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The Manganuioteao River fishery

by

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The correct spelling of the name is "Manganuioteao" (New Zealand Gazette 1985, p. 403). It means, literally, "the big tributary of the (coming from the) clouds", which describes how it may be viewed from the Wanganui valley, the "clouds" being those surrounding the central volcanoes. Other meanings are; "great river of the world" (Reed 1961), "river of ever dancing waters and steep echoing cliffs" and "great and powerful waters of Rongomai" (Voelkerling 1980).

CONTENTS

Page

TABLES

Page

Page

FIGURES

Page

SUMMARY

The Manganuioteao River is the third largest tributary of the Wanganui River and its water quality is among the highest, comparable with that of streams flowing from undeveloped bush catchments. It has a variable flow pattern similar to that of other New Zealand rivers which are affected by mountain climates, but it has a very stable bouldery bed and a high base flow which is important in maintaining flows in the lower Wanganui River during dry periods. The comparatively unmodified state of a large part of the river and its environs, and its size, quality, and proximity to the sea, are important reasons for the diversity of aquatic life it supports and for its high quality trout fishery.

Eleven species of indigenous fishes inhabit the river, more than have been found in any other Wanganui River tributary investigated. Ten species migrate between freshwater and the sea to complete their life cycles and seven of them contribute to traditional, commercial, and recreational fisheries in the Wanganui River.

The Manganuioteao River is a nationally important scenic river fishery for brown and rainbow trout and it compares favourably with other highly regarded New Zealand trout rivers in many respects. Both species of trout are about the same average size (50 cm and 1.6 kg) and are distributed through more than 60 km of the 80-km-long river; on average there are three large fish per pool (12 fish per kilometre). Rainbow trout are predominant in the upper reaches and brown trout in the lower; both co-exist in the middle reaches and are most abundant there (average 5 fish per pool or 21 fish per kilometre). A change from an overall predominance of rainbow trout (61%) to brown trout (67%) was

noted during the 3 year study period. Both species move extensively throughout the system and one tagged brown trout was caught over 200 km away after travelling a considerable distance in coastal marine waters. The shift to brown trout predominance is attributed to an influx, during winter 1980, of Wanganui River estuarine or sea-run fish which did not disperse completely afterward.

The most important spawning tributary of the Manganuioteao River is the Orautoha Stream which enters the river's middle reaches. It is used by both species of trout formerly seen from throughout the system. A concentration of spawning rainbow trout in the Manganuioteao headwaters was not noted after 1979 when the final liberation of hatchery reared rainbow trout was made. Some spawning and most rearing of juveniles appears to take place in the mainstem of the river.

The Manganuioteao River is fished by anglers from throughout New Zealand and from overseas, but most of its anglers live within 100 km of the river and visit it repeatedly. Anglers generally catch the smaller fish, and catch more rainbow trout and fewer brown trout than are sampled by other means. Spoon fishing is the most successful method and the average catch rate is 0.3-0.5 fish per hour. Experienced anglers average 0.7 fish per hour, a rate which has not changed during the past 40 years.

Hydro-electric development and land use practices which increase sedimentation are the greatest threats to the river and its fishery. Hydro-electric development was first proposed in 1978. The effects seen after the diversion of a substantial flow from a prime fishing river in an adjacent catchment clearly indicate that it is not possible to establish a compromise between hydro-electric development and maintenance of the present values of the river.

The many attributes of the Manganuioteao River, its linkage between two areas of National Park, and its status as the last unmodified trout river in the Wanganui River catchment, make it worthy of protection that would maintain it in its present state forever.

1. INTRODUCTION

1.1 The Setting

The Manganuioteao River is a moderate-sized tributary of the Wanganui River. It begins on the slopes of Mount Ruapehu, one of the central North Island volcanoes, and flows in a south-westerly direction to join the Wanganui River 11 km upstream from Pipiriki (Fig. 1). The nearest town is Raetihi (population 1260, New Zealand Year Book 1983); other towns nearby, all of a similar size, are Ohakune, National Park, and Waiouru. State Highway 4 (S.H. 4) and the North Island main trunk railway cross the upper reaches, and Ohura Road leaves S.H. 4 north of Raetihi and gives access to the middle reaches where Pukekaha and Makakahi Roads run parallel to much of the river. Most of the upper and lower reaches of the river have no road access.

1.2 Regulating Bodies

The river is in the Waimarino County, and the headwaters lie within the Tongariro National Park. The water resource is administered by the Rangitikei-Wanganui Catchment Board (RWCB) under the provisions of the Water and Soil Conservation Act 1967. The Central North Island Wildlife Conservancy (CNIWC) is responsible for managing the Manganuioteao fishery and associated wildlife. Reticulation and supply of electricity in the area is the responsibility of the Wanganui-Rangitikei Electric Power Board (WREPB).

