 fish per man hour on the Worcester-Birmingham canal, but later published (Ayton, 1976) overall catch rates of between 0.25 and 4.70 fish per man hour for a particular reach of the same canal. Catch rates on the R. Nidd at Kirk Hammerton were 1.26 fish rod h^{-1} in 1966, but had fallen to 0.38 fish rod h^{-1} by 1968 (Parry, 1974). Parry attributed the fall to the decline in the roach population.

In lake A the catch rate exceeded 1.0 fish rod h^{-1} or >50% anglers with catch on 9 census days in 1976 (Fig. 31) but only on 3 days in 1975. Similarly, species catch rates (Fig. 32) were generally higher in 1976 than in 1975. These observations show that angling success was affected by changes in fish population density that took place during the study (Fig. 28a) and demonstrate the value of angler census operations to fishery management.

Individual anglers fishing lake A during the routine census often managed to catch fish far in excess of the overall catch rate; 10.6 fish rod h^{-1} (June, 1975) and 10.9 fish rod h^{-1} (July, 1976) were the maximum catch rates recorded for individual anglers in the two years stated. These rates may be exceeded however if a skilled angler fishes a shoal of small fish.

Test anglers fishing lake A during June to August inclusive caught 0.85 fish rod h^{-1} in 1975 and 1.63 fish rod h^{-1} in 1976. These catch rates were high compared with the routine census (see above) and may have been exaggerated by some non-reporting of zero returns. Crisp and Mann (1977a) found that generally only successful anglers offered information during a voluntary census, but it is possible, of course, that the good catch rates to lake A test anglers were due to their expertise relative to other anglers.

During matches catch rates (Table 38) were frequently less than those obtained under routine census conditions (Fig. 41), and rudd and tench made up the bulk of match catches during 1975 and 1976. Match effort and catch were not significantly correlated, but Fig. 33 suggests that catch per unit effort was reduced under match conditions. Matches at Barham were usually held during the summer between 10.00 and 15.00 h corresponding to the brightest time of day. Yellow perch (Perca flavescens) and roach (Helfman, 1979 and Kukko, 1974 respectively) have summer-time activity peaks at sunrise and sunset; possibly therefore the poor catches during matches were due to the inactivity of the vulnerable fish. On the other hand, Craig (1977) has suggested that in eutrophic waters, with low water clarity, perch become more active during the day in the summer months. If this was the case with the fish in lake A, the poor catches may rather have been due to (a) the disturbance caused by the simultaneous arrival of anglers at the start of the match, or (b) the practice of holding matches on successive days and at weekends. Lack of angling skill was hardly a likely factor because match anglers were among the most accomplished seen.

The limited census of lake B (Appendix 14) suggested that in 1975 at least roach were the most important species in catches, particularly those from the 1973 year class (Fig. 14); roach catch rates were high during February 1975 and in a match held in June the same year. Overall catch rates to test anglers fishing lake B were 0.88 fish rod h^{-1} in 1975 (June to August inclusive) and 1.86 fish rod h^{-1} in 1976 over the same period. Overall catch rates to test anglers fishing lake A from June to August (inclusive) were similar but this was coincidental.

In view of the relationship between catch rate and population density (Fig. 44) observed in this study and by Lagler and De Roth (1953), it was surprising that Ayton (1974) failed to find such a relationship; perhaps his dependence on catch data from matches or on population estimates by multiple removal methods were responsible. It must be pointed out however that La Faunce et al (1964) were also unable to show any significant correlation between catch per hour and population estimates for largemouth bass, for which they offered two explanations: (i) the type of angler visiting the fishery changed during the study, (ii) water temperature and other limnological factors varied and altered the catchability of the bass.

The catchability or ease of capture of fish may be simply assessed on the basis of catch rod h^{-1} (i.e. ≡ angling success) and Buckley and Stott (1977) found that catch rates for rudd, perch and roach were higher than those for bream, tench and grass carp. Parry (1974) observed that catch rates for dace were higher than for other species in the River Nidd. In the case of lake A, rudd and tench catch rates were consistently higher than for other species.

A more realistic assessment of catchability may be made by comparing catch in a given time with population size (Ricker, 1975), and catchability indices (Table 52 and Fig. 37) were calculated for specific summer/autumn periods for 1974, 1975 and 1976. Rudd and tench catchability indices were high compared with those for roach in all three years; crucian carp and perch catchability was also high by this method, which shows that an assessment based on catch rates alone (Fig. 32) can be misleading.

The catchability index for bream was slightly lower than the index for roach except in 1975 (Fig. 37) when stock bream (Fig. 29) improved anglers' catches at a time when the fish population was generally low (see Fig. 28a), by the summer of 1976 however the bream population had increased considerably and the proportion caught declined.

Calculation of catchability indices from Buckley and Stott's (1977) catch and population data (their Tables I and II) for 1975 resulted in the following ranking (highest catchability first):

rudd > perch > roach > bream.

They did not rank tench because the population estimate was judged unreliable. Ranking according to catchability index for lake A fish was as follows:

1974: perch > tench > rudd > cru. carp > roach > bream
1975: tench > rudd > perch > cru. carp > bream > roach
1976: tench > cru. carp > rudd > perch > roach > bream

Changes in catchability ranking from year to year and in the shorter term may be attributed to variation of a wide range of factors e.g. climatic, acting through water temperature and stock density (see later, 4.3). Not surprisingly evidence from catch rate/density regressions (Table 63) supports the differences in catchability and gives rise to the following ranking:

Perch ≥ rudd > roach > bream

Ayton (1974) also identified the low catchability of roach; finding that even when roach densities exceeded the density of gudgeon by several times, the latter were always caught more easily.

The apparent wide difference in catchability of roach and rudd was a particularly interesting observation not only because of their outward similarity but because anglers have declared that rudd are easier to catch.

What are the causes of the catchability differences between species? In relation to population size tench >280 mm were the most catchable fish in lake A, and some anglers have claimed that this was primarily due to the employment of angling techniques directed specifically to their capture. Anglers fished their baits on the bottom, and introduced free baits in sufficient quantity for them to become part of the zoobenthos on which adult tench feed (see 4.1(i)); under these circumstances, it is reasonable to expect tench to feed heavily on anglers' baits, and run a high risk of capture, especially if natural zoobenthos is scarce. Moreover, crucian carp may become similarly accustomed to and dependant upon anglers' baits (see later).

Rudd length for length appeared to have larger mouths than roach (Fig. 34) which probably allowed them to accept anglers' baits more readily. Furthermore a survey of the existing food preferences of roach and rudd (Burrough, 1978 and 4.1(i)) has indicated that their diets are different, roach feeding more on the benthos, including detritus, and rudd on plant material and insects from the surface waters. Because of their habit of often feeding close to the surface rudd probably encounter anglers' baits before they enter the lower levels occupied by roach. Alternatively, in a lake such as lake A, where aquatic macrophytes are restricted to a narrow band round the margin (Fig. 4), rudd may have been directed by their need for plants as food and shelter (Holčik, 1967b) to spend more time in the vicinity of anglers' baits and therefore run a greater risk of capture compared with roach. Roach too are often associated with the littoral region, but may tend towards a pelagic mode of life (Svardson, 1976), actively exploiting the zooplankton and reducing their own catchability by being spatially remote from anglers' baits or preoccupied with feeding on zooplankton (Barber, 1976).

The feeding strategies of bream in lake A were probably similar to those adopted by roach, but the catchability of bream may have been further reduced by their restriction to certain areas with limited angler access: anglers were generally prevented from fishing close to the wash-water outlet (Fig. 3), but when they did fish there, bream were usually caught; moreover catches of bream were often taken from the same area during seine netting and shoals of bream were regularly seen there.

The high catchability of perch may arise from their attraction to moving food objects (Deelder, 1951); in this context live baits i.e. maggots or worms.

A competitive mechanism could also account for some of the catchability differences that appear to exist between species in the high catchability group (i.e. rudd, perch, crucian carp and tench) and the low catchability group (roach and bream). Roach and bream tend to dominate eutrophic standing waters in Europe and this may be partially due to effective and efficient use of food resources, forcing less successful species (i.e. those in the high catchability group) into greater dependency on anglers' baits. Such a simple concept is difficult to support however and although Burrough et al (1979) present evidence for roach populations having an adverse effect on populations of rudd and perch, they believed that competition was only active between the juvenile fish feeding predominately on crustacean zooplankton.

In the United States, Cooper (1953) found that anglers removed 9977 out of an estimated population of 13480 bluegills (Lepomis machrochicus) i.e. % catchability index = 74.0, and the catch of largemouth bass actually exceeded the estimated vulnerable population (possible through growth recruitment) but anglers only removed small percentages of the standing crop of other species. The % catchability index for bluegills in a lake studied by Ricker (1942b) was much lower at 38.3.

Żolczynski and Davies (1976) observed a catchability difference between sub-species of largemouth bass; Micropterus salmoides floridanus was shy and less catchable than Micropterus salmoides salmoides. Beukema (1969) found similar catchability differences between strains of common carp, with domesticated strains generally being more catchable. The degree of fright reaction that fish display affects catchability and probably depends on the nature of the environment and the degree of domestication of the stock.

Catchability differences between species and varieties are well established and presumably have some genetic basis. However variation in catchability from year to year, within seasons and from lake to lake suggests that it is influenced by a number of environmental variables, including the variety and population density of co-existing species. The effects of environmental variables on catchability (as catch rate) are discussed in the next section, but further work is required to confirm the catchability differences observed in this study.

(ii) Effects of angling on the fish

Because most of the coarse fisheries in Britain are managed on a catch-and-return basis, actual rates of exploitation in the commercial sense (proportion of fish harvested) are probably very low if fish are handled carefully. Exploitation rates have been calculated for coarse fisheries (Linfield, 1980b) but they indicate the proportion of the population caught and returned in a defined period and are equivalent to catchability indices (see below).

Taking into account the total estimated angling effort for 1975 and 1976 as 7604 and 5520 hours respectively on lake A (Table 36) with the June to September catch rates (Table 39), the estimated total catches become $7604 \times 0.3043 = 2314$ fish (1975) and $5520 \times 0.8268 = 4564$ fish (1976). The estimated total catch for 1975 exceeds the estimated population for July of that year (Appendix 16); the estimated total catch for 1976 also exceeds the total estimated population for April but is about half the number estimated to be present in October. From the above data alone it is reasonable to suppose that the majority of vulnerable fish experience capture by angling at least once during the period June to September. Additional data (see below) suggests that certain species of fish experience more than one capture over a summer angling season.

The number of large tench and crucian carp caught and examined during the census (Table 7) was high compared with population estimates and when this is considered with incidence of mouth damage, recapture data and catchability indices it is clear that the large tench at least must have experienced >7 captures from the time of their introduction in 1969 up to 1976, and the crucian carp (introduced in 1970) >6 captures. Linfield (1980b) found that over four years 155 out of 294 tagged common carp (53%) were recaptured on at least one occasion, but 25% were caught no less than three times.

The proportion of fish caught may be under- or over-estimated if mouth damage data is used alone; over-estimation may be off-set by distinguishing between 'new' and 'old' mouth damage, but this is not easily done in the field. Assuming that not every fish caught by angling suffers mouth damage, Table 53 data suggests that most rudd surviving >2 years had experienced capture. An estimated total of 1960 rudd (total estimated effort, June to September, 1976 × rudd catch rate, June to November, 1976; see Table 36 and Appendix 16) exceeds the estimated population of vulnerable rudd for 1976 (Appendix 16) and emphasises the high catchability of this species and the capacity of older rudd to survive damage. Gee (1976) also observed that approximately 70% of rudd (>2 years old) in a small gravel pit had mouth damage caused by angling.

Moore (1973) felt that up to 100% of adult roach from the River Nene, where the species was dominant, would experience one or more captures in their lifetime. This was not the case with roach or bream in lake A however, and their low incidence of mouth damage (Figs. 13 and 15) may have been due to their poor survival after capture, low catchability (see previous section) or a reduced tendency for them to sustain mouth damage on capture, possibly because small hooks were in general use (Table 44).

With regard to other species, Hunt (unpublished) found that up to 50% of some year classes of barbel (Barbus barbus L.) from the River Severn had fin and/or mouth damage and Axford (1974b) observed that ∿45% of dace and ∿34% of barbel, caught by electrofishing part of the River Nidd, had some form of mouth damage inflicted by angling. Thus it was interesting that Ayton (1974) should claim that <5% of a mixed coarse fish population was caught by angling in a year (see comment 4.1(ii)). During the census of lake A, 5.1% of the estimated vulnerable fish population was caught by angling from mid-August to late September 1974 but in 1975 when the population was low, 49.0% were caught (from June to September, inclusive). Finally in 1976, the catch comprised 8.4% of the population during a similar summer period. The proportion of the vulnerable population caught as a result of the total estimated angling effort (see earlier) was of course higher, but it is reasonable to state that the proportion of the population caught is related to population density and angling effort (see previous discussion).

Mouth damage is an obvious effect of angling on individual fish and its incidence appears to vary with age. Moore (1973) found that 2+ to 5+ roach had 8, 16, 17 and 35% hook-damaged mouths respectively. Roach were relatively less common in lake A but the rudd displayed a similar age-related pattern of mouth damage (Table 53). There was however a slight tendency for the proportion of rudd with mouth damage to increase through the summer, presumably related to exposure to angling; the low incidence of hook-damaged mouths in the younger fish can be explained by their shorter period of vulnerability relative to older fish.

The incidence of mouth damage in the tench of lake A did not vary significantly between the sexes, neither was there any evidence to suggest that one sex was more prone to damage than the other. These findings for tench were consistent with them having acquired mouth damage prior to 1974.

It has been suggested (Axford, 1974b), on the evidence that coarse fish with bad mouth damage display eroded scales with poor scale growth, that mouth damage exerts a serious effect on fish physiology and growth. Accordingly fish with mouth damage might be expected to show some reduction in condition, but efforts to demonstrate statistically significant differences (i.e. at $p \leq 0.05$) between the length/weight regressions of roach with and without mouth damage have failed (Moore; pers. comm.), seasonal variation of the slopes of the regressions exceeding any differences existing between the two groups.

Rather surprisingly the condition (K) of mouth-damaged rudd (Fig. 8) was often better than undamaged rudd, this apparent anomaly may be explained if: (i) only rudd in good condition survive mouth damage, (ii) spawn is retained by rudd subjected to mouth damage, (iii) the effects of mouth damage are minimal. If the latter were true, the relatively good condition of mouth-damaged rudd may be an artefact associated with the use of sparse data. Differences between length/weight regressions for rudd with and without mouth damage were not significant (3.3(iv); Appendix 10). On heavily fished waters where most of the fish have a high probability of capture, differences between the length/weight regressions or condition of fish with and without mouth damage may often be too small to be detected. In addition fish severely damaged by angling may be removed by predators.

The condition (K) of tench with mouth damage was frequently not as good as the condition of undamaged tench (Fig. 38). This situation was in contrast to that observed for rudd (see above) but was the more expected result. It is possible in the case of large (>200 mm) tench, whose survival rates were high, that the adverse effects of mouth damage on feeding produced a fall in condition large enough to be detected. Nilsson (1978) has drawn attention to the importance of the mouth of fishes in the capture and handling of food, but a small experiment (Howard, unpublished) indicated that rudd ($\sim$ 120 mm) with the entire pre-maxillary bone missing were able to capture and eat chironomid larvae, implying that the mouth could be seriously damaged yet feeding continue. Unfortunately the data for tench with and without mouth damage was sparse and further work is necessary to assess the response of coarse fish to damage/stress caused by angling; in particular the response of fish in spawning condition should be studied.

Occasionally fish die immediately after capture by angling; blood loss and the trauma associated with tissue damage probably being the main causes of death. Most fish that die after capture are small; Moore (1973) recorded that 76% (numbers not stated) of roach dead in anglers' keep-nets were <120 mm, and the majority died after being held under crowded conditions inside keep-nets when water temperatures were high. Axford (1974b) also found that small fish (<125 mm) were most common among those fish dead after the weigh-in but the % dead varied with species e.g. 7% dace; 9% roach; 25% bleak; 2% gudgeon; 3% ruffe. Small roach, rudd and perch were sometimes found dead among catches taken from lakes A and B, particularly during summer, but the proportion of small rudd found dead was generally less than for the other species.

Scales were often dislodged from small bream, roach and rudd during the weigh-in at Barham. Axford (1974b) noted that scales lost from chub during handling were replaced and grew to 80% of their original size within 35 days. If pathogenic micro-organisms invade the damage sites however, death may intervene (i.e. delayed mortality). The evidence (above) suggests that some species are more easily killed than others e.g. roach and bleak, and this may be due to their scales being less securely attached. It has been claimed (Moore and O'Hara, 1974) that keep-nets made from knotless small mesh netting reduces scale loss and fin damage, but this claim has not been subjected to thorough examination.

The use of barb-less hooks has often been advocated in the popular angling press as a means of reducing damage to fish, but Falk and Gilman (1975) have studied the post-capture mortality rates of arctic grayling (Thymallus arcticus) and northern pike (Esox lucius) caught on barbed and barb-less hooks. Up to four days after capture there was no significant difference between the groups; however, they noticed that pike caught on lures equipped with barb-less hooks suffered the most damage with greater penetration of tissues and blood loss than that suffered by pike caught with barbed hooks. Total mortality i.e. including both groups was ∼7% for pike and grayling, but the authors felt that this could have been reduced by releasing the fish immediately after capture.

The development of hook avoidance behaviour by coarse fish has been observed on a number of occasions; Beukema (1970a) reported a decrease in the catchability of common carp after a single capture by angling, and in some carp the behavioural change persisted for a whole year. Linfield (1980b) also investigated the effects of capture on the catchability of common carp held in a lake at a similar density to that employed by Beukema (1970a), but with a high biomass of other species present (i.e. roach, tench and crucian carp). He could not however show any decrease in the catchability of the common carp following their capture by angling and he felt that the difference between his own and Beukema's observations were linked to a generally higher catchability in his lake, due to the greater total fish density producing high competition for food.

During the week immediately following their capture, the probability of recapture for River Nene roach (Moore, 1973) was low, but rose sharply in the second week after capture and remained high thereafter. Moore argued that his observations were not consistent with short-term learned hook avoidance behaviour, because in such cases a gradual rise in the probability of recapture might be expected following the period of avoidance. He thought that the cessation of feeding for a short time after capture was a more likely explanation for his observations.

Pike appear to be able to develop an ability to avoid recapture on lures (Beukema, 1970b) but may be caught repeatedly on live baits.

Recapture data for roach and common carp in lake A were few but data for rudd and other species show (Fig. 39) that hook avoidance behaviour, even if it did develop, was not obvious or was restricted to <1 week duration. The numbers of lake A rudd recaptured within one week of initial capture or first recapture suggests dependence on anglers' baits as food, which helps to explain their high catchability (see 4.3(ii)). Indeed, it would be unusual for hook avoidance behaviour to obviously occur where baits have achieved the status of natural foods or where other naturally-occurring foods are used as baits (see above i.e. the repeated recapture of pike on live baits).

An anaesthetic (MS-222) was used to facilitate the handling of fish caught at Barham, and its use may have compromised the fishes' ability to establish hook avoidance behaviour. This would appear to be unlikely however, in view of experiments with rainbow trout (McNicholl and Mackay, 1975) which have shown that MS-222 has no effect on trout learning a simple conditioned response.

A rapid decline in catch rates for largemouth bass (Bennett, 1954) and common carp (Beukema, 1970a) may occur over the first few days of an angling season (see 1.3 Introduction). The implication of these and other similar observations e.g. Anderson and Heman, 1969 is that bass exposed to angling or experiencing capture, develop decreased catchability through learning. La Faunce et al (1964) did not however consider declining catch rates through the season to be a universal phenomenon on bass fisheries.

In lake A tench catch rates declined towards the end of the summer in 1976 when the total fish stock was high compared with 1975 (see Fig. 40a). According to Linfield (1980b) (see above), it would be reasonable to expect an increase in catchability under these circumstances, but it is reasonable to suggest that tench catch rates declined because other species became more abundant.

Although the results do not support them, anglers felt that the tench in lake A became harder to catch as the season advanced. It is possible that the tench, in spite of their probable acceptance of baits as natural food, developed subtle modifications of their feeding behaviour as a result of capture experience. The existence of such behavioural modifications were probably disguised by skilled anglers continuing to fish on, through the season, after many of the less able anglers had given up.

4.3 Factors influencing angling success

The effects of various factors (e.g. water temperature, baits, zooplankton etc) over angling success are considered below under two headings: (i) Abiotic factors and (ii) Biotic factors.

(i) Abiotic factors

A number of abiotic environmental variables were monitored during the routine census (see Chapter 2 and Table 57) and an exploratory multiple regression analysis (Chapter 3.3) was carried out in an attempt to assess the influence of various variables on catch rates. The effect of environmental variables on catch or catch rates have rarely been studied in this country even where adequate records exist (Garrard, MAFF Lowestoft; pers. comm.); an exception is Parry's (1974) multiple correlation analysis which involved four variables, (flow, water temperature, turbidity and a seasonal factor, i.e. theoretical allowance for an independent tendency for catch rates to change with the seasons; detailed explanation not given). However, Stone (1976) has presented detailed analyses (cross correlations, factor analyses and multiple regressions) of the relationship between selected environmental variables and menhaden (Brevoortia sp.) catches off coastal Louisiana, using data collected over twenty-one years; there appears to have been little relevant literature available for Stone to refer to and little new literature since then. Analyses to determine the impact of multiple variables on other animal populations are relatively common e.g. Davidson and Andrewartha (1948b); Cassie (1963b); Cassie and Michael (1968).

The multiple regressions computed (Table 58) retained several variables and accounted for between 25 and 41% of catch rate variances. The remaining variation may be accounted for by variables such as fish population density, zooplankton abundance and angler behaviour.

Comparison of observed and expected catch rates for rudd

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The multiple regressions computed (Table 58) retained several variables and accounted for between 25 and 41% of catch rate variances. The remaining variation may be accounted for by variables such as fish population density, zooplankton abundance and angler behaviour.

Comparison of observed and expected catch rates for rudd (calculated from CATR; Table 58c) show (Fig. 42) a close agreement, but the predictive value of a regression must be tested on further data, not used during its establishment, before it is accepted. Once fully developed however, a model that predicts fish catch rates from a readily measured set of variables will be of great value to fishery management. It will, for example, allow for impact assessment of proposed environmental changes and rational decisions on stocking.

Unfortunately the number of data points available for analysis were limited, and strictly causal mechanisms cannot be deduced from multiple regressions where the independent variables are strongly correlated (Appendix 5). With the shortcomings of multiple regression in mind, it is nevertheless interesting to speculate on the effect of individual variables retained in the regressions and those having significant single correlations with catch rates (Table 59).

Retention of the year variable (YEAR; Table 58) probably signifies the importance of year-to-year stock variation (Fig. 28a) as well as climatic differences.

Water temperature was the dominant factor affecting total catch rate in Yorkshire rivers (Parry, 1974) and recently, North (1980) has demonstrated its influence over angling success on the River Severn. He found that the relationship between water temperature and catch rate or % anglers with catch was best described by parabolic regressions with optima between 15 and 20°C. Stott (1969) found that catches of perch in unbaited traps were positively correlated with water temperature up to 10.5°C but negatively correlated at higher temperatures, and he considered that temperature influenced catch by regulating the activity of the fish. On the other hand, water temperature is known to affect the feeding behaviour of fish; Elliott (1975) has shown that the food eaten at a meal by brown trout increases up to 18.1°C but declines at higher temperatures, and Hellawell (1972) has found that the stomach fullness/ temperature relation for roach was curvilinear up to a maximum observed temperature (18°C). In view of these findings, North (1980) has suggested that roach feeding may decline above 18°C, and if this were so his own observations of angling success (see above) could be explained by a temperature effect.

North (1980) also observed that the species common in anglers' catches varied with water temperature, gudgeon and ruffe (Gymnocephalus cernua) were present in catches through the observed temperature range (0 - 28°C), but bleak, bream, barbel, dace and eels were only common in catches at high temperatures (17 - 28°C) and chub and roach at lower temperatures (0 - 16°C).

Water temperature was positively correlated with total catch rate for lake A (Table 59) and inspection of Fig. 41 reveals that catch rates generally increased in late spring when water temperatures were ≥10°C. All species were caught over a wide temperature range (Table 56) but catches were poor in lake A during autumn and winter. In lake B however catch rates for roach and rudd were as high in winter (water temperatures ≈5°C) as in the summer; there is no obvious explanation for the differences in catch rates between the two gravel-pits, but the good catches in lake B frequently coincided with the entry of floodwater from the River Gipping. Water temperature (WTEM) was retained in the multiple regressions for all species and rudd (Table 58), and was positively correlated ($p < 0.05$) with rudd catch rate (Table 59). These latter observations for rudd suggest that they are most active under warm water conditions in ponds that are not subject to flooding, tench might be expected to behave similarly, but this was not apparent in the results. Water temperature obviously influences angling success but the effect may not be simple. It is not surprising therefore that Lux and Smith (1960) were unable to find any clear-cut relationship between catch rates and water temperature.

