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The Amateur Fishery for Marron (*Cherax Tenuimanus*) in Western Australia - Summary of Logbook Data 1971-83

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DR N. MORRISSY
C. FELLOWS
N. CAPUTI

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Department of Fisheries and Wildlife
108 Adelaide Terrace
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Western Australian Marine Research Laboratories,
Department of Fisheries and Wildlife,
P.O. Box 20, North Beach,
Western Australia, 6020.

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THE AMATEUR FISHERY FOR MARRON *Cherax tenuimanus* IN WESTERN AUSTRALIA - SUMMARY OF LOGBOOK DATA, 1971-83.

N.M. Morrissy, C.J. Fellows and N. Caputi.
Western Australian Marine Research Laboratories.
P.O. Box, North Beach, Western Australia, 6020.

ABSTRACT

The large, native crayfish called marron, Cherax tenuimanus, supports an extensive recreational fishery in the southwest of Western Australia. This report examines annual catch and effort statistics gathered from a logbook programme, initiated in the 1971/72 season and supplemented by an end of season telephone survey from 1977. Logbook data gave estimates of relative abundance, but were too biased for projection to total catch and effort for the fishery, while telephone surveys gave unbiased estimates of total annual fishing effort (trips).

Relative abundance showed a significant decline in the major rivers and the most popular dam (Wellington) over the monitoring period. Taking total fishing effort into account, marron stocks in the major rivers appeared to be adversely affected by eutrophication (sourced in inland agricultural catchments) intensified by low flow conditions due to prolonged drought. Catch rates recovered in Wellington Dam towards the end of the period, following relief of low water conditions, but low catch rates and adverse water conditions persisted in rivers.

I INTRODUCTION

The large, indigenous freshwater crayfish called marron, *Cherax tenuimanus*, provides most of the inland recreational fishing in the southwest of Western Australia (Morrissy 1978a). A programme of monitoring catches and fishing effort, employing logbooks, was commenced for the 1971-72 season and this report examines data collected to the end of the 1982-83 season.

Previous analysis of the logbook data, for the first five seasons (1971-76), indicated a downward trend in catch rate (catch per unit of fishing effort - cpue) (Morrissy 1978a). Over this period, total annual fishing effort increased steeply, due to increasing numbers of licensed fishermen. For the present, longer, series of data, besides fishing effort, environmental factors may have influenced catches. A long-term contraction in the distribution of marron stocks along the major rivers towards the coast, due to increasing eutrophication inland, has been a cause for concern (Morrissy 1978b). Also a severe drought occurred over the southwest during most of the latter half of the period.

The history of management of the marron fishery, by Regulations under the W.A. Fishery Act, and a description of fishing methods were documented by Morrissy (1978a). Regulations were uniform throughout the fishery. The open season extended from 16 December to 30 April, the bag limit of 30 per day was reduced to 20 per day from the 1980-81 season, the minimum legal size was a (rostrum) carapace length of 76 mm (≈ 120 g), and there were three legal methods of capture, viz, one scoop net, six drop nets, and one snare per licensee. Scoop nets are used over baits laid along long lengths of shallow shorelines in large dams, baited drop, or lift, nets are used from steep banks in deep river pools, and snares over baits are rarely used nowadays. Most fishing occurs in the early evening, post-sunset (Appendix 1).

The amateur marron fishery of the southwest constitutes a large number of geographically, and therefore reproductively, isolated marron stocks. However, for analysis of a catch and effort relationship, traditional fisheries methodology requires that the fishery operates on a 'unit breeding stock'. Of the 70 marron fishing waters recorded in logbooks, 39 occurred in separate watersheds extending from just north of Perth to east of Albany (Appendix 2). For many watersheds, the presence of dams, and the extent of major rivers, further increases the number of separate breeding stocks, of this non-migratory species. Sufficient continuity of logbook data was available for individual examination of some fishing waters, especially Wellington Dam and the Warren River where the majority of fishing effort occurred.

The extent of the marron fishery precluded monitoring by means of 'creel surveys' or research sampling, i.e. any random or standardized sampling for catch rates. Fishermen volunteering for the logbook programme were likely to be more successful in their catches and more enthusiastic in their fishing efforts than marronners in general (Morrissy 1978a). However, unbiased estimates of fishing effort and one aspect of fishing success were obtained by an end-of-season telephone survey, commencing after the 1977-78 season. Any bias in the logbook estimates could be expected to be greatly magnified by the, unavoidably, large projection factor (about 400X) for the fishery, i.e., the total number of marronners divided by the number of logbook returns (Emig 1971). However, the logbook programme provided virtually the only avenue for obtaining information on catches from this fishery and represented a considerable sampling effort, i.e., about 250 sampling trips, in a season of 135 days, with an average of 1.54 licensed fishermen per trip.

In summary, management of this amateur fishery on the basis of catch and fishing effort analysis is difficult because of the nature of the data available from the research monitoring programme. Of primary concern are changes in catches and catch rates both over the years and between localities, at least between the large dams and rivers.

In section II, these comparisons are confined to the catches, fishing efforts, and catch rates of logbook fishermen on a trip basis. In section III, the mean number of legal-sized marron caught per trip by a logbook fishermen is compared to the bag limit. In section IV refined estimates of trip fishing effort by logbook fishermen are arrived at by considering the different methods of capture of marron in dams and rivers. In section V, the catches of logbook fishermen (known to be higher than those of the average fishermen) are taken as estimates of the (relative) abundance of stocks of marron by calculating catch rates based on the refined estimates of trip fishing effort for dams and rivers, derived in section IV. In section VI, total fishing effort by all marronners in the state each year is calculated from licence returns and from the results of telephone surveys,, i.e. independently of the biased log data. In section VII, rainfall and resulting water conditions over the years are presented and discussed in section VIII, as an environmental factor possibly influencing marron stocks. Finally, in section IX the estimates of (relative) abundance of marron stocks in dams and rivers over the years (section V) are related to those of total fishing effort (section VI) and to water conditions (section VII) to arrive at a picture of the state of the fishery.

II TRIP CATCH AND EFFORT FROM LOGBOOKS

Mean values per fisherman per trip were computed for catch weight of legal-sized marron, fishing effort per fisherman per trip, and hence, catch rate or catch per unit of effort (cpue). Fishing effort was calculated as length of bank or shoreline fished (km) x hours fished x number of 'effective' nets ÷ number of licensed fishermen in the trip party. One 'effective' net equalled one scoop net, or six drop nets, or one snare (Morrissy 1978a).

For all fishing waters combined, the catch per trip per fisherman showed a slight downward trend, effort per trip per fisherman a marked increase and cpue a marked decline after the 1977-78 season (Fig. 1). A similar decline in cpue was apparent for both dams and rivers (Fig. 2).

For dams, Wellington Dam was the most popular fishing water (65.5% of trips) and for rivers, the Warren River (22.7%).

For Wellington Dam, the catch levels at the beginning and end of the period were similar at about 3.25 kg/fisherman/trip. Changes in cpue between years, as well as a general decline over the period, can be compared with opposite yearly changes, and a general upward trend, in fishing effort per trip (Fig. 3). However, as noted previously (Morrissy 1978a), there was a marked change in trip effort commencing in the 1974-75 season, most noticeable in the 1975-76 season and the new fishing pattern continued until the end of the period. Distance fished in Wellington Dam (length of shoreline baited) doubled, or trebled, and fishing time decreased. Fishing strategy changed from several passes with a scoop net over less than a kilometre of bank to one or two passes over up to two kilometres of bank. This represented an unmeasured increase in efficiency since catch rate declines with successive passes with a scoop net over the baits in the daily post- sunset fishing period. That is one (the first) pass with a scoop net over 1 500 m of baited shoreline represents a greater fishing effort than three consecutive passes over 500 m of baits.

For the Warren River, the catch oscillated with increasing amplitude around 3.25 kg per trip per fisherman, c.f. Wellington Dam, and then declined (Fig. 4). Trip effort increased until this decline commenced and then tended to decline too. However, cpue showed a pronounced decline over the whole period. The increase in trip effort was due to both increased fishing time and distance fished (changes in positions of drop nets after one or two hauls).

The trends in these catches and catch rates, given as weights of marron, were based upon records of the sizes of marron in logbooks up to the 1975-76 season. Later in order to maintain the co-operation of logbook fishermen it was necessary to discontinue the request for them to record individual sizes of marron. Mean weights of 265 g for rivers, 219 g for dams, and 243 g for tributaries from the previous five seasons were employed (Morrissy 1978a), to calculate catch weights from the numbers recorded in logbooks.

The above trends are examined more closely in a subsequent section employing estimates of relative abundance (cpue) based upon numbers of marron and different units of effort for scoop netting in dams and drop netting in rivers.

III CATCH NUMBER PER TRIP

A major concern for the fishery is the continuing capacity of stocks to provide a worthwhile number of legal-sized marron per trip per fisherman. With a bag limit of 30 per day in force, the mean catch during the 1973-76 period was 13 marron and somewhat lower in the 1977-80 period (Table 1). This bag limit was not exerting any significant control on fishing catches, since less than 5% of trips yielded 30, or more, marron; however, 14-21% of trips yielded 20, or more, marron. Subsequently, the bag limit was reduced to 20, commencing in the 1980-81 season. This reduction cannot be expected to improve the mean catch statistics in the short term, even though the 'extra' marron available to the fishermen catching below the bag limit may improve individual catches, by one or two marron. The 'extra' marron are those returned by fishermen attaining the reduced bag limit, or not subsequently caught by these fishermen due to this restriction on a trip. These marron may be captured on a subsequent trip, die, or survive to increase the breeding stock. In the latter case, if the size of the breeding stock has been limiting the production of catchable stock in two, or more, years time, a reduced bag limit may be beneficial in the longer term. In the short term, since only a proportion of the 'extra' marron are captured, the mean catch per day per fisherman can be expected to decrease somewhat (Table 1).

TABLE 1. Statistics of the frequency distributions for the number of legal-sized marron taken per trip per logbook fisherman.

	Bag Limit	No. of logbooks	Mean arithmetic geometric	Mode (% frequency)	Median, arithmetic	Proportion (%) of Catches ≥20		≥30
1973-76	30	90	13.3 9.8	9 (10.8)	11.9	21.2		4.7
1977-78	30	56	11.4 7.6	1 (15.4)	9.8	18.3		2.5
1978-79	30	55	11.9 8.3	3 (15.9)	10.5	14.0	17.6	5.2
1979-80	30	50	11.7 8.4	3 (14.8)	9.7	17.9		4.9
1980-81	20	44	10.7 7.2	1 (14.8)	9.9	15.5		-
1981-82	20	40	11.9 8.2	20 (19.0)	9.4	21.4	17.7	-
1982-83	20	44	10.0 7.1	20 (16.3)	8.7	16.3		-

Characteristic of amateur, as opposed to commercial, fisheries is a wide disparity in fishing success (Fig. 5); the majority of amateurs continue to participate for intangible reasons despite a very low catch number per trip. Moreover, these logbook catches were mainly made by country residents who were more successful than metro residents. The latter carried out only 12% of the trips recorded in logbooks from 1977 to 1983, while this value was 46% for the population at large (from telephone surveys). Despite this bias in logbook catches the catch frequency distributions for the logbook fishermen showed a statistically normal response for a population (Morrissy 1978a), truncated at zero and by the bag limit.

As indicated previously, logbook fishermen were unlikely to be representative of licensed marronners at large, i.e., their catches would be higher because of more years of fishing experience, mostly country residence, and other factors. Estimates of the proportion of trips where no legal-sized marron were taken were very much lower for logbook fishermen than for marronners in general, based upon the telephone surveys (Table 2). The telephone survey was unable to record any other estimate of catch rate, enabling projected total annual catch for the fishery to be derived from logbook estimates, by correcting for bias. However, the logbook catch rates can be taken as good indices of the state of marron stocks, i.e., as estimates of relative abundance, and the remainder of this report examines this aspect.

Table 2. Proportion of trips in which no legal-sized marron were taken

	Logbooks	Telephone survey
1973-76	2.1	-
1977-78	8.0	15.1
1978-79	4.1	27.3
1979-80	2.9	17.0
1980-81	0.7	24.1
1981-82	2.6	17.0
1982-83	6.3	18.5

IV UNITS OF FISHING EFFORT FOR ESTIMATES OF RELATIVE ABUNDANCE

Estimates of the relative abundance of legal-sized marron were based upon numbers and different units of fishing effort for dams and rivers, utilizing only scoop net trip data for dams and drop net data for rivers. For the units of effort, research sampling has shown that catch numbers of legal-sized marron tend to be the same by each of the (three) fishing methods with the following effort specifications. The number of baits laid for scooping or snaring or the number of baited drop nets set, must be the same, the bait spacing along the shoreline must be the same, i.e., over the same length of shoreline, in the same locality, and the bait setting time (sunset) and number of passes over baits or hauls of drop nets, i.e. fishing time, must be the same. The three methods of capture differ inherently in size selectivity, markedly affecting catch numbers of undersized marron (Morrissy 1978a).