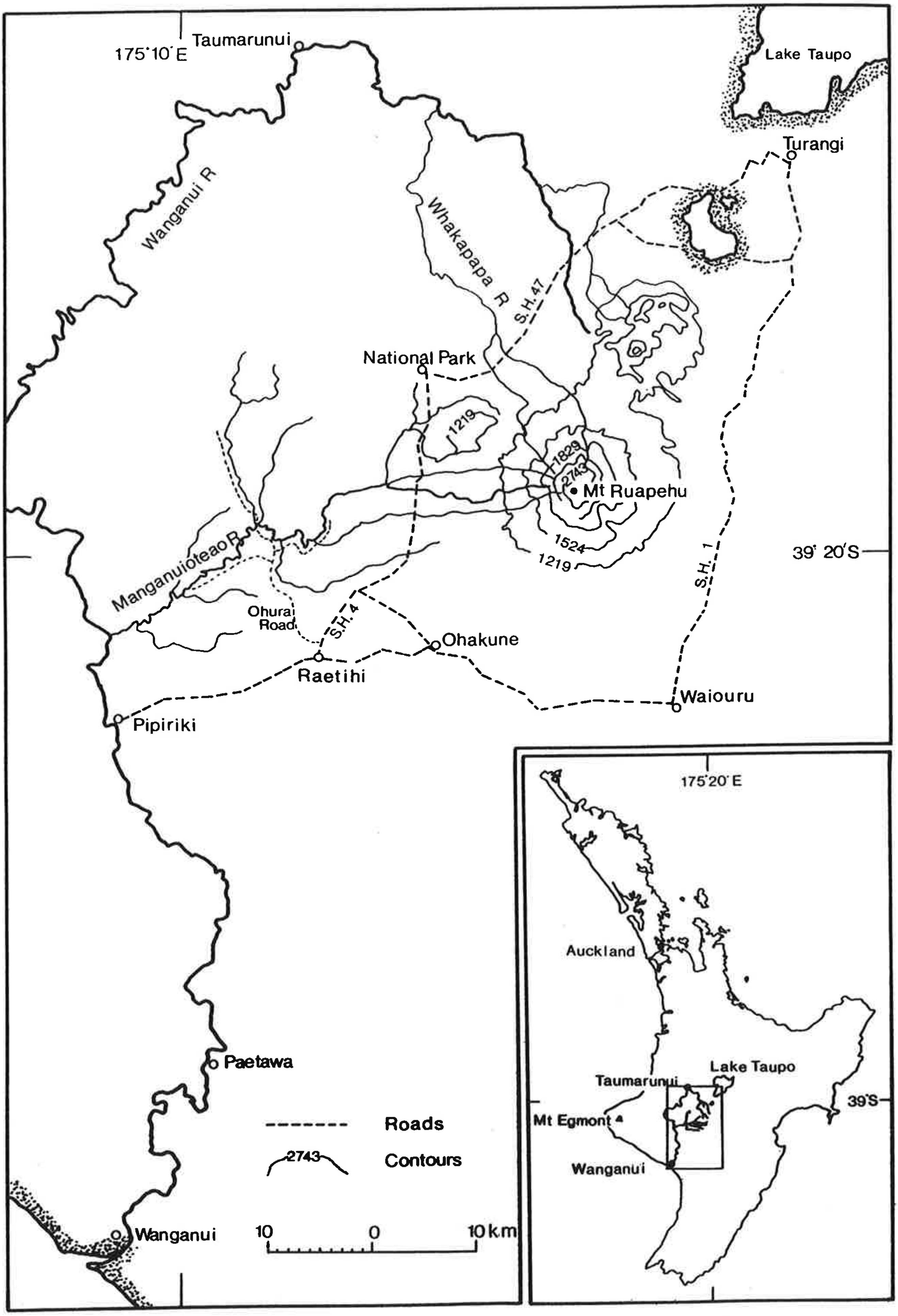

FIGURE 1. Location and setting.

1.3 Fishery Responsibilities

The Fisheries Act 1983 is administered by the Ministry of Agriculture and Fisheries (MAF) and provides for the management and conservation of fisheries and fishery resources within New Zealand. Part V of the Act refers to freshwater fisheries and it charges acclimatisation societies with responsibility for the protection, management, and enhancement of all acclimatised fish species and their habitats and with the conservation of all indigenous fish species and their habitats.