Stone (1976) found that out of 19 environmental variables, 8 were retained in a multiple regression that accounted for maximum (i.e. 86%)

of menhaden catch variance. The variables included air temperature and wind direction, both lagged for 12 months. Stone felt that lagged variables could often increase the predictive value of regressions, although he was aware that his analyses may not have detected the critical time periods for the lags. Parry (1974) included the variable 'historic river flow' (i.e. average flow 3 days prior to actual catch rate observations) into his analysis but found that it did not improve the correlation; unfortunately he did not consider lagged water or air temperature and more work is required to select suitable biologically important variables for lagging and then to decide on the optimal lag for each.

Wind direction (as SIWD; Table 57) was positively correlated ($p < 0.01$) with catch rates for bream and rudd (Table 59) and retained in the multiple regression for rudd catch rate (Table 58) as SIWD and COWD (Table 57). These results suggest that the action of the predominantly westerly winds improved the catch rates of the above species in the leeward sector 2 of lake A. Fish may be attracted to the leeward shore to feed on planktonic organisms concentrated there (see George and Edwards, 1976) but waves may improve catch rates in other ways, e.g. by producing turbid zones close to the shore which screen anglers from the fish or by imparting attractive movements to float-fished baits. In addition the disturbance of the water surface by wind action may stimulate feeding activity in certain species (see below).

Catches of largemouth bass and bluegills on fly rod lures may fall sharply when water clarity is reduced (Bennett, Thompson and Parr, 1940 in Bennett 1970); Lux and Smith (1960) also found that catch rates for largemouth bass, bluegills and pike were poor when algal blooms caused turbidity, however, the relationship between catch rates and turbidity was never consistent. Vinyard and O'Brien (1976) noted that the reactive distance (Nilsson, 1978) of bluegills to their zooplankton prey was lowered under turbid conditions, and it may be that fish are simply less likely to locate lures in turbid waters. In lake A water clarity (SECI; Table 57) was significantly negatively correlated with catch rate for all species, bream and tench (Table 59), however SECI only reached the level of significance necessary (i.e. $p \leq 0.05$) for retention in the overall catch rate multiple regression (CATN b), see Table 58.

Improved catch rates at low water clarity may have resulted from an extension of fish activity through the daytime because of reduced light penetration (see 4.2(i)), coupled with a reduced awareness of anglers (see above). The improvement in catch rates also suggests that turbid conditions will not reduce angling success on those fisheries where edible baits are used. This is a reasonable suggestion because many fish can detect food by olfaction and benthophagous fish particularly e.g. post-juvenile bream, tench, carp and roach are able to collect their food from within the silt (Nikolsky, 1963) when vision presumably plays a minor role in feeding. On the other hand, increased visibility of baits by virtue of their size or colouration may account for improved angling success under turbid conditions (see Hynes, 1960).

Wind action may cause turbidity in lakes, but the high turbidity on lake A was due to the almost continuous inflow of effluent from the washing plant and planktonic algae, overriding any major contribution from wind action. A declining catch rate through the season (see also 4.2(ii)) was indicated by negative and positive correlations with Cosine day and Sine day (COSD and SIND; Table 57) respectively, see Appendix 5. These observations suggest that resistance to capture increases as the season progresses (but see previous comments, 4.2(ii)), however, seasonally-changing factors may have been responsible for the effect. Winter migrations of perch (Craig, 1977) and shoaling of carp are further examples of events which may produce seasonal changes in angling success, although in small gravel-pits migrations may be unimportant.

Measured solar radiation, rainfall and dissolved oxygen appeared to affect catch rates on lake A (Table 59). Solar radiation (RADN; Table 57) was strongly correlated (r = +0.8193) with water temperature (Appendix 5) and may have affected fish behaviour indirectly (via changes in water temperature) or by regulating the behaviour of fish food organisms. RADN was not significantly correlated with SECI on lake A (Appendix 5) but may have improved catch rates by increasing the visibility of baits (see above) or by directly stimulating the activity of certain species e.g. rudd.

Disturbance of the water surface by rain may act as a 'feeding trigger' for rudd (Table 59) which are generally regarded as 'surface feeders'. On the other hand, overcast skies reducing awareness of the presence of anglers (see above) may have been the significant changes associated with a 'rainfall effect'.

Dissolved oxygen (DISO; Table 57) was normally within the range 8 - 12 mg l^{-1} in lake A; the concentrations of oxygen recorded were high because sampling was restricted to late morning or afternoon. Despite the limited observed variation of DISO it was, as expected, negatively correlated with water temperature (Apendix 5). Bream catch rate was positively correlated with DISO (Table 59), but not significantly negatively correlated with water temperature (Appendix 5), although it is interesting to note that some good catches of bream were made in lake A during February to March, 1977. A more detailed examination of dissolved oxygen/catch rate relationship is necessary before the impact of dissolved oxygen variability can be fully assessed.

Catch rates and catch, particularly of rudd, were consistently high at pegs 19 and 20 (Fig. 43) on lake A. Wortley (pers. comm.) has also observed that certain pegs on rivers in the Norfolk Broads regularly produce better catches than others and the combined evidence at least suggests a non-random distribution of vulnerable fish through a fishery. The two most successful pegs on lake A were popular with anglers, but not markedly more so than pegs where catches were relatively poor, e.g.

pegs 7, 12 and 18. This suggests that it was not the accumulation of ground bait that accounted for the success of a peg, rather features like deep water or overhanging trees (both present at pegs 19 and 20).

Because the census was normally carried out during the afternoon and evening, the effects of time of day on catch rates was not investigated; however, it is known that the activity of coarse fish changes through the day (e.g. Craig, 1977; Kukko, 1974).

The retention of angling effort (EFFT; Table 57) in two regressions (Table 58a,e) and the relatively poor catch rates during matches (see 4.2(i)) suggest that disturbances caused by the presence of a large number of anglers around a lake may reduce catch rates; however, EFFT did not achieve statistical significance as a single correlate with catch rate.

It can be seen from the foregoing discussion that the effects of environmental abiotic variables are far from simple and are often interacting, however, the following variables are suggested, in order of likely importance, as having high predictive value for angling success on standing waters:

> water temperature, year or season, water clarity, peg, solar radiation, dissolved oxygen and effort.

(ii) Biotic factors

The abundance and quality of naturally-occurring food would appear to be one of the most important biotic factors influencing angling success and accordingly the important qualitative and quantitative changes in the crustacean zooplankton of lake A were assessed during the summers of 1975 and 1976; time did not permit a similar evaluation of the benthos.

Lux and Smith (1960) found that angling success was inversely related to food supply but Bennett (1970) has suggested that the presence of abundant food organisms may 'switch on' general feeding behaviour and thereby increase catch rates. Barber (1976) has shown however that roach may become pre-occupied with feeding on specific food items, which implies that catch rates will be poor when the items inducing preoccupation are available.

There was no firm evidence from this study to suggest that catch rates were correlated with crustacean zooplankton density (No. m^{-3}) either as total zooplankton or as specific groups (Table 65). There appeared to be some accord with Bennett's (1970) suggestion (see above) because the mean length of daphnids from lake A were significantly positively correlated with catch rates for rudd and perch (Table 66a), but further examination of the results did not reveal any significant correlations between catch rates of rudd and perch and the numbers of crustacean zooplankton particles in any of the size (length) groups selected (Table 66b). The latter results suggest that the significant correlations between catch rate and daphnid length may be unreal. The numbers of daphnids >1 mm long were often low during the summer of 1976 and it was not surprising that they did not correlate with catch rates for rudd and perch. When relatively large daphnids are present at low densities, fish probably do not feed on them selectively and may therefore be more susceptible to capture on anglers' baits.

Although it is established that coarse fish >1 year old are planktophagous (see previous discussion) their dependence on crustacean zooplankton may generally decline with age; Sbikin (1974) for example has observed that roach 50 - 100 mm begin to show feeding activity that is less dependent on light, and this may indicate an increase in benthophagy. It appears likely therefore that any relationship between catch rates and zooplankton size and abundance in lake A was also obscured because of the varied diet of the size of fish vulnerable to angling.

Consistent with the size of their mouths, fish often selectively eat the largest crustacean zooplankton available and this type of predation has been held responsible for the development of crustacean zooplankton populations dominated by small organisms e.g. Bosmina (see Brooks and Dodson, 1965; Galbraith, 1967; Cook, 1979 and others) which may favour the survival of young fish (see 4.1(i)). Similar developments may have occurred in lake A, where the crustacean zooplankton was dominated (Appendix 18) by small <1 mm organisms in the summers of 1975 and 1976; Bosmina first appeared in samples during 1976 when the fish stocks were high compared with 1975. It is well known however that changes in the size and species composition of crustacean zooplankton populations occur independently of fish predation and may not be simply related to changes in the density of planktophagous fish (Cook, 1979; Noble, 1975).

Coarse anglers use maggots more than any other bait and Parry (1974) found that between 56% (Barbel) and 96% (Dace) of fish caught from the River Nidd were taken on maggots. In lake A during 1976 (Table 61) maggots accounted for 76% (Crucian carp) to 97% (Roach) of species captures. Catch rates of roach, rudd and perch were highest when maggots were used, but tench, bream and crucian carp catch rates appeared to be independent of bait type.

The effectiveness of maggot baits may arise partially from their widespread use (see 4.2(i)), and in part from their movements when impaled on a hook. In a recent study of the success of fly, spinner and worm for catching rainbow trout (O'Grady and Hughes, 1980), worms were most successful overall. Such a result may be explained by the extra time that a worm bait is at risk of capture by the trout, but it also indicates the innate attractiveness of moving live baits (see previous discussion).

A simple comparison of catch and catch rates to anglers using large and small hooks (Table 62) suggests that small hooks are associated with better catches (see also 4.2(i)), but, interpretation of the results is difficult because anglers often use large hooks with large baits (and vice versa). Hook size effects are complicated further by the type and size of bait selected; apart from the influence of bait type (see above) there is evidence (Coulson, 1971) that the size of bait used determines the size and number of fish caught.

Creel records (e.g. Bennett, 1970; Crisp and Mann, 1977a) and evidence from this study (see 4.2(i)) indicate that a few anglers catch the majority of fish, and the skill of these individuals accounts for their success. Unfortunately skill is not readily quantified as it comprises intangibles such as diligence, observation, knowledge of fish habits, selection of fishing time etc. Regular visitors to a fishery are also more successful than casual visitors (Crisp and Mann, 1977a), presumably experience gained during previous visits increases the probability of catching fish.

Angling success may also be influenced by the density (Table 63; Fig. 44) and species composition (4.2(i)) of fish stocks; these have been discussed previously. Relative to abiotic factors, biotic factors are much more difficult to assess and it is hardly surprising that they have been studied less often. The full impact of the abundance and quality of fish food organisms on angling success remains unclear and a long-term simultaneous study of zooplankton, zoobenthos, fish populations and catch rates is needed.

4.4 Management implications and recommendations

Coarse fisheries are valuable recreational resources (National Angling Survey, 1971; Henderson and Welcomme, 1976) and represent a potentially useful food resource (Barber, 1976b; Cross, 1974); they should therefore be carefully managed and the state of affairs where ill-informed persons influence fishery management decisions should cease. Anglers do however have a role to play in fishery management, and it is essential that their requirements are recognised during the planning of management schemes; their assistance in recording catches for management and research studies should be particularly encouraged.

Gravel-pit lakes, irrigation reservoirs and the other small water bodies have been created on a large scale in recent years and they provide ideal facilities for the investigation and assessment of the value of various fishery management practices.

Several management suggestions have arisen from the work in this thesis; most are aimed at Barham gravel-pit lakes but others are of more general application:

(i) The adoption of census operations

For successful management, reliable information is needed to aid decision-making. A census may provide more reliable data than those supplied by occasional nettings (although netting may be necessary for complete sampling, or to offset any bias in angling samples due to catchability differences). The census has been a tool of management for more than forty years in the United States (Bennett, 1970) but has only been widely adopted over the past decade in the United Kingdom (e.g. Moore, 1971 and 1973; Parry 1974, Ayton 1974, Easton and Morgan, 1974).

A census of the type referred to in this study as the routine census does not require expensive equipment, but is relatively labour intensive; however, data of similar quality (see 4.2(i)) can be gathered easily from test or match anglers.

Points that are relevant to the management of census operations are:

(a) If manpower is limited an intensive census (i.e. routine census) could be restricted to June and July when most fish appear to be caught (Table 46).

(b) If an initial effort to gather data on the fish community is successful the census may be adapted to examine only the sensitive components e.g. concentrate on a species believed to be in decline.

(c) Test anglers are best employed in small groups so that they can be easily contacted during their contract, enabling unused census forms to be recovered and errors noted or corrected.

(d) The validity of test angler data should be confirmed by checking that actual catches correspond with recorded returns.

(e) Test anglers should be encouraged by incentives and penalties (Lagler and de Roth, 1953 and section 4.2).

(f) Census data should be recorded directly to a format compatible with easy computer input.

(g) Whenever possible the collection, analysis and interpretation of census data should be undertaken by fishery biologists; with the aid of a computer one biologist should be able to supervise several census schemes simultaneously.

(h) Census statistics should be made available to anglers at regular intervals to encourage their continued co-operation.

A census should reveal most of the important changes in the status of the vulnerable fish stock, but it will usually be necessary to assess 0+ fish by netting or trapping.

To aid decisions on future stocking policy the survey work at Barham should continue by the census of matches and the use of test anglers.

Population estimates by mark-recapture can be combined with a census particularly if hook avoidance behaviour does not exist to affect the probability of recapture of marked fish.

Once the census data has been analysed it may be difficult to decide on an acceptable level of angling success. Bennett and Childers (1972) thought that 1.0 bass rod h^{-1} was highly satisfactory, but Parry (1967) felt that 1.5 fish rod h^{-1} was more appropriate for coarse fisheries in the United Kingdom. Anglers fishing lake A were dissatisfied with their success in 1975 (see Fig. 31) and scarcely more satisfied in 1976. It appears therefore that a catch rate approaching 2 fish rod h^{-1} would be reasonable on a coarse fishery, such as Barham, which is managed for anglers of mixed ability.

(ii) Fish stock adjustments and angling

The catch rate/stock density regressions for Barham (Table 63) were based on limited data but they suggest that the density of stock (all species) would need to rise to $\sim$ 1.0 fish m^{-2} to provide a catch rate of $\sim$ 1.0 fish rod h^{-1}. If however fish of high catchability e.g. perch and rudd were used for stocking similar catch rates could be achieved with a density of $\leq$ 0.5 fish m^{-2}. Although the catch rate/stock density relationship appeared linear over the range of observations, it may break down at higher densities when the catching capacity of anglers is saturated.

Fish were stocked into lakes A and B at Barham before and during this study (Tables 32 and 33); the bream introduced in 1975 survived particularly well and improved catch rates (see 3.3(v)b). Their relative success may have been due to the decline of the resident stock at the time of their introduction and it may therefore be an important principle to stock only when populations are low. The bream stocked were medium size (100 - 200+ mm) fish and this was also considered to be important in their successful establishment. Stocking with coarse fish is most likely to succeed, if it takes place during early spring, this will ensure that they will be utilised by anglers before they are removed by natural mortality, moreover, they will have time to reproduce before being subjected to angling.

Attempts to stock lake A with roach and perch were not immediately successful. Disease was evident in the resident roach and perch populations before stocking, and it was probably unwise to stock under such circumstances, however, by 1977 a strong year class (Fig. 13) of roach was present.

Production increased in lake A after it was stocked in 1975 and 1976.(Fig. 30a and Table 34); the increase may have been coincidental or it may indicate that a high stock density is needed to realise full production. It is widely believed that a lake can only support a fixed biomass, known as the carrying capacity (Bennett, 1970) which may vary seasonally or from year to year. If the carying capacity of a water is exceeded the biomass will subsequently fall back to the carrying capacity. In lake A the increase in biomass and production after stocking suggests that the carrying capacity was not exceeded by the introduction of stock, and that the lake was previously under-stocked.

Stocking may have reduced the growth rates of fish in lake A (see 4.1(i)) resulting in populations dominated by small relatively slow-growing fish; this may be a normal development in standing waters populated with cyprinids (Backiel and Le Cren, 1978). If anglers appreciated the possible effects of regular stocking they might not request it so often.

Further observations of angling success under different conditions and over a wide range of stock densities are required to confirm the conclusions of this study; it would also be interesting to study the effects of biomass increase (i.e. by stocking) on waters that are judged to be below or at carrying capacity.

Predators (e.g. Pike) have been stocked to control the growth of fish populations for many years in the United States (e.g. Swingle and Smith, 1941; Bennett, 1970) but their effect on the growth of cyprinid populations in the United Kingdom has not been studied in detail. In lake A, pike consumed about 30% of annual cyprinid production in 1976 but if pike were eliminated it is unlikely that the 'saved' production would improve the quality of anglers' catches (see also 4.1(ii)). Predation by cormorants (McIntosh, 1978; Van Dobben, 1952 and section 4.1(i)) may be as selective as pike predation, but appears to carry the risk of drastic stock reductions. More work is needed to assess the value of various predators to cyprinid management, but in the absence of adequate control by predators the density of cyprinids may be controlled by trapping, netting and poisoning, particularly on small enclosed waters.

Roach are popular with many coarse anglers and it should be possible biomass, known as the carrying capacity (Bennett, 1970) which may vary seasonally or from year to year. If the carying capacity of a water is exceeded the biomass will subsequently fall back to the carrying capacity. In lake A the increase in biomass and production after stocking suggests that the carrying capacity was not exceeded by the introduction of stock, and that the lake was previously under-stocked.

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Roach are popular with many coarse anglers and it should be possible to create a roach fishery especially on recently-formed lakes that do not contain other potentially competing species. The presence of other species with similar habits e.g. bream may be detrimental to the development of 'normal' roach populations (see 4.1(i)), and their stocking in combination with roach as suggested by Gee (1976) is not recommended. Roach/perch combinations may be successful if the resource partitioning concepts of Cook (1979) and Burrough et al (1979) extends beyond year 1. A lake stocked with rudd should provide high catch rates to inexperienced anglers, but they are unlikely to establish vigorous populations when stocked with roach or bream.

Gee (1976) also suggested that carp or tench were suitable for stocking gravel-pit lakes as single species because their sporadic breeding in the British Isles reduces the risk of over-population. There is evidence (e.g. Cahn, 1929) that carp and presumably other large benthophagous fish e.g. bream and tench may modify their environment sufficiently to adversely affect other species. Where waters are heavily fished by anglers, however, stocking with tench may be advisable. They can grow to a considerable size, appear to be long-lived and are sufficiently robust to withstand repeated capture.

(iii) Environmental modifications

The suitability of gravel-pit lakes for use as coarse fisheries may be improved by judicious earth moving to shape lake basins so that they are suitable for netting, safe and offer some shallow water, where suitable macrophytes should be encouraged to grow. Macrophytes are important because they provide shelter, feeding and spawning areas which are probably necessary for the successful establishment of several coarse fish e.g. rudd and tench. To increase production and make more space for anglers it is also sensible to maximise shoreline development.

The probable adverse and beneficial effects of turbidity have already been discussed; depending on the type of fishery required it may be necessary to regulate turbidity by controlling inputs of suspended solids and nutrient salts. Recent experiments with lake enclosures (Andersson et al, 1978) have emphasised the role of fish stocks in encouraging eutrophic conditions, therefore, stock adjustment may also be necessary to regulate turbidity (see 4.4(ii) above).

It is recommended that the effluent from the gravel washing plant at Barham is passed through a settlement lagoon before discharge into lake A, this will limit siltation and halt the loss of water area (see Fig. 3). Once gravel extraction has ceased, existing silt banks should be removed and any steep banks graded, and if more trees are to be planted, they should be sited away from the lake shores so that they do not shade the water, interfere with angling, management or wind action. Within reason, existing trees and bushes should be removed from the immediate shore.

(iv) Fishery regulation

The evidence for hook avoidance behaviour in fish is conflicting (see 4.2(ii)) and it is therefore generally unnecessary to follow Beukema's (1970a) advice to remove (i.e. kill) fish after capture as a remedy for reduced catch rates caused by hook avoidance. In any event, coarse anglers are accustomed to a catch-and-return policy and would probably not be prepared to kill their catch in the interests of fishery management, also, The Salmon and Freshwater Fisheries Act, 1975 forbids them to remove more than two fish on any day. It is surprising that the effects of deliberately cropping of coarse fish populations by angling appears not to have been studied.

Anglers at Barham were free to use any hook bait but some angling clubs restrict particular baits (e.g. hemp seeds and chironomid larvae) while others e.g. Leisure Sport Angling Club* may limit the use of

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* Leisure Sport Angling Club, 47/49 Church Street, Staines, Middlesex. TW18 4EN. Manages angling on >20 gravel-pit lakes in SE England.

ground bait. There was little evidence that ground bait decomposed to cause deoxygenation at any of the pegs in lake A, or that its use rendered the fish less catchable. Indeed, ground bait was probably an important food source and may have increased production in the lake, therefore, it appears unnecessary to limit its use at Barham and probably on many other waters. Bennett, Adkins and Childers (1973) recorded improved growth of bass and bluegills offered supplemental feeding broadly comparable with ground baiting.

The size of hooks used may regulate the nature of the catch (see previous discussion) and it may be wise to limit the use of larger hooks which may cause more tissue damage than small hooks. Whatever their other advantages, barbless hooks appear to cause as much damage to fish as barbed hooks (see 4.2(ii)).

The Salmon and Freshwater Fisheries Act 1975 provides for a close season of 93 consecutive days, fixed to cover the main spawning periods of common coarse fish. Angling success on lake A was no better during the close season than in the immediate post-close season (Table 60), and ripe rudd and bream were caught during the 1977 close season although there were no observed mortalities among those caught. The close season did not cover the entire period when rudd and tench were spawning because ripe fish were common in catches during the post-close season. Spawning rudd and tench survived capture, and there was little evidence that eggs or milt were lost on capture.

Average to poor catch rates during the close season, may be explained by the reluctance of fish to feed before and during spawning (Frost, 1954; Moore, pers. comm.). If such a response were widespread, fish would be automatically protected at a time when they might be particularly vulnerable to injury, and angling might continue through the close season with little effect on the mature fish. In view of foregoing comments on the absence of hook avoidance, the value of the close season as a 'forgetting period' (Beukema, 1970a) is doubtful.

The main value of the close season appears to lie in the conservation in the flora and fauna associated with a fishery (but see 4.2(ii) regarding spawning fish).

Match angling on lake A and on other waters may often result in mortalities (see 3.3(iv)) particularly among 0+ to 1+ cyprinids such as roach and may therefore adversely affect fish population structures. On the other hand, a cull of fish at that stage in life may have little effect. It is recommended that weigh-in procedures are reviewed to minimise mortalities e.g. fish to be weighed in keep-nets at the peg, and if this is done it is unlikely that the fish stocks at Barham would improve if match angling were curtailed.

Keep-nets are essential accessories to traditional match angling and most water authorities govern their size and net mesh dimensions by byelaw. Angling clubs (e.g. Leisure Sport Angling Club) may rule that common carp and barbel are not to be held in keep nets because of the risk of fin damage; now that keep-nets made from knotless netting are available this rule may be unnecessary (see 4.2(ii)). It is therefore advisable to use knotless nets, but they must not be overcrowded with fish or located in very shallow water. It may also be unwise to hold fish in a keep-net at night in eutrophic lakes during summertime. The design of keep-nets requires review because it is common for fish to be crushed when the net is lifted from the water.

Access to the shore of some gravel-pit lakes e.g. lake A Barham may be difficult, and as at Barham, pegs may be restricted to parts of the shoreline. Fig. 43 suggests that the success of angling on a fishery may be reduced if pegs are restricted to certain positions, whenever possible therefore numbered pegs should be regularly spaced around a lake so that the maximum area of water is accessible to anglers; boats could be used on large lakes to reach inaccessible areas.

The above recommendations apply to small standing-waters, in particular gravel-pit lakes, and may not be valid for large gravel pits or reservoirs.

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Appendix 1

Fish age and length data; individual year classes (I) and composite (II).
(Lengths are back-calculated lengths-at-age)

Rudd. Lake A.