In practice, this equality of effort, specified above, can be markedly influenced by weather and water conditions (underwater visibility) and the type of locality (shallow shorelines or steep banks). In the fishery, too, the number and spacing of baits for scooping in dams and netting in rivers is markedly different. Each drop net represents one bait and the six nets used by a fisherman are set well-separated, by virtue of habitat heterogeneity in rivers, so that the baits are not competing for marron (Morrissy 1975). In this case, catch number is related to bait (net) number and is independent of distance of bank fished. However, the single scoop net used in a dam by a fisherman is passed over many more than six baits, which are usually closely spaced along a uniform shoreline. Here, adjacent baits are competing for marron, and catch number is independent of bait number but related to distance of shoreline fished.

For rivers, relative abundance was calculated from the logbook trip data as the catch number of legal-sized marron divided by the number of drop nets and fishing time (hours). For dams, the catch number from scoop netting was divided by distance and time fished, with distance in metres divided by ten to represent an arbitrary number of non-competing baits.

V RELATIVE ABUNDANCE IN DAMS AND RIVERS

Unlike the previous values of cpue, estimates of relative abundance for 'all dams' and 'all rivers' displayed a significant negative linear trend from the start of the period (Fig. 6). This trend, to various degrees, was a feature of the time series of relative abundance for individual fishing waters, detailed below. The cause of this trend, whether due to increasing total fishing effort or associated with the long drought over the period, or both, is a major preoccupation of the remainder of this report. In this section the statistical significance of the trend is given to the end of the 1981-82 season since the values for the 1982-83 season appeared to represent a change in the trend (Fig. 6). The significance of the latter change is examined later in relation to effort and river conditions.

The annual pattern of the general decline in relative abundance in dams was closely paralleled by that for Wellington Dam, which supplied most of the logbook data for dams (Fig. 7). However, that for the Warren River differed markedly from the pattern for all rivers, indicating differences between rivers (Fig. 7).

North of Wellington Dam, the five other major marronning dams, fed by small streams on the forested western escarpment, showed, collectively, a decline which was not statistically significant (Fig. 8, (2)). On the south coast, the short, Shannon, Deep and Gardner Rivers in State Forest and, further to the east, the Kent River system also showed no significant trend (Fig. 8 (1) and (3)). However, the short Donnelly River just west of the Warren River, showed a significant decline until the 1980-81 season but then a marked upturn (Fig. 8, (4)). Of the major rivers, extending inland through State Forest to the agricultural crop and grazing areas, the Frankland River did not show a significant trend but the level of abundance was low, compared to that of other major rivers, at the start of the period (Fig. 8,(5)). However, the other major rivers, the Murray River and the Blackwood River both showed significant declines, similar to that of the Warren River (Fig. 8, (6) and (7)).

In summary, a significant long-term decline, or low, relative abundance appeared to occur in all the major river systems, including the Collie River (Wellington Dam), but was not evident, or significantly so, in shorter river systems. The Donnelly River was anomalous in this regard. There was some indication of a reversal of the trend by the 1981-82 season.

Interesting generalizations can be derived from the estimates of relative abundance. The abundance of marron in dams per length of shoreline or bank was much less than in rivers, at least, early in the period, and there seemed to be no relationship between size of river, i.e., pools, and abundance. Carrying capacity appears to be related to shoreline or banks, rather than pool or dam area. In rivers, the amount of cover, as logs, rocks, etc., for daytime refuge from predators is very much greater than in dams (Morrissy 1978a). Despite this difference between dams and rivers in abundance of marron, equivalent catches per trip can be taken because of the greater fishing power of a scoop net, using many baits laid over a long length of shoreline, compared with six drop nets.

VI TOTAL ANNUAL FISHING EFFORT

While logbook trip data provided useful information on the (relative) abundance of stocks, both catch and fishing effort values from this source were biased and, therefore, unsuitable for extrapolation to give total annual catch and fishing effort. However, realistic estimates of total annual fishing effort could be derived separately from the total number of marronners each season, calculated from licence records, (i) and (ii) below, and the mean number of fishing trips carried out each year, could be calculated from the results of telephone surveys, (iii) below.

(i) Number of licensed inland fishermen

The number of licences issued for each financial year was estimated from revenue received by State Treasury. The proportion of free licences for students (≯ 13 years old), pensioners and others, was estimated from a large sample (≈ 500) of licence duplicates. This factor showed no significant change until a fee increase in the 1980-81 season, when it increased from a previous mean level of 11.3%, to 20.3% in 1981-82 and 16.8% in 1982-83. The number of annual licences (Table 3) was estimated by dividing the revenue value by the licence fee and, then, by applying a correction for free licences.

TABLE 3. Number of Inland Fisherman's licences, the proportion of licensed marronners*, both total and practising (≥ 1 trips), and the number of logbooks.

	Licences	Marronners (%) of total licences			Logbooks
		Total	≥1 trips	Zero trips	
1970-71[a]	6 862				-
71-72	9 582				47
72-73	10 151				36
73-74	14 485				32
74-75[b]	21 119				24
75-76	19 329				34
76-77	22 226				-
77-78	20 270	96.7	74.8	21.9	56
78-79	21 631	96.9	52.3	44.6	55
79-80	15 686	91.7	63.3	28.4	50
80-81[cd]	17 052	93.3	64.3	29.0	44
81-82[e]	19 677	87.5	72.2	15.3	40
82-83	23 710	89.7	73.4	16.3	44

* Estimated from telephone surveys, see text.

a Introduction of separate inland licensing.

b Use of boats banned.

c Fee raised from $2 to $5.

d Bag limit reduced from 30 to 20 per day.

e Fee raised from $5 to $6.

(ii) Number of marronners

Since current Inland Fisherman's Licence is a multi-species one, it has been necessary to estimate, by some independent method, the proportion of licences held by marronners. Marronners may be defined as the (large) proportion of people who purchased a licence with the intention of pursuing marron but not necessarily doing so, or the lesser proportion of people who carried out at least one marronning trip during a season.

Questionnaires attached to the licence application, for recording either the species intention or the number of marronning trips carried out in the previous season, gave poor data and were abandoned in favour of an end-of-season telephone survey. For the latter, the ordering of stored licence duplicates, alphabetically by surname, was taken to be random and one in every five duplicates was extracted systematically for contact. About 1% of these represented interstate tourists and were not pursued further. The proportion of Perth metropolitan residents in the total licences sampled averaged only 42.8% from 1977 and 1983, despite the residence of a high proportion (69%) of the southwest population in Perth. However, this lower metro representation was reversed in the telephone directory listing to 59.0%, because of the lower usage of telephones in the country, and remained at a similar level of 60.0% for the proportion of people listed actually contacted. This change in representation was an important source of bias, requiring correction, since the fishing efforts and catches of metro and country dwellers differed markedly. Estimates of marronners, as defined previously and corrected for the above bias, are shown in Table 3.

These statistics do not include a large category of legal, but unlicensed, marronners represented by children under the age of 13 years who may fish when accompanied by a licensed adult. Of licensed marronners ($\geq$ 1 trips) contacted after the 1982-83 season, 33.6% had been accompanied by children who fished - a mean of 1.5 children per adult - and these children, therefore, were equivalent in number to 50.4% of the number of licensed marronners who fished. Although the fishing efforts of these children are probably not equivalent to those of adults, their presence may be used to justify the use of extra nets and marron to be taken in excess of the legal entitlement of the licensed fishermen present.

The total number of inland fisherman's licences reached a peak of about 20 000 in the mid-Seventies, and then declined the (Table 3). This decline in licence purchase accompanied a major drought (section VII). In the 1977-78 season about 97% of licences were purchased with the intention of marronning but only 75% of licencees actually went fishing ($\geq$ 1 trip), i.e. 22% of marronners did not fish. Subsequently the reaction of fishermen to the effects of the drought, on river and dam conditions and catches, was reflected in changes in these values

(Table 3). Other results of the telephone surveys showed that metropolitan residents were slower, by about one season, to react to either deteriorating or improving fishing conditions. Marronners with more years of experience of fishing also reacted more strongly, by not purchasing licences as the drought worsened (Table 4).

(iii) Effort estimates

Telephone surveys provided further estimates (corrected for metro/country contact bias), for the mean number of trips per season per licensed marronner (carrying out one or more trips), and the proportion of these trips to rivers and dams (Table 5). (Corresponding logbook values were considerably biased - up to twice as many trips per season and near equal partitioning between rivers and dams). From the annual estimates for total licences and the proportion of marronners ($\geq$ 1 trips) (Table 3), the estimates in Table 5 were used to calculate the total number of trips carried out in rivers and dams, respectively (Fig. 9). For the years preceding the telephone surveys, the following values were assumed; for the proportion of marronners - 75% (the 1977-78 season value); for the mean number of trips per season - logbook values reduced by a correction factor of 0.575, based upon the mean of later logbook/ telephone annual ratios; and for partitioning of trips between rivers and dams - a ratio of 7:3, a mean again of later values.

Most of the increase in total effort during the first half of the Seventies was due to increased licensing while the later changes were closely associated with the influence of drought conditions (previous section). It is assumed that the increase in licenses from the 1970-71 season, when a specific inland licence was introduced, was a true registration of fishermen and not a slow appreciation of the legal necessity of licensing by a constant body of fishermen over these years. Large increases occurred in licensing for other water sports over the same period, supporting this assumption (Morrissy 1978a).

It was not possible to enlarge these estimates of total effort further by inclusion of fishing effort within trips, i.e., distance and time fished, etc., since the telephone surveys would not yield reliable data by recall and the logbook estimates were likely to be biased.

Table 4. Telephone surveys: Mean number of years of previous experience in fishing for marron.

	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83
Metro	9.3	8.3	7.1	6.6	7.6	8.7
Country	15.4	13.8	9.5	8.7	11.8	13.8

TABLE 5.

Fishing effort from telephone surveys: Number of trips is based upon a licence holder carrying out one or more trips per season. Estimates are corrected for bias in the contact sample with respect to metro and country residence.

		1977-78	1978-79	1979-80	1980-81	1981-82	1982-83
Mean number of trips/season/ marronner		3.71	3.81	2.96	4.24	3.13	2.91
% of trips to	Rivers	80.7	75.0	66.5	64.6	74.2	64.3
	Public dams	19.3	25.0	33.5	35.4	25.8	35.7

VII RAINFALL

Rainfall over the southwest was examined as an obvious environmental factor likely to influence marron abundance and fishing success through its effect on water conditions, particularly in view of the severe drought during the period. Annual rainfalls for six places embracing the fishery, i.e., Perth, Albany, Collie, Pemberton, Dwellingup and Cape Leeuwin, were expressed as proportions of the long-term mean annual rainfall for each place and finally, as a single mean proportion representing an annual value for the southwest. From, and including 1968, there were only five years, all before 1975, when the annual rainfall exceeded the long-term mean (Fig. 10). The drought has been taken to commence after the low winter rainfall of 1975, since dam storages then fell to low levels for a number of years. All the major dams are understored and are dependent upon, at least, average winter rainfall for complete filling and overflow, following heavy summer drawdown for irrigation water. Wellington Dam filled in early January 1982 following a heavy summer rainfall on the inland agricultural areas, but the other dams, on shorter rivers, did not fill until the winter of 1983.

While deteriorating riverine and dam conditions were evident as a result of the recognized drought after 1975, and catch and effort estimates reflected these conditions, the longer term trends in relative abundance indicated a possible earlier influence. In particular, the above average rainfalls of the early half of the Seventies may not have compensated for the extremely dry years of 1969 and 1972. Short and long term influences of water conditions on marron stocks are discussed later.

To examine this possible longer term factor for rainfall, a cumulative rainfall index (C.R.I.) was calculated. From 1968, the successive annual departures (±) from the long term mean annual rainfall, averaged, as before, over six places in the southwest, were progressively summed. C.R.I. can be calculated as a percentage, or absolute (mm) value. The time series for C.R.I. from 1968 showed a highly significant decline over this period (Fig. 11). Since these values of C.R.I. depend upon the arbitrary starting year of 1968, greater perspective on this recent rainfall pattern can be seen from the long-term records, e.g. for Perth (Fig. 12). The C.R.I. time series for Perth appears to indicate that the southwest has benefited from a rainfall surplus since the late Twenties, but that this surplus was rapidly eroded during the Seventies.

VIII EFFECT OF DROUGHT ON MARRON STOCKS AND FISHING

From the foregoing description of drought, an explanation for the changes in the apparent abundance of stocks of legal-sized marron over the period 1971-83, and in future years, should be sought in the effects of an environmental factor as well as in changes in total fishing effort.

Marron are a crayfish ecotype characteristic of well-oxygenated, nutrient-poor, i.e. non-eutrophied, rivers (Morrissy 1984). Catchability of marron using a bait response is dependent on feeding activity, influenced unfavourably by stagnant, or low flow conditions at the height of summer. High water temperatures, approaching lethal levels, may be experienced at this time in shallow water close to shoreline in large dams. Deeper water in river pools becomes deoxygenated at low or zero, flows due to temperature stratification with depth (Morrissy 1978b). Logbook records show that catches are higher in the period from mid-December to the end of January and in late March to the end of April than in the intervening period of highest temperatures and lowest flows. Catch rate improves markedly during mid -summer at times of sudden change in river conditions caused by thunderstorms (G. Cassells, pers. comm.). Therefore, lower estimates of relative abundance may represent lower catchability and not a decline in marron stocks.