Acclimatisation societies are governed by the Wildlife Act 1953, which is administered by the Wildlife Service, Department of Internal Affairs (WS). In the tourist areas of Rotorua-Taupo and southern lakes WS itself acts in lieu of an acclimatisation society. Since 1980, preceded by a 3 year trial period, WS has taken over the management of the former Waimarino Acclimatisation Society district which is now known as the Waimarino ward of the Central North Island Wildlife Conservancy Council (CNIWCC). The former Society's executive continues to operate as an advisory body acting on behalf of the district's sports people and is represented on the governing Conservancy Council.

Fisheries Research Division (FRD) of MAF is responsible for the conservation of fish and fishery resources and habitats and for providing support and management advice for recreational fisheries.

1.4 Background

A 1978 proposal by the WREPB to develop the hydro-electric potential of the Manganuioteao River (WREPB 1978) caused concern amongst local trout fishermen who foresaw the degradation and possible loss of a valued resource. This concern spread to other groups and individuals, some of whom had a direct interest in the river, while others had more general concerns about loss of recreational areas, manipulation of natural resources etc.

Protest against the WREPB proposals was initiated by the Waimarino ward of the CNIWCC whose members lobbied widely and finally presented a petition to Parliament asking that the river be preserved in perpetuity (Dobson 1979). In their view the river has high status as a trout fishery, is the last large river remaining in the Waimarino district and flowing from the central mountains which is unmodified, and should be afforded protection. This view attracted wide support from the New Zealand public (the petition gained 5433 signatures) and also from several government departments and agencies including MAF, WS, the Commission for the Environment, Lands and Survey Department, and the Queen Elizabeth the Second National Trust (QEII Trust).

In May 1980 the Lands and Agriculture Committee of Parliament House returned the Manganuioteao petition to Government "for consideration" with a recommendation that the petitioners explore the possibility of achieving the desired protection under the Town and Country Planning Act.

In October 1980 the QEII Trust sought protection for the river under the Water and Soil Conservation Act on behalf of the petitioners and the departments and agencies which had supported the petition. The QEII Trust asked the National Water and Soil Conservation Authority (NWASCA) to set a minimum flow equalling the natural flow of the river at all times. The request was referred to RWCB for consideration and a recommendation. RWCB called for submissions from interested parties and conducted a hearing on 23 July 1981 to hear and consider the submissions. On 24 August 1981, RWCB recommended to NWASCA "that for a period of five years, the minimum flow for the Manganuioteao River from its source to its confluence with the Wanganui River and for the Orautoha, Mangaturuturu, Makatote and Waimarino Streams from their sources to their confluences with the Manganuioteao River be fixed at 90% of the existing or remaining natural flow of those rivers and streams" (Hogg 1981). On 9 June 1982, after considering the QEII Trust's application, the submissions, report, and recommendation of RWCB, and the report of the Water Resources Council, NWASCA adopted the recommendation of RWCB and fixed the minimum flow until 31 July 1987.

From the time its hydro-development proposals were made public in 1978, WREPB sought comments from interested parties and also maintained contact with these groups and individuals. Project development was then shelved in June 1980 until government grants could be obtained to carry out the feasibility studies, design, and construction of the power scheme.

FRD commented upon the WREPB proposals in September 1978 stating its concern that the proposed development could have a major impact upon the fishery and outlining the information required to assess that impact. WREPB then commissioned Cawthron Technical Group (CTG) to investigate the environmental and social effects of its proposals, and ensuing discussions between CTG, FRD, and WS representatives resulted in a study during 1979 in which all three groups participated and shared the information gained.

The 1979 study provided sufficient information to encourage FRD to support the Manganuioteao petition and to include the river in a list of six North Island rivers which it wished to protect (Teirney 1979). In March 1980, the Director-General of MAF released a press statement calling for the preservation of the Manganuioteao River in its natural state and with the Director, FRD, commissioned a film portraying the range of natural values supported by the river. The film, "River in Question - Manganui-a-te-ao", was released during 1984. FRD also made submissions and appeared at the RWCB hearing in July 1981 in support of the QEII Trust application for a minimum flow equalling the naturally occurring flow to be set (Cudby 1981).

An introduction to understanding the Manganuioteao fishery was gained during the summer 1979 study, but critical questions remained unanswered and FRD, supported by WS, continued the investigation through 1980-81.

2. THE STUDY

2.1 Previous Work

Earlier studies included parts of the Manganuioteao or gave results gained indirectly, for example, from anglers' diaries. It was not until the WREPB and their consultants began investigating the feasibility of hydro-electric development in 1978 that comprehensive studies of the fishery were undertaken.