(I) Year class — Length(mm) at age(years)

Year class		1	2	3	4	5	6	7	8	9	10
1965	$\bar{x}$	36	51	79	100	129	141	151	165	175	182
	s	-									
	n	1									
1966		38	69	84	93	103	111	118	125		
		-									
		1									
1967		29	42	73	95	115	139	153	161		
		-									
		1									
1968		31	49	65	84	97	122	135			
		-									
		1									
1969		35	60	86	107	124	140				
		5.2	8.0	6.8	14.1	18.8	26.2				
		7	7	7	7	7	5				
1970		30	52	70	88	106					
		4.4	8.9	12.4	15.1	11.6					
		12	12	12	12	7					
1971		35	60	85	107	149	157				
		9.6	13.5	17.7	18.2	18.8	-				
		14	14	14	11	4	1				
1972		36	67	102	128	144					
		8.5	16.0	21.8	19.8	16.8					
		20	20	12	6	2					
1973		40	80	112	128						
		7.8	12.4	15.8	15.8						
		38	36	21	6						
1974		33	89	130							
		5.1	15.5	-							
		29	7	1							
1975		52	94								
		7.7	5.2								
		42	3								
1976		45									
		4.2									
		13									

Measurements of 0+ Rudd

Year class	Sampling date	$\bar{x}$	s	n
1974	14-2-75	34	3.7	6
1975	4-76	53	4.2	5
1976	19-10-76	45	2.9	5

(II) Composite

Age (year)	Fork length (mm)	$s/\sqrt{n}$	n	± 95% CL
1	40	0.76	179	1.5
2	70	1.71	103	3.4
3	93	2.63	71	5.2
4	106	3.17	46	6.3
5	122	4.47	24	8.8
6	137	6.77	10	13.3
7	140	8.75	4	17.2
8	150	12.59	3	24.7
9	175	-	1	-
10	182	-	1	-

Appendix 1 continued:

Roach. Lake A

Length(mm) at age(years)

(I) Year class		1	2	3	4	5
1969	$\bar{X}$	69	113	134	157	173
	s	-				
	n	1				
1970		73	120	157	192	
		6.9	14.3	28.6	7.8	
		2	2	2	2	
1971		62	92	136	161	
		15.0	18.6	30.3	-	
		5	5	5	1	
1972		59	111	169	193	
		11.9	12.1	-	-	
		10	10	1	1	
1973		70	113	157		
		7.8	4.4	7.6		
		15	3	3		
1974		58	103			
		14.6	-			
		2	1			
1975		92				
		2.7				
		4				
1976		57				
		5.0				
		7				

Measurements of 0+ roach. Lake A.

Year class	Sampling date	$\bar{X}$	s	n
1974	28-2-75	66	-	1
1975	18-7-75	41	1.0	3
"	[illegible]-76	93	2.6	3
1976	5-10-76	62	5.8	9

(II) Composite

Age (years)	Fork length (mm)	$s/\sqrt{n}$	n	±95 % CL
1	66	1.89	45	3.7
2	107	3.18	22	6.2
3	148	6.96	12	13.6
4	179	8.50	5	16.7
5	173	-	1	-

Roach. Lake B

Lengths(mm) at age(years)

(I) Year class	1	2	3	4	5	6	7
1968	51	81	132	166	190	211	232
	3.0	5.9	9.5	19.4	15.0	12.9	-
	3	3	3	3	3	3	1
1969	42	105	146	176	212	239	
	-						
	1						
1970	41	72	106	156			
	5.2	21.0	33.0	34.9			
	2	2	2	2			
1972	-						
1973	47	83					
	6.4	8.0					
	34	11					
1974	49						
	12.6						
	4						

Measurement of 0+ roach. Lake B

Year class	Sampling date	$\bar{X}$	s	n
1975	18-7-75	48	4.2	2

(II) Composite

Age (years)	Fork length (mm)	$s/\sqrt{n}$	n	± 95 % CL
1	47	0.95	48	1.9
2	84	2.25	21	4.4
3	133	6.13	10	12.0
4	170	7.57	8	14.8
5	196	8.35	4	16.4
6	218	8.70	4	17.1
7	232	-	1	-

Appendix 1 continued:

Bream. Lake A

(I) Lengths(mm) at age(years)

Year class		1	2	3	4	5	6	7	8
1968	$\bar{X}$	58	110	148	172	233	297	334	364
	s	7.0	31.0	27.7	19.7	36.0	29.1	22.6	14.9
	n	2							
1969		63	100	140	195	259	297	327	
		-							
		1							
1970		63	105	140	167	213	257	295	
		-							
		1							
1971		56	109	169	210	250	255		
		4.7	14.0	35.3	37.3	36.3	-		
		7	7	7	6	5	1		
1972		61	122	199	273				
		9.8	16.9	17.3	25.3				
		9	9	4	4				
1973		61	118	181					
		10.8	27.5	46.3					
		11	4	3					
1974		47	106	129					
		8.4	24.4	9.5					
		11	8	3					
1975		63							
		10.4							
		14							
1976		46							
		1.6							
		6							

Measurements of 0+ bream

Year class	Sampling date	$\bar{X}$	s	n
1974	13-6-75	43	-	1
1975	21-4-76	67	11.5	5
1976	5-10-76	48	9.0	11

(II) Composite

Age (years)	Fork length (mm)	$s/\sqrt{n}$	n	± 95 % CL
1	57	1.35	62	2.7
2	113	3.54	32	6.9
3	166	7.72	21	15.1
4	219	12.64	14	24.8
5	243	10.63	9	20.8
6	281	11.99	5	23.5
7	322	11.40	4	22.3
8	364	10.54	2	20.7

Tench. Lake A

(I) Lengths(mm) at age(years)

Year class		1	2	3	4	5	6	7
1969	$\bar{X}$	40	78	155	213	254	278	296
	s	-						
	n	1						
1970		40	73	108	131	154	176	
		4.9	10.7	24.0	17.9	15.3	19.5	
		3	3	3	3	3	3	
1971		53	95	129	150	170		
		11.9	20.4	22.2	19.6	15.7		
		4	4	4	4	4		
1972		48	81	112	134			
		6.7	13.8	18.6	18.3			
		15	15	15	15			

Year class	1	2	3
1973	46	83	107
	6.1	7.5	9.6
	16	16	16
1974	37	62	
	4.6	5.9	
	10	10	
1975	48		
	5.5		
	4		

(II) Composite

Age (years)	Fork length (mm)	$s/\sqrt{n}$	n	± 95% CL
1	45	1.13	54	2.2
2	79	2.06	48	4.0
3	111	2.71	38	5.3
4	137	4.01	22	7.9
5	163	6.24	7	12.2
6	176	11.26	3	22.1
7	296	-	1	-

Appendix 2

a) Mark recapture data.

Lake A ; Barham. 28 and 29 August, 1974.

Species.	Size group (mm)	Day 1 M_1	Day 2 C_2	R_1
Roach	75 - 109	112	138	4
	110 - 144	168	124	14
	145 - 279	60	19	3
Bream	75 - 144	105	161	6
	185 - 219	8	15	1
Rudd	70 - 109	28	15	0
	125 - 174	7	5	0
Perch	60 - 94	8	2	0
	All sizes	11	3	0
Tench	74 - 119	14	0	0
	320 - 394♂	13	19	1
	335 - 434♀	11	7	0
Pike	155 - 209	4	4	1
	> 210	4	1	0
Crucian carp	115 - 164	19	7	2
	185 - 254	12	9	3
	270 - 329	14	7	3

Lake A ; Barham. 14, 21 and 28 February, 1975.

Species.	Size group (mm)	Day 1	Day 2			Day 3			
		M_1	C_2	M_2	R_1	C_3	R_1	R_2	R_{1+2}
Roach	60 - 70	0	0	-	-	8	-	-	-
	80 - 120	0	16	16	-	59	-	2	-
	121 - 154	0	29	29	-	48	-	2	-
	All sizes	0	52	52	-	126	-	4	-
Bream	95 - 145	6	28	28	1	28	3	0	0
	205 - 230	9	0	0	0	1	0	-	-
	260 - 360	2	0	0	0	0	-	-	-
Rudd	30 - 45	26	0	-	-	0	-	-	-
	70 - 130	0	44	39	-	81	-	2	-
	131 - 180	0	8	7	-	13	-	0	-
	> 180	0	1	0	-	1	-	0	-
Perch	65 - 90	0	6	6	-	2	-	0	-
Tench	60 - 80	0	2	2	-	0	-	-	-
	380 - 430	0	7	7	-	1	-	0	-
Pike	220 - 240	0	3	3	-	1	-	0	-
	450 - 460	0	2	2	-	0	-	-	-
Crucian carp	40 - 70	0	5	5	-	2	-	0	-
	All sizes	0	10	10	-	4	-	0	-

2 a) cont.

Lake A ; Barham. June 6–July 18, 1975.

Species.	Size group (mm)	Day 1	Day 2			Day 3			
		M_1	C_2	M_2	R_1	C_3	R_1	R_2	R_{1+2}
Roach	75 - 190	22	0	-	-	7	1	0	0
Rudd	70 - 175	25	12	8	0	0	-	-	-
Perch	85 - 130	0	7	6	-	0	-	-	-
Bream	85 - 245	19	2	1	0	10	0	-	-
	280 - 394	6	10	10	1	0	-	-	-
Tench	290 - 440	43o	21	21	12	4	2	0	0
		42°	22	22	14	3	0	0	0
Crucian carp	60 - 350	7	0	-	-	0	-	-	-

Lake A , Barham. 19, 21 and 23 April, 1976

Species	Size group (mm)	Day 1		Day 2			Day 3			
		C_1	M_1	C_2	M_2	R_1	C_3	R_1	R_2	R_{1+2}
Roach	65 - 109	20	18	89	82	0	33	1	1	0
	110 - 214	105	101	19	18	1	24	3	0	0
	All sizes	125	119	111	103	1	60	4	1	0
Bream	60 - 99	3	1	3	0	0	75	0	-	-
	100 - 154	1	1	3	3	0	5	0	0	-
	All sizes	10	8	12	7	0	83	0	0	-
Perch	75 - 109	17	17	44	41	2	59	0	5	0
	120 - 199	2	2	8	8	0	19	0	0	-
	All sizes	19	19	52	49	2	78	0	5	0
Rudd	70 - 109	0	0	196	188	0	37	-	14	-
	110 - 174	0	0	121	119	0	19	-	7	-
Tench	330 - 414o	21	21	7	7	3	9	0	0	0
	305 - 434°	10	10	4	4	1	3	1	0	0
	All sizes	34	34	12	12	4	12	1	0	0
Pike	300 - 627	6	6	0	-	-	7	3	-	-
Crucian carp	300 - 350	2	2	0	-	-	0	-	-	-

Lake B ; Barham. June to July, 1975

Species	Size group (mm)	Day 1 (Seine)	Day 2 (Angling)			Day 3 (Angling)			Day 4 (Seine)	
		M_1	C_2	M_2	R_1	C_3	M_3	R_1	C_4	R_2
Tench	280 - 438	6	16	16	0	12	12	1	22	3

Species	Size group (mm)	Day 1 (Seine)		Day 2 (Seine)	
		C_1	M_1	C_2	R_1
Roach	70 - 155	362	356	810	8

2 a) cont.

Lake A, Barham. 4, 12 and 19 October, 1976.

Species.	Size group (mm)	Day 1 C_1	M_1	Day 2 C_2	M_2	R_1	Day 3 C_3	R_1	R_2	R_{1+2}
Rudd	35 - 59	9	7	104	2	0	34	0	0	-
	60 - 110	-	579	313	307	134	238	76	36	22
	111 - 184	-	28	31	31	3	7	2	2	0
Roach	50 - 75	478	304	337	58	0	186	0	0	-
	80 - 264	-	21	2	2	0	3	0	0	-
Bream	40 - 55	240	54	124	0	0	135	0	0	-
	85 - 139	-	243	214	209	8	34	2	0	0
	80 - 450	-	247	235	230	8	38	2	0	0
Perch	50 - 94	-	164	127	112	7	77	3	5	0
	All sizes	-	165	132	117	7	78	3	5	0
Tench	350 - 424	-	7	2	2	0	0	-	-	-
Pike	300 - 540	-	4	2	2	0	1	0	0	-

Lake A ; Barham 16 and 24 September 1977.

Species.	Size group (mm)	Day 1 M_1	Day 2 C_2	R_1
Roach	75 - 125	177	453	3
	180 - 250	5	4	0
Bream	70 - 110	224	577	1
	111 - 160	77	29	0
	161 - 220	6	3	0
	260 - 360	19	1	1
Rudd	65 - 90	45	204	10
	95 - 120	28	37	9
	130 - 240	12	9	0
Perch	50 - 80	2	13	0
	90 - 130	17	26	1
Tench	80 - 30	2	0	0
	350 - 410♂	26	4	0
	340 - 440♀	22	3	0
Pike	160 - 250	0	3	-
	360 - 400	3	3	2
	440 - 600	1	3	0
	> 800	2	0	-

Abbreviations :

C_1 Total fish caught and examined and marked on Day 1
M_1 Total number of marked fish released on Day 1
C_2 Total number of fish examined for marks on Day 2
M_2 Total number of marked fish released on Day 2
R_1 Total number of fish caught on Day 2(or Day 3) that had been marked on Day 1
C_3 Total number of fish examined for marks on Day 3
R_2 Total number of fish caught on Day 3 (or later) that had been marked on Day 2
R_{1+2} Total number of fish caught on Day 3 that had been marked on both Day 1 and Day 2

Appendix 2 b)

Schnabel estimates for rudd captured and recaptured by angling. Lake A, June to August, 1975.

Week & date	C_i	M_i	R_i	C_iM_i	Schnabel
1) 16/6	114	0	0	0	
18/6	47	114	3	5358	
20/6	5	161	1	805	
21/6	14	166	4	2324	
22/6	18	180	2	3240	
			10	11727	1066
2) 23/6	5	198	1	990	
25/6	0	203	0	0	
27/6	7	203	1	1624	
29/6	1	210	1	210	
			3	2824	706
3) 1/7	4	211	0	1055	
2/7	0	215	0	0	
5/7	13	215	2	2795	
6/7	2	228	0	456	
			2	4306	1435
4) 8/7	1	230	0	230	
9/7	2	231	0	462	
11/7	0	233	0	0	
12/7	0	233	0	0	
13/7	17	233	1	3961	
			1	4653	2327
5) 15/7	1	250	1	250	
17/7	1	251	1	251	
20/7	43	252	3	10836	
			5	11337	1890
6) 21/7	0	295	0	0	
23/7	6	295	0	1770	
25/7	4	301	1	1204	
28/7	18	305	1	5490	
			2	8464	2821

2b continued-

7) 28/7	0	323	0	0	
30/7	5	323	1	1615	
1/8	4	328	0	1312	
2/8	19	332	1	6308	
			2	9235	3078
8) 11/8	1	351	0	351	
13/8	5	352	0	1760	
15/8	8	357	0	2856	
17/8	2	365	1	730	
			1	5697	2849

Schnabel estimates for male and female tench captured and recaptured by angling. Lake A, June to July, 1976.

Date	Sex	$\sum R_i$	$\sum C_i M_i$	Schnabel
16/6 to	M	3	789	198
11/7	F	4	978	196
13/7 to	M	1	559	280
29/7	F	6	641	92
Overall	M	4	1348	270
	F	10	1619	147

M = Male; F = Female.

Appendix 2 c)

Value of μ (Gee, 1976) derived from mark recapture data for fish in lake A, 1975 and 1976.

Date	Species & size(mm).	Estimated μ
Feb. 1975	Bream, 95 - 145	0.65
Jul. 1975	Tench(M), 290 - 440	0.98
Apr. 1976	Tench(F), 305 - 434	0.40
" "	Roach, all sizes	9.10
Oct. 1976	Rudd, 60 - 110	1.09
" "	Rudd, 111 - 184	0.74
" "	Bream, 86 - 139	1.72
" "	Perch, all sizes	0.35

$$\mu = \frac{M_2\ (R_1)}{M_1\ (R_2+1)}$$

Appendix 3 Census forms

FISHERY SURVEY, BARHAM PITS

PIT ____ SUB-SECT. ____ DATE ____

WIND DIR. 1 2 3 4 5 6 7 8

WIND SPEED 0 1 2 3 4 5 6 7 8

RAIN 0 1 2 3

INCIDENT LIGHT ____

TURBIDITY ____ cm.

LIGHT PENETRATION ____

DEPTH GAUGE ____ m

DISSOLVED OXYGEN 1 2 3 av. ____ mgl^{-1}

AIR TEMP. ____ °C

WATER TEMP. °C 1 2 3 av. ____

ANGLER	PEG	06:00	12:00	18:00	TOTAL HRS	RUDD I	II	III	IV	V	ROACH I	II	III	IV	V	TENCH I	II	III	CRUCIAN CARP I	II	III	BREAM I	II	III	PERCH I	II	III	CARP C. I	II	PIKE I	II	BAITS	HOOK	METHOD	B.S./LINE	G.BT.

TOTALS

FISH RECORD

PIT ____ SUB-SECT. ____ DATE ____

SPECIES	FORK LENGTH (cm.)	WEIGHT (g.)	HOOK DAMAGE OLD	HOOK DAMAGE NEW	SEX	MARKS/TAGS PRESENT	MARK/TAG ADDED	REMARKS.

Test angler census

NAME	DATE	PEG(S)

FISHING TIME
START am/pm
FINISH am/pm

PIT
use new form if you change pits

FISH CAPTURES – fill in numbers of fish in the correct spaces below.

FISH SIZE GROUPS (FORK LENGTH)

SPECIES	UP TO 4"	4-6"	6-8"	8-10"	10-12"	12-14"	14-16"	over 16"
ROACH								
RUDD								
TENCH								
BREAM								
CRUCIAN								
PERCH								
COMMON CARP								
PIKE								
EEL								

DETAILS OF INK MARKED OR TAGGED FISH:

Record species, length, weight, tag. no., ink colour, position of ink mark

continue over:

BAITS	HOOK SIZE	LINE B.S.	GROUND BAIT	FISHING STYLE
			HEAVY	FLOAT
			LIGHT	LEDGER
			NONE	LAY ON FLOAT

tick

PLEASE – RECORD BLANK DAYS
LEAVE TAGS ON FISH

Appendix 4 Environmental data and angling effort . Lake A.

DAYN	YEAR	MAXT	MINT	RAIN	WIDR	WIRN	RADN	EFFT	WTEM	SECI	DISO	YRDU
213	75	23.0	16.0	0.0	2.0	159.0	490.0	42.0	22.5	132.0	11.0	2
214	75	23.5	10.5	0.0	3.0	136.0	559.0	54.0	23.7	158.0	10.9	2
223	75	27.0	16.0	0.0	7.0	114.0	584.0	31.0	25.2	90.0	11.3	2
225	75	28.0	13.5	0.0	7.0	74.0	591.0	49.7	25.0	100.0	11.7	2
227	75	24.5	16.0	2.2	8.0	236.0	339.0	20.0	23.0	70.0	7.8	2
229	75	22.5	12.0	0.0	7.0	171.0	496.0	40.0	22.5	85.0	6.7	2
231	75	22.5	16.0	0.1	6.0	269.0	223.0	48.0	21.0	55.0	6.3	2
232	75	22.5	17.5	1.2	6.0	206.0	264.0	38.5	20.5	67.0	5.7	2
234	75	20.5	9.5	0.6	6.0	132.0	366.0	28.1	19.5	48.0	6.4	2
238	75	22.5	9.0	0.0	6.0	88.0	463.0	9.5	20.0	96.0	7.5	2
240	75	24.5	12.5	0.0	3.0	90.0	431.0	33.5	21.2	54.0	10.1	2
243	75	22.0	15.0	0.0	1.0	187.0	296.0	14.0	20.0	73.0	8.5	2
248	75	21.5	9.5	0.0	7.0	70.1	304.0	5.0	20.0	55.0	0.0	2
256	75	18.0	7.5	32.9	8.0	220.0	304.0	12.5	17.0	60.0	8.2	2
271	75	17.0	8.5	0.0	6.0	226.0	219.0	96.0	15.0	60.0	7.7	2
168	76	16.0	12.5	0.0	2.0	87.0	234.0	77.4	20.5	53.0	8.9	3
169	76	20.0	6.5	0.0	6.0	139.0	421.0	80.4	21.7	65.0	8.8	3
170	76	25.0	12.5	0.0	6.0	236.0	669.0	67.0	23.5	57.0	9.4	3
172	76	20.0	11.0	0.0	7.0	130.0	384.0	105.0	20.5	55.0	8.0	3
174	76	24.0	14.0	0.0	6.0	115.0	680.0	100.8	22.7	67.0	8.7	3
175	76	26.0	13.5	0.0	5.0	149.0	696.0	58.6	24.3	50.0	9.2	3
177	76	29.5	8.5	0.0	3.0	107.0	673.0	52.1	26.7	77.0	9.3	3
179	76	29.0	15.5	0.0	3.0	78.0	728.0	70.0	27.2	55.0	9.6	3
181	76	25.5	13.5	0.0	3.0	270.0	797.0	76.4	26.7	33.0	10.0	3
182	76	26.0	12.0	0.0	3.0	396.0	902.0	38.2	25.0	42.0	9.4	3
184	76	27.5	12.5	0.0	3.0	244.0	850.0	21.7	24.7	34.0	8.9	3
188	76	27.0	14.5	0.0	3.0	222.0	763.0	54.4	25.0	35.0	9.7	3
189	76	27.0	12.5	0.0	2.0	227.0	810.0	52.2	24.7	28.0	9.4	3
193	76	22.5	12.0	0.0	2.0	156.0	647.0	115.0	22.7	56.0	9.5	3
195	76	26.0	16.5	0.0	2.0	102.0	518.0	31.7	23.3	38.0	9.9	3
196	76	25.0	16.5	0.0	7.0	192.0	596.0	35.5	22.7	51.0	10.1	3
204	76	19.5	9.5	0.0	1.0	92.0	459.0	49.6	20.0	32.0	7.4	3
209	76	21.5	10.0	0.0	2.0	187.0	584.0	38.2	21.7	42.0	9.3	3
222	76	22.5	10.5	0.0	2.0	273.0	519.0	29.9	20.0	50.0	11.6	3
224	76	25.0	12.0	0.0	2.0	87.0	521.0	20.2	20.0	41.0	11.4	3
226	76	24.0	10.0	0.0	2.0	116.0	461.0	13.5	21.2	50.0	12.0	3
228	76	23.5	12.0	0.0	2.0	258.0	544.0	100.0	21.7	50.0	12.0	3
232	76	24.5	12.5	0.0	2.0	139.0	508.0	13.2	22.0	57.0	11.3	3
237	76	26.0	11.5	0.0	3.0	131.0	553.0	29.7	21.2	43.0	10.0	3
249	76	18.0	9.0	0.0	3.0	35.0	210.0	14.0	17.0	49.0	13.7	3
256	76	17.0	10.5	0.0	7.0	78.0	165.0	84.0	15.2	45.0	12.3	3
297	76	15.0	10.5	0.1	4.0	243.0	104.0	33.0	11.5	47.0	10.5	3
325	76	8.0	6.5	0.0	1.0	166.0	44.0	51.2	7.5	70.0	13.7	3
22	77	8.0	4.5	3.0	5.0	81.0	40.0	15.1	4.0	80.0	15.0	4
72	77	12.0	5.0	0.0	5.0	151.0	170.0	28.0	10.3	71.0	14.2	4
114	77	15.0	10.0	4.9	6.0	420.0	414.0	52.0	12.0	78.0	9.8	4
122	77	12.0	2.5	0.0	2.0	108.0	126.0	21.0	12.0	80.0	12.8	4
129	77	13.0	6.0	0.0	8.0	56.0	161.0	38.5	13.0	75.0	13.0	4
143	77	17.0	7.5	0.0	2.0	269.0	572.0	52.5	15.5	55.0	13.4	4
157	77	18.0	10.0	0.0	7.0	153.0	211.0	45.5	16.2	51.0	12.8	4
224	74	21.0	12.5	1.8	6.0	166.0	250.0	24.5	18.2	18.2	8.6	1
226	74	23.0	14.0	0.0	6.0	303.0	352.0	36.0	19.5	0.0	8.4	1
228	74	22.0	16.0	0.0	6.0	168.0	377.0	48.5	21.0	0.0	9.8	1
230	74	20.5	8.5	3.7	1.0	110.0	272.0	190.0	21.0	0.0	10.1	1
232	74	19.5	9.5	0.0	4.0	105.0	454.0	69.0	18.7	0.0	10.4	1
234	74	21.0	9.0	0.0	8.0	137.0	357.0	51.5	20.2	0.0	11.0	1
236	74	24.0	15.0	0.0	6.0	178.0	449.0	57.0	20.5	0.0	10.7	1
237	74	23.0	12.0	0.0	6.0	250.0	408.0	150.0	20.0	0.0	10.6	1
260	74	19.5	11.0	0.0	6.0	189.0	273.0	21.5	18.4	0.0	11.1	1
262	74	17.5	5.5	0.0	7.0	151.0	305.0	9.0	16.5	0.0	10.3	1
264	74	16.0	10.0	7.0	6.0	216.0	181.0	28.0	14.8	0.0	9.1	1
265	74	15.0	8.5	2.6	6.0	322.0	361.0	16.5	14.7	0.0	9.3	1
272	74	12.5	3.5	0.0	8.0	110.0	154.0	19.0	11.8	0.0	10.3	1
278	74	11.5	7.0	0.0	8.0	195.0	98.0	24.0	10.6	0.0	11.1	1
279	74	11.5	5.5	4.9	6.0	243.0	61.0	9.5	10.4	0.0	10.7	1
18	75	7.0	3.5	8.7	2.0	168.0	13.0	33.0	5.7	0.0	10.9	2
25	75	12.0	4.0	0.1	5.0	426.0	21.0	35.0	5.3	0.0	11.6	2
32	75	10.5	3.0	0.1	6.0	77.0	39.0	36.0	5.4	0.0	11.3	2
39	75	4.5	2.0	0.0	3.0	151.0	22.0	21.0	4.9	0.0	10.1	2
46	75	6.0	1.0	0.0	4.0	281.0	46.0	13.5	4.8	0.0	12.1	2
53	75	8.0	2.0	0.0	6.0	137.0	86.0	9.0	4.9	0.0	12.6	2
60	75	9.5	3.5	0.1	4.0	130.0	90.0	15.0	5.0	0.0	12.9	2
67	75	8.5	2.5	4.3	6.0	183.0	57.0	14.0	6.5	0.0	11.7	2
81	75	6.5	2.5	0.5	6.0	141.0	66.0	18.6	5.0	0.0	12.7	2

continued :-

4 cont.