This within-season influence of (summer) drought on catchability may be extended to the longer term to, at least, partly explain the decline in (relative) abundance over the drought years in the second half of the Seventies. In this respect the major rivers, eutrophied by organic loadings from the inland agricultural areas, showed a significant decline in marron abundance in contrast to the nutrient-poor coastal streams in State forest. In the far inland reaches of the major rivers, the combination of normal zero summer flow and increasing eutrophication has resulted in a considerable contraction in the distribution of marron towards the coast (Morrissy 1978b). Near the inland limit to the present distribution along these rivers, breeding failure occurs due to poor oxygen conditions and catchability is low. One concern for the fishery, previously expressed (Morrissy 1978b), is that this unfavourable development in the major rivers may continue to encroach towards the coast. Perhaps this tendency has been exacerbated, in terms of actual decline in marron abundance, by the drought in reducing summer flow through the lower reaches. Contraction in the extent of productive fishing waters also implies increased concentration of total fishing effort.

Reduction of the distribution of a species due to this type of environmental factor is also accompanied by a decline in abundance within the distribution (Andrewartha and Birch 1954).

Whether the decline in apparent abundance is due to decreased catchability or absolute abundance of marron stocks, or both, can be inferred, to some extent, from the response to changed dam and river conditions in the early eighties.

Until the end of 1981, Wellington Dam was at a low level and had become increasingly eutrophied by inference from increasing salinity levels (Morrissy 1978b) (Fig. 13). Very heavy flooding occurred during early January 1982 on inland areas and the dam filled during the winter of 1982 after receiving considerable summer inflow. Immediately after the January inflow there was a reported improvement in catch rate. In the 1982-83 catch rates improved further, departing from the downward trend (Fig. 7), and this response has continued, reportedly, in the 1983-84 season. Salinity and nutrients, were markedly reduced by a Public Works flushing programme and winter overflow (Fig. 13).

Although the early 1982 inflow reportedly improved catch rates the estimate of relative abundance for the 1981-82 season did not depart significantly from the negative trend (Fig. 7). The 1982-83 estimate did so, but not to a level indicating a similar stock of marron to that in the early Seventies because of different levels of total fishing effort (see later). This perspective indicates that the current trend towards higher abundance started with increased survival of 0+ and 1+ year old marron after early 1982. Because of the high growth rate of marron in Wellington Dam (Morrissy 1974), these 1+ marron would be of legal size in the 1982-83 season.

The Blackwood River catchment received the brunt of the early 1982 inland rainfall and a record level of flooding occurred. As with previous such summer flooding, 'walking out' of pools by marron occurred upstream, and downstream improved catches were reported when the flood abated. However, in the following summer, mass mortalities of marron and fish occurred in downstream pools, near tidal waters, as a result of eutrophication and oxygen depletion. Research sampling in 1974 showed that marron stocks in the lower Blackwood River were poor compared with those in the lower Warren River (Morrissy 1978b).

The Donnelly River was most markedly affected of all the south-coast waters by the drought, and many upstream pools dried up each summer up to 1981. However, in this non-eutrophied river, stocks remaining in permanent downstream pools apparently maintained early abundance levels; flooding as a result of rainfall on the upper catchment during early 1982 resulted in an immediate increase in relative abundance (Fig. 8(4)). However, in this case it is likely that the total stock of marron along the river was substantially lower than earlier and that the increase in relative abundance represented an increase in catchability.

Annual flow of the Warren River followed annual rainfall at Pemberton (Fig. 14). Minimum summer flow, for February or March, showed a similar pattern to annual rainfall or flow of the previous year. However, summer flow also showed a negative trend with time (Fig. 14). The Warren River received only a mild flooding in early 1982, above average rainfall at Pemberton and annual flow in 1981 and, then, below average values in 1982 and 1983 (Fig. 14). Relative abundance showed a continuing downward trend over the last two seasons (Fig. 7).

Standardized drop net research sampling was carried out during February 1983 on the Warren River in a far downstream pool, previously sampled between April 1969 and July 1971 on eleven occasions when this area was open to public fishing. Absolute numbers of 1+ year old and older marron were estimated at 1914, compared with the range 1047 to 1947 in the 1969-71 period. Access to the pool was barred by a locked gate in 1983, unlike the previous period; probably as a consequence, the proportion of legal-sized marron in catches was 16.8% in 1983 compared with 9.4%, 4.1%, and 5.1% on three occasions in February 1970 and 1971. Taking into account the influence of water temperature variation between nights on February catches, cpue was very similar in 1970-71 and 1983. This sampling on the lower Warren River therefore could not establish whether the long-term decline in relative abundance shown by logbook catches for the river in general was due to reduced catchability or reduced marron stocks, or both factors.

IX RELATIONSHIP BETWEEN RELATIVE ABUNDANCE, TOTAL ANNUAL FISHING EFFORT (TRIPS) AND WATER CONDITIONS FOR RIVERS AND DAMS

The most probable explanation for the time series in relative abundance was illustrated by plotting abundance i.e. cpue, against total fishing effort (total trips per season) in the traditional fisheries manner. For rivers, the decline in relative abundance to the 1977-78 season was closely associated with the increase in total fishing effort (Fig. 15(a)). Through the 1978-79 and 1979-80 season, at the height of the drought, although effort declined, relative abundance fell to a lower level than previously, and remained at this level until the end of the 1982-83 season. In Figure 15(a), the 'A' line indicates the abundance/effort relationship under 'normal' water conditions and the 'B' line, under, or as a delayed consequence of, drought conditions. For dams, predominantly Wellington Dam, a similar interpretation is possible too (Fig. 15(b)). However, the relationship is more variable from year to year which may be a consequence of those marron stocks showing faster growth rates, i.e., earlier recruitment to the fishery as takeable marron and a lower mean stock age structure than those in rivers. The abundance of dam stocks declined earlier, in 1977-78, than in rivers in response to the onset of the drought but also recovered by the 1982-83 season, a response not yet shown by river stocks or expected from rainfall records.

X CONCLUSIONS

1. The amateur marron fishery is widely dispersed over the south-west of Western Australia extending from the Moore River north of Perth to small streams east of Albany. The many separate stocks occur in 4 major rivers, 29 coastal rivers, 20 tributaries, 7 large dams, 4 small dams, and 6 natural lakes.

2. Monitoring of this fishery has been carried out since the 1971-72 season by employing catch and fishing effort statistics from trips recorded in logbooks supplied to some fishermen. However, these statistics are not representative of the (poorer) fishing success and efforts of marron fishermen in general; so they cannot be extrapolated to give total annual catch and fishing effort. Instead logbook catch rates have been taken as relative estimates

of the abundance of marron stocks in different localities.

3. Annual estimates of abundance of marron stocks for localities grouped as dams or rivers showed a significant decline over the years in both groups. The particular localities within each group showing declines were the major rivers extending to the inland agricultural areas and Wellington Dam on the Collie River which also rises well inland.

4. To provide an explanation for these changes in abundance, total annual fishing effort was estimated from the numbers of licensed fishermen and fishing effort statistics (trips per season) gathered from telephone surveys. As well, the incidence of drought was examined from rainfall records as a likely environmental factor influencing marron stocks over the period. In this regard previous research on the distribution of marron along the major rivers had shown that stocks had been adversely affected upstream by eutrophication originating from the inland agricultural catchments. Drought conditions could be expected to exacerbate eutrophication and extend this unfavourable influence further downstream.

5. Changes in annual catch rates (catch per unit of fishing effort on a trip basis), as relative estimates of marron abundance, were negatively correlated with total annual fishing effort (total trips) for both rivers and dams. This correlation represented the decline in catch rate per fisherman in the early to mid Seventies, largely due to an increasing number of marronners. Subsequently, and independently of total fishing effort, relative abundance fell to a lower level during the years of drought. This change is considered to be a real decrease in abundance rather than an apparent one due to lower catchability. In rivers this situation persisted until the close of the 1982/83 season. However, in the major fishing dam, Wellington Dam, abundance was reestablished at the higher earlier level, albeit at a high level of total fishing effort, during the 1982/83 season after water level and quality reverted to former favourable levels.

XI ACKNOWLEDGEMENTS

The Department of Fisheries and Wildlife thanks all the marron fishermen who have recorded their catches in logbooks untiringly over the past years.

The first five years of the programme was carried out by a former Technical Officer, R.A. Emiliani. Credit is also due to Computer Staff, I. Lethbridge and W. Lehre under Research Officer N. Hall for computerization of the logbook data. Rainfall records were obtained from the Bureau of Meteorology, Perth and salinity values from the W.A. Government Chemical Laboratories, Perth.

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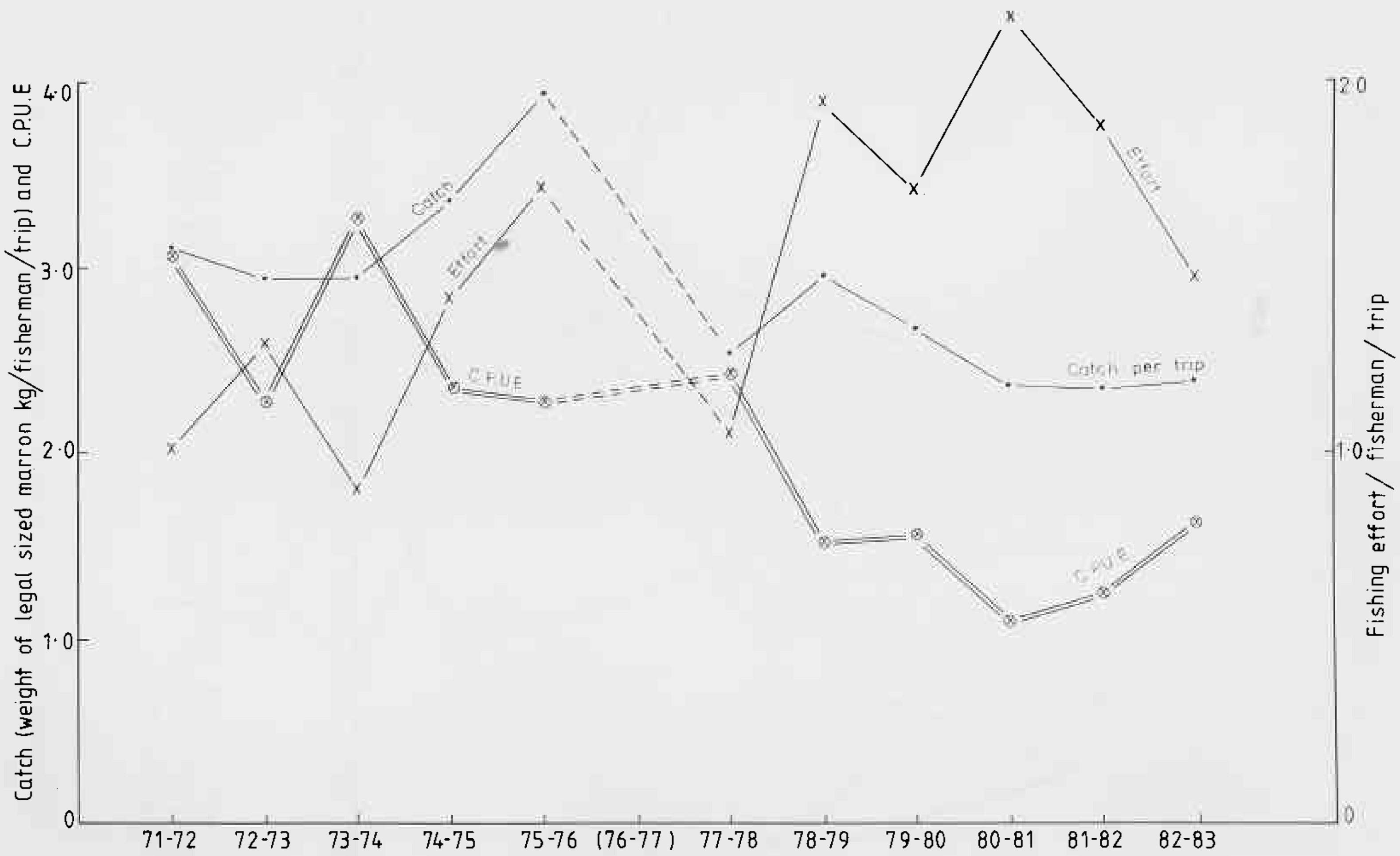


Figure 1 Mean annual logbook trip estimates for catch, effort, and catch per unit effort (cpue) for all localties and fishing methods. For effort units in Figs. 1–4, see text.