Anglers' diaries collected between 1947-52 were analysed as part of a nationwide study by Allen and Cunningham (1957). Graynoth (1973b, 1974c) analysed diaries collected in 1962-63 and 1967-68. Samples of benthic fauna were collected in the Orautoha Stream during an investigation of sedimentation from a gravel plant (Cudby 1966). From 1969 to 1971 the acidity of the Mangaturuturu Stream at S.H. 4 was monitored after the 1969 eruption of Mount Ruapehu (Cudby 1976). Electric fishing surveys carried out in the district included the Manganuioteao River and several of its tributaries (Turner and Allen 1970, Allen 1971). After the 1975 Mount Ruapehu eruption, members of the Waimarino Acclimatisation Society collected samples and assessed damage (Turner 1975) and after-effects of the eruption on aquatic life were monitored by drift diving and benthic sampling (Cudby 1976). A consultant spent several days in 1978 inspecting the river and interviewing people for an ecological assessment of the impact of hydro-electric proposals (Darby 1978), and Tonkin and Taylor (1978) give climatological and hydrological data for the river and its catchment and discuss these in relation to the Wanganui River catchment.

Hydrological records from 1961 to 1980 have been collected at Ashworth by the Ministry of Works and Development (MWD 1982). RWCB also collected flow records in the upper catchment from 1979 to 1981. These data are stored in the Tideda system (RWCB pers comm).

The 1979 study carried out by CTG, WS, and FRD was aimed at describing the existing environment with emphasis on fish and blue duck populations, and was also aimed at identifying possible impacts of the hydro-electric development proposals on these populations (Armstrong 1979). The questions that arose from the study were:

- Where do the trout spawn?
- What is the extent of their movements?
- How important are the tributaries and upper reaches to the trout fishery?
- How would an altered flow regime affect the fishery?
- What are the angling values of the fishery?

- How do these values compare with other fisheries?
- What changes take place within the system over a longer term?

The results of fishery studies from 1979 to 1981, and information from other sources giving an insight into the fishery and conditions affecting it, are brought together in this report.

2.2 Study Aims

1. To locate trout spawning areas and evaluate their relative importance within the system;
2. To investigate trout movements;
3. To examine seasonal and long-term trends in the distribution of trout;
4. To investigate the effect of different flows upon the physical habitat of juvenile trout;
5. To examine angling values associated with the river;
6. To acquire further information upon the distribution and importance of indigenous species within the system;
7. To gain a broader view of the Manganuioteao River's place within the Wanganui River system and its relationship with physical, chemical, and climatic factors;
8. To estimate the impacts of current resource use strategies and proposals, and to advise upon future management and protection of the river.

2.3 The Study Area

The study area in the Manganuioteao River extends from 2.5 km upstream of S.H. 4 downstream to the confluence of the Manganuioteao and Wanganui rivers, and it includes most of the tributaries between (Fig. 2). Some tributaries were examined after the study period to fill in gaps in fish distributions and spawning records.

The area is divided into four zones based upon gradient, geology, and land use. They are:

- the subalpine zone which is within the Tongariro National Park;
- the upper zone which extends from the National Park boundary to the Mangamingi Stream-Manganuioteao confluence;
- the middle zone extending from the Mangamingi Stream-Manganuioteao confluence to the river's confluence with the Makakahi Stream;
- the lower zone, which is the remainder of the river (Fig. 2).

The upper, middle and lower zones are the study area; the sub-alpine zone was not included because of access difficulties and also because it is protected by the status of the surrounding land.

3. HISTORY

3.1 Maori

Maori people are thought to have first occupied the Wanganui Valley over 800 years ago in 1100 AD, but the tribes who lived there when Europeans first arrived during the first half of last century originated from the canoes of the so-called "great fleet" which came 250 years