DAYN	YEAR	MAXT	MINT	RAIN	WIDR	WIRN	RADN	EFFT	WTEM	SECI	DISO	YRDU
81	75	6.5	2.5	0.5	6.0	141.0	66.0	18.6	5.0	0.0	12.7	2
95	75	7.0	1.0	0.5	8.0	115.0	112.0	18.5	5.2	0.0	12.6	2
109	75	15.0	8.5	0.1	6.0	189.0	169.0	35.5	11.5	0.0	11.5	2
137	75	12.0	7.0	0.1	2.0	234.0	125.0	24.0	12.0	0.0	10.4	2
167	75	17.0	6.0	0.6	6.0	94.0	422.0	78.2	20.8	0.0	10.7	2
169	75	19.0	6.0	0.1	6.0	151.0	530.0	58.7	20.3	0.0	10.7	2
171	75	20.5	10.0	0.0	5.0	181.0	673.0	85.7	20.6	0.0	11.0	2
172	75	23.0	9.5	0.0	2.0	358.0	699.0	53.5	20.5	0.0	11.0	2
173	75	21.5	13.5	0.1	2.0	342.0	618.0	220.0	20.0	0.0	10.4	2
174	75	20.5	12.5	0.1	1.0	300.0	327.0	58.5	18.3	0.0	9.6	2
176	75	18.0	11.0	0.0	2.0	83.3	455.0	61.5	19.7	0.0	9.5	2
178	75	15.5	8.5	0.1	2.0	194.0	235.0	56.2	18.0	0.0	10.2	2
180	75	18.5	7.0	0.1	2.0	280.0	558.0	245.0	18.2	0.0	10.3	2
182	75	14.5	6.0	0.0	8.0	81.0	532.0	41.5	19.7	0.0	10.9	2
186	75	19.0	12.0	0.0	2.0	188.0	312.0	168.0	19.0	0.0	10.8	2
187	75	19.5	9.5	0.0	2.0	265.0	613.0	195.0	19.7	0.0	10.5	2
189	75	21.5	13.5	2.1	2.0	94.0	269.0	39.5	20.1	0.0	10.5	2
190	75	22.5	14.5	4.2	6.0	128.0	415.0	53.5	20.5	0.0	10.7	2
192	75	21.5	15.5	1.4	6.0	190.0	356.0	63.5	20.6	0.0	10.3	2
193	75	21.5	13.0	2.1	7.0	255.0	452.0	80.0	21.0	0.0	10.3	2
194	75	25.0	15.0	0.1	6.0	237.0	365.0	220.0	22.0	0.0	9.6	2
196	75	22.0	15.0	1.0	6.0	431.0	500.0	62.5	21.2	0.0	9.7	2
198	75	21.0	15.0	0.8	6.0	159.0	321.0	39.5	21.2	0.0	10.4	2
201	75	21.5	16.5	0.1	6.0	148.0	238.0	200.0	21.7	0.0	11.0	2
202	75	22.5	12.0	0.1	1.0	145.0	548.0	29.0	22.2	0.0	11.2	2
204	75	21.0	14.5	0.7	6.0	302.0	385.0	58.0	20.2	0.0	9.7	2
206	75	20.0	10.0	0.0	1.0	135.0	472.0	25.5	19.2	0.0	10.7	2
207	75	22.0	12.0	0.0	7.0	81.0	213.0	195.0	21.0	0.0	11.2	2
209	75	23.0	11.5	0.0	5.0	154.0	477.0	22.0	21.7	0.0	11.3	2
211	75	27.0	12.5	0.0	6.0	112.0	644.0	60.0	24.0	0.0	10.5	2
245	75	20.5	12.5	0.0	2.0	76.0	142.0	43.5	19.5	0.0	8.9	2
264	75	19.0	8.0	0.0	7.0	57.0	267.0	150.0	16.7	0.0	9.0	2
206	76	21.0	11.5	3.4	1.0	80.0	415.0	120.0	20.2	0.0	8.2	3
211	76	23.0	9.5	0.0	8.0	233.0	638.0	39.0	21.7	0.0	11.3	3
238	74	19.5	10.5	3.0	5.0	235.0	203.0	39.5	19.3	0.0	0.0	1
243	74	21.0	12.5	2.0	7.0	283.0	326.0	52.5	18.5	0.0	0.0	1
244	74	17.5	12.0	8.1	5.0	288.0	284.0	32.0	18.0	0.0	0.0	1
246	74	17.5	13.0	6.6	6.0	344.0	429.0	17.5	16.7	0.0	0.0	1
248	74	15.0	10.5	5.0	5.0	215.0	121.0	19.5	16.0	0.0	0.0	1
251	74	18.5	10.5	0.2	7.0	282.0	442.0	14.0	16.4	0.0	0.0	1
255	74	18.0	13.0	1.3	3.0	220.0	165.0	2.5	15.8	0.0	0.0	1
256	74	21.5	14.5	0.0	6.0	176.0	217.0	10.5	17.2	0.0	0.0	1
257	74	18.0	9.5	0.0	6.0	138.0	277.0	26.5	17.8	0.0	0.0	1
183	75	21.0	6.5	0.0	5.0	140.0	620.0	58.0	20.0	0.0	0.0	2
263	76	18.0	7.0	0.0	7.0	75.0	224.0	21.5	15.1	55.0	0.0	3
50	77	9.0	3.0	9.0	5.0	306.0	139.0	32.0	5.9	50.0	0.0	4
124	75	11.0	5.0	0.0	2.0	0.0	376.0	14.0	11.3	0.0	10.5	2
151	75	14.0	3.0	0.5	2.0	0.0	387.0	22.0	14.0	0.0	10.0	2

Note:- See Table 57 for variable definitions.

Appendix 5 Example of multiple regression analysis (see Tables 57 & 58 for details)

RUDD. LAKE A.

MEANS OF VARIABLES

```
 2 201. 6800     3   75. 84000    6  0. 9000000    8  165. 4200
 9 453. 2600    10   48. 71999   11    20.00000   12   61. 30000
13 9. 895999    18-0. 6472634    19-0.  2874469   20 0. 1171773E-01
21 0. 1082853   22   16. 38000   16 0.  2936001
```

STANDARD DEVIATIONS OF VARIABLES

```
 2  52. 67670    3 0. 6502746    6  4. 698198     8  82. 41262
 9 220. 3134    10   32. 66275   11  5. 074618   12  24. 10034
13  2. 592535   18 0. 4424410    19 0. 5593231   20 0. 5713083
21 0. 8257785   22  3. 991458    16 0. 3159744
```

CORRELATION HALF-MATRIX

```
VARIABLE  2
   2  1. 0000    3 -0. 6861    6   0. 0777    8 -0. 0207     9 -0. 0646    10  -0. 1105
  11  0. 2011   12 -0. 0631   13 -0. 3271   18  0. 0421    19 -0. 8813    20   0. 2188
  21  0. 1053   22  0. 2762   16  0. 0501
VARIABLE  3
   3  1. 0000    6 -0. 1463    8   0. 0698    9 -0  0867    10  0. 1159    11  -0. 4521
  12 -0. 2899   13  0. 6098   18   0. 1373   19  0. 7870    20 -0. 2052    21   0. 1692
  22 -0. 4950   16 -0. 0846
VARIABLE  6
   6  1. 0000    8  0. 1577    9  -0. 1367   10 -0.1817    11 -0. 1539    12   0. 0200
  13 -0. 0888   18  0. 1701   19  -0. 1231   20  0.2460    21 -0. 0726    22  -0. 1707
  16  0. 3436
VARIABLE  8
   8  1. 0000    9  0. 2851   10   0. 0612   11  0.0466    12 -0. 1755    13  -0. 0972
  18 -0. 0626   19  0. 1251   20  -0. 1286   21  0.0002    22  0. 1141    16   0. 1755
VARIABLE  9
   9  1. 0000   10 0. 2784    11   0. 8193   12 -0.1790    13 -0. 1656    18  -0. 7284
  19  0. 0840   20 -0. 3013   21   0. 2807   22  0.7358    16  0. 4013
VARIABLE 10
  10  1. 0000   11 0. 2381    12 -0.  0711   13 -0.0410    18 -0. 3015    19   0. 2590
  20 -0. 1005   21 -0. 1609   22   0. 1416   16 -0.0383
VARIABLE 11
  11  1. 0000   12 -0.0862    13 -0.  4170   18 -0.8563    19 -0. 8563    20  -0. 0999
  21  0. 1957   22  0. 9116   16   0. 3385
VARIABLE 12
  12  1. 0000   13 0. 1204    18   0. 1459   19  0.0049    20  0. 1034    21  -0. 1818
  22 -0. 1098   16 -0.2375
VARIABLE 13
  13  1. 0000   18 0. 3182    19   0. 3416   20 -0.1903    21  0. 3116    22  -0. 3801
  16 -0. 2253
VARIABLE 18
  18  1. 0000   19 -0.1101    20 -0. 0369   21 -0.2059    22 -0. 7117    16  -0. 2774
VARIABLE 19
  19  1. 0000   20 -0.1570    21 -0. 0431   22 -0.3261    16 -0. 0542
VARIABLE 20
  20  1. 0000   21 -0.2623    22 -0. 0949   16  0.1171
VARIABLE 21
  21  1. 0000   22  0.1205    16  0. 3204
VARIABLE 22
  22  1. 0000   16  0.2080
VARIABLE 16
  16  1. 0000
```

DETERMINANT = 0. 8289863D-05

B COEFFICIENTS AND STANDARD ERRORS

```
 2 -0. 18066E-02    0. 16428E-02     3  0. 15885       0. 19879
 6  0. 19129E-01    0. 85732E-02     8  0. 41043E-03   0. 54942E-03
 9  0. 45198E-03    0. 40818E-03    10 -0. 11222E-03   0. 13059E-02
11  0. 78116E-01    0. 38270E-01    12 -0. 11534E-02   0. 22884E-02
13 -0. 36362E-01    0. 23696E-01    18  0. 47341       0. 23237
19 -0. 15741        0. 21110        20  0. 21020       0. 80456E-01
21  0. 13739        0. 59538E-01    22 -0  50186E-01   0. 26229E-01
INTERCEPT(BO) WITH STANDARD ERROR
 -11. 739       15. 342
```

continued over :-

5 cont.

```
B COEFFICIENTS CORRELATIONS
COEFF  2
   2  1. 0000     3  0. 0177     6  0. 1634     8  -0. 2896     9  0. 1063    10 -0. 3026
  11 -0. 0955    12  0. 0645    13  0. 0122    18  -0. 0148    19  0. 6647    20  -0. 2494
  21 -0. 2387    22  0. 1631
COEFF  3
   3  1. 0000     6  0. 1984     8  0. 1715     9  -0. 2901    10 -0. 0014    11  0. 4614
  12  0. 7105    13 -0. 5649    18  0. 3167    19  -0. 5564    20  0. 0861    21  -0. 1693
  22 -0. 0401
COEFF  6
   6  1. 0000     8 -0. 2017     9 -0. 1011    10  0. 0711    11 -0. 0098    12  0. 1550
  13 -0. 0831    18 -0. 0289    19  0. 0403    20  -0. 2451    21 -0. 0489    22  0. 2135
COEFF  8
   8  1. 0000     9 -0. 4457    10 0. 0397    11  0. 4198    12  0. 1128    13  0. 0915
  18  0. 1332    19 -0. 3107    20  0. 1346    21  0. 0004    22 -0  3109
COEFF  9
   9  1. 0000    10 -0. 0601    11 -0.5894    12  -0.0831    13 -0. 0116    18 -0. 2340
  19  0. 0779    20  0. 1034    21  -0.0546    22  0. 0471
COEFF 10
  10  1. 0000    11 -0. 1015    12  0.0591    13  -0.1115    18  0. 0514    19 -0. 2390
  20  0. 1309    21  0. 3604    22   0.1347
COEFF 11
  11  1. 0000    12  0. 1373    13 -0.0032    18   0.6862    19 -0. 1926    20  0. 2128
  21 -0. 1630    22 -0. 5962
COEFF 12
  12  1. 0000    13 -0  5422    18  0.0876    19  -0.3946    20 -0. 0119    21  0. 0112
  22  0. 0930
COEFF 13
  13  1. 0000    18 -0. 2026    19  0.2395    20  -0.0394    21 -0. 2874    22 -0. 1861
COEFF 18
  18  1. 0000    19  0. 0730    20  0.4264    21   0.1299    22 -0. 1309
COEFF 19
  19  1. 0000    20 -0. 1057    21  0.0715    22   0.2574
COEFF 20
  20  1. 0000    21  0. 2423    22 -0.0684
COEFF 21
  21  1. 0000    22  0. 2443
COEFF 22
  22  1. 0000

ANALYSIS OF VARIANCE
                          SS              DF            MS               F

  REGRESSION         0. 27999E+01         14        0.19999E+00        3.345
RESIDUAL (ERROR)     0. 20923E+01         35        0.59779E-01
    TOTAL            0. 48922E+01

MULTIPLE CORRELATION COEFFICIENT, R= 0.75652            R-SQUARED= 0. 57232
RESIDUAL STANDARD ERROR =  0. 24450

MULTIPLE REGRESSION AT  90.0 PER CENT LEVEL

B COEFFICIENTS AND STANDARD ERRORS
   3   0. 27903          0. 96440E-01         6  0. 26413E-01         0. 78682E-02
  11   0. 63028E-01      0. 20854E-01        13 -0. 48053E-01         0. 19135E-01
  18   0. 47126          0. 21394            20  0. 16076             0. 74902E-01
  21   0. 14868          0. 48712E-01
INTERCEPT(BO) WITH STANDARD ERROR
  -21. 390        7. 4354

B COEFFICIENTS CORRELATIONS
COEFF  3
   3  1. 0000    6  0. 0989     11  0. 7050     13  -0. 4719     18  0. 5623      20  0.4025
  21 -0. 0057
COEFF  6
   6  1. 0000    11 0. 0667     13  0. 0602     18  -0. 0316     20 -0. 1756      21 -0.0812
COEFF 11
  11  1. 0000    13 -0.0995     18  0. 9058     20  0.  4756     21 -0. 0866
COEFF 13
  13  1. 0000    18 -0.2545     20 -0. 0647     21  -0. 3459
COEFF 18
  18  1. 0000    20  0.4728     21  0. 0710
COEFF 20
  20  1. 0000    21  0.1702
COEFF 21
  21  1. 0000

ANALYSIS OF VARIANCE
                              SS            DF          MS              F
    REGRESSION           0. 24131E+01        7      0. 34472E+00      5. 840
    RESIDUAL(ERROR)      0. 24791E+01       42      0. 59026E-01
        TOTAL            0. 48922E+01

MULTIPLE CORRELATION COEFFICIENT, R= 0. 70232             R-SQUARED= 0. 49325
RESIDUAL STANDARD ERROR =  0.24295

ENTER 1 IF BACK SUBSTITUTION  REQUIRED , 0 IF NOT

0

NO CHANGE AT 95. 0 PER CENT LEVEL
```

Appendix 6 Numbers of fish (in size groups) caught by angling

Rudd. Lake A, 1975 to 1977.

Date	GP1	GP2	GP3	GP4	GP5
18.1.75 to 31.5.75	0	0	0	0	0
16.6.75	97	22	8	0	0
18.6.75	36	14	0	0	0
20.6.75	0	4	0	1	0
21.6.75	1	11	0	0	0
22.6.75*	6	9	3	0	0
23.6.75	1	3	1	0	0
25.6.75	0	0	0	0	0
27.6.75	0	3	0	5	0
29.6.75*	0	0	0	1	0
1.7.75	3	1	1	0	0
2.7.75	0	0	0	0	0
5.7.75*	9	3	1	0	0
6.7.75*	1	1	0	0	0
8.7.75	0	0	1	0	0
9.7.75	20	0	1	0	0
11.7.75	0	0	0	0	0
12.7.75*	0	0	0	0	0
13.7.75*	3	20	0	1	0
15.7.75	0	0	1	0	0
17.7.75	0	0	1	0	0
20.7.75*	16	24	1	2	0
21.7.75	0	0	0	0	0
23.7.75	1	7	0	0	0
25.7.75	3	1	1	0	0
26.7.75*	2	11	5	0	0
28.7.75	0	0	0	0	0
30.7.75	0	2	3	0	0
1.8.75	0	3	1	0	0
2.8.75*	2	15	3	0	0
11.8.75	1	1	1	0	0
13.8.75	17	3	0	1	0
15.8.75	2	8	0	0	0
17.8.75	0	9	1	0	0
19.8.75	0	2	0	0	0
20.8.75	1	0	0	0	0
22.8.75	1	4	0	0	0
26.8.75	0	0	0	0	0
28.8.75	0	1	0	0	0
31.8.75	0	2	0	0	0
2.9.75	18	3	0	0	0
5.9.75	4	0	0	0	0
13.9.75	2	12	0	0	0
21.9.75*	11	8	1	0	0
28.9.75*	2	5	1	0	0

Date	GP1	GP2	GP3	GP4	GP5
16.6.76	2	14	2	0	0
17.6.76	4	3	0	0	0
18.6.76	15	5	2	0	0
20.6.76	0	4	1	0	0
22.6.76	2	2	3	0	0
23.6.76	2	6	0	0	0
25.6.76	0	4	1	0	0
27.6.76*	19	8	1	0	0
29.6.76	49	4	2	0	0
30.6.76	30	4	2	0	0
2.7.76	8	4	0	0	0
6.7.76	0	0	0	0	0
7.7.76	70	0	0	0	0
11.7.76*	108	8	1	0	0
13.7.76	7	1	0	0	0
14.7.76	9	0	0	0	0
22.7.76	26	3	0	0	0
24.7.76*	39	7	0	0	0
27.7.76	4	0	0	0	0
29.7.76	13	8	1	0	0
9.8.76	0	0	1	0	0
11.8.76	2	4	0	0	0
13.8.76	9	0	0	0	0
15.8.76*	18	19	6	0	0
19.8.76	5	0	0	0	0
24.8.76	3	0	0	0	0
5.9.76	0	0	0	0	0
12.9.76*	13	4	1	0	0
19.9.76	0	0	1	0	0
23.10.76	0	2	1	0	0
20.11.76	0	0	0	0	0
18.12.76	Ice	0	0	0	0
22.1.77	0	0	0	0	0
19.2.77	0	0	0	0	0
12.3.77	2	0	1	0	0
23.4.77	0	0	1	0	0
1.5.77	0	4	3	0	0
8.5.77	0	4	1	0	0
22.5.77	0	3	7	0	0
5.6.77	1	7	1	0	0

* = Match dates.

6 cont.

Tench. Lake A, 1975 to 1977.

Date	GP1	GP2	GP3
18.1.75	0	0	1
25.1.75 to 19.4.75	0	0	0
4.5.75	0	0	2
17.5.75	0	0	9
31.5.75	0	0	10
16.6.75	0	0	6
18.6.75	0	0	2
20.6.75	2	0	9
21.6.75	0	1	5
22.6.75*	0	3	5
23.6.75	0	2	10
25.6.75	1	2	3
27.6.75	0	4	5
29.6.75*	0	3	1
1.7.75	1	0	6
2.7.75	4	0	2
5.7.75*	0	1	2
6.7.75*	0	0	3
8.7.75	3	0	5
9.7.75	4	0	15
11.7.75	1	1	4
12.7.75*	0	2	3
13.7.75*	0	1	5
15.7.75	1	1	7
17.7.75	2	1	6
20.7.75*	2	2	11
21.7.75	2	3	8
23,7.75	1	0	5
25.7.75	6	2	1
26.7.75*	2	1	1
28.7.75	0	0	3
30.7.75	0	4	5
1.8.75	0	1	4
2.8.75*	0	2	1
11.8.75	0	2	0
13.8.75	c	0	3
15.8.75	0	0	1
17.8.75	1	0	0
19.8.75	6	7	7
20.8.75	2	1	5
22.8.75	4	2	1
26.8.75	0	0	0
28.8.75	0	0	1
31.8.75	0	0	1
2.9.75	1	1	2
5.9.75	0	0	1
13.9.75	0	0	0
21.9.75*	0	0	1
28.9.75*	0	0	3

Date	GP1	GP2	GP3
16.6.76	1	3	11
17.6.76	2	0	1
18.6.76	0	6	7
20.6.76*	0	13	7
22.6.76	4	22	10
23.6.76	9	7	4
25.6.76	4	1	5
27.6.76*	3	4	1
29.6.76	4	5	8
30.6.76	11	4	5
2.7.76	10	4	2
6.7.76	3	0	9
7.7.76	3	2	7
11.7.76*	2	3	7
13.7.76	4	0	6
14.7.76	11	3	9
22.7.76	39	2	1
24.7.76*	10	4	3
27.7.76	9	1	0
29.7.76	8	2	2
9.8.76	2	1	3
11.8.76	2	0	0
13.8.76	10	0	1
15.8.76*	0	2	11
19.8.76	4	0	1
24.8.76	5	0	2
5.9.76	0	0	2
12.9.76*	0	0	2
19.9.76	0	0	0
23.10.76	0	1	1
20.11.76	0	0	1
18.12.76	0	0	0
22.1.77	0	0	0
19.2.77	0	0	0
12.3.77	0	0	0
23.4.77	0	1	17
1.5.77	0	0	4
8.5.77	0	2	30
22.5.77	0	0	19
5.6.77	0	0	33

6 cont.

Roach. Lake A, 1975 to 1977

Date	GP1	GP2	GP3	GP4	GP5
18.6.75	0	0	1	0	0
20.7.75*	0	0	2	1	0
30.7.75	0	0	1	0	0
1.8.75	0	0	1	0	0
2.8.75	0	1	0	0	0
15.8.75	0	0	0	1	0
20.8.75	0	2	1	2	0
22.8.75	0	1	2	0	0
21.9.75*	0	0	1	0	0
28.9.75*	0	1	0	1	0
16.6.76	0	12	14	0	0
17.6.76	0	6	1	0	0
18.6.76	0	3	1	1	2
20.6.76*	0	0	3	0	0
22.6.76	0	0	17	1	0
23.6.76	0	7	3	0	0
25.6.76	0	2	7	1	0
27.6.76*	0	0	3	0	0
29.6.76	0	4	7	1	0
30.6.76	0	2	1	0	0
2.7.76	0	1	3	0	0
6.7.76	0	2	1	1	0
7.7.76	0	3	1	0	0
11.7.76*	0	1	0	0	0
14.7.76	0	3	2	0	0
22.7.76	0	2	2	0	0
24.7.76*	0	2	0	0	0
27.7.76	0	2	0	0	0
29.7.76	0	0	1	1	1
9.8.76	0	2	2	0	0
11.8.76	0	1	1	0	1
13.8.76	0	1	2	0	0
15.8.76*	0	3	3	0	0
23.10.76	0	0	3	1	0
20.11.76	0	0	1	0	0
12.3.77	0	0	2	0	0
23.4.77	0	0	1	0	0
1.5.77	0	0	2	0	0
8.5.77	0	0	1	0	0
22.5.77	0	0	0	0	2

The above are positive records.

Perch. Lake A, 1975 to 1977

Date	GP1	GP2	GP3
29.6.75*	1	0	0
5.7.75*	0	1	0
9.7.75	0	1	0
15.7.75	50	0	0
20.7.75*	2	1	0
23.7.75	0	1	0
26.7.75*	1	0	0
30.7.75	1	0	0
13.8.75	1	0	0
20.8.75	1	0	0
5.9.75	0	1	0
21.9.75*	4	1	0
28.9.75*	2	4	0
16.6.76	1	4	0
18.6.76	0	4	0
20.6.76*	0	1	0
22.6.76	0	2	0
23.6.76	0	1	0
25.6.76	0	1	0
27.6.76*	0	1	0
29.6.76	0	3	0
2.7.76	0	1	0
11.7.76*	0	4	0
13.7.76	1	0	0
22.7.76	0	3	0
24.7.76*	1	1	0
29.7.76	0	1	0
9.8.76	0	1	0
11.8.76	1	0	0
13.8.76	0	1	0
15.8.76*	1	2	0
19.9.76	0	1	0
20.11.76	0	2	0
12.3.77	0	1	0
23.4.77	0	1	0
8.5.77	0	3	0
22.5.77	0	4	0
5.6.77	1	1	0

The above are positive records.

6 cont.