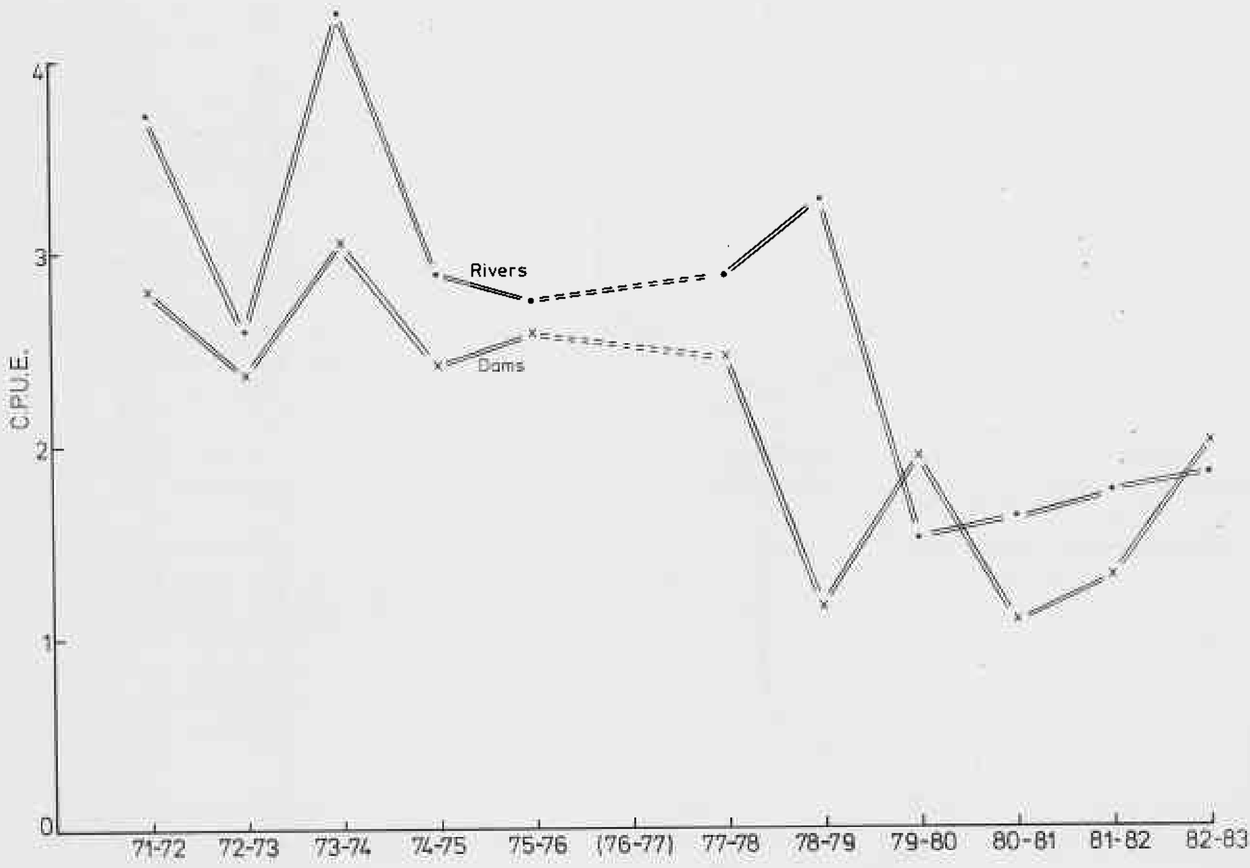


Figure 2 Mean annual logbook trip estimates for catch per unit of effort (cpue) for all dams and all rivers, respectively.

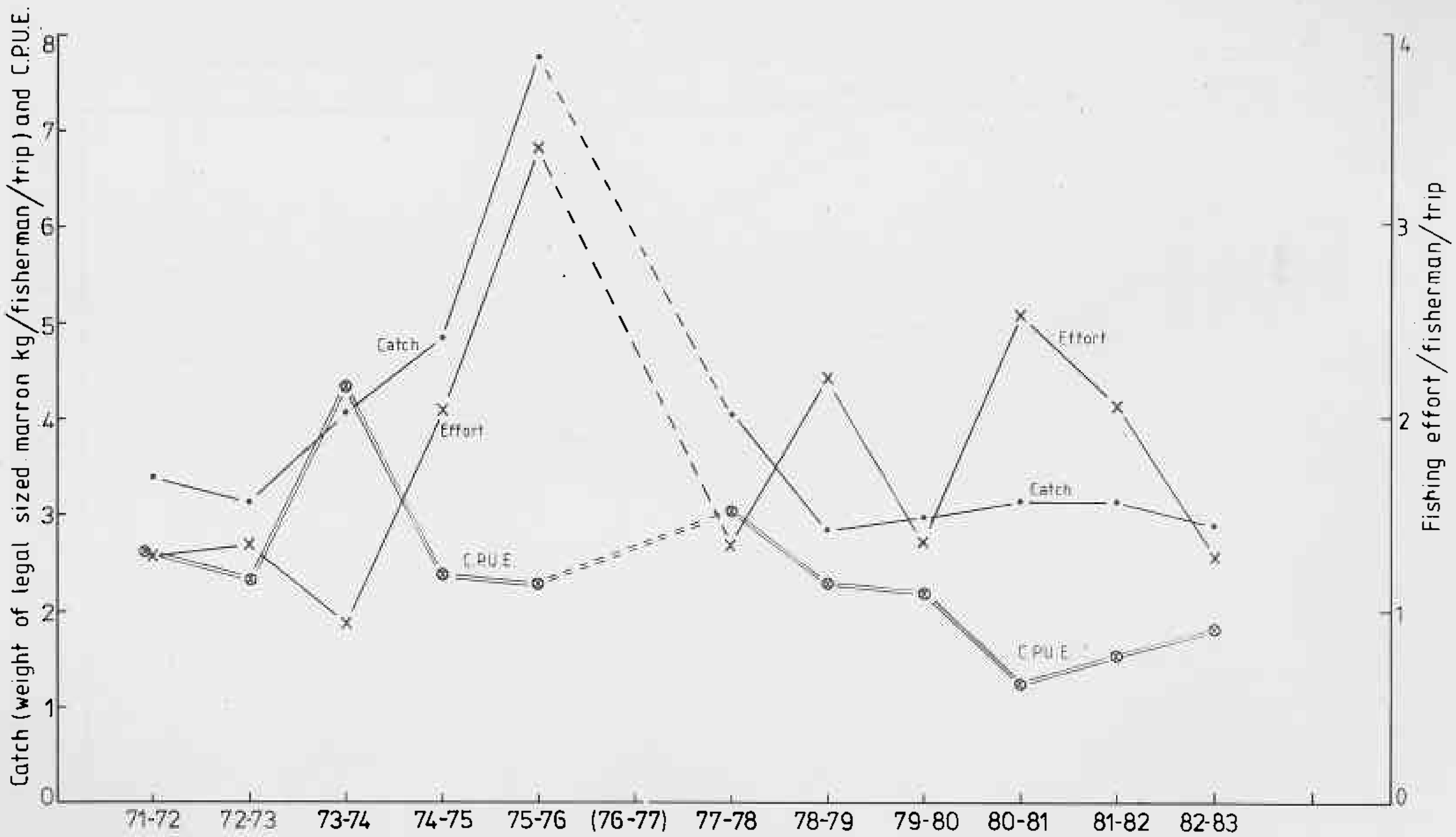


Figure 3 Logbook trip estimates for catch, effort and cpue for Wellington Dam.

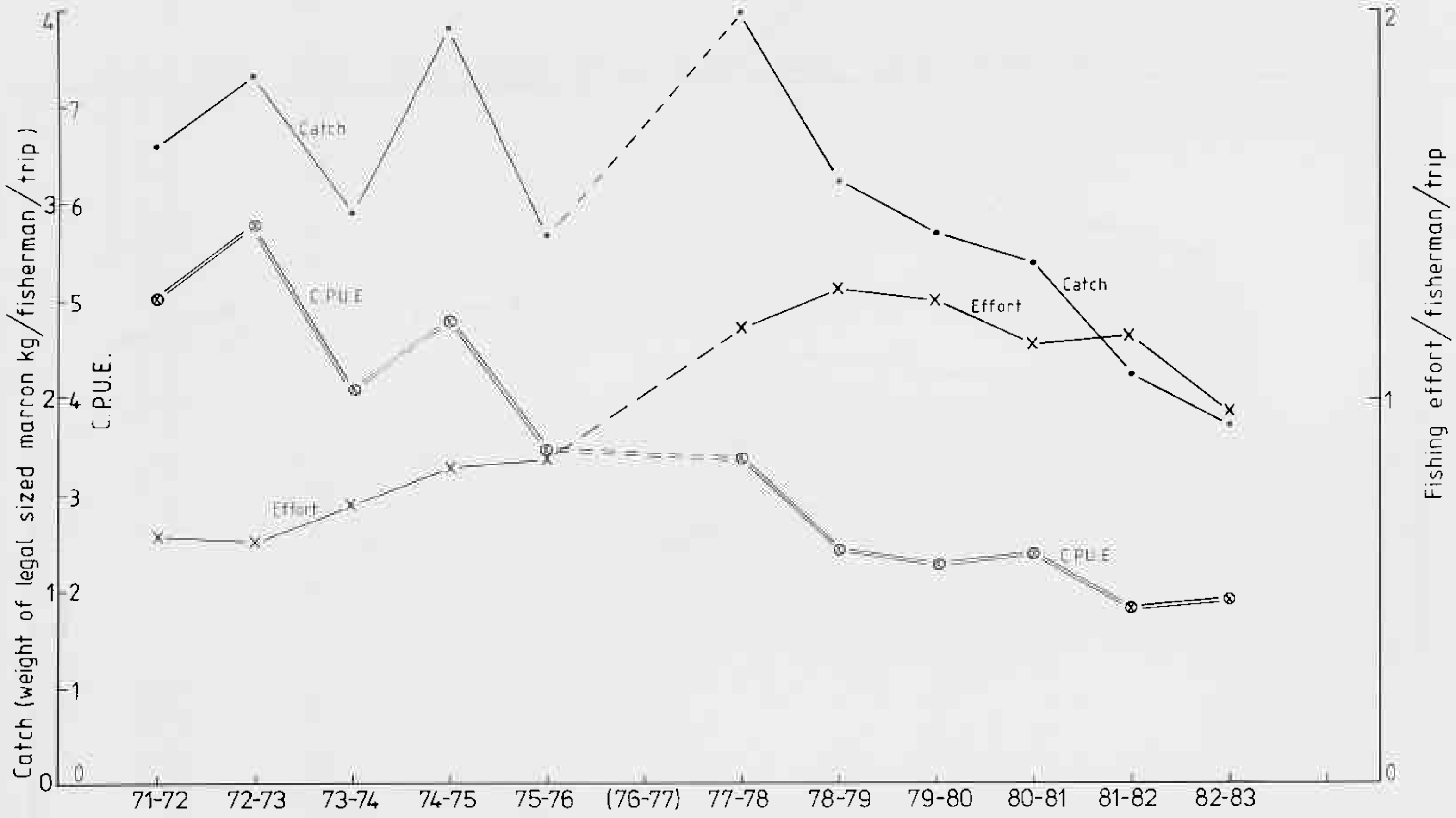


Figure 4 Logbook trip estimates for catch, effort and cpue for Warren River.

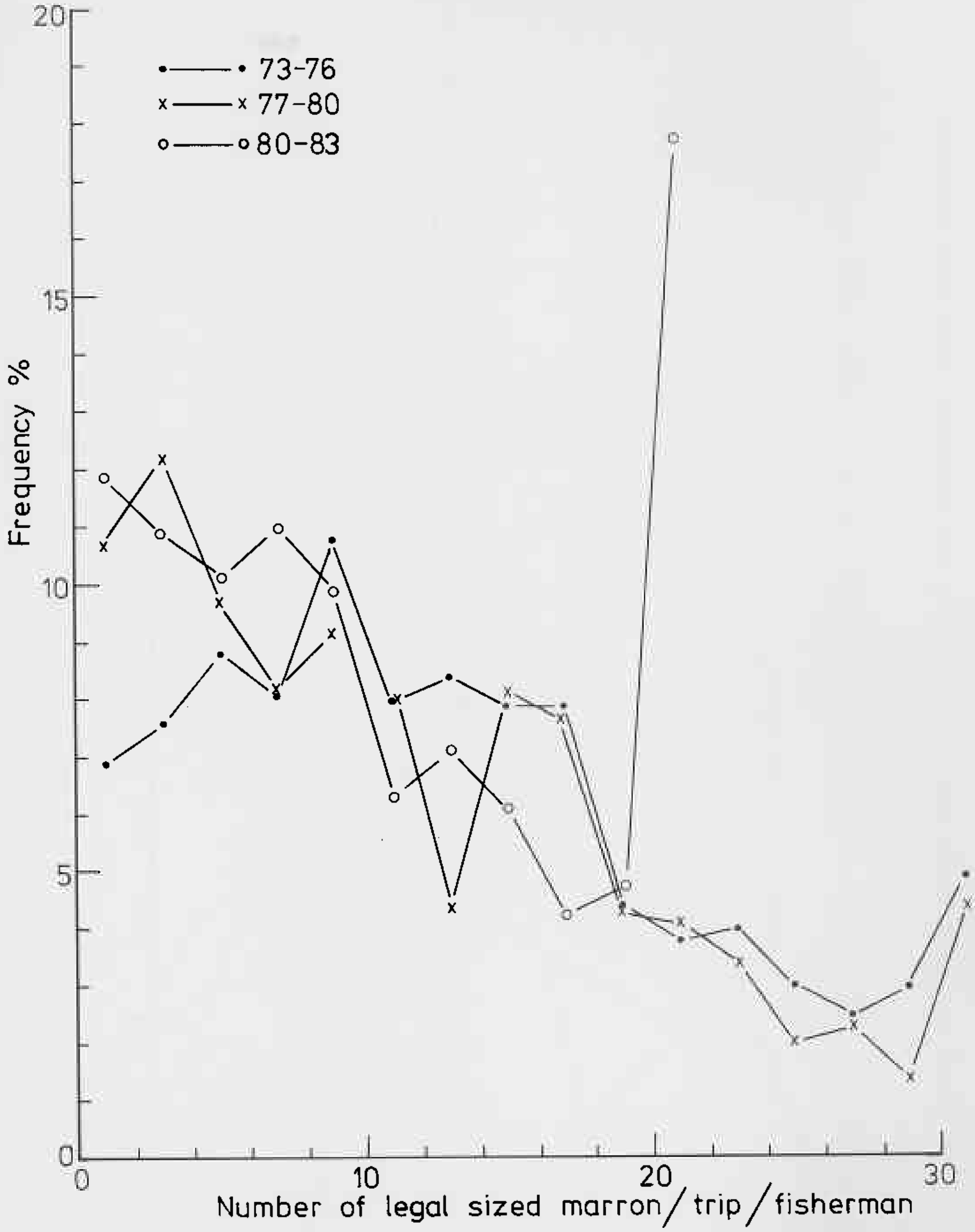


Figure 5 Frequency distributions for the number of legal-sized marron captured per trip per logbook fisherman.