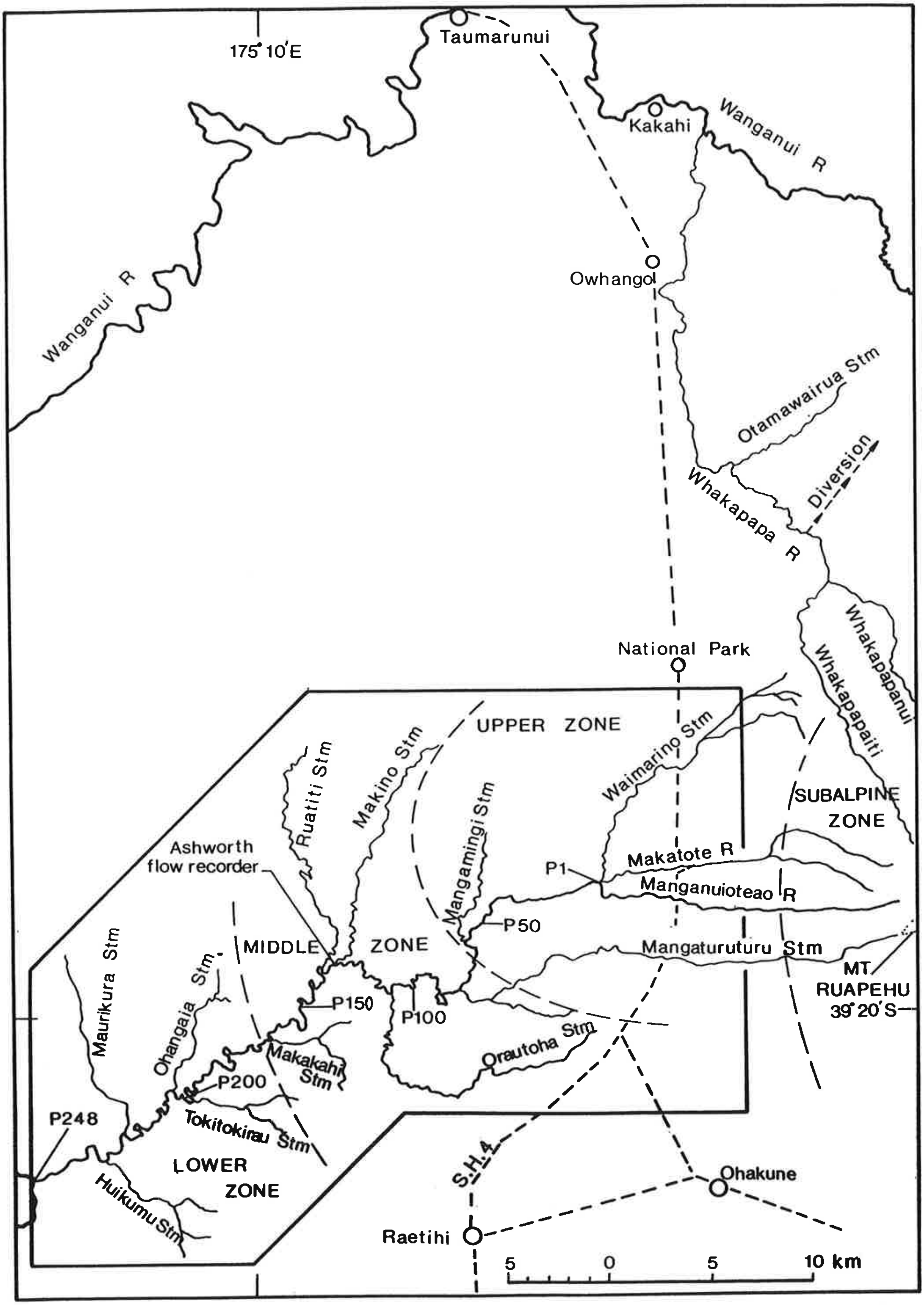

FIGURE 2. Study area.

after the first occupants had established themselves (Ombler and Ombler, n.d.). These later arrivals spread upstream and into the valleys of suitable tributaries including the Manganuioteao where they cleared land for cropping and for living space and also trapped birds and fish.

In the 1840s the Maori population in the Wanganui Valley, between the present town of Taumarunui and the sea, was estimated by Downes (1921) at 25 000-30 000 people, there were as many pa and kainga in the Manganuioteao valley as there were in (a comparable length of) the Wanganui. This population estimate is considered to be much too high, but the comparability of the two valleys is likely to be true. Extrapolating from a census carried out in 1843 by Reverend Richard Taylor, in which 2241 people were counted and named between Wanganui and Pipiriki, Cawthron Technical Group (1979) estimated a total population of 4000-5000 people along the Wanganui River, including the Ongarue and Manganuioteao tributaries. Wakefield (1845) when travelling up the Manganuioteao valley in 1841 noted that most of it had been formerly occupied, but had since been abandoned, and the Reverend Taylor made several trips through the valley during the 1840s and 1850s and mentioned only three villages and several small kainga during that period (Taylor 1846-52). The villages contained 10-50 people on most of his visits, but in 1849 Taylor recorded 100 canoes drawn up 3.5 km upstream from the Wanganui River-Manganuioteao confluence and a congregation of 2000 people at a village where normally only 50 lived. Here again 2000 seems to be an overestimate.

The Manganuioteao valley was an important route between the Wanganui valley and the central North Island. Travellers used canoes in the lower reaches and then followed tracks upstream crossing and recrossing the river and sometimes leaving the valley to bypass difficult country.