Crucian carp. Lake A, 1975 to 1977. (positive records only)

Date	GP1	GP2	GP3	Date	GP1	GP2	GP3
25.1.75	0	0	1	1.8.75	0	1	0
18.6.75	0	1	0	11.8.75	0	1	0
20.6.75	0	0	1	17.8.75	0	1	0
21.6.75	0	1	0	19.8.75	0	1	0
22.6.75*	0	1	0	31.8.75	0	0	1
23.6.75	0	2	0	16.6.76	0	0	1
25.6.75	0	1	2	18.6.76	0	0	1
1.7.75	0	2	0	22.6.76	0	0	1
2.7.75	0	2	0	23.6.76	1	0	0
6.7.75*	0	1	0	25.6.76	1	2	1
8.7.75	0	0	1	27.6.76*	1	0	0
9.7.75	0	0	2	29.6.76	0	0	1
12.7.75*	0	1	0	30.6.76	0	1	3
15.7.75	0	0	1	6.7.76	0	1	2
17.7.75	0	2	0	7.7.76	0	1	0
20.7.75	0	1	0	11.7.76*	0	1	0
21.7.75	0	1	0	24.7.76*	0	2	0
23.7.75	0	3	0	27.7.76	1	0	0
25.7.75	1	1	0	24.8.76	0	0	2
30.7.75	1	1	0	5.6.77	0	0	1

Numbers of fish caught and angling effort. Lake A, 1974.

Date	Rudd	Roach	Bream	Tench	Perch	Cru.carp	Com.carp	Pike	Effort (h)
12.8.74	2	2	0	5	0	0	3	0	24.5
14.8.74*	36	4	0	0	1	0	1	0	52.0
16.8.74	2	0	0	7	1	0	0	0	48.5
18.8.74*	248	21	4	7	4	2	2	0	190.0
20.8.74	1	5	0	0	0	6	2	0	69.0
22.8.74	16	7	3	0	1	0	1	0	51.5
24.8.74	6	9	0	2	0	1	0	0	56.5
25.8.74*	36	49	3	5	1	1	0	0	175.0
26.8.74	22	6	0	2	2	1	0	0	39.5
31.8.74	56	3	1	1	0	0	0	0	52.5
1.9.74	6	1	0	0	1	0	0	0	32.0
3.9.74	4	1	0	0	0	0	2	0	17.5
5.9.74	0	0	0	0	0	0	1	0	19.5
8.9.74	2	0	0	0	0	1	0	0	14.0
12.9.74	0	0	0	0	0	0	0	0	2.5
13.9.74	1	0	0	1	0	0	1	0	10.5
14.9.74	0	0	0	1	1	0	0	0	26.5
15.9.74*	0	2	2	6	2	0	0	0	-
17.9.74	1	1	0	0	2	1	0	0	21.5
19.9.74	1	0	0	0	0	0	3	0	9.0
21.9.74	1	4	1	0	1	0	2	0	28.0
22.9.74	2	0	0	0	0	0	0	0	16.5
29.9.74	0	0	0	1	0	0	0	0	19.0
5.10.74	2	2	1	0	0	0	0	0	24.0
6.10.74	0	4	0	0	0	0	0	0	9.5

6 cont.

Bream. Lake A, 1975 to 1977.

Date	GP1	GP2	GP3
18.1.75 to 31.5.75	0	0	0
16.6.75	0	3	4
18.6.75	0	0	0
20.6.75	0	4	0
21.6.75	1	0	0
22.6.75*	0	3	0
23.6.75	0	2	0
25.6.75	0	0	0
27.6.75	0	1	0
29.6.75*	0	3	0
1.7.75	0	0	0
2.7.75	0	0	0
5.7.75*	0	1	0
6.7.75*	0	1	0
8.7.75	0	1	0
9.7.75	0	8	0
11.7.75	0	4	0
12.7.75*	0	1	0
13.7.75*	0	9	0
15.7.75	0	0	0
17.7.75	0	0	0
20.7.75*	0	10	0
21.7.75	0	0	0
23.7.75	0	2	0
25.7.75	0	1	0
26.7.75*	0	3	0
28.7.75	0	0	0
30.7.75	0	2	0
1.8.75	0	0	0
2.8.75*	0	0	0
11.8.75	0	0	0
13.8.75	0	0	0
15.8.75	1	2	0
17.8.75	0	0	0
19.8.75	0	2	0
20.8.75	0	0	0
22.8.75 to 13.9.75	0	0	0
21.9.75*	0	3	0
28.9.75*	0	3	0
16.6.76	0	14	0
17.6.76	0	3	0
18.6.76	0	0	0
20.6.76*	0	2	0
22.6.76	0	3	0
23.6.76	0	2	0

Date	GP1	GP2	GP3
25.6.76	1	0	0
27.6.76*	3	5	0
29.6.76	2	1	1
30.6.76	1	1	0
2.7.76	2	0	0
6.7.76	0	0	0
7.7.76	2	0	0
11.7.76*	1	1	0
13.7.76	1	0	0
14.7.76	5	0	0
22.7.76	5	0	0
24.7.76*	11	0	0
27.7.76	8	0	0
29.7.76	5	2	1
9.8.76	10	0	0
11.8.76	3	3	1
13.8.76	2	0	0
15.8.76*	53	0	0
19.8.76	1	0	0
24.8.76	0	0	2
5.9.76	1	0	0
12.9.76*	2	1	0
19.9.76	0	0	0
23.10.76	2	5	3
20.11.76	0	3	2
18.12.76	0	0	0
22.1.77	0	0	0
19.2.77	0	0	6
12.3.77	0	0	2
23.4.77	0	0	0
1.5.77	0	1	0
8.5.77	0	3	7
22.5.77	0	6	2
5.6.77	3	2	2

Note: Rudd, Roach groups GP1=<100 GP2=100-149 GP3=150-199 GP4=200-249 GP5=>250mm

Bream, Tench, Perch & Cru.carp groups GP1=<149 GP2=150-299 GP3=>300mm

Comm.carp Pike GP1=<300 GP2=>300 mm

6 cont.

Bream. Lake A, 1975 to 1977.

Date	GP1	GP2	GP3
18.1.75 to 31.5.75	0	0	0
16.6.75	0	3	4
18.6.75	0	0	0
20.6.75	0	4	0
21.6.75	1	0	0
22.6.75*	0	3	0
23.6.75	0	2	0
25.6.75	0	0	0
27.6.75	0	1	0
29.6.75*	0	3	0
1.7.75	0	0	0
2.7.75	0	0	0
5.7.75*	0	1	0
6.7.75*	0	1	0
8.7.75	0	1	0
9.7.75	0	8	0
11.7.75	0	4	0
12.7.75*	0	1	0
13.7.75*	0	9	0
15.7.75	0	0	0
17.7.75	0	0	0
20.7.75*	0	10	0
21.7.75	0	0	0
23.7.75	0	2	0
25.7.75	0	1	0
26.7.75*	0	3	0
28.7.75	0	0	0
30.7.75	0	2	0
1.8.75	0	0	0
2.8.75*	0	0	0
11.8.75	0	0	0
13.8.75	0	0	0
15.8.75	1	2	0
17.8.75	0	0	0
19.8.75	0	2	0
20.8.75	0	0	0
22.8.75 to 13.9.75	0	0	0
21.9.75*	0	3	0
28.9.75*	0	3	0
16.6.76	0	14	0
17.6.76	0	3	0
18.6.76	0	0	0
20.6.76*	0	2	0
22.6.76	0	3	0
23.6.76	0	2	0
25.6.76	1	0	0
27.6.76*	3	5	0
29.6.76	2	1	1
30.6.76	1	1	0
2.7.76	2	0	0
6.7.76	0	0	0
7.7.76	2	0	0
11.7.76*	1	1	0
13.7.76	1	0	0
14.7.76	5	0	0
22.7.76	5	0	0
24.7.76*	11	0	0
27.7.76	8	0	0
29.7.76	5	2	1
9.8.76	10	0	0
11.8.76	3	3	1
13.8.76	2	0	0
15.8.76*	53	0	0
19.8.76	1	0	0
24.8.76	0	0	2
5.9.76	1	0	0
12.9.76*	2	1	0
19.9.76	0	0	0
23.10.76	2	5	3
20.11.76	0	3	2
18.12.76	0	0	0
22.1.77	0	0	0
19.2.77	0	0	6
12.3.77	0	0	2
23.4.77	0	0	0
1.5.77	0	1	0
8.5.77	0	3	7
22.5.77	0	6	2
5.6.77	3	2	2

Note: Rudd, Roach groups — GP1=<100 GP2=100-149 GP3=150-199 GP4=200-249 GP5=>250mm

Bream, Tench, Perch & Cru.carp groups — GP1=<149 GP2=150-299 GP3=>300mm

Comm.carp Pike — GP1=<300 GP2=>300 mm

6 cont.

Numbers of fish caught by angling. Lake B ; 1975 to 1977.

Rudd / Roach

Date	Rudd GP1	Rudd GP2	Rudd GP3	Rudd GP4	Rudd GP5	Roach GP1	Roach GP2	Roach GP3	Roach GP4	Roach GP5
18.1.75	14	0	0	0	0	8	0	0	0	0
25.1.75	0	0	0	0	0	1	0	1	0	0
1.2.75	7	0	0	0	0	2	0	0	0	0
8.2.75	23	0	0	0	0	22	0	0	0	0
15.2.75	32	0	0	0	0	46	0	0	0	0
8.3.75	6	0	0	0	0	3	0	0	0	0
22.3.75	0	0	0	0	0	0	0	1	3	0
5.4.75	0	0	0	0	0	0	0	1	0	0
17.5.75	1	1	0	0	0	15	2	0	0	0
31.5.75	0	1	0	0	0	2	1	0	0	0
26.7.75						0	8	0	0	0
20.6.76	0	5	0	0	0	0	2	7	0	0
18.7.76	2	3	0	0	0	0	0	3	0	0
20.7.76	0	0	0	0	0	18	15	0	0	0
29.8.76	0	0	0	0	0	0	1	6	0	0
3.10.76	0	0	0	0	0	0	0	1	0	0
10.10.76	0	0	0	0	0	0	0	2	0	0
7.11.76	0	0	0	0	0	0	0	3	0	0
6.2.77	0	0	0	0	0	0	0	2	0	1
5.3.77	0	0	0	0	0	0	0	1	0	0

Tench

Date	GP1	GP2	GP3
22.6.75	0	1	15
27.6.75	0	2	10
29.6.75	0	2	0
13.7.75	0	2	1
26.7.75	0	0	1
20.6.76	0	0	5
18.7.76	0	1	3
20.7.76	0	3	5
20.8.76	1	1	1
29.8.76	0	0	2
3.10.76	0	2	0
10.10.76	0	1	1
7.11.76	0	0	3

Bream

Date	GP1	GP2	GP3
22.6.75	0	0	2
18.7.76	0	1	1
28.8.76	3	0	0

Perch

Date	GP1	GP2	GP3
20.6.76	0	5	0
18.7.76	0	2	0
20.7.76	0	4	0
29.8.76	0	1	0
3.10.76	0	1	0
10.10.76	0	4	0
7.11.76	1	6	0

Common carp

Date	GP1	GP2
18.7.76	6	1
20.7.76	1	0
20.8.76	1	2
29.8.76	7	0
10.10.76	2	0

Appendix 7 Length , weight and condition for rudd and tench. Lake A.

Rudd ; length,weight and condition. Lake A , 1975 to 1977 .

	FL (mm)	W_o (g)	W (g)	K_n	K
June, 1975 (No mouth damage)	95	16.5	14.9	110.7	1.924
	120	31.0	31.4	98.7	1.794
	103	19.2	19.3	99.5	1.757
	95	13.0	14.9	87.2	1.516
	127	39.5	37.7	104.9	1.928
	122	29.5	33.1	89.1	1.625
	100	18.2	17.6	103.7	1.820
	100	14.0	17.6	79.7	1.400
	108	24.6	22.4	109.6	1.953
	171	91.0	97.4	93.5	1.820
	134	45.5	44.7	101.8	1.891
	92	15.0	13.5	111.5	1.926
(With mouth damage)	215	210.4	202.2	104.0	2.117
	115	28.0	27.4	102.1	1.841
	120	28.5	31.4	90.7	1.649
	138	47.0	49.1	95.7	1.788
July, 1975 (No mouth damage)	102	17.5	18.3	95.6	1.649
	104	18.0	19.5	92.5	1.600
	100	15.5	17.2	90.1	1.550
	104	19.0	19.5	97.7	1.689
	111	22.0	23.9	92.2	1.609
	113	23.0	25.2	91.1	1.594
	99	15.5	16.7	93.0	1.597
	100	16.0	17.2	93.0	1.600
	94	15.0	14.2	105.9	1.806
	100	15.5	17.2	90.1	1.550
	127	35.0	36.4	96.2	1.709
	89	13.0	11.9	108.9	1.844
	123	36.0	32.9	109.4	1.935
	110	24.5	23.2	105.6	1.841
	101	21.0	17.7	118.3	2.038
	137	51.0	46.1	110.5	1.983
	96	16.0	15.1	105.7	1.808
	108	25.0	21.9	114.2	1.985
	103	22.0	18.9	116.6	2.013
	124	32.0	33.8	94.8	1.678
	115	26.0	26.7	97.5	1.709
	122	34.0	32.1	105.9	1.872
	115	25.0	26.7	93.8	1.644
	113	29.0	25.2	114.9	2.009
(With mouth damage)	92	11.5	13.2	86.8	1.477
	148	60.0	58.8	102.6	1.851
	115	25.5	26.7	95.6	1.677
	147	55.0	57.6	95.5	1.731
	100	17.0	17.2	98.8	1.700
	90	14.0	12.4	113.2	1.920
	115	24.5	26.7	91.9	1.611
	201	152.0	153.5	99.0	1.872
	205	152.0	163.3	93.1	1.764
	154	64.0	66.6	96.1	1.752
	167	85.0	85.9	99.0	1.825
	125	32.0	34.6	92.4	1.638
	103	17.5	18.9	92.7	1.601
	119	26.0	29.7	94.3	1.662
	142	46.5	51.6	90.0	1.624
	163	83.0	79.6	104.3	1.917
	106	23.0	20.7	111.4	1.931
	154	71.5	66.6	107.3	1.958
	113	28.0	25.2	110.9	1.941
	111	30.5	23.9	127.8	2.230
	147	60.0	57.6	104.2	1.889
	168	79.5	87.5	90.9	1.677
	198	153.0	146.5	104.5	1.971
	211	195.0	178.8	109.1	2.076
	187	104.0	114.4	90.9	1.697
	198	144.0	146.5	98.3	1.855
	175	97.0	99.4	97.5	1.810
	173	92.0	95.9	95.9	1.777
	146	67.0	56.4	118.9	2.153
	196	150.0	141.8	105.7	1.992
August, 1975 (No mouth damage)	111	21.0	22.1	94.8	1.536
	120	30.0	28.6	104.7	1.736
	107	20.0	19.6	101.9	1.633
	115	25.5	24.9	102.4	1.677
	122	31.0	30.3	102.4	1.707
	121	31.5	29.5	106.9	1.778
	126	31.5	33.7	93.5	1.575
	138	35.0	45.5	76.9	1.332
	112	21.0	22.8	92.1	1.495
	110	21.5	21.5	100.0	1.615
	121	32.5	29.5	110.3	1.835
	123	30.0	31.1	96.5	1.612
	142	51.5	50.0	102.9	1.799
	145	52.0	53.6	97.0	1.706
	119	29.0	27.9	104.0	1.721
	115	28.0	24.9	112.5	1.841
	139	49.0	46.6	105.2	1.825

continued over:-

7 cont.

	FL (mm)	W_o (g)	W (g)	K_n	K
	127	33.0	34.6	95.5	1.611
	125	34.5	32.8	105.2	1.766
	94	13.0	12.8	101.7	1.565
	135	41.5	42.3	98.1	1.687
	123	29.5	31.1	94.9	1.585
	107	19.0	19.6	96.9	1.551
(With mouth damage)	177	127.0	103.6	122.6	2.290
	193	150.0	138.0	108.7	2.087
	170	85.0	90.7	93.7	1.730
	144	58.0	52.4	110.7	1.942
	147	57.0	56.1	101.7	1.794
	151	61.5	61.3	100.4	1.786
	178	99.5	105.6	94.3	1.764
	126	34.0	33.7	100.9	1.670
	124	29.0	31.9	90.8	1.521
	185	136.0	120.0	113.4	2.148
	198	141.0	150.1	93.9	1.816
	183	108.0	115.7	93.3	1.762
	202	155.0	160.4	96.6	1.881
	140	48.5	47.7	101.6	1.767
	165	75.0	82.2	91.3	1.670
	162	76.0	77.3	98.3	1.788
Sept., 1975 (No mouth damage)	133	38.5	36.3	106.1	1.636
	118	24.5	23.6	103.6	1.491
	130	34.0	33.4	101.7	1.548
	134	38.5	37.3	103.3	1.600
	114	21.3	20.9	101.9	1.438
	97	11.5	11.7	98.1	1.260
	96	10.5	11.3	92.9	1.187
	113	21.0	20.2	103.7	1.455
	139	42.5	42.5	100.0	1.583
	118	20.5	23.6	86.7	1.248
	136	39.0	39.3	99.3	1.550
	143	42.5	47.0	90.4	1.453
	139	41.0	42.5	96.5	1.527
(With mouth damage)	126	28.8	29.9	96.3	1.440
	104	16.0	15.0	106.4	1.422
	213	185.5	195.8	94.7	1.920
	140	48.0	43.6	110.1	1.749
June, 1976 (No mouth damage)	105	19.2	19.6	98.0	1.659
	93	12.5	13.5	92.9	1.554
	70	9.5	5.6	169.9	2.770
	73	5.7	6.4	89.5	1.465
	129	32.0	37.0	86.4	1.491

	FL (mm)	W_o (g)	W (g)	K_n	K
	138	47.0	45.6	103.0	1.788
	109	25.0	22.0	113.7	1.930
	66	4.5	4.7	96.6	1.565
	127	35.7	35.3	101.2	1.743
	67	7.0	4.9	143.4	2.327
	112	21.5	23.9	89.9	1.530
	65	4.5	4.4	101.2	1.639
	107	24.0	20.8	115.6	1.959
	72	5.5	6.1	90.2	1.474
	68	7.5	5.1	146.7	2.385
	80	7.5	8.4	88.8	1.465
	118	30.0	28.1	106.7	1.826
	115	27.0	26.0	104.0	1.775
	76	5.5	7.2	76.3	1.253
	145	52.0	53.2	97.8	1.706
	111	22.0	23.3	94.6	1.609
	91	11.5	12.6	91.4	1.526
	76	5.5	7.2	90.2	1.253
	159	77.0	70.7	108.9	1.916
	65	2.7	4.4	60.7	0.983
(With mouth damage)	140	44.5	47.7	93.3	1.622
	161	69.0	73.5	93.9	1.653
	156	59.0	66.6	88.5	1.554
	144	48.5	52.0	93.2	1.624
	208	176.0	162.2	108.5	1.956
	81	8.5	8.8	96.8	1.599
July, 1976 (No mouth damage)	87	9.5	10.8	87.7	1.443
	104	24.0	18.9	126.9	2.134
	75	5.5	6.8	80.7	1.304
	81	7.5	8.7	86.5	1.411
	84	7.5	9.7	77.2	1.265
	88	10.0	11.2	89.1	1.467
	82	6.5	9.0	72.2	1.179
	134	39.0	41.7	93.5	1.621
	135	35.0	42.7	82.0	1.423
	82	8.0	9.0	88.8	1.451
(With mouth damage)	153	64.0	63.1	101.4	1.787
	140	48.0	47.8	100.3	1.749
	93	10.0	13.3	74.9	1.243
	122	27.5	31.1	88.3	1.514
	110	20.0	22.5	88.8	1.503
	180	102.0	104.8	97.3	1.749
August, 1976 (No mouth damage)	127	35.0	32.6	107.3	1.709
	150	52.0	56.5	92.1	1.541
	82	6.5	7.7	84.2	1.179

continued over :-

7 cont.

	FL (mm)	w_o (g)	w (g)	K_n	K
	90	12.0	10.5	114.4	1.646
	91	12.0	10.9	110.3	1.592
(With mouth damage)	175	97.0	93.9	103.4	1.809
	140	41.5	45.0	92.3	1.512
	123	28.0	29.4	95.4	1.505
	83	6.5	8.0	80.9	1.137
	88	11.0	9.7	112.9	1.614
	85	10.0	8.7	115.1	1.628
Sept., 1976 (No mouth damage)	188	112.0	112.6	99.4	1.686
	84	9.5	9.3	102.6	1.603
	118	27.0	26.6	101.6	1.643
	86	10.0	9.9	100.4	1.572
	88	10.5	10.7	98.2	1.541
	85	10.0	9.6	104.1	1.628
	87	10.0	10.3	96.9	1.519
	91	12.0	11.9	101.1	1.592
	87	10.5	10.3	101.7	1.595
	90	11.5	11.5	100.3	1.578
	105	18.5	18.5	100.0	1.598

	FL (mm)	w_o (g)	w (g)	K_n	K
	120	29.0	28.0	103.6	1.678
	89	11.0	11.1	99.3	1.560
	116	24.0	25.2	95.3	1.538
	89	10.0	11.1	90.3	1.419
	90	11.5	11.5	100.3	1.578
	84	9.5	9.3	102.6	1.603
	97	15.0	14.5	103.7	1.644
April to May, 1977 (No mouth damage)	196	122.0	132.6	92.0	1.620
	138	33.0	39.6	83.3	1.256
	135	38.0	36.7	103.4	1.544
	136	40.0	37.7	106.1	1.590
	134	35.0	35.8	97.7	1.455
	153	59.0	56.5	104.4	1.647
	153	56.0	56.5	99.1	1.564
	142	43.0	43.7	98.3	1.502
	117	21.0	22.4	93.5	1.311
	195	125.0	130.3	95.9	1.686
	163	71.0	70.3	101.0	1.639
(With mouth damage)	155	63.0	59.1	106.6	1.692
	170	79.0	81.2	97.2	1.608
	222	210.0	203.6	103.1	1.919

Tench ; length, weight and condition. Lake A, 1975 to 1977.

	FL (mm)	w_o (g)	w (g)	K_n	K
June, 1975 Males	354	672	761	88.3	1.515
	335	782	627	124.6	2.080 +
	375	924	932	99.2	1.752
	370	830	889	93.4	1.639 +
	228	235	163	144.2	1.983
	380	953	976	97.7	1.737 +
	388	1000	1050	95.3	1.712 +
	369	845	880	96.0	1.682
	367	807	864	93.4	1.633
	351	774	739	104.8	1.790
	382	964	994	97.0	1.729
	390	988	1069	92.4	1.666
	215	193	133	145.5	1.942 +
	385	1120	1022	109.6	1.963
	405	1257	1220	103.0	1.892
	378	1110	958	115.9	2.055
	378	883	958	92.2	1.635
	367	795	864	92.0	1.608 +
	361	931	815	114.2	1.979

	FL (mm)	w_o (g)	w (g)	K_n	K
	357	727	784	92.7	1.598
	385	1091	1022	106.8	1.912 +
	257	353	248	142.4	2.080
	350	814	732	111.3	1.899
	360	801	807	99.2	1.717
	338	712	647	109.9	1.844
	381	928	985	94.2	1.678 +
	382	1006	994	101.2	1.805
	362	971	823	117.9	2.047
	370	820	889	92.3	1.619
	390	1002	1069	93.8	1.689
	273	381	306	124.4	1.873
	260	353	258	136.7	2.008
	375	944	932	101.3	1.790 +
	220	224	1438	155.8	2.104 +
	287	344	365	94.2	1.455
June, 1975 Females	398	954	1115	85.6	1.513
	400	1059	1130	93.7	1.654 +
	430	1369	1376	99.5	1.722 +

+ = with mouth damage

continued over :-

7 cont.

	FL (mm)	w_o (g)	w (g)	K_n	K		FL (mm)	w_o (g)	w (g)	K_n	K
	90	12.0	10.5	114.4	1.646		120	29.0	28.0	103.6	1.678
	91	12.0	10.9	110.3	1.592		89	11.0	11.1	99.3	1.560
(With mouth							116	24.0	25.2	95.3	1.538
damage)	175	97.0	93.9	103.4	1.809		89	10.0	11.1	90.3	1.419
	140	41.5	45.0	92.3	1.512		90	11.5	11.5	100.3	1.578
	123	28.0	29.4	95.4	1.505		84	9.5	9.3	102.6	1.603
	83	6.5	8.0	80.9	1.137		97	15.0	14.5	103.7	1.644
	88	11.0	9.7	112.9	1.614	April to					
	85	10.0	8.7	115.1	1.628	May, 1977					
Sept., 1976						(No mouth					
(No mouth						damage)	196	122.0	132.6	92.0	1.620
damage)	188	112.0	112.6	99.4	1.686		138	33.0	39.6	83.3	1.256
	84	9.5	9.3	102.6	1.603		135	38.0	36.7	103.4	1.544
	118	27.0	26.6	101.6	1.643		136	40.0	37.7	106.1	1.590
	86	10.0	9.9	100.4	1.572		134	35.0	35.8	97.7	1.455
	88	10.5	10.7	98.2	1.541		153	59.0	56.5	104.4	1.647
	85	10.0	9.6	104.1	1.628		153	56.0	56.5	99.1	1.564
	87	10.0	10.3	96.9	1.519		142	43.0	43.7	98.3	1.502
	91	12.0	11.9	101.1	1.592		117	21.0	22.4	93.5	1.311
	87	10.5	10.3	101.7	1.595		195	125.0	130.3	95.9	1.686
	90	11.5	11.5	100.3	1.578		163	71.0	70.3	101.0	1.639
	105	18.5	18.5	100.0	1.598	(With mouth					
						damage)	155	63.0	59.1	106.6	1.692
							170	79.0	81.2	97.2	1.608
							222	210.0	203.6	103.1	1.919

Tench ; length, weight and condition. Lake A, 1975 to 1977.