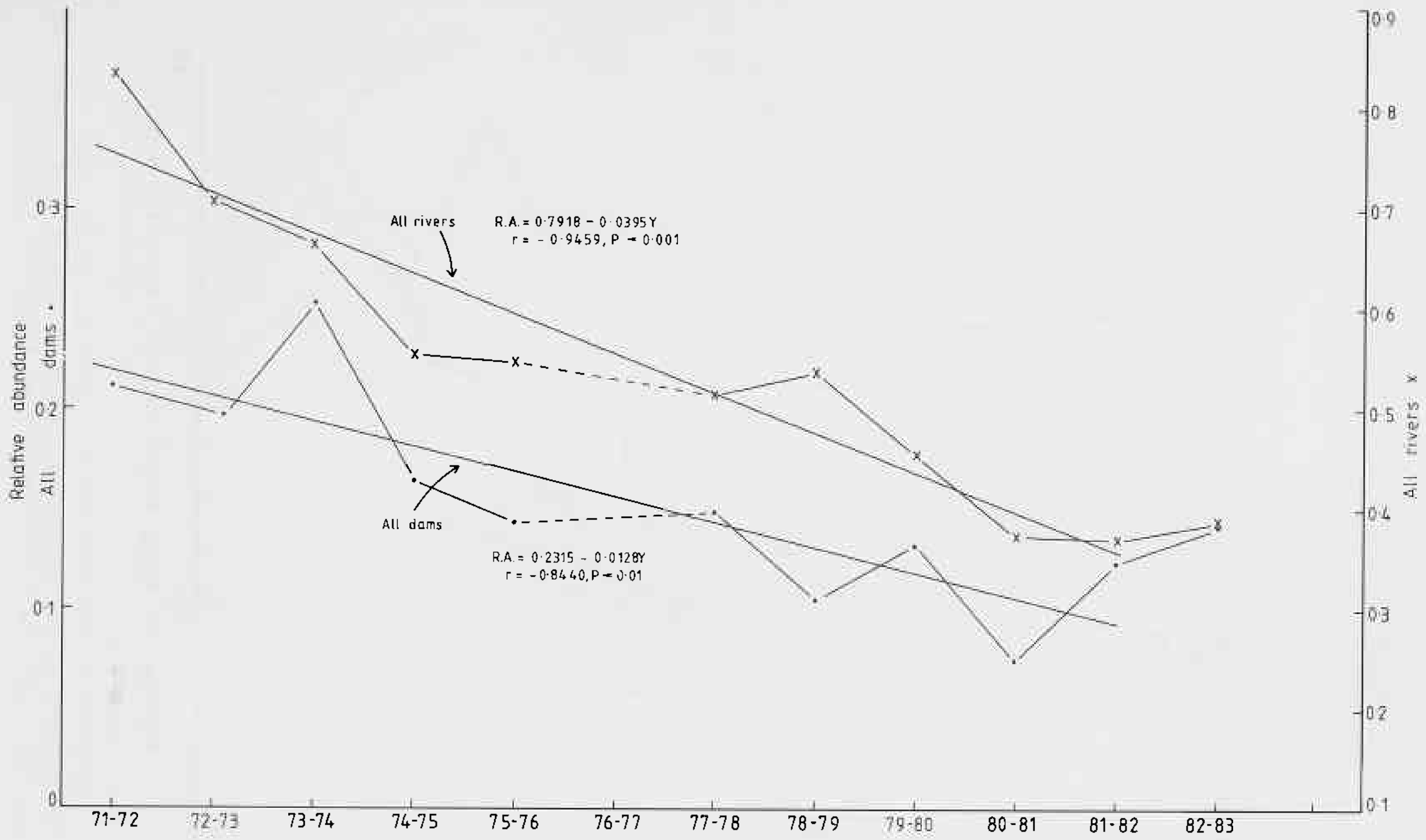


Figure 6 Relative abundance of legal-sized marron for all rivers and all dams, respectively.

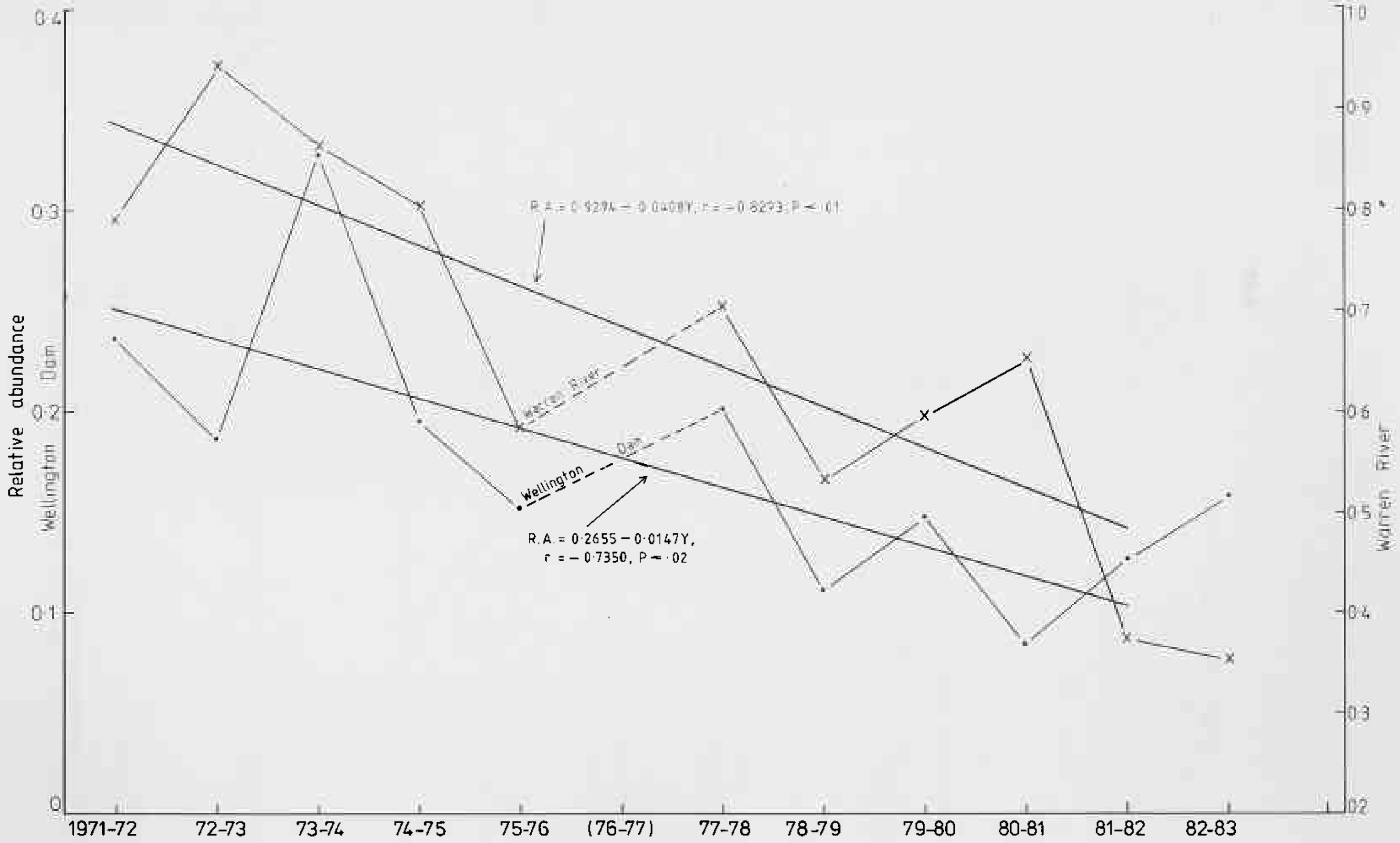


Figure 7 Relative abundance for Wellington Dam and Warren River.

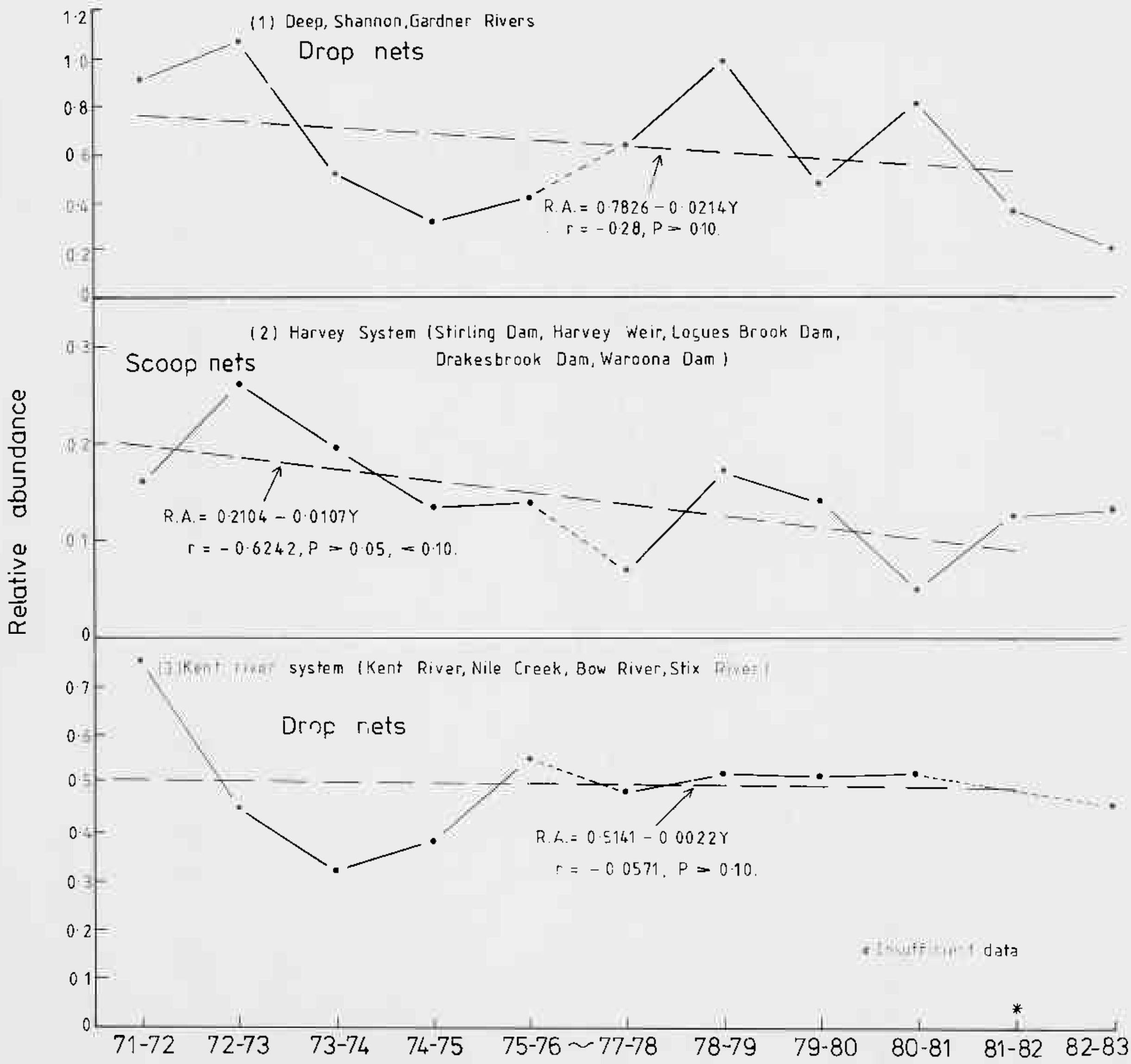


Figure 8 Trends in relative abundance for various localities.