The route left the river in the vicinity of the Mangaturuturu Stream and descended to it again at the Manganuioteao-Makatote confluence before leaving it finally between the Waimarino-Makatote confluence and ascending to open country near Erua (Taylor 1846-52, Wakefield 1845, Kerry-Nicholls 1884, Grace 1959).

3.2 European

The first recorded landing of Europeans at Wanganui took place in 1831 when a group endeavouring to establish a trade in dried human heads landed and were killed (except for a Negro and a European). The attackers were from the Taupo area and they returned there via the Manganuioteao valley with the captive European (Taylor 1855). European settlement of the present city of Wanganui began in 1840, but did not proceed far upriver (Smart and Bates 1972). Downes (1921) stated that in 1892 there were no white settlers further than 22 km upstream. Instead settlement moved inland toward Raetihi and in 1886 the Waimarino district was purchased by the government and the Manganuioteao valley was subsequently surveyed and subdivided into 81 ha sections. The sections were taken up by Europeans from 1895 onward and the road from Raetihi down the Orautoha valley (Ohura Road) reached the Manganuioteao River in 1898 (Voelkerling 1980).

Settlers gradually spread up and down the river and into the valleys of tributaries such as the Ruatiti Stream. By 1920 the easy land had been taken up and surveyors and settlers were moving further afield into more difficult country (Bogle 1975). Bates (1981) described the transformation of an adjoining valley between 1917 and 1943.

The first European settler in the lower valley of the Manganuioteao began farming and bush clearing opposite the Makakahi Stream confluence in mid 1912 (Barton n.d.).

3.3 Vegetation and Wildlife

The biota of the valley has been considerably modified by man's activities. Large areas of bush were cleared from the level parts of the valley floor in pre-European times and crops were grown extensively. Taylor (1846-52) described "undulating plains of grass broken by deep ravines ... considerable cultivations", and a picture made from a sketch in 1884 of the area near the mouth of the Makakahi Stream shows an expanse of grassland in the valley and bush on the hillsides (Kerry-Nicholls 1884). The first European settler in the above area in 1912 described the valley as flat with bush-clad hills on either side. Most of the flat land had been cleared of bush by the Maoris, but it was reverting to manuka (*Leptospermum scoparium*) and broom (*Sacrothamnus scoparius*) (Barton n.d.). Downes (1921) stated that "large numbers of pigs" and "great quantities of grapes" were sent to Wanganui from the Manganuioteao valley.

The European settlers cleared the bush from most of the hillsides and the remaining valley floor in the middle and lower zones of the study area during the early part of this century and cultivated grassland in its place. However, the flanking hillsides between the Wanganui River and the Ruatiti Stream-Manganuioteao confluence on the northern side of the Manganuioteao and the Tokitokirau Stream-Manganuioteao confluence on the southern side still carry extensive areas of their original bush cover.

In pre-European times the Manganuioteao valley would have supported a similar range and density of wildlife to that of the Wanganui valley, see Downes (1921). Taylor (1846-52) mentioned a bat being found and eaten en route up the valley in 1846 and collection of the skins of the now extinct huia (*Heteralocha acutirostris*) in 1849. He also mentioned that 12 pigeons (*Hemiphaga novaeseelandiae*) and a blue duck (*Hymenolaimus malacorynchus*) were shot and eaten during the same trip. Wakefield (1845) stated that "about half a dozen" blue ducks, which were abundant, were shot at each ford of the river in 1841. His party forded the river five times. Mead (1979) provided early records of several species of birds in the Tongariro National Park area which are now rare or extinct and suggested that many of these migrated seasonally between the high and low altitude forests. He mentioned huia, kokako (*Callaeas cinerea*) and the kakapo (*Strigops habroptilus*) though the latter is likely to have already been restricted to the high altitude forest (Falla, Sibson, and Turbott 1966).

3.4 Indigenous Fishes

In the Wanganui valley indigenous fishes were an important source of food to the Maori people, Mair (1880), Downes (1918) and Best (1929) gave details of various fishing methods and their results. Extensive and elaborate traps were constructed to catch various species during migratory periods and much tradition and ceremony governed each operation. Voelkerling (1980) listed eels (*Anguilla* spp.), lamprey (*Geotria australis*), and whitebait (juveniles of *Galaxias* spp.) as important food sources in the Manganuioteao River during early times and no doubt there were others because species mentioned as food items by the above writers, such as smelt (*Retropinna retropinna*), torrentfish (*Cheimarrichthys fosteri*) and bullies (*Gobiomorphus* spp.), still live in the Manganuioteao River. Mair (1880) recorded a catch of fish in the Wanganui River 200 km from the sea that included the now extinct grayling (*Prototroctes oxyrynchus*). The mouth of the Manganuioteao

River is 100 km from the sea and so it is likely that the grayling would have been caught in it as well.