	FL (mm)	w_o (g)	w (g)	K_n	K		FL (mm)	w_o (g)	w (g)	K_n	K
June, 1975											
Males	354	672	761	88.3	1.515		357	727	784	92.7	1.598
	335	782	627	124.6	2.080 +		385	1091	1022	106.8	1.912 +
	375	924	932	99.2	1.752		257	353	248	142.4	2.080
	370	830	889	93.4	1.639 +		350	814	732	111.3	1.899
	228	235	163	144.2	1.983		360	801	807	99.2	1.717
	380	953	976	97.7	1.737 +		338	712	647	109.9	1.844
	388	1000	1050	95.3	1.712 +		381	928	985	94.2	1.678 +
	369	845	880	96.0	1.682		382	1006	994	101.2	1.805
	367	807	864	93.4	1.633		362	971	823	117.9	2.047
	351	774	739	104.8	1.790		370	820	889	92.3	1.619
	382	964	994	97.0	1.729		390	1002	1069	93.8	1.689
	390	988	1069	92.4	1.666		273	381	306	124.4	1.873
	215	193	133	145.5	1.942 +		260	353	258	136.7	2.008
	385	1120	1022	109.6	1.963		375	944	932	101.3	1.790 +
	405	1257	1220	103.0	1.892		220	224	1438	155.8	2.104 +
	378	1110	958	115.9	2.055		287	344	365	94.2	1.455
	378	883	958	92.2	1.635	June, 1975					
	367	795	864	92.0	1.608 +	Females	398	954	1115	85.6	1.513
	361	931	815	114.2	1.979		400	1059	1130	93.7	1.654 +
							430	1369	1376	99.5	1.722 +

+ = with mouth damage

continued over :-

7 cont.

	FL (mm)	W_e (g)	W (g)	K_n	K		FL (mm)	W_e (g)	W (g)	K_n	K
	395	1139	1092	107.0	1.848		259	344	339	101.3	1.980
	216	206	211	97.4	2.044		372	816	885	92.2	1.585
	382	953	997	95.6	1.709		350	801	753	106.4	1.868 +
	392	1127	1070	105.3	1.871 +		390	994	1003	99.1	1.676 +
	413	1213	1233	98.4	1.722 +		273	475	390	121.7	2.335
	412	1272	1225	103.8	1.819		400	1139	1072	106.2	1.780 +
	280	404	428	94.3	1.840		380	865	936	92.4	1.576 +
	238	290	275	105.3	2.151		372	875	885	98.9	1.699 +
	412	1185	1225	96.7	1.694 +		375	910	904	100.7	1.726
	412	1365	1225	111.2	1.952		190	149	149	99.5	2.172
	398	1115	1115	100.0	1.769		374	888	897	98.9	1.697 +
	198	161	167	96.5	2.074		384	981	962	101.9	1.733 +
	391	1054	1062	99.2	1.763		378	935	923	101.3	1.731
	221	223	225	99.1	2.066		390	1009	1003	100.6	1.701
	288	629	462	136.0	2.633		278	381	409	93.0	1.773
	281	442	433	102.2	1.992		225	220	234	93.9	1.931 +
	420	1302	1291	100.9	1.757 +		375	954	904	105.5	1.809
	395	1050	1092	96.1	1.670		240	281	278	101.2	2.033
	428	1277	1359	93.9	1.629		240	287	278	103.3	2.076
	410	1263	1209	104.5	1.833		378	855	923	92.6	1.583 +
	360	1017	849	119.8	2.180		354	811	776	104.5	1.828 +
	394	1055	1085	97.3	1.725 +		373	826	891	92.7	1.592 +
	366	971	888	109.4	1.981		362	847	823	102.9	1.785 +
	388	1052	1040	101.1	1.801		370	891	872	102.1	1.759 +
	231	255	254	100.5	2.069		364	865	835	103.5	1.794 +
	214	207	206	100.4	2.112		365	861	842	102.3	1.771 +
	233	282	260	108.5	2.229		358	792	799	99.1	1.723 +
July, 1975							380	859	936	91.8	1.565
Males	365	813	841	96.6	1.672 +		345	754	725	104.0	1.836
	384	986	962	102.5	1.741		260	345	343	100.5	1.963
	371	842	879	95.8	1.649 +		236	263	266	99.0	1.009
	374	896	897	99.8	1.713		246	287	296	96.8	1.928
	274	444	394	112.6	2.158	July, 1975					
	235	271	263	103.2	2.088	Females	240	274	278	98.6	1.982 +
	358	815	799	101.9	1.776 +		365	956	893	107.1	1.966 +
	370	894	872	102.5	1.765 +		410	1284	1234	104.0	1.863 +
	371	995	879	113.3	1.949 +		390	972	1074	90.5	1.639 +
	373	997	891	111.9	1.921 +		235	272	262	104.0	2.096
	375	896	904	99.1	1.699		190	144	145	99.4	2.099
	365	914	841	108.6	1.880 +		274	493	402	122.7	2.397
	370	824	872	94.5	1.627 +		412	1228	1251	98.1	1.756
	358	751	799	93.9	1.637		395	1071	1113	96.3	1.738 +
	368	765	860	88.9	1.535 +		273	474	398	119.2	2.330
	330	639	645	99.1	1.778		225	229	232	98.7	2.010
	235	251	263	95.6	1.934		415	1182	1277	92.6	1.654 +
	384	955	962	99.2	1.687		430	1434	1409	101.7	1.804 +
	365	841	842	99.9	1.729		360	921	859	107.2	1.974
	348	818	742	110.3	1.941 +		220	234	218	107.3	2.198
	348	706	742	95.2	1.675		405	1314	1193	110.2	1.978 +
	375	802	904	88.7	1.521 +		410	1202	1234	97.4	1.744 +
	373	828	891	92.9	1.596		385	1068	1036	103.1	1.871
	403	1127	1093	103.1	1.722 +		425	1355	1364	99.3	1.765

continued over :-

7 cont.

FL (mm)	W_e (g)	W (g)	K_n	K
395	1139	1092	107.0	1.848
216	206	211	97.4	2.044
382	953	997	95.6	1.709
392	1127	1070	105.3	1.871 +
413	1213	1233	98.4	1.722 +
412	1272	1225	103.8	1.819
280	404	428	94.3	1.840
238	290	275	105.3	2.151
412	1185	1225	96.7	1.694 +
412	1365	1225	111.2	1.952
398	1115	1115	100.0	1.769
198	161	167	96.5	2.074
391	1054	1062	99.2	1.763
221	223	225	99.1	2.066
288	629	462	136.0	2.633
281	442	433	102.2	1.992
420	1302	1291	100.9	1.757 +
395	1050	1092	96.1	1.670
428	1277	1359	93.9	1.629
410	1263	1209	104.5	1.833
360	1017	849	119.8	2.180
394	1055	1085	97.3	1.725 +
366	971	888	109.4	1.981
388	1052	1040	101.1	1.801
231	255	254	100.5	2.069
214	207	206	100.4	2.112
233	282	260	108.5	2.229

July, 1975

Males

FL (mm)	W_e (g)	W (g)	K_n	K
365	813	841	96.6	1.672 +
384	986	962	102.5	1.741
371	842	879	95.8	1.649 +
374	896	897	99.8	1.713
274	444	394	112.6	2.158
235	271	263	103.2	2.088
358	815	799	101.9	1.776 +
370	894	872	102.5	1.765 +
371	995	879	113.3	1.949 +
373	997	891	111.9	1.921 +
375	896	904	99.1	1.699
365	914	841	108.6	1.880 +
370	824	872	94.5	1.627 +
358	751	799	93.9	1.637
368	765	860	88.9	1.535 +
330	639	645	99.1	1.778
235	251	263	95.6	1.934
384	955	962	99.2	1.687
365	841	842	99.9	1.729
348	818	742	110.3	1.941 +
348	706	742	95.2	1.675
375	802	904	88.7	1.521 +
373	828	891	92.9	1.596
403	1127	1093	103.1	1.722 +

FL (mm)	W_e (g)	W (g)	K_n	K
259	344	339	101.3	1.980
372	816	885	92.2	1.585
350	801	753	106.4	1.868 +
390	994	1003	99.1	1.676 +
273	475	390	121.7	2.335
400	1139	1072	106.2	1.780 +
380	865	936	92.4	1.576 +
372	875	885	98.9	1.699 +
375	910	904	100.7	1.726
190	149	149	99.5	2.172
374	888	897	98.9	1.697 +
384	981	962	101.9	1.733 +
378	935	923	101.3	1.731
390	1009	1003	100.6	1.701
278	381	409	93.0	1.773
225	220	234	93.9	1.931 +
375	954	904	105.5	1.809
240	281	278	101.2	2.033
240	287	278	103.3	2.076
378	855	923	92.6	1.583 +
354	811	776	104.5	1.828 +
373	826	891	92.7	1.592 +
362	847	823	102.9	1.785 +
370	891	872	102.1	1.759 +
364	865	835	103.5	1.794 +
365	861	842	102.3	1.771 +
358	792	799	99.1	1.723 +
380	859	936	91.8	1.565
345	754	725	104.0	1.836
260	345	343	100.5	1.963
236	263	266	99.0	1.009
246	287	296	96.8	1.928

July, 1975

Females

FL (mm)	W_e (g)	W (g)	K_n	K
240	274	278	98.6	1.982 +
365	956	893	107.1	1.966 +
410	1284	1234	104.0	1.863 +
390	972	1074	90.5	1.639 +
235	272	262	104.0	2.096
190	144	145	99.4	2.099
274	493	402	122.7	2.397
412	1228	1251	98.1	1.756
395	1071	1113	96.3	1.738 +
273	474	398	119.2	2.330
225	229	232	98.7	2.010
415	1182	1277	92.6	1.654 +
430	1434	1409	101.7	1.804 +
360	921	859	107.2	1.974
220	234	218	107.3	2.198
405	1314	1193	110.2	1.978 +
410	1202	1234	97.4	1.744 +
385	1068	1036	103.1	1.871
425	1355	1364	99.3	1.765

continued over :-

7 cont.

	FL (mm)	w_o (g)	w (g)	K_n	K		FL (mm)	w_o (g)	w (g)	K_n	K
	392	986	1089	90.5	1.637		385	855	993	86.1	1.498
	401	1145	1160	98.7	1.776 +		375	955	931	102.6	1.811
	373	929	948	97.7	1.786	August, 1975					
	332	783	686	111.2	2.140	Females	409	1202	1951	61.6	1.757 +
	426	1334	1373	97.1	1.726		276	411	662	62.1	1.955 +
	370	874	927	94.2	1.725 +		420	1372	2098	65.4	1.852 +
	364	891	886	100.6	1.847		199	178	269	66.1	2.259
	247	334	300	110.9	2.216		383	1115	1629	68.5	1.985
	290	465	471	98.8	1.907 +		173	121	183	66.0	2.337
	227	196	238	82.4	1.676 +		410	1267	1964	64.5	1.838 +
	360	825	859	96.0	1.768		420	1450	2098	69.1	1.957
	393	1051	1097	95.8	1.732 +		428	1500	2210	67.8	1.913
	397	1123	1128	99.5	1.795	June, 1976					
	367	913	907	100.7	1.847 +	Males	391	1009	1050	96.1	1.688 +
	412	1288	1251	102.9	1.842 +		207	157	171	92.0	1.770
	421	1285	1329	96.7	1.722 +		315	596	566	105.2	1.907
	404	1123	1185	94.8	1.703 +		373	942	918	102.6	1.815 +
	418	1350	1303	103.6	1.848		392	1113	1058	105.2	1.848
	235	295	262	112.6	2.273		320	642	593	108.3	1.959 +
	405	1236	1193	103.6	1.861		370	962	897	107.2	1.899
	269	404	382	105.9	2.076		373	879	918	95.7	1.694 +
	417	1114	1294	86.1	1.536		410	1216	1203	101.1	1.764
	367	973	907	107.3	1.968		366	916	869	105.3	1.868 +
	244	281	291	96.6	1.934		338	700	693	101.0	1.813 +
	420	1231	1320	93.3	1.662		370	840	897	93.6	1.658 +
	239	286	275	104.2	2.095		360	876	830	105.6	1.878
	404	1245	1185	105.1	1.888		252	313	299	104.5	1.956
	390	1064	1074	100.9	1.827		274	391	380	102.8	1.901
	395	1030	1113	92.6	1.671		408	1164	1186	98.1	1.714 +
	404	1130	1185	95.4	1.714		210	173	178	97.3	1.868
	410	1301	1234	105.4	1.888 +		387	1039	1020	101.9	1.793
	388	1027	1059	97.0	1.758 +		317	641	577	111.1	2.012
	210	183	191	95.6	1.976 +		203	151	161	93.5	1.805
	216	208	207	100.4	2.064		405	1168	1162	100.6	1.758 +
	410	1200	1234	97.2	1.741 +		370	899	897	100.2	1.775
	392	1121	1089	102.9	1.861		225	224	217	103.4	1.967
	250	321	311	103.1	2.054		380	967	968	99.9	1.762 +
August, 1975							405	1169	1162	100.6	1.760
Males	387	1137	1005	113.1	1.962 +		384	888	998	89.0	1.568
	369	847	895	94.7	1.686 +		394	1042	1074	97.1	1.704 +
	372	888	913	97.3	1.725		267	379	353	107.3	1.991
	385	1039	993	104.7	1.821		379	943	961	98.1	1.732 +
	404	1178	1117	105.5	1.786		400	984	1121	87.8	1.538
	372	891	913	97.6	1.731		376	784	939	83.5	1.475
	375	953	931	102.4	1.807 +		295	486	470	103.5	1.893 +
	370	962	901	106.8	1.899 +		380	1043	968	107.7	1.901 +
	380	968	961	100.7	1.764	June, 1976					
	365	782	871	89.8	1.608 +	Females	332	747	666	112.1	2.041
	392	959	1038	92.4	1.592 +		235	236	242	97.3	1.818
	348	807	775	104.1	1.915		387	1004	1043	96.2	1.732
	381	942	968	97.3	1.703 +		380	935	989	94.5	1.704
	390	1029	1025	100.4	1.735 +		415	1212	1280	94.7	1.696 +

continued over :-

7 cont.

Group	FL (mm)	w_o (g)	w (g)	K_n	K
	247	268	281	95.5	1.778
	390	1127	1067	105.6	1.899
	370	867	915	94.8	1.712
	400	1107	1149	96.3	1.730
	396	1191	1116	106.7	1.918
	387	1261	1043	120.9	2.176
	245	278	274	101.5	1.890
	407	1140	1209	94.3	1.691 +
	425	1590	1372	115.9	2.071 +
	249	308	287	107.2	1.995
	243	258	267	96.5	1.798
	317	670	582	115.1	2.103
	198	145	147	98.7	1.868
	400	1051	1149	91.5	1.642 +
	427	1296	1391	93.2	1.665
	388	1029	1051	97.9	1.762 +
	421	1362	1335	102.0	1.825
	430	1353	1420	95.3	1.702 +
	386	1063	1034	102.7	1.848
	400	952	1149	82.8	1.488 +
	418	1194	1307	91.3	1.635
	410	1275	1235	103.2	1.850 +
July, 1976 Males	192	125	116	108.2	1.766
	377	836	928	90.1	1.560 +
	394	988	1064	92.9	1.615
	164	63	71	88.7	1.428
	370	930	876	106.1	1.836
	379	932	943	98.8	1.712 +
	316	619	538	115.0	1.962 +
	383	1055	975	108.2	1.878 +
	365	863	840	102.7	1.775 +
	320	606	559	108.3	1.849 +
	382	881	967	91.1	1.580
	331	643	621	103.5	1.773
	369	848	869	97.6	1.688
	390	937	1031	90.9	1.580 +
	355	804	771	104.3	1.797
	363	872	826	105.6	1.823
	358	822	791	103.9	1.792 +
	346	826	712	116.0	1.994
	380	911	951	95.8	1.660
	366	896	847	105.8	1.828
	391	952	1039	91.6	1.593 +
	376	772	921	83.8	1.452
July, 1976 Females	400	917	1082	84.8	1.433 +
	418	1136	1216	93.5	1.555
	336	673	681	98.9	1.774
	401	1065	1089	97.8	1.652
	427	1160	1286	90.2	1.489
	400	1119	1082	103.5	1.748
	232	228	255	89.6	1.826
	431	1342	1319	101.8	1.676 +
	420	1216	1231	98.8	1.641
	342	822	713	115.2	2.055
	420	1160	1231	94.2	1.566 +
	402	1167	1096	106.5	1.796
	391	1035	1018	101.7	1.731
	405	1166	1118	104.3	1.755
	422	1130	1247	90.6	1.504
	406	1022	1125	90.8	1.527 +
	416	1192	1200	99.3	1.656
	380	1102	943	116.8	2.008
	322	645	608	106.1	1.932
	402	1047	1096	95.5	1.612
	412	1283	1170	109.7	1.835
	432	1306	1327	98.4	1.620
	376	1101	918	120.0	2.071
	241	281	282	99.8	2.007
	425	1225	1270	96.4	1.596
	268	397	373	106.3	2.062
August, 1976 Males	395	1012	1068	94.8	1.642
	392	996	1044	95.4	1.653 +
	376	745	924	80.6	1.401 +
	393	900	975	92.3	1.602 +
	414	1276	1225	104.2	1.798
	397	1036	1084	95.6	1.656
	390	1086	1029	105.5	1.831 +
	384	917	983	93.3	1.619
August, 1976 Females	395	994	1078	92.3	1.613 +
	405	1055	1162	90.8	1.588
	239	219	234	93.5	1.604
	404	1075	1153	93.2	1.630
	376	942	927	101.6	1.772
	425	1270	1345	94.4	1.654
	385	1108	996	111.2	1.942
	383	1074	980	109.5	1.912
	392	1050	1052	99.8	1.743
	340	756	683	110.7	1.923
	253	286	278	102.7	1.766
	375	943	910	102.5	1.788
April, 1977 Males	372	840	871	96.4	1.632
	373	960	878	109.3	1.850
	370	930	858	108.4	1.836 +
	375	747	892	83,8	1.417 +
	359	843	786	107.2	1.820

continued over :-

7 cont.

	FL (mm)	w_o (g)	w (g)	K_n	K	
	385	1120	963	116.4	1.963	
	323	590	579	102.0	1.751	
	271	312	347	89.8	1.568	
	318	586	553	106.0	1.822	
April, 1977 Females	400	1000	1159	86.3	1.563	+
	392	1000	1095	91.3	1.660	
	416	1358	1292	105.1	1.886	
	428	1306	1399	93.4	1.666	
	425	1282	1372	93.5	1.670	+
	360	820	864	94.9	1.758	
	402	1073	1175	91.3	1.652	
	417	1240	1301	95.3	1.710	
May, 1977 Males	378	945	913	103.6	1.750	
	404	1048	1107	94.7	1.589	+
	368	751	844	88.9	1.507	+
	375	960	892	107.7	1.820	+
	370	864	858	100.7	1.706	
	400	1002	1075	93.2	1.566	
	378	935	913	102.5	1.731	+
	360	880	792	111.1	1.886	
	374	833	885	94.1	1.592	+
	387	924	977	94.6	1.594	
	390	940	999	94.1	1.585	+
	394	1015	1029	98.6	1.660	
	386	1017	970	104.9	1.768	
	360	899	792	113.5	1.927	
	385	940	963	97.7	1.647	+
	347	795	712	111.7	1.903	
	255	307	291	105.4	1.851	
	332	647	626	103.3	1.768	
	325	700	589	118.9	2.039	
	360	812	792	102.5	1.740	
	350	864	730	118.4	2.015	
	385	903	963	93.8	1.582	+
	390	1018	999	101.9	1.716	+
	402	1146	1091	105.0	1.764	+
	400	1072	1075	99.7	1.675	+
May, 1977 Females	425	1298	1372	94.6	1.691	+
	348	803	786	102.1	1.905	
	421	1130	1336	84.6	1.514	+
	407	1130	1216	92.9	1.676	
	419	1234	1318	93.6	1.678	
	390	1145	1080	106.1	1.930	+
	435	1251	1464	85.5	1.519	+
	395	967	1119	86.4	1.569	
	380	1064	1004	105.9	1.939	
	378	960	990	97.0	1.777	
	422	1520	1345	113.0	2.023	+
	418	1147	1310	87.6	1.570	+
	385	1106	1042	106.2	1.938	
	400	1153	1159	99.5	1.802	
	346	827	774	106.9	1.997	
	355	820	831	98.7	1.833	
	356	752	837	89.8	1.667	
	281	406	433	93.7	1.829	
	345	823	767	107.2	2.004	
	435	1389	1464	94.9	1.687	
	378	945	990	95.5	1.749	
	383	1102	1027	107.3	1.961	
	416	1284	1292	99.4	1.784	
	385	1092	1042	104.8	1.914	
	417	1222	1301	93.6	1.685	
	415	1225	1284	95.4	1.714	
	352	892	812	109.9	2.045	
June, 1977 Males	400	1045	1075	97.2	1.633	+
	407	1135	1131	100.4	1.683	
	415	1197	1197	100.0	1.675	
	382	948	941	100.8	1.701	+
	370	932	858	108.7	1.840	+
	365	872	825	105.8	1.793	+
	380	900	927	97.1	1.640	
	385	1008	963	104.7	1.766	
	372	827	871	94.9	1.606	+
	417	1464	1214	120.6	2.019	
	390	1093	999	109.4	1.843	
	381	922	934	98.7	1.667	+
	375	919	892	103.1	1.743	
	390	923	999	92.4	1.556	
	337	782	654	119.6	2.043	
	395	955	1040	92.1	1.550	
	356	872	767	113.7	1.933	
	375	952	892	106.8	1.805	
	387	1035	977	105.9	1.786	
	380	949	927	102.4	1.729	
June, 1977 Females	399	1028	1151	89.4	1.618	
	423	1360	1354	100.5	1.797	+
	396	916	1127	81.3	1.475	
	382	995	1019	97.6	1.785	
	403	1123	1183	94.9	1.716	
	350	888	799	111.2	2.071	
	380	1195	1004	118.9	2.178	
	444	1541	1549	99.5	2.138	
	405	1057	1199	88.1	1.591	+
	365	995	898	110.8	2.046	
	375	887	968	91.6	1.682	
	410	1410	1241	113.6	2.046	

7 cont.

	FL (mm)	W_o (g)	W (g)	K_n	K
	385	1120	963	116.4	1.963
	323	590	579	102.0	1.751
	271	312	347	89.8	1.568
	318	586	553	106.0	1.822
April, 1977 Females	400	1000	1159	86.3	1.563 +
	392	1000	1095	91.3	1.660
	416	1358	1292	105.1	1.886
	428	1306	1399	93.4	1.666
	425	1282	1372	93.5	1.670 +
	360	820	864	94.9	1.758
	402	1073	1175	91.3	1.652
	417	1240	1301	95.3	1.710
May, 1977 Males	378	945	913	103.6	1.750
	404	1048	1107	94.7	1.589 +
	368	751	844	88.9	1.507 +
	375	960	892	107.7	1.820 +
	370	864	858	100.7	1.706
	400	1002	1075	93.2	1.566
	378	935	913	102.5	1.731 +
	360	880	792	111.1	1.886
	374	833	885	94.1	1.592 +
	387	924	977	94.6	1.594
	390	940	999	94.1	1.585 +
	394	1015	1029	98.6	1.660
	386	1017	970	104.9	1.768
	360	899	792	113.5	1.927
	385	940	963	97.7	1.647 +
	347	795	712	111.7	1.903
	255	307	291	105.4	1.851
	332	647	626	103.3	1.768
	325	700	589	118.9	2.039
	360	812	792	102.5	1.740
	350	864	730	118.4	2.015
	385	903	963	93.8	1.582 +
	390	1018	999	101.9	1.716 +
	402	1146	1091	105.0	1.764 +
	400	1072	1075	99.7	1.675 +
May, 1977 Females	425	1298	1372	94.6	1.691 +
	348	803	786	102.1	1.905
	421	1130	1336	84.6	1.514 +
	407	1130	1216	92.9	1.676
	419	1234	1318	93.6	1.678
	390	1145	1080	106.1	1.930 +
	435	1251	1464	85.5	1.519 +
	395	967	1119	86.4	1.569
	380	1064	1004	105.9	1.939
	378	960	990	97.0	1.777
	422	1520	1345	113.0	2.023 +
	418	1147	1310	87.6	1.570 +
	385	1106	1042	106.2	1.938
	400	1153	1159	99.5	1.602
	346	827	774	106.9	1.997
	355	820	831	98.7	1.833
	356	752	837	89.8	1.667
	281	406	433	93.7	1.829
	345	823	767	107.2	2.004
	435	1389	1464	94.9	1.687
	378	945	990	95.5	1.749
	383	1102	1027	107.3	1.961
	416	1284	1292	99.4	1.784
	385	1092	1042	104.8	1.914
	417	1222	1301	93.6	1.685
	415	1225	1284	95.4	1.714
	352	892	812	109.9	2.045
June, 1977 Males	400	1045	1075	97.2	1.633 +
	407	1135	1131	100.4	1.683
	415	1197	1197	100.0	1.675
	382	948	941	100.8	1.701 +
	370	932	858	108.7	1.840 +
	365	872	825	105.8	1.793 +
	380	900	927	97.1	1.640
	385	1008	963	104.7	1.766
	372	827	871	94.9	1.606 +
	417	1464	1214	120.6	2.019
	390	1093	999	109.4	1.843
	381	922	934	98.7	1.667 +
	375	919	892	103.1	1.743
	390	923	999	92.4	1.556
	337	782	654	119.6	2.043
	395	955	1040	92.1	1.550
	356	872	767	113.7	1.933
	375	952	892	106.8	1.805
	387	1035	977	105.9	1.786
	380	949	927	102.4	1.729
June, 1977 Females	399	1028	1151	89.4	1.618
	423	1360	1354	100.5	1.797 +
	396	916	1127	81.3	1.475
	382	995	1019	97.6	1.785
	403	1123	1183	94.9	1.716
	350	888	799	111.2	2.071
	380	1195	1004	118.9	2.178
	444	1541	1549	99.5	2.138
	405	1057	1199	88.1	1.591 +
	365	995	898	110.8	2.046
	375	887	968	91.6	1.682
	410	1410	1241	113.6	2.046

Appendix 8 Length/weight regression statistics. 1975 to 1977. Lake A.