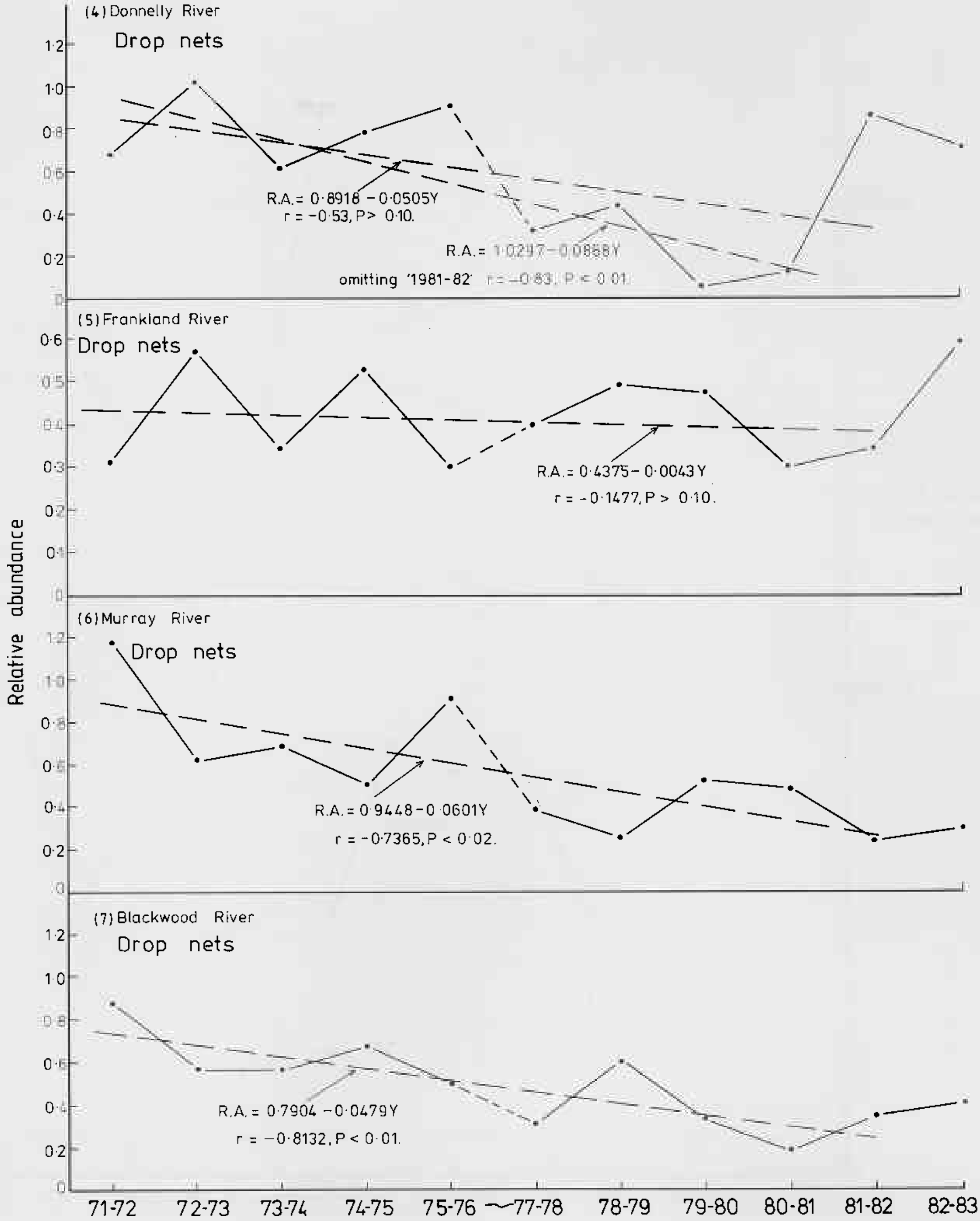


Figure 8 Trends in relative abundance for various localities.

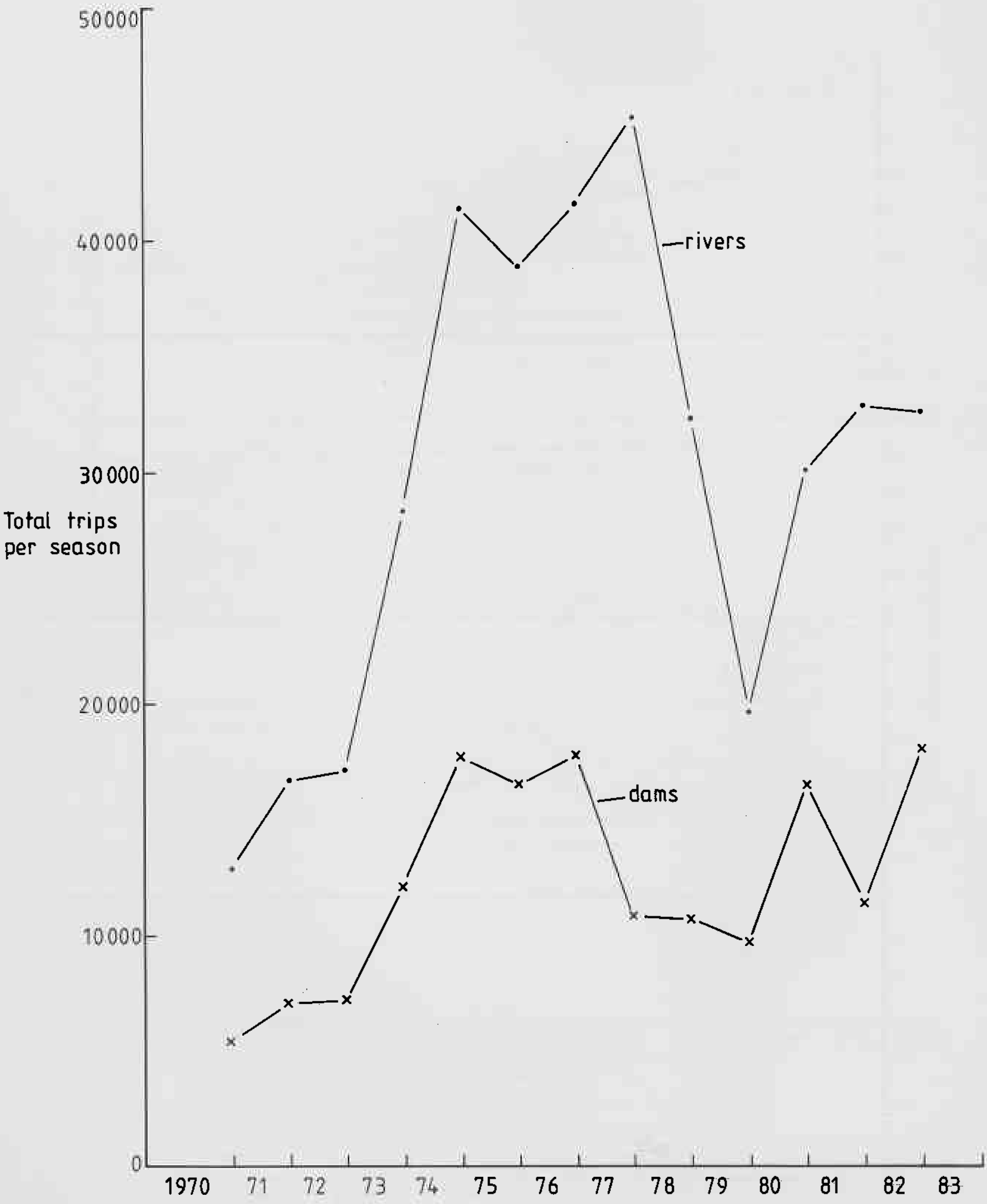


Figure 9 Total annual fishing effort (trips per season) by licensed marronners in southwest dams and rivers.

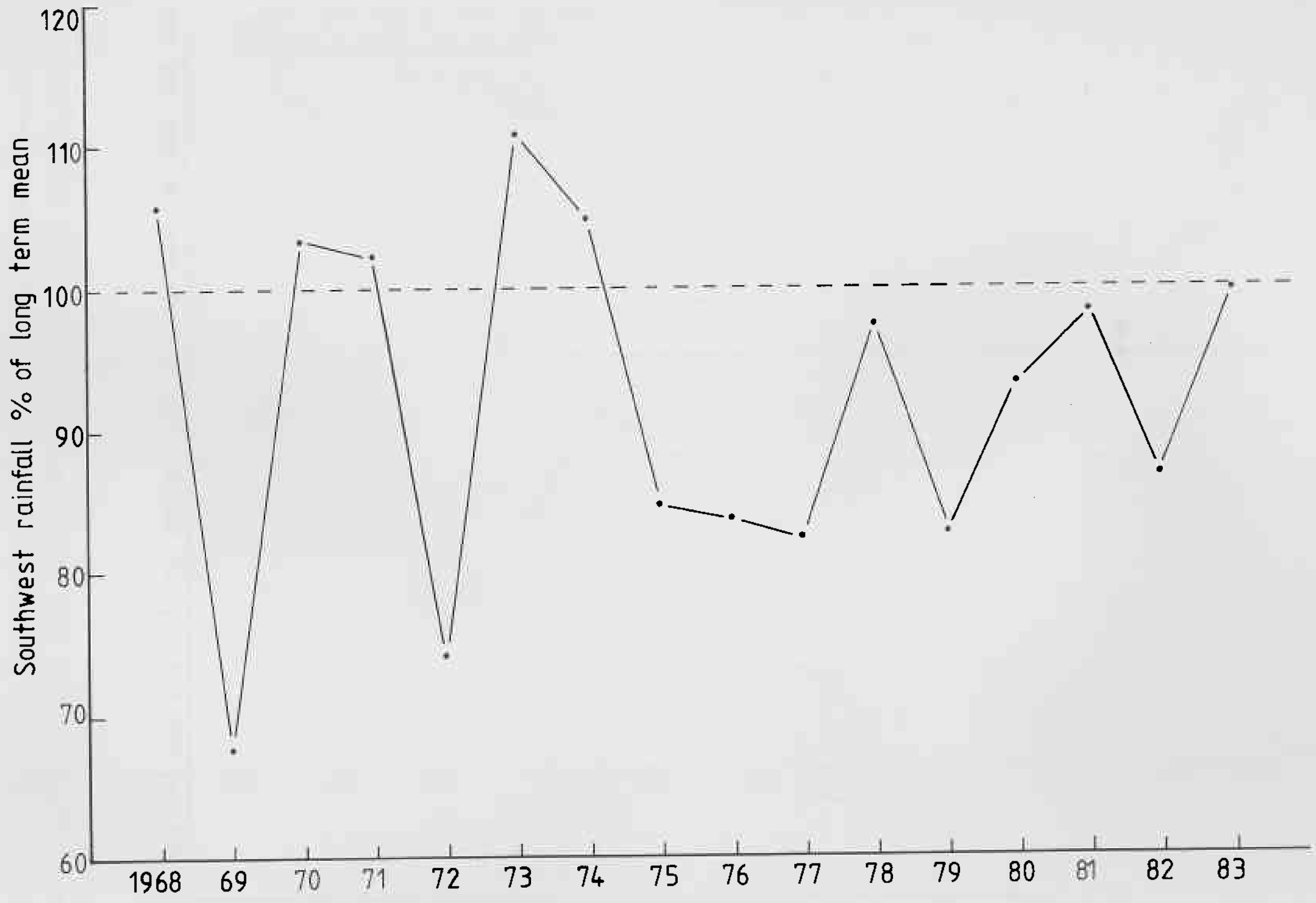


Figure 10 Annual rainfall over the southwest as a percentage of the long-term mean.