Some of the traditional fishing methods are still used in the Wanganui River. Todd (1979) described lamprey weirs and Hubbard (1979) described the catching of smelt by old-time methods near Pipiriki, 10-12 km downstream from the Manganuioteao-Wanganui confluence. Traditions and methods still practiced in the catching of eels in the Wanganui River were described on the television programme "Koha" (Koha 1982).

3.5 Introduced Fishes

The first liberations of exotic fishes which could have had access to the Manganuioteao River were made by the Wanganui Acclimatisation Society beginning in 1876. By 1880 15 000 brown trout (*Salmo trutta*), 3500 "Californian" salmon (*Oncorhynchus tshawytscha*) and 600 perch (*Perca fluviatilus*) had been introduced to various waters (Arthur 1881). All of the salmon, "a number" of trout and "some" perch were put into the Wanganui River which was described as "a perfect paradise for salmon" (Brewer 1880). Although perch did not become established in the Wanganui River and runs of salmon did not eventuate, the trout evidently became established. Liberations continued, rainbow trout (*Salmo gairdnerii*) were sent from Masterton in 1898 with the intention of stocking streams south of Ohakune (Wellington Acclimatisation Society 1883-1909). From 1899 onward both species of trout were introduced widely and in increasing numbers to Wanganui tributaries by various groups (Ashby 1967, Cowan 1927).

The success of these introductions can be gauged from the comments of early visitors to the area. Bullock (1899) mentioned "numberless streams" between Raetihi and Karioi "most of them stocked with trout" and Allen (1902) described the excellent trout fishing offering in the same area though he did not comment upon it 8 years earlier (Allen 1894). Hamilton (1904) in his description of angling waters throughout New Zealand stated that the Manganuioteao River contains brown and rainbow trout and that both species had been brought into the district several years before. Brown trout have, therefore, had access to the river since about 1880 and rainbow trout since 1896, but the establishment of the Manganuioteao River fishery most likely resulted from extensive liberations of both species of trout within the district from 1898-99 onward.

In October 1903, the Waimarino Acclimatisation Society opened its first fishing season, at the same time prohibiting fishing in the Orautoha Stream for 2 years in order to protect trout which had been liberated there (Orders in Council 1903a and b). From that time onward the river received frequent mention in the Society's Annual Reports and has obviously been a highly regarded and locally important fishery.

4.0 THE CATCHMENT

4.1 General Description

The Manganuioteao River begins on the western slopes of the active volcano Mount Ruapehu and flows 80 km south-westward into the Wanganui River over an altitudinal range of 2088 m (2134-2146 m a.s.l.). It has a catchment area of 620 km^2 and is the third largest of the Wanganui tributaries after the Ongarue and Ohura rivers. It's water quality is regarded as being among the highest of the Wanganui River tributaries and comparable with that of smaller streams which drain undeveloped bush catchments (Tonkin and Taylor 1978). Upper tributaries drain extensive areas of unmodified indigenous forest and middle and lower zone tributaries carry run-off from pasture and scrubland, but most of the Maunganuioteao River and its tributaries gain protection from direct effects of this run-off by being in an entrenched channel with a buffer of vegetation along either bank.

4.2 Vegetation

The vegetation of the Manganuioteao catchment is described by Daly (1979), while Muirhead and Turner (1980) described that of an adjacent catchment which is similar to the middle and lower zones of the Manganuioteao.

The headwaters of the Manganuioteao River and its tributaries, the Makatote and Mangaturuturu Rivers, begin on alpine slopes and flow through herb field and grassy scrubland. The timberline is about 1350 m a.s.l. and the scrub forest of mountain beech (*Nothofagus solandrii var. cliffortioides*), mountain toatoa (*Phyllocladus alpinus*), and kaikawaka (*Libocedrus bidwillii*) soon changes to silver beech (*N. menziesii*). The silver beech changes progressively through red beech (*N. fusca*) to podocarp to mixed podocarp to kamahi (*Weinmannia racemosa*) forest. East of S.H. 4, the land which these tributaries drain is National Park and State Forest which is unmodified except for tramping tracks and huts and some skifield development in the alpine-subalpine area. The upper zone of the study area extends 6 km east of S.H. 4. West of the highway, on plateaux above the river courses, first logging and later pasture development have modified the original vegetation, but the rivers are entrenched in steep sided channels surrounded by wide tracts of native forest and are virtually unmodified throughout the upper zone.