		Log_{10} intercept	Slope	95% confidence interval for slope	r	n
Rudd						
1975	Jun.	-5.1416	3.1930	2.9799 - 3.4061	0.9901	19
	Jul.	-5.0350	3.1353*	3.0394 - 3.2312	0.9934	56
	Aug.	-5.4186	3.3070*	3.1907 - 3.4233	0.9937	41
	Sep.	-6.0429	3.5796*	3.3951 - 3.7641	0.9948	17
1976	Jun.	-4.9583	3.0924	2.8000 - 3.3048	0.9814	32
	Jul.	-5.0204	3.1220	2.5639 - 3.6801	0.9266	19
	Aug.	-5.4197	3.2956	2.9980 - 3.5932	0.9904	11
	Sep.	-5.0016	3.1015*	3.0183 - 3.1847	0.9985	18
1977	Apr-Jun.	-5.7635	3.4423*	3.2746 - 3.6100	0.9938	22
Roach						
1975	Jun-Sep.	-4.3976	2.8582	2.6195 - 3.0968	0.9918	11
1976	Jun-Oct.	-4.8639	3.0383	2.8789 - 3.1977	0.9881	35
1977	Mar-May.	-4.2628	2.7856*	2.7310 - 2.8404	0.9998	6
Bream						
1975	Jun.	-5.0245	3.1212	2.8568 - 3.3859	0.9955	9
	Jul.	-4.7636	3.0315	2.7896 - 3.2534	0.9720	38
	Aug.	-5.1667	3.1884	2.8181 - 3.5587	0.9980	5
	Sep.	-5.2035	3.2049	2.0532 - 4.3566	0.9996	3
1976	Jun.	-5.1739	3.1891*	3.0880 - 3.2902	0.9986	15
	Jul.	-5.4064	3.2876*	3.1353 - 3.4499	0.9966	15
	Aug.	-5.4922	3.3020*	3.2126 - 3.3914	0.9986	19
	Sep.	-5.1177	3.1499	0.9541 - 5.3457	0.9734	4
	Oct-Dec.	-5.1425	3.1686*	3.0535 - 3.2837	0.9985	13
1977	Jan-Mar[1]	-5.3276	3.2388	2.9275 - 3.5501	0.9976	6
	Apr-Jun.	-5.3743	3.2654*	3.1012 - 3.4296	0.9945	21

1 - all fish 300 mm.

		Log_{10} intercept	Slope	95% confidence interval for slope	r	n
Crucian Carp						
1975	Jun.	-3.8752	2.7048	2.4487 - 2.9609	0.9918	9
	Jul.	-4.3714	2.9044	2.7886 - 3.0202	0.9971	16
	Aug.	-4.8312	3.1107	2.9456 - 3.2758	0.9989	5
1976	Jun.	-4.8641	3.0954	2.9704 - 3.2204	0.9983	10
	Jul.	-4.7556	3.0590	2.8733 - 3.2447	0.9976	7
Perch						
1975	Jun-Sep.	-5.3420	3.2581*	3.1799 - 3.3363	0.9991	14
1976	Jun-Oct.	-5.1406	3.1531*	3.0854 - 3.2208	0.9988	22
1977	Mar-Jun.	-5.9914	3.5237	2.8478 - 4.1996	0.9659	9

Note.

Fork lengths (mm) ; Weight (g)

* Slope deviates significantly from 3 ($p < 0.05$)

Appendix 8 Length/weight regression statistics. 1975 to 1977. Lake A.

		Log_{10} intercept	Slope	95% confidence interval for slope	r	n
Rudd						
1975	Jun.	-5.1416	3.1930	2.9799 - 3.4061	0.9901	19
	Jul.	-5.0350	3.1353*	3.0394 - 3.2312	0.9934	56
	Aug.	-5.4186	3.3070*	3.1907 - 3.4233	0.9937	41
	Sep.	-6.0429	3.5796*	3.3951 - 3.7641	0.9948	17
1976	Jun.	-4.9583	3.0924	2.8000 - 3.3048	0.9814	32
	Jul.	-5.0204	3.1220	2.5639 - 3.6801	0.9266	19
	Aug.	-5.4197	3.2956	2.9980 - 3.5932	0.9904	11
	Sep.	-5.0016	3.1015*	3.0183 - 3.1847	0.9985	18
1977	Apr-Jun.	-5.7635	3.4423*	3.2746 - 3.6100	0.9938	22
Roach						
1975	Jun-Sep.	-4.3976	2.8582	2.6195 - 3.0968	0.9918	11
1976	Jun-Oct.	-4.8639	3.0383	2.8789 - 3.1977	0.9881	35
1977	Mar-May.	-4.2628	2.7856*	2.7310 - 2.8404	0.9998	6
Bream						
1975	Jun.	-5.0245	3.1212	2.8568 - 3.3859	0.9955	9
	Jul.	-4.7636	3.0315	2.7896 - 3.2534	0.9720	38
	Aug.	-5.1667	3.1884	2.8181 - 3.5587	0.9980	5
	Sep.	-5.2035	3.2049	2.0532 - 4.3566	0.9996	3
1976	Jun.	-5.1739	3.1891*	3.0880 - 3.2902	0.9986	15
	Jul.	-5.4064	3.2876*	3.1353 - 3.4499	0.9966	15
	Aug.	-5.4922	3.3020*	3.2126 - 3.3914	0.9986	19
	Sep.	-5.1177	3.1499	0.9541 - 5.3457	0.9734	4
	Oct-Dec.	-5.1425	3.1686*	3.0535 - 3.2837	0.9985	13
1977	Jan-Mar[1]	-5.3276	3.2388	2.9275 - 3.5501	0.9976	6
	Apr-Jun.	-5.3743	3.2654*	3.1012 - 3.4296	0.9945	21

1 - all fish 300 mm.

		Log_{10} intercept	Slope	95% confidence interval for slope	r	n
Crucian Carp						
1975	Jun.	-3.8752	2.7048	2.4487 - 2.9609	0.9918	9
	Jul.	-4.3714	2.9044	2.7886 - 3.0202	0.9971	16
	Aug.	-4.8312	3.1107	2.9456 - 3.2758	0.9989	5
1976	Jun.	-4.8641	3.0954	2.9704 - 3.2204	0.9983	10
	Jul.	-4.7556	3.0590	2.8733 - 3.2447	0.9976	7
Perch						
1975	Jun-Sep.	-5.3420	3.2581*	3.1799 - 3.3363	0.9991	14
1976	Jun-Oct.	-5.1406	3.1531*	3.0854 - 3.2208	0.9988	22
1977	Mar-Jun.	-5.9914	3.5237	2.8478 - 4.1996	0.9659	9

Note.
Fork lengths (mm) ; Weight (g)
* Slope deviates significantly from 3 ($p < 0.05$)

8 cont.

Tench, length/weight regression statistics. 1975 to 1977. Lake A.

			Log_{10} intercept	Slope	95% confidence interval for slope	r	n
1975							
May	Male	NMD	-1.4283	2.7906	0.3187 - 5.2625	0.7691	4
		MD	-2.0722	3.2241	1.5831 - 4.8651	0.7266	9
	Female	NMD	-0.9214	2.4869	1.2341 - 3.7397	0.9237	4
		MD	-1.1725	2.6329	1.2349 - 4.0309	0.9237	4
Jun.	Male	NMD	-3.2076	3.9238	2.9121 - 4.9354	0.8605	17
		MD	-1.3220	2.7256	1.5416 - 3.9096	0.8393	8
	Female	NMD	-2.3904	3.4037	1.8874 - 4.9199	0.7990	9
		MD	-1.4309	2.7943	1.7147 - 3.8739	0.9190	6
Jul.	Male	NMD	-1.5315	2.8479	2.3464 - 3.3494	0.9418	16
		MD	-1.5315	2.8542	2.1517 - 3.5567	0.7983	25
	Female	NMD	-3.2159	3.9126	2.6929 - 5.1323	0.7029	22
		MD	-1.7510	3.0020	2.4485 - 3.5555	0.9265	18
Aug.	Male	NMD	-1.4546	2.8092	1.4365 - 4.1819	0.8302	7
		MD	-3.5191	4.1162	2.1440 - 6.0884	0.7627	9
1976							
Jun.	Male	NMD	-1.1402	2.6101	2.0536 - 3.1665	0.9263	17
		MD	-1.0434	2.5492*	2.2561 - 2.8422	0.9844	11
	Female	NMD	-1.1764	2.6486	2.1636 - 3.1336	0.9369	16
		MD	-4.6962	4.8328	2.4355 - 7.2301	0.8988	5
Jul.	Male	NMD	-0.4743	2.1791	1.4780 - 2.8802	0.9156	8
		MD	-0.8626	2.4225	1.7307 - 3.1143	0.8994	11
	Female	NMD	-0.6636	2.3121*	1.9220 - 2.7022	0.9349	19
		MD	-4.8569	4.8840*	4.1498 - 5.6182	0.9941	4
Aug.	Male	NMD	-4.1348	4.4754*	3.8377 - 5.1131	0.9947	4
		MD	-8.3083	7.1029	5.0083 - 9.1975	0.9771	4
	Female	NMD	-0.6141	2.2828	1.6782 - 2.8874	0.9339	9
		MD	-	-	- -	-	-
1977							
Apr.	Male	NMD	-2.1276	3.2477	2.5158 - 3.9796	0.9732	6
	Female	NMD	-1.7894	3.0144	2.3264 - 3.7024	0.9655	7
May	Male	NMD	-0.2067	1.7523*	1.1935 - 2.3111	0.9026	9
		MD	-2.4928	3.4467	1.6905 - 5.2029	0.8137	7
	Female	NMD	-1.0828	2.5794	1.9293 - 3.2295	0.9226	11
		MD	-1.9021	3.0812	0.3842 - 5.8782	0.3768	6
Jun.	Male	NMD	-1.3914	2.7703	2.0105 - 3.5301	0.8634	15
		MD	-0.9008	2.4511	0.9595 - 3.9427	0.8431	5
	Female	NMD	-2.1221	3.2407	2.0534 - 4.4280	0.8066	12

* Slope deviates significantly from 3 ($p < 0.05$)

All data from tench > 300 mm. NMD = No mouth damage. MD = Mouth damaged

Fork Lengths (cm); weight (g).

Appendix 9 Mean K values with 95 % confidence limits for rudd and tench. Lake A, 1975 to 1977.

Rudd

		1975	1976	1977
April to May	NMD	-	-	1.529 ± 0.095(11)
	MD	-	-	1.740 ± 0.399(3)
Jun.	NMD	1.780 ± 0.113(12)	1.596 ± 0.106(22)	-
	MD	1.849 ± 0.312(4)	1.668 ± 0.152(6)	-
Jul.	NMD	1.763 ± 0.070(24)	1.470 ± 0.188(10)	-
	MD	1.818 ± 0.065(30)	1.591 ± 0.221(6)	-
Aug.	NMD	1.660 ± 0.054(23)	1.533 ± 0.258(5)	-
	MD	1.839 ± 0.104(16)	1.534 ± 0.235(6)	-
Sep.	NMD	1.460 ± 0.086(13)	1.588 ± 0.031(18)	-
	MD	1.633 ± 0.387(4)	-	-

NMD = No mouth damage MD = With mouth damage

Tench

		1975	1976	1977
April	M	-	1.777 ± 0.036(34)	1.740 ± 0.129(9)
	F	-	1.798 ± 0.065(17)	1.696 ± 0.079(8)
May	M	-	-	1.736 ± 0.059(25)
	F	-	-	1.793 ± 0.060(27)
Jun.	M	1.803 ± 0.058(35)	1.801 ± 0.044(33)	1.751 ± 0.064(20)
	F	1.894 ± 0.083(30)	1.816 ± 0.060(27)	1.839 ± 0.139(13)
Jul.	M	1.793 ± 0.045(56)	1.725 ± 0.067(22)	-
	F	1.882 ± 0.049(56)	1.736 ± 0.077(26)	-
Aug.	M	1.753 ± 0.065(16)	1.650 ± 0.109(8)	-
	F	1.984 ± 0.148(9)	1.745 ± 0.083(12)	-

M = Male F = Female

continued over:-

9 cont

Mean K values with 95 % confidence limits for male and female tench with and without mouth damage. Lake A , June to August, 1975 and 1976.

Male tench

1975		Mean K ± 95 % C.L.	n	1976		Mean K ± 95 % C.L.	n
Jun.	MD	1.820 ± 0.128	10	Jun.	MD	1.783 ± 0.054	14
	NMD	1.796 ± 0.073	25		NMD	1.815 ± 0.072	19
Jul.	MD	1.741 ± 0.048	28*	Jul.	MD	1.739 ± 0.094	12
	NMD	1.845 ± 0.078	28		NMD	1.707 ± 0.117	10
Aug.	MD	1.749 ± 0.110	8	Aug.	MD	1.622 ± 0.281	4
	NMD	1.756 ± 0.101	8		NMD	1.679 ± 0.129	4

Female tench

1975		Mean K ± 95 % C.L.	n	1976		Mean K ± 95 % C.L.	n
Jun.	MD	1.735 ± 0.063	7*	Jun.	MD	1.738 ± 0.142	8
	NMD	1.943 ± 0.105	23		NMD	1.849 ± 0.071	19
Jul.	MD	1.803 ± 0.049	22*	Jul.	MD	1.562 ± 0.158*	4
	NMD	1.934 ± 0.074	34		NMD	1.769 ± 0.082	22
Aug.	MD	1.851 ± 0.129	4	Aug.	MD	1. - -	1
	NMD	2.090 ± 0.240	5		NMD	1.757 ± 0.087	11

* Mean K of tench with and without mouth damage significantly different at $p < 0.05$ (t-test)

n = number of observations.

Appendix 10

Outline of analysis of covariance applied to the comparison of length/weight regressions.

Background

X data	Y data	See Snedecor & Cochran (1967), Chapt.14
$\frac{\Sigma X}{n} = \bar{X}$	$\frac{\Sigma Y}{n} = \bar{Y}$	
X^2	Y^2	
$\frac{(\Sigma X)^2}{n}$	$\frac{(\Sigma Y)^2}{n}$	

Corrections

$$\Sigma x^2 = \Sigma X^2 - \frac{(\Sigma X)^2}{n} \qquad \Sigma y^2 = \Sigma Y^2 - \frac{(\Sigma Y)^2}{n}$$

$$\Sigma xy = \Sigma XY - \frac{(\Sigma X)(\Sigma Y)}{n}$$

Slope of the functional regression $= v = \pm\sqrt{\frac{y^2}{x^2}}$

Deviations from regression:-

1) Sum of squares of deviations (SS) =

$$\Sigma dy.x^2 = \Sigma y^2 - ((\Sigma xy)^2/\Sigma x^2)$$

2) Mean square (MS)=

$$\Sigma dy.x^2/(n-2)$$

Example: Male tench; no mouth damage cf. mouth damaged fish. Lake A, July, 1975.

No mouth damage	With mouth damage
$n=28$	$n=28$
$Log_{10}wt. = -3.7478 + 2.6032\ Log_{10}FL$	$Log_{10}wt. = -4.2470 + 2.7996\ Log_{10}FL$
$r=0.9947$	$r=0.9730$
$\Sigma x^2=0.2398$	$\Sigma x^2=0.0512$
$\Sigma y^2=1.6247$	$\Sigma y^2=0.4013$
$\Sigma xy=0.6208$	$\Sigma xy=0.1395$

Within	n-1 df.	Σx^2	Σxy	Σy^2	Slope	Devs. from regression *	SS	MS
NMD	27	0.2398	0.6208	1.6247	2.6032	26	0.0176	0.00068
MD	27	0.0512	0.1395	0.4013	2.7996	26	0.0212	0.00082
						52	0.0388	0.00075
Pooled	54	0.2910	0.7603	2.0260	2.6386	53	0.0396	0.00075
Diffs. between slopes						1	0.0008	0.0008

Obs.F = 0.0008/0.00075 = 1.067 df.1,52
Obs.F < Tabulated F @ $p<0.01$
ie. Slopes not significantly different at 1% level.

Variance ratio = 1.206
ie. homogeneity of variance @ $p<0.01$

* = n-2 df

Appendix 11 Fish mouth and length measurements.

Species	Date of capture	Source	Age	Upper jaw x (mm)	Lower jaw y (mm)	Gape z (mm)	Fork length (mm)
Bream	7.75	A	1+	2.7	1.8	3.0	81
	4.76	A	1	2.6	1.9	3.2	71
	4.76	A	1	2.5	1.8	3.1	70
	10.76	A	1+	3.2	2.6	4.1	90
	10.76	A	1+	3.7	3.3	5.0	106
	10.76	A	0+	2.3	2.0	3.1	53
	10.76	A	0+	1.8	1.2	2.2	51
	10.76	A	0+	1.5	1.1	1.9	43
	10.76	A	0+	1.7	1.2	2.1	48
	10.76	A	0+	2.0	1.4	2.4	52
	10.76	A	0+	2.6	1.6	3.1	58
	10.76	A	0+	2.4	1.8	3.0	60
	9.77	A	1+	3.1	3.0	4.3	88
	9.77	A	1+	2.6	2.2	3.4	75
	9.77	A	1+	2.8	2.7	3.9	79
	9.77	A	1+	2.6	2.5	3.6	87
	9.77	A	1+	2.9	2.4	3.8	83
Rudd	7.75	A	1+	3.1	2.8	4.2	67
	4.76	A	2	4.0	3.1	5.2	83
	4.76	A	1	2.8	2.3	3.6	58
	4.76	A	1	2.4	1.9	3.1	51
	4.76	A	2	4.2	3.1	5.2	89
	10.76	A	0+	2.3	1.8	2.9	47
	10.76	A	0+	2.2	2.0	3.0	48
	10.76	A	0+	2.0	1.9	2.8	47
	10.76	A	0+	2.2	1.9	2.9	46
	10.76	A	1+	3.0	2.7	4.0	76
	10.76	A	1+	4.0	3.4	5.3	82
	10.76	A	0+	1.8	1.5	2.3	42
	10.76	A	0+	2.4	1.6	2.9	46
	9.77	A	1+	3.7	3.0	4.8	75
	9.77	A	1+	3.7	3.4	5.0	77
	9.77	A	1+	3.7	3.2	4.9	73
	9.77	A	2+	4.5	3.7	5.8	101
Roach	7.75	A	0+	1.6	1.5	2.2	39
	7.75	A	1+	3.5	2.1	4.1	79
	10.76	A	0+	2.6	1.7	3.1	63
	10.76	A	0+	2.3	1.6	2.8	57
	10.76	A	0+	2.4	1.6	2.9	60
	10.76	A	0+	2.2	1.9	2.9	57
	10.76	A	0+	2.6	1.9	3.2	66
	10.76	A	0+	2.4	1.6	2.9	61
	9.77	A	1+	3.2	2.5	4.1	81
	9.77	A	1+	3.5	3.2	4.7	97
	9.77	A	1+	3.2	2.5	4.1	78
	9.77	A	1+	3.5	3.0	4.6	94
	9.77	A	1+	3.9	2.7	4.7	91

Appendix 11 Fish mouth and length measurements.

Species	Date of capture	Source	Age	Upper jaw x (mm)	Lower jaw y (mm)	Gape z (mm)	Fork length (mm)
Bream	7.75	A	1+	2.7	1.8	3.0	81
	4.76	A	1	2.6	1.9	3.2	71
	4.76	A	1	2.5	1.8	3.1	70
	10.76	A	1+	3.2	2.6	4.1	90
	10.76	A	1+	3.7	3.3	5.0	106
	10.76	A	0+	2.3	2.0	3.1	53
	10.76	A	0+	1.8	1.2	2.2	51
	10.76	A	0+	1.5	1.1	1.9	43
	10.76	A	0+	1.7	1.2	2.1	48
	10.76	A	0+	2.0	1.4	2.4	52
	10.76	A	0+	2.6	1.6	3.1	58
	10.76	A	0+	2.4	1.8	3.0	60
	9.77	A	1+	3.1	3.0	4.3	88
	9.77	A	1+	2.6	2.2	3.4	75
	9.77	A	1+	2.8	2.7	3.9	79
	9.77	A	1+	2.6	2.5	3.6	87
	9.77	A	1+	2.9	2.4	3.8	83
Rudd	7.75	A	1+	3.1	2.8	4.2	67
	4.76	A	2	4.0	3.1	5.2	83
	4.76	A	1	2.8	2.3	3.6	58
	4.76	A	1	2.4	1.9	3.1	51
	4.76	A	2	4.2	3.1	5.2	89
	10.76	A	0+	2.3	1.8	2.9	47
	10.76	A	0+	2.2	2.0	3.0	48
	10.76	A	0+	2.0	1.9	2.8	47
	10.76	A	0+	2.2	1.9	2.9	46
	10.76	A	1+	3.0	2.7	4.0	76
	10.76	A	1+	4.0	3.4	5.3	82
	10.76	A	0+	1.8	1.5	2.3	42
	10.76	A	0+	2.4	1.6	2.9	46
	9.77	A	1+	3.7	3.0	4.8	75
	9.77	A	1+	3.7	3.4	5.0	77
	9.77	A	1+	3.7	3.2	4.9	73
	9.77	A	2+	4.5	3.7	5.8	101
Roach	7.75	A	0+	1.6	1.5	2.2	39
	7.75	A	1+	3.5	2.1	4.1	79
	10.76	A	0+	2.6	1.7	3.1	63
	10.76	A	0+	2.3	1.6	2.8	57
	10.76	A	0+	2.4	1.6	2.9	60
	10.76	A	0+	2.2	1.9	2.9	57
	10.76	A	0+	2.6	1.9	3.2	66
	10.76	A	0+	2.4	1.6	2.9	61
	10.76	A	1+	3.2	2.5	4.1	81
	9.77	A	1+	3.5	3.2	4.7	97
	9.77	A	1+	3.2	2.5	4.1	78
	9.77	A	1+	3.5	3.0	4.6	94
	9.77	A	1+	3.9	2.7	4.7	91
	9.77	A					

11 cont.

Species	Date of capture	Source	Age	Upper jaw x (mm)	Lower jaw y (mm)	Gape z (mm)	Fork length (mm)
Perch	6.75	Bos.	0+	3.0	2.3	3.8	35
	6.75	Bos.	0+	2.3	2.0	3.1	32
	6.75	Bos.	0+	2.7	2.2	3.5	35
	6.75	Bos.	0+	2.7	2.2	3.5	31
	7.75	A	0+	4.0	3.7	5.5	53
	7.75	A	0+	4.1	4.1	5.8	56
	9.75	B	0+	3.9	3.6	5.3	52
	9.75	B	0+	4.4	4.1	6.0	59
	9.75	B	0+	4.7	4.1	6.2	62
	4.76	A	1+	6.6	5.7	8.7	82
	4.76	A	1+	7.1	5.8	9.2	95
	4.76	A	1+	6.0	5.3	8.0	86
	10.76	A	0+	4.8	4.2	6.4	65
	10.76	A	0+	4.7	3.9	6.1	62
	10.76	A	0+	4.5	4.0	6.0	60
	10.76	A	0+	4.0	3.4	5.3	56
	10.76	A	0+	3.8	3.4	5.1	58
Tench	7.75	A	1+	2.7	1.9	3.3	49
	7.75	A	1+	3.1	2.5	4.0	64
	4.76	A	2	3.9	2.3	4.5	80
	10.76	A	1+	2.3	1.2	2.6	53
	10.76	A	2+	4.5	2.2	5.0	85
Cru. carp	6.75	A	1+	2.5	1.6	3.0	52
	7.75	A	1+	2.7	2.1	3.4	54

A = Lake A , Barham

B = Lake B , Barham

Bos. = Bosmere, Needham Market, Suffolk.

$$z = \sqrt{x^2 + y^2}$$

Appendix 12 Catch rates. Lake A.