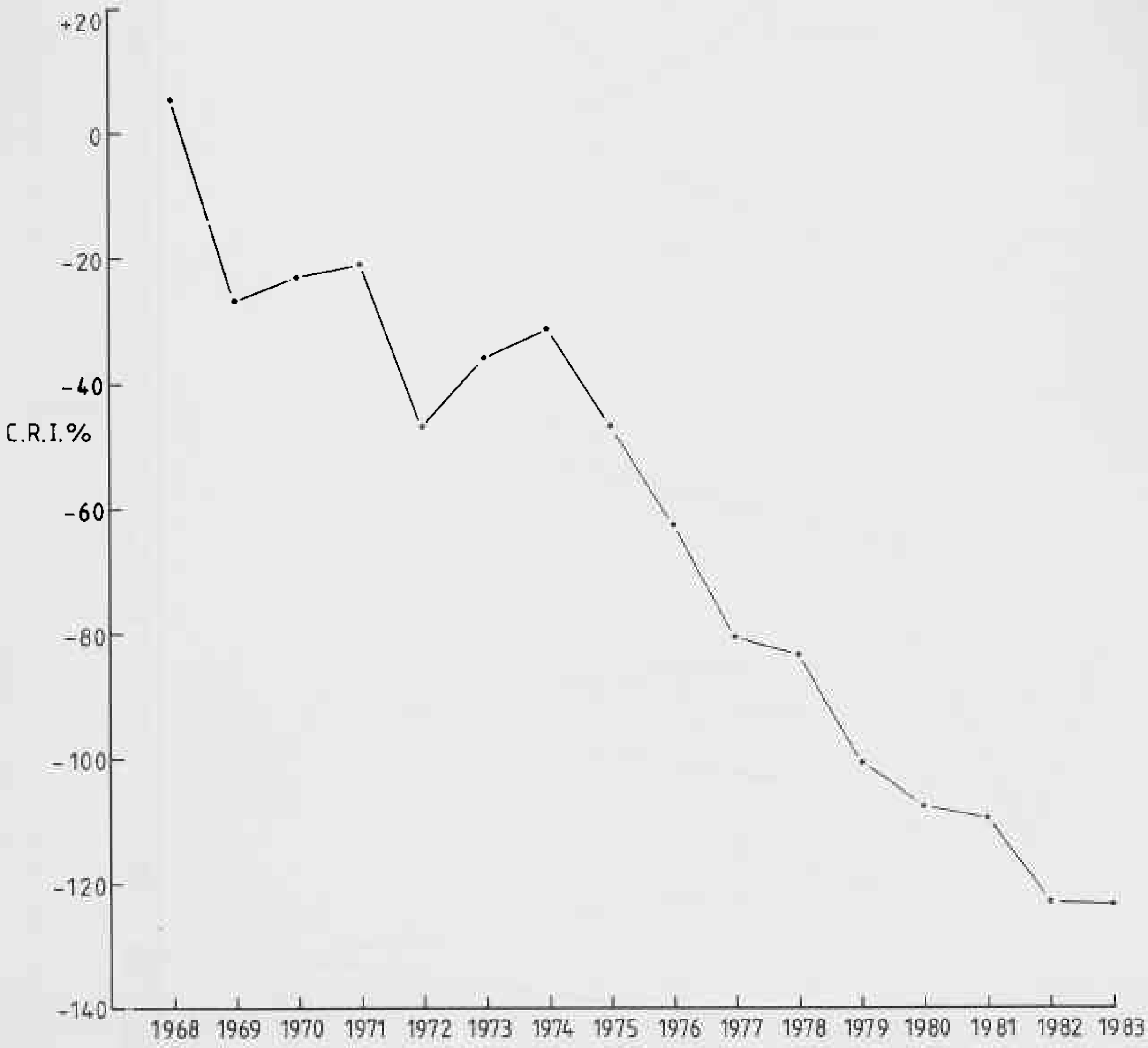


Figure 11 Time series for the Cumulative Rainfall Index (C.R.I.).

Figure 12 Cumulative Rainfall Index (C.R.I.) for Perth from 1876 to 1983. C.R.I. is calculated in absolute terms (mm) based upon the current long-term median annual rainfall of 873 mm (mean = 874 mm).

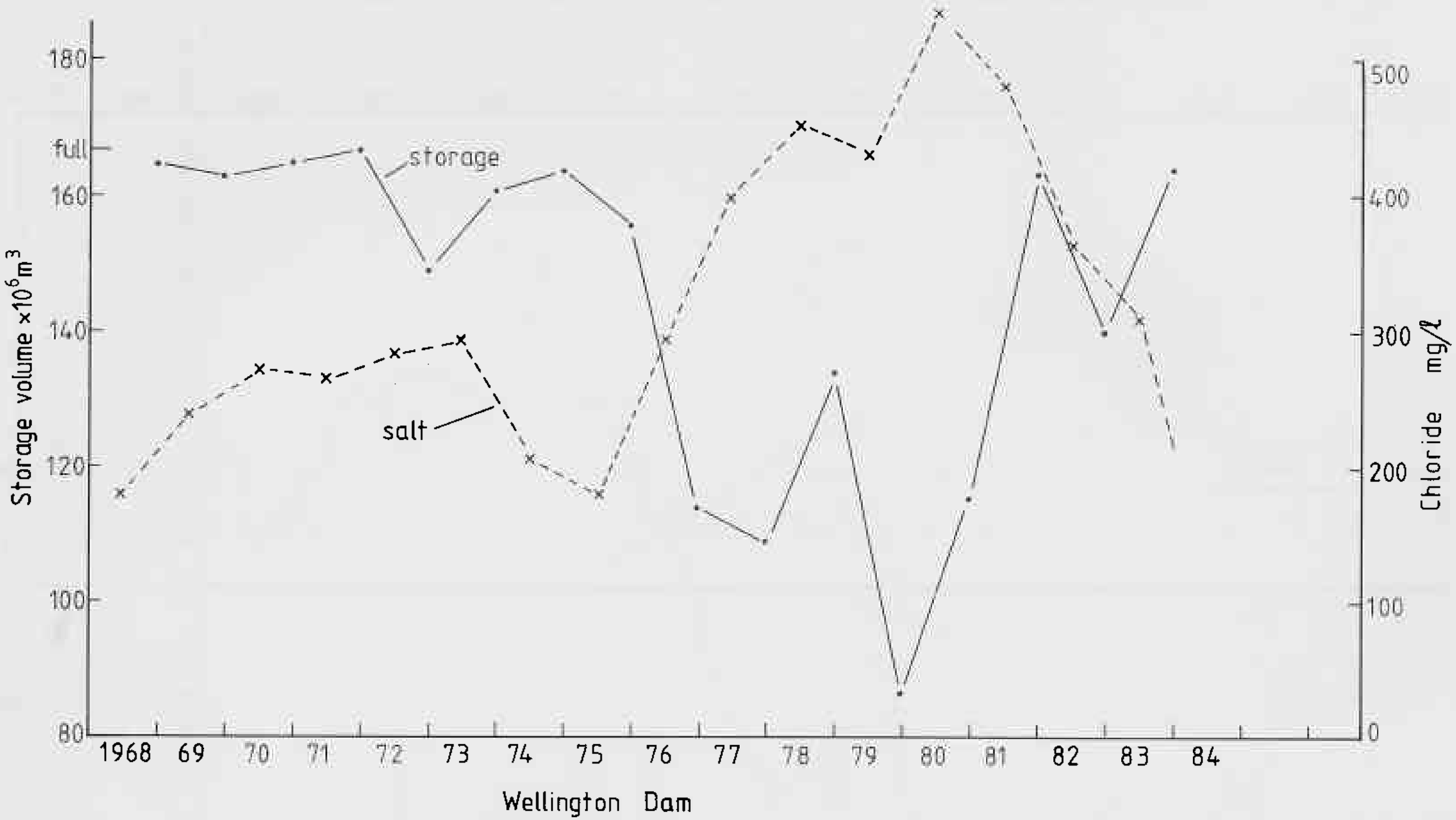


Figure 13 The storage volume in early January and the surface salinity of Wellington Dam.

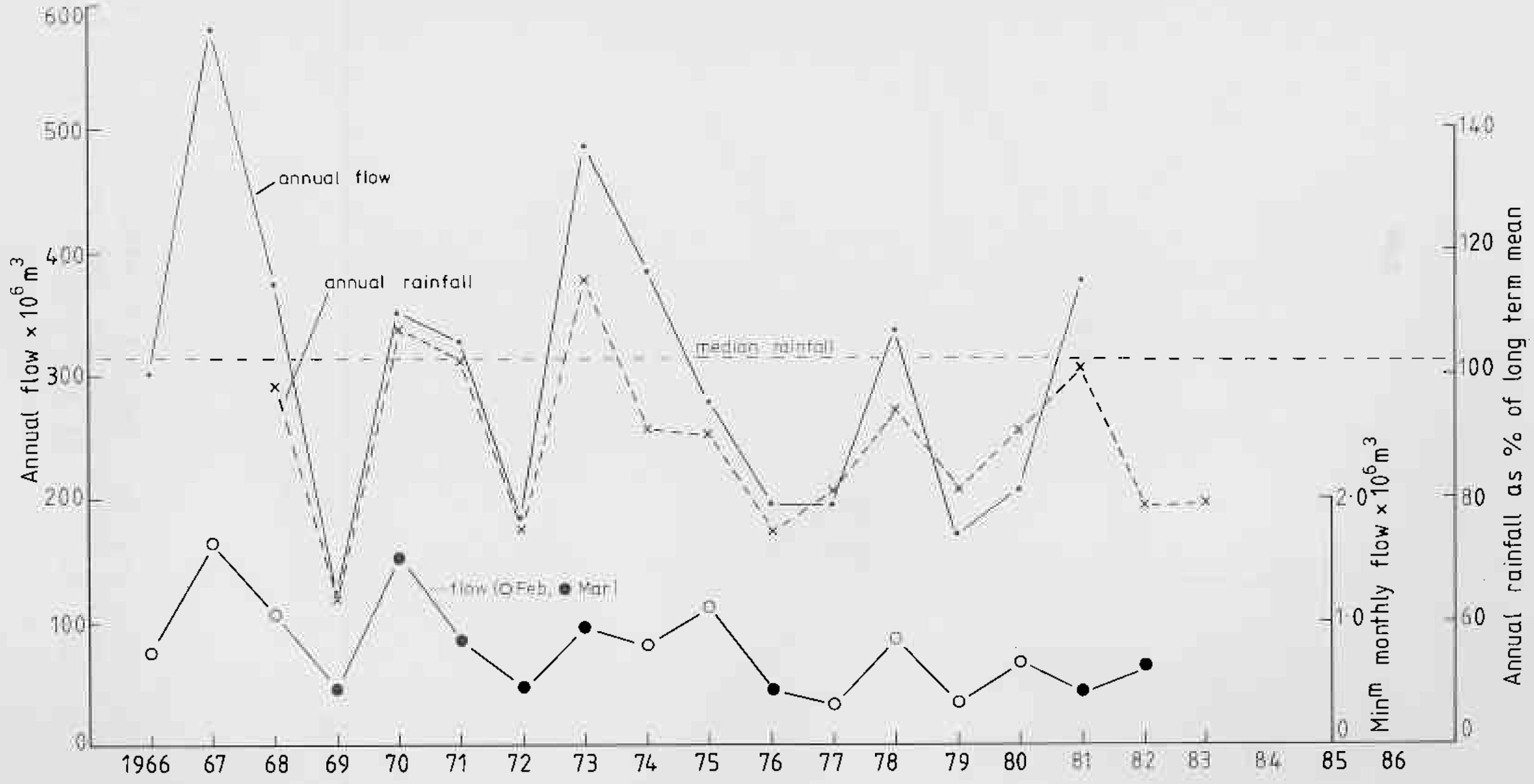


Figure 14 Rainfall and flow records for the Warren river.

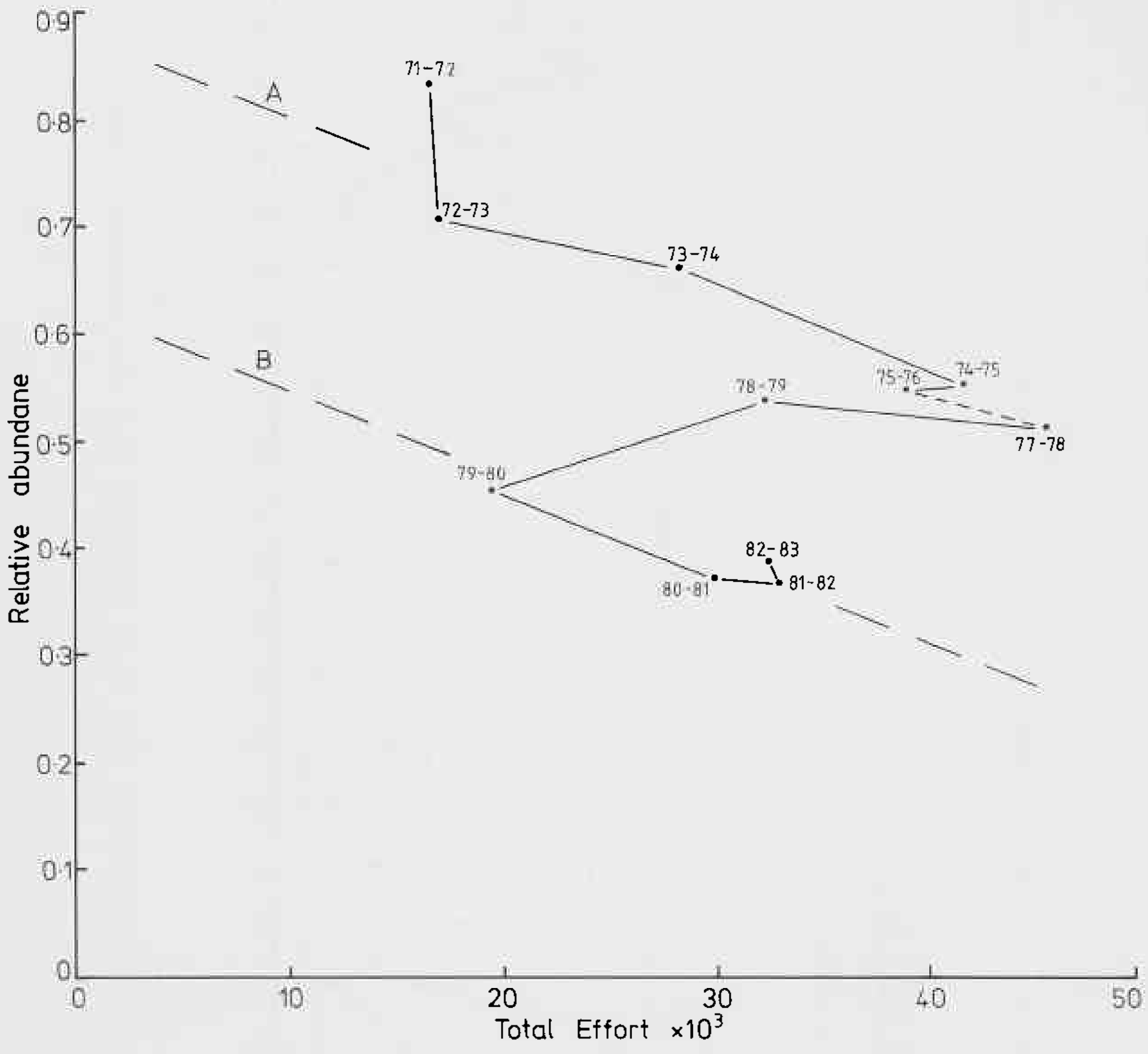


Figure 15 Relationship between relative abundance and total annual fishing effort (trips per season). A and B lines, see text. (a) for rivers, (b) for dams.

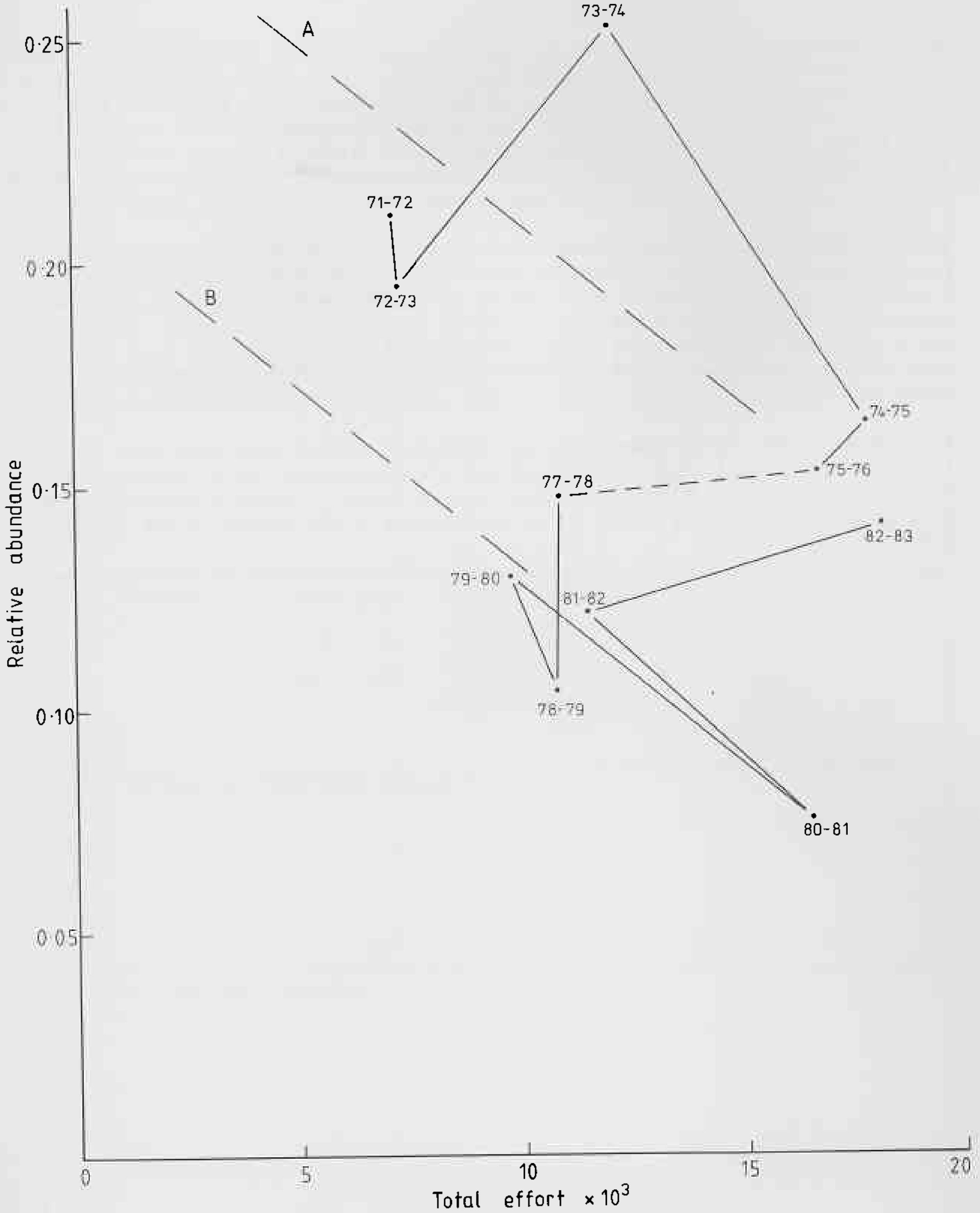


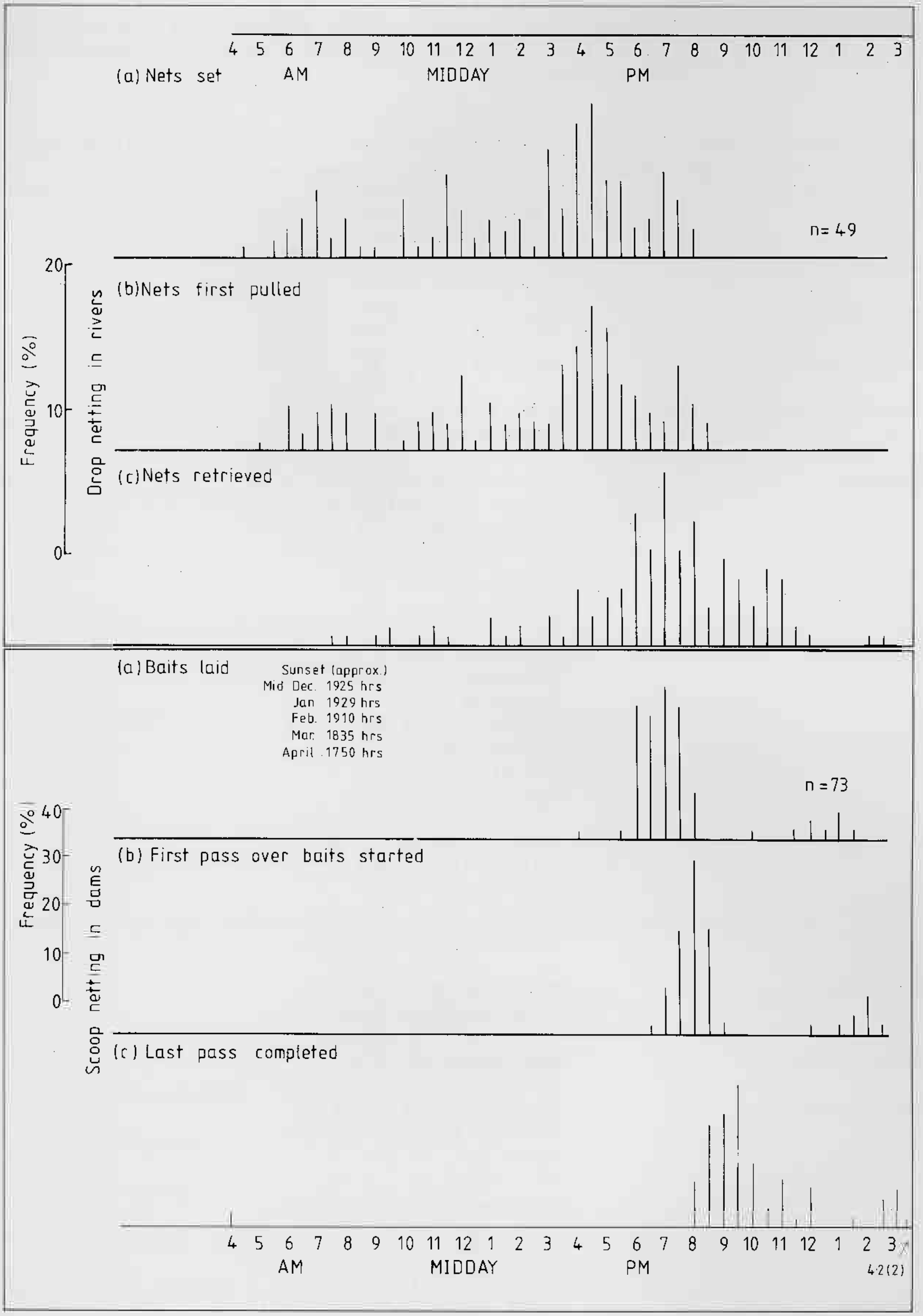
Figure 15 Relationship between relative abundance and total annual fishing effort (trips per season). A and B lines, see text. (a) for rivers, (b) for dams.

APPENDIX 1: DAILY FISHING TIMES FROM LOGBOOKS

The appendix figure shows frequency data from the 1979-80 season for three fishing times recorded, i.e. (a), time of day baited drop nets were set in rivers or baits were laid in dams for scoop netting, (b), time of day drop nets were first pulled or the first pass was made over the baits with a scoop net, and (c), time of day drop nets were retrieved or the last pass over the baits with a scoop net was completed.

The distributions for these three times for drop netting in rivers were trimodal. There were peaks of activity just after sunrise, around midday and, most predominantly, associated with sunset. For scoop netting in dams (mainly Wellington Dam) the main period of activity was around and after sunset but there was also a smaller peak at and after midnight attributable to mine-workers at Collie coming off shift work at 2300 hours.

The mean time fishermen waited between first setting the baits (or baited nets) and the start of fishing was 24.6 minutes for drop nets and 40.8 minutes for scoop nets. Mean fishing time was then 4.27 hours with drop nets and 1.37 hours with scoop nets.



4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3
(a) Nets set
AM
MIDDAY
PM
n= 49
(b)Nets first pulled
Frequency (%)
Drop netting in rivers
20
10
0
(c)Nets retrieved
(a) Baits laid
Sunset (approx.)
Mid Dec. 1925 hrs
Jan 1929 hrs
Feb. 1910 hrs
Mar. 1835 hrs
April 1750 hrs
n = 73
(b) First pass over baits started
Frequency (%)
Scoop netting in dams
40
30
20
10
0
(c) Last pass completed
4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3
AM
MIDDAY
PM
4.2(2)

APPENDIX 2 (a) MARRON FISHING LOCALITIES RECORDED FROM LOGBOOKS 1971-83. RIVER BASINS AS LISTED IN PUBLIC WORKS DEPARTMENT (1974).

1, major rivers (n=4); 2, coastal rivers (n=29); 3, tributaries (n=20); 4, large dams (n=7); 5, small dams (n=4); 6, natural lakes (n=6).

River basin	
Moore-Hill	Moore R. - 2
Swan-Avon	Helena R. - 2
Canning Serpentine	Canning R. - 2 Serpentine R. - 2
Murray	North Dandelup R. - 2 South Dandelup R. - 2 Oakley Dam - 5 Murray R. - 1 Williams R. - 3 Nanga Br. - 3
Harvey	Waroona Dam - 4 Drakesbrook Dam - 4 Samsons Dam - 4 Logue Brook Dam - 4 Harvey R. - 2 Stirling Dam - 4 Harvey Weir - 4
Collie	Brunswick R. - 2 Collie R. - 2 Harris R. - 3 Little Dam, Collie - 5 Wellington Dam - 4
Preston	Preston R. - 2 Glen Mervyn Dam - 5
Busselton	Margaret R. - 2
Blackwood	Blackwood R. - 1 Arthur R. - 3 Rosa Br. - 3 St. John Br. - 3 Chapman Br. - 3 Mill Br. - 3 Scott R. - 2 Lake Frederick - 6 Lake Wilson - 6
Donnelly	Donnelly R. - 2 Record Br - 3 Carey Br. - 3 Beedelup Br. - 3 Barlee Br. - 3

Warren	Warren R. - 1 Tone R. - 3 Wilgarup R. - 3 Lefroy Br. - 3 Lake Yeagerup - 6
Shannon	Meerup R. - 2 Doggerup Lake - 6 Gardner R. - 2 Boorara Br. - 3 Lake Maringup - 6 Shannon R. - 2 Shannon R. Dam - 5 Deep R. - 2 Weld R. - 3
Frankland	Frankland R. - 1
Kent	Kent R. - 2 Nile Cr. - 3 Styx R. - 3 Bow R. - 2 Kordubup R. - 2
Denmark	Denmark R. - 2 Hay R. - 2 Sleeman R. - 2
Albany Coast	Marbellup Br. - 2 King R. - 2 Kalgan R. - 2 Napier Br. - 3 Goodga R. - 2 King Cr. - 2 Waychinicup R. - 2 Moates Lake - 6

APPENDIX 2 (b) WATER TYPES AND LOGBOOK TRIP DISTRIBUTION

	Frequency of trips (%), 1971-83
1, MAJOR RIVERS	34.8
2, COASTAL RIVERS	27.0
3, TRIBUTARIES	2.9
4, LARGE DAMS	30.5
5, SMALL DAMS	0.3
6, NATURAL LAKES	1.4
PRIVATE DAMS	1.8

TOTAL NUMBER OF TRIPS = 2 776

MEAN NUMBER OF TRIPS PER SEASON = 252

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