Daily catch rates (catch h^{-1}) and % anglers with catch during the census 1975 to 1977. Lake A.

Date 1975	% anglers with catch	Overall catch h^{-1}	Rudd	Roach	Bream	Tench	Cru. Carp	Com. Carp	Perch
18.1	9.1	0.03				0.03			
25.1	8.3	0.03					0.03		
1.2	0.0	0.00							
8.2	0.0	0.00							
15.2	0.0	0.00							
22.2	0.0	0.00							
1.3	0.0	0.00							
8.3	0.0	0.00							
16.6	66.7	1.79	1.62		0.09	0.08			
18.6	30.0	0.90	0.85	0.02		0.02	0.02		
20.6	36.8	0.25	0.06		0.05	0.13	0.01		
21.6	38.5	0.36	0.22		0.02	0.09	0.02		
23.6	56.2	0.36	0.09		0.03	0.21	0.03		
25.6	46.7	0.15				0.10	0.05		
27.6	50.0	0.32	0.14		0.02	0.16			
1.7	57.1	0.34	0.12			0.17	0.05		
2.7	25.0	0.14				0.10	0.03		
8.7	35.3	0.26	0.03		0.03	0.20	0.03		
9.7	61.5	0.95	0.39		0.15	0.36	0.04		0.02
11.7	31.6	0.16			0.06	0.09			
15.7	37.5	0.18	0.02			0.14	0.02		
17.7	38.5	0.30	0.03			0.23	0.05		
21.7	60.0	0.48				0.45	0.03		
23.7	43.7	0.34	0.14		0.03	0.10	0.05		0.02
25.7	75.0	0.67	0.20		0.04	0.35	0.08		
28.7	20.0	0.14				0.14			
30.7	50.0	0.33	0.08	0.02	0.03	0.15	0.03		0.02
1.8	46.2	0.26	0.10	0.02		0.12	0.02		
11.8	41.7	0.19	0.10			0.06	0.03		
13.8	35.3	0.50	0.42			0.06			0.02
15.8	100.0	0.75	0.50	0.05	0.15	0.05			
17.8	44.4	0.30	0.25			0.03	0.03		
19.8	78.6	0.52	0.04		0.04	0.42	0.02		
20.8	50.0	0.39	0.03	0.13		0.21			0.03
22.8	44.4	0.53	0.18	0.11		0.25			
28.8	18.2	0.06	0.03			0.03			
31.8	33.3	0.29	0.14			0.07	0.07		
2.9	46.2	0.57	0.48			0.09			
5.9	50.0	1.20	0.80			0.20			0.20
13.9	100.0	1.12	1.12						
1976									
16.6	66.7	1.04	0.22	0.33	0.18	0.19	0.01		0.06
17.6	50.0	0.26	0.09	0.09	0.04	0.04			
18.6	63.2	0.70	0.33	0.09		0.19	0.01		0.05
22.6	66.7	0.66	0.07	0.18	0.03	0.36	0.01		0.02
23.6	44.4	0.61	0.12	0.15	0.03	0.29	0.01		0.01
25.6	52.9	0.61	0.10	0.19	0.02	0.19	0.08		0.02
29.6	66.7	1.18	0.72	0.16	0.05	0.22	0.01		0.04
30.6	100.0	1.65	0.94	0.08	0.05	0.52	0.10		
2.7	62.5	1.61	0.55	0.18	0.09	0.74			0.05
6.7	64.3	0.35		0.07		0.22	0.06		
7.7	87.6	1.51	1.34	0.08	0.04	0.23	0.02		
13.7	77.8	0.63	0.25		0.03	0.32			0.03
14.7	72.7	1.21	0.25	0.14	0.14	0.65			
22.7	52.9	1.65	0.58	0.08	0.10	0.85			0.06
27.7	66.7	0.65	0.10	0.05	0.21	0.26	0.03		
29.7	75.0	1.10	0.49	0.08	0.21	0.31			0.03
9.8	63.6	0.74	0.03	0.13	0.33	0.20			0.03
11.8	62.5	0.94	0.30	0.15	0.35	0.10			0.05
13.8	60.0	1.92	0.67	0.22	0.15	0.81			0.07
19.8	50.0	0.83	0.38		0.08	0.38			
24.8	55.6	0.47	0.10		0.07	0.24	0.07		
5.9	33.3	0.21			0.07	0.14			
19.9	40.0	0.09	0.05						0.05
23.10	72.7	0.58	0.09	0.12	0.30	0.06			
20.11	31.3	0.20		0.04	0.10	0.02			0.04
1977									
22.1	0.0	0.0							
19.2	10.0	0.19			0.19				
12.3	62.5	0.29	0.11	0.07	0.07				0.04

12 cont.

Weekly catch, effort and catch rates. Lake A, Summer, 1976.

Week No.	Weekly total catch census + matches	Weekly total catch census only	Weekly effort(h) census + matches	Weekly effort(h) census only	Overall weekly catch h^{-1} census + matches	Overall weekly catch h^{-1} census only
1	188	141	291.5	221.5	0.645	0.637
2	188	188	136.3	136.3	1.379	1.379
3	235	98	221.6	106.6	1.061	0.919
4	63	63	67.2	67.2	0.938	0.938
5	163	82	169.6	49.6	0.961	1.653
6	68	68	77.2	77.2	0.881	0.881
7	41	41	50.1	50.1	0.818	0.818
8	147	25	113.5	13.5	1.295	1.852
9	11	11	13.2	13.2	0.833	0.833
10	14	14	29.7	29.1	0.471	0.471
11	28	5	119.5	36.5	0.234	0.137
12	17	-	35.8	-	0.476	-

Week No.	Weekly overall rudd catch h^{-1} census + matches	Weekly overall rudd catch h^{-1} census only	Weekly rudd(<100mm) catch h^{-1} census + matches	Weekly rudd(<100mm) catch h^{-1} census only	Weekly overall roach catch h^{-1} census + matches	Weekly overall roach catch h^{-1} census only
1	0.165	0.090	0.079	0.018	0.141	0.172
2	0.756	0.638	0.638	0.638	0.139	0.139
3	0.844	0.657	0.803	0.657	0.041	0.075
4	0.253	0.253	0.238	0.238	0.074	0.074
5	0.442	0.585	0.383	0.524	0.041	0.101
6	0.337	0.337	0.220	0.220	0.065	0.065
7	0.140	0.140	0.040	0.040	0.140	0.140
8	0.458	0.667	0.238	0.667	0.079	0.222
9	0.379	0.379	0.379	0.379	0	0
10	0.101	0.101	0.101	0.101	0	0
11	0.160	0.027	0.109	0	0	0
12	0.084	-	0.084	-	0.056	-

Week No.	Weekly overall perch catch h^{-1} census + matches	Weekly overall perch catch h^{-1} census only	Weekly overall bream catch h^{-1} census + matches	Weekly overall bream catch h^{-1} census only
1	0.017	0.018	0.048	0.027
2	0.029	0.029	0.059	0.059
3	0.018	0	0.018	0.019
4	0.015	0.015	0.089	0.089
5	0.029	0.061	0.094	0.101
6	0.013	0.013	0.207	0.207
7	0.040	0.040	0.339	0.339
8	0.035	0.074	0.485	0.148
9	0.076	0.076	0.076	0.076
10	0	0	0.067	0.067
11	0	0	0.034	0.027
12	0	-	0.224	-

12 cont.

Catch rates (catch h^{-1}) used in the calculation of catch rate/density relationships.

Species	1974	1975		1976	1977
	Aug. - Oct.	Jan.-May	Jun.-Sep.	Jun.-Nov.	Jan.-Jun.
Roach	0.118	0.000	0.006	0.088	0.029
Rudd	0.441	0.000	0.161	0.355	0.126
Bream	0.015	0.000	0.024	0.104	0.122
Perch	0.016	0.000	0.023	0.023	0.040
All species	0.655	0.074	0.307	0.831	0.700

Note: All periods inclusive of the stated months.

All species includes tench, crucian carp and common carp in addition to those listed above.

Catch rates = Total catch/Total effort(h).

12 cont.

Catch rates (catch h^{-1}) used in the calculation of catch rate/density relationships.

Species	1974	1975		1976	1977
	Aug. - Oct.	Jan.-May	Jun.-Sep.	Jun.-Nov.	Jan.-Jun.
Roach	0.118	0.000	0.006	0.088	0.029
Rudd	0.441	0.000	0.161	0.355	0.126
Bream	0.015	0.000	0.024	0.104	0.122
Perch	0.016	0.000	0.023	0.023	0.040
All species	0.655	0.074	0.307	0.831	0.700

Note: All periods inclusive of the stated months.

All species includes tench, crucian carp and common carp in addition to those listed above.

Catch rates = Total catch/Total effort(h).

Appendix 13

Test angler's catch rates ;

Lake A & B; 1975 and 1976 (June, July & August.)

Lake A

		1975 i	ii	iii	iv	v	vi	vii	viii	Catch h^{-1}	1976 i	ii	iii	iv	v	vi	vii	viii	Catch h^{-1}
Roach	J	1								0.007	8	25	10	7	4				0.280
	J	1	1							0.009	32	4	1						0.439
	A	3	2							0.081	4	3	1						1.185
Rudd	J	22	6	3						0.202	85	34	10	3					0.732
	J	35		3						0.164	7	8		1					0.190
	A	88	7	31	4					2.097	6								0.689
Bream	J			7	10	3	2			0.144	4	2	5	7	3				C.117
	J		3	12	8	2	1		1	0.116	6	2	1	3	3				0.178
	A			2	7	2	1			0.194									0
Tench	J		1	1	4	10	11			0.176	4	8	8	8	29	33	4		0.522
	J	4	2	2	3	20	20	4		0.237	7	1	2	6	8	14			0.451
	A	6	1	2	3	1	6	1		0.323				2					0.296
Cru. Carp	J	1			1					0.013		1			1				0.011
	J				2		1			0.013					1				C.012
	A									0									0
Perch	J	1								0.007		11	1						0.067
	J	1								0.004	1		1						0.024
	A		2	1						0.048			1						0.148

Lake B

		1975 i	ii	iii	iv	v	vi	vii	viii	Catch h^{-1}	1976 i	ii	iii	iv	v	vi	vii	viii	Catch h^{-1}
Roach	J	8								0.102		11	5	1					0.395
	J	17	12	2						0.827	87	100	58	11	1	1			1.536
	A		11							0.667	11	31	13						0.579
Rudd	J	18								0.229		1							0.023
	J	9	1							0.267	17	20	4	2					0.256
	A									0	6	2							0.084
Tench	J					7	2			0.114					1	3	10		0.326
	J					2	7	1		0.267		2	1	2	16	14	3	6	0.262
	A			2	1	2	3			0.485	3	9	1	2	2	7	1		0.263
Eel	J				3		1			0.051						1		2	0.070
	J					1				0.053				1	6	3		3	0.077
	A							1		0.061					1	2			0.032
Perch	J												1	1					0.047
	J										7	8	21	1					0.220
	A										7	3	4	1					0.158
Com.	J																		0
	J													1	6	4			C.066
	A														1	16	1		0.190

Note: i - viii refer to size groups defined previously (see Appendix 3 and Fig. 35)

Appendix 14

Summary angling data. Lake 3, 1975 to 1977.

Date	No. Anglers	Effort (h)	Ru.	Ro.	T.	Br.	Pe.	CCp.	Overall	Water temp. °C.
			Catch and catch h^{-1}							
18. 1.75	11	32	14 (0.44)	9 (0.28)					23 (0.72)	6.1
25. 1.75	10	29		2 (0.07)					2 (0.07)	5.0
1. 2.75	11	33	7 (0.21)	2 (0.06)					9 (0.27	5.7
8. 2.75	7	19	26 (1.37)	22 (1.16)					48 (2.53)	4.9
15. 2.75	6	17	32 (1.88)	46 (2.71)					78 (4.59)	5.4
22. 2.75	3	9	0 (0)	0 (0)					0 (0)	5.8
8. 3.75	5	15	7 (0.47)	3 (0.20)					10 (0.67)	7.0
22. 3.75	5	18.6	0 (0)	4 (0.22)					4 (0.22)	5.3
5. 4.75	5	19	0 (0)	1 (0.05)					1 (0.05)	5.6
19. 4.75	FLOOD									
4. 5.75	5	16	0	0					0	11.2
17. 5.75	5	19	2 (0.11)	17 (0.89)					19 (1.00)	12.0
31. 5.75	5	16	1 (0.06)	3 (0.19)					4 (0.25)	13.7
22. 6.75	10	50	0	0	18 (0.36)	2 (0.04)			20 (0.40)	-
27. 6.75	2	10	0	0	12 (1.20)	0			12 (1.20)	-
29. 6.75	1	6	0	0	2 (0.40)	0			2 (0.40)	-
13. 7.75	10	50	0	136 (2.72)	3 (0.06)	0			139 (2.78)	-
20. 6.76*	15	75	5 (0.07)	9 (0.12)	5 (0.07)	0 (0)	5 (0.07)	0 (0)	24 (0.32)	19.0
18. 7.76*	13	65	5 (0.08)	3 (0.05)	4 (0.06)	2 (0.03)	2 (0.03)	7 (0.11)	23 (0.35)	25.0
20. 7.76	9	26.7	0 (0)	24 (0.90)	8 (0.30)	0 (0)	4 (0.15)	1 (0.04)	37 (1.39)	22.0
20. 8.76	14	49	6 (0.12)	2 (0.04)	4 (0.08)	0 (0)	1 (0.02)	3 (0.06)	16 (0.33)	21.7
29. 8 76*	42	126	0	7 (0.06)	2 (0.02)	3 (0.02)	1 (0.01)	7 (0.06)	20 (0.16)	19.6
3.10.76	9	29	0 (0)	1 (0.03)	2 (0.07)	0 (0)	1 (0.03)	0 (0)	4 (0.14)	17.0
10.10.76*	13	39	0 (0)	2 (0.05)	2 (0.05)	0 (0)	2 (0.05)	2 (0.05)	8 (0.21)	16.2
7.11.76	25	87	0 (0)	3 (0.03)	3 (0.03)	0 (0)	7 (0.08)	0 (0)	17 (0.20)	9.5
4.12.76	10	30	ICE							3.3
6. 2.77	10	35	0	3 (0.09)	0	0	0	0	3 (0.09)	5.5
5. 3.77	9	31.5	0	1 (0.03)	0	0	0	0	1 (0.03)	9.0

* = Match dates

Ru. Ro. = Rudd, reach and so on.

Catch rates in parentheses.

Appendix 15

Close season angling.

Lake A.

Date	No. of anglers	Effort(h)	Total catch	Ov.catch h^{-1}	% of anglers with catch
22.3.75	5	18.6	0	0.00	0
5.4.75	5	18.5	0	0.00	0
19.4.75	9	35.5	0	0.00	0
4.5.75	4	14.0	2	0.14	50.0
17.5.75	6	24.0	9	0.38	66.7
31.5.75	5	22.0	10	0.45	60.0
23.4.77	15	52.0	21	0.40	66.7
1.5.77	6	21.0	15	0.71	66.7
8.5.77	11	38.5	51	1.32	100.0
22.5.77	15	52.5	43	0.82	80.0
5.6.77	13	45.5	53	1.16	69.2

Lake B.

22.3.75	5	18.6	4	0.22	20.0
5.4.75	5	19.0	1	0.05	20.0
4.5.75	5	16.0	0	0.00	0
17.5.75	5	19.0	19	1.00	20.0
31.5.75	5	16.0	4	0.25	50.0

Appendix 16 Estimated numbers[1] and densities of fish vulnerable to angling. Lake A, 1974 to 1977.

Species and size range	1974 Aug.	1975 Feb.	1975 Jul.	1976 Apr.	1976 Oct.	1977 Sep.
Roach > 65mm						
N	4300	780	90	2700	3000*	10800
No. m^{-2}	0.276	0.045	0.005	0.155	0.178	0.642
Rudd > 60mm						
N	1620	1280	500	800	1900	1070
No. m^{-2}	0.093	0.074	0.029	0.046	0.113	0.064
Bream > 75mm						
N	2500	850	300	6000	6300	8100
No. m^{-2}	0.144	0.049	0.017	0.346	0.374	0.481
Tench > 280mm						
N	230	200*	175	160	155*	150
No. m^{-2}	0.013	0.012	0.010	0.009	0.009	0.009
Crucian carp > 70mm						
N	130	85*	65*	50*	40*	30*
No. m^{-2}	0.007	0.005	0.004	0.003	0.002	0.002
Perch > 50mm						
N	150	100	100	700	1900	495
No. m^{-2}	0.009	0.006	0.006	0.040	0.109	0.029
> 100mm						
N	50	25	100	270	200	250
No. m^{-2}	0.003	0.001	0.006	0.016	0.012	0.015
Total[2]						
N	9330	3220	1230	4180	11595	20400
No. m^{-2}	0.540	0.185	0.071	0.241	0.689	1.210

Note: * Interpolated values.

1. Data from population estimates, section 3.1. Areas used to calculate densities: 17367 m^2 1974 to Apr. 1976; 16829 m^2 Oct. 1976 and Sep. 1977. 2. Inc. perch > 100mm

Appendix 17 Fork lengths (mm) for bream and roach used as standards (Hickley and Dexter, 1979).

Age (yrs.)	Bream	Roach	Age (yrs.)	Bream	Roach
1	50.0	50.0	9	364.1	245.6
2	97.2	91.9	10	390.6	255.7
3	142.0	127.0	11	406.9	264.3
4	184.3	156.4	12	419.2	271.4
5	224.3	181.1	13	428.1	277.4
6	262.2	201.7	14	435.8	282.4
7	298.1	219.0	15	441.2	286.6
8	332.0	233.5			

Appendix 18 Zooplankton data. Lake A.

i) Volumes sampled with numbers of organisms counted and measured and aliquot sizes.

Date	Vol. sample(l).	No. organisms counted & measured (Aliquot size %) CALA	CYCL	DAPH	BOSM	ASPL	CHYD	EURY
1.5.75	86.81	-	-	-	-	-	-	-
28.7.75	238.00	76(3)	195(1)	54(8)	0(8)	8(8)	2(8)	0(8)
28.7.75	6.63	28(35)	99(15)	34(35)	0(35)	4(35)	0(35)	0(35)
13.8.75	154.00	23(12)	149(2)	55(12)	0(12)	57(2)	0(12)	0(12)
26.8.75	252.00	20(5)	138(1)	26(5)	0(5)	5(5)	0(5)	0(5)
26.8.75	19.89	16(30)	111(10)	45(30)	0(30)	0(30)	0(30)	0(30)
5.9.75	252.00	240(16)	146(2)	34(16)	0(16)	29(16)	0(16)	0(16)
5.9.75	13.26	72(50)	113(25)	29(50)	0(50)	3(50)	0(50)	0(50)
22.6.76	79.56	152(5)	128(10)	60(30)	0(30)	71(5)	0(30)	0(30)
29.6.76	79.56	169(5)	103(15)	28(25)	0(25)	131(15)	0(25)	3(25)
6.7.76	72.93	264(10)	88(10)	13(30)	0(30)	99(10)	0(30)	0(30)
14.7.76	72.93	163(55)	54(55)	1(55)	0(55)	108(25)	0(55)	0(55)
20.7.76	72.93	181(45)	115(65)	0(65)	0(65)	130(25)	0(65)	0(65)
27.7.76	72.95	108(75)	63(75)	2(75)	1(75)	93(35)	1(75)	0(75)
5.8.76	72.93	178(30)	75(40)	0(40)	0(40)	92(40)	0(40)	0(40)
12.8.76	72.93	158(15)	108(20)	1(30)	3(30)	99(5)	0(30)	0(30)
19.8.76	72.93	149(15)	86(25)	1(35)	4(35)	82(5)	0(35)	0(35)
26.8.76	66.30	188(10)	95(10)	9(30)	67(30)	178(5)	0(30)	0(30)
8.9.76	72.93	128(10)	104(30)	9(30)	47(10)	117(5)	2(30)	0(30)
3.10.76	72.93	194(10)	110(10)	43(25)	268(5)	86(25)	0(25)	0(25)

18 cont.

ii) Crustacean zooplankton measurements and density estimates. Lake A.

1975.

Sampling date and method.	Calanoid copepods No. m^{-3} (95% CL)	Calanoid copepods Mean size (mm) ± SE	Cyclopoid copepods No. m^{-3} (95% CL)	Cyclopoid copepods Mean size (mm) ± SE	Daphnia spp. No. m^{-3} (95% CL)	Daphnia spp. Mean size (mm) ± SE	Chydorus sp. No. m^{-3} (95% CL)	Chydorus sp. Mean size (mm) ± SE
01.05.75	4920	-	150	-	6840	-	-	-
net	-	-	-	-	-	-	-	-
28.07.75	10644	0.731	81932	0.516	2836	0.719	105	0.400
pump	(8445-13403)	±0.025	(71008-94496)	±0.009	(2151-3730)	±0.027	(17-425)	±0.050
28.07.75	12066	0.683	99548	0.494	14652	0.652	-	-
core	(8172-17703)	±0.032	(81316-121738)	±0.009	(10305-20732)	±0.199	-	-
13.08.75	1245	0.847	48377	0.556	2976	0.587	-	-
pump	(807 - 1901)	±0.055	(41057-56969)	±0.011	(2263-3904)	±0.027	-	-
26.08.75	1587	0.761	54761	0.528	2063	0.828	-	-
pump	(996 - 2501)	±0.063	(46172-64908)	±0.010	(1375-3071)	±0.044	-	-
26.08.75	2681	0.803	55807	0.541	7541	0.654	-	-
cores	(1585-4461)	±0.077	(46115-67476)	±0.013	(5564-10187)	±0.028	-	-
05.09.75	5952	0.611	28968	0.517	843	0.693	-	-
pump	(5234-6768)	±0.016	(24543-34172)	±0.011	(593 - 1193)	±0.050	-	-
05.09.75	10360	0.727	34087	0.466	4374	0.778	-	-
cores	(8557-13759)	±0.034	(28217-41144)	±0.012	(2983-6372)	±0.047	-	-

1976

Sampling date.	Calanoid copepods No. m^{-3} (95% CL)	Calanoid copepods Mean size (mm) ± SE	Cyclopoid copepods No. m^{-3} (95% CL)	Cyclopoid copepods Mean size (mm) ± SE	Daphnia spp. No. m^{-3} (95% CL)	Daphnia spp. Mean size (mm) ± SE	Bosmina sp. No. m^{-3} (95% CL)	Bosmina sp. Mean size (mm) ± SE
22.06.76	38210	0.775	16088	0.613	2514	0.668	-	-
	(32483-44923)	±0.015	(13474-19196)	±0.008	(1935-3259)	±0.028	-	-
29.06.76	42484	0.761	8631	0.587	1408	0.605	-	-
	(36426-49526)	±0.013	(7079-10512)	±0.008	(953-2065)	±0.045	-	-
06.07.76	36199	0.749	12066	0.608	594	0.831	-	-
	(32023-40910)	±0.009	(9733-14941)	±0.010	(330-1046)	±0.029	-	-
14.07.76	4064	0.723	1346	0.614	25	-	-	-
	(3474-4751)	±0.012	(1020-1771)	±0.016	(5 - 163)	-	-	-
20.07.76	5515	0.792	2426	0.585	25	-	-	-
	(4754-6396)	±0.013	(2012-2923)	±0.008	-	-	-	-
27.07.76	1974	0.687	1152	0.578	37	0.538	18	0.275
	(1627-2394)	±0.017	(892-1484)	±0.010	(6 - 148)	±0.188	(4 - 119)	-
05.08.76	8136	0.625	2571	0.522	-	-	-	-
	(7004-9446)	±0.010	(2036-3242)	±0.007	-	-	-	-
12.08.76	14443	0.801	7404	0.563	46	0.700	137	0.267
	(12317-16927)	±0.015	(6102-8976)	±0.009	(9 - 298)	-	(34-438)	±0.008
19.08.76	13620	0.788	4717	0.566	39	0.775	157	0.256
	(11560-16040)	±0.016	(3795-5855)	±0.009	(8 - 255)	-	(49-432)	±0.006
26.08.76	28356	0.913	14329	0.580	452	0.386	3369	0.280
	(24511-32791)	±0.017	(11654-17598)	±0.008	(220-393)	±0.016	(2630-4306)	±0.005
08.09.76	17551	0.305	4753	0.547	411	0.481	6445	0.284
	(14699-20941)	±0.018	(3903-5784)	±0.009	(200-812)	±0.040	(4787-8648)	±0.005
03.10.76.	26601	0.709	15083	0.557	2358	0.491	73495	0.273
	(23048-30690)	± 0.020	(12453-18253)	±0.009	(1727-3208)	±0.025	(65077-82983)	±0.003

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END