An exception is the Waimarino Stream which begins in alpine grassland on Mount Hauhangatahi at an altitude of 1370 m and drains bushland dominated first by kaikawaka and Hall's totara (*Podocarpus hallii*), and then by mixed podocarp-kamahi forest. The Waimarino also drains an expanse of low relief, swampy land which supports associations of flax (*Phormium* sp.), wire rush (*Hypolaena lateriflora*), umbrella fern (*Gleichenia* sp.), and tussock heath, and near S.H. 4 there is a small area of pasture and a settlement which discharges treated sewage effluent into the stream. From about S.H. 4 to the Waimarino's confluence with the Makatote River the river's catchment vegetation has been modified by planting the heathland with exotic conifers and by a certain amount of logging.

In the middle zone of the Manganuioteao River the predominant catchment vegetation is pasture, but there are frequently extensive stands of manuka scrub where the pasture has reverted after a reduction in grazing pressure. In the valley bottoms there are frequent thickets of introduced silver wattle (*Acacia dealbata*), and willows (*Salix* spp.) grow near water courses. A few stands of indigenous forest remain in which the dominant tree is frequently tawa (*Beilschmeidia tawa*), but other lowland species such as rewarewa (*Knightia excelsa*), mahoe (*Melicytis ramiflorus*), and tree ferns are common with various podocarps and kamahi.

The lower zone begins in farmland on the most extensive river flats in the system. These extend to the Manganuioteao's confluence with the Tokitokirau Stream where the valley closes in again and hills and gorges flank the river until it reaches the Wanganui River. Apart from pasture on the river flats, the vegetation of the lower zone is predominantly scrub interspersed with clearings containing pasture and bracken fern

(*Pteridium esculentum*). There are extensive stands of indigenous forest dominated by tawa and kamahi with scattered podocarps in unmodified stands on the hillsides surrounding the river and many of its tributaries. Exotic afforestation extends into the catchment from the south and riparian areas contain stands of silver wattle and willows.

Riparian vegetation remains either unmodified or only slightly modified despite changes which have affected other parts of the catchment. The entrenched, steep sided channel which the river has formed protects it from direct impact throughout most of its length. Between the Waimarino-Makatote confluence and the mouth the steep fern banks and cliffs of the Manganuioteao River are dominated by the long hard-fern (*Blechnum capense*), tuhara (*Cladium sinclairii*), and parataniwha (*Elatostema rugosum*) wherever there is sufficient moisture. Drier banks have indigenous shrubs, mountain flax and toetoe (*Cortaderia richardii*). A notable species on dry banks is *Dracophyllum strictum* which has probably spread from Mount Ruapehu along with other riparian vegetation in the middle zone such as red beech, mountain beech, mountain foxglove (*Ourisia macrophylla*), and pohuehue (*Muehlenbeckia axillaris*) (Daly loc. cit.). Exotic shrubs become more common in the riparian area of the middle zone; stands of silver wattle dominate many flats and willows line the banks in a few places. Occasionally grasses extend to the river bank.

4.3 Geology and Soils

The geology of the Taranaki to Ruapehu region is mapped and described by Hay (1967). In the headwaters of the Manganuioteao catchment Ruapehu andesite, dating from the upper Pleistocene era, is the principal geological formation. The system then crosses the 20 km wide Raetihi-Ohakune lahar plain, and an earlier laharic agglomerate of andesitic boulders, pebbles, and sand of unknown thickness through which the Makatote, Manganuioteao, and Mangaturuturu Rivers have cut channels up to 100 m deep.

The Waimarino Stream begins on the andesitic cone Hauhangatahi and drains a 1.5-3-km-wide swampy plain on Taupo pumice alluvium, a formation which dates from 1819 $\pm$ 17 years ago before 1950 (Healy, Vucetich, and Pullar 1964).

A prominent fault scarp of late quaternary origin which is downthrown toward the east runs in a NNE-SSW direction at right angles to the Manganuioteao system from Raurimu in the north to near Horopito in the south (Fig. 3). The Waimarino Stream follows the base of the scarp southward and joins the Makatote River near its confluence with the Manganuioteao, and it falls 100 m over the last 3 km of its course. The Manganuioteao itself follows the scarp northward for 600 m before joining the Makatote River, and several small tributaries which begin on the lahar plain also flow northward along the base of the scarp into the Manganuioteao.

The lahar plain overlies and gives way to massive mudstone and sandstone formations which date from the Pliocene era and which contain shell beds and scattered concretions (round or oval masses of the parent material formed by chemical action) and are up to 2750 m thick. The Manganuioteao has cut a deep, sinuous channel through these rock formations (Figs. 4 and 5).

FIGURE 3. The upper zone from above pool 50 and looking upstream towards the flanks of Mount Ruapehu.

FIGURE 4. The middle zone from pool 119 at lower left upstream to pool 105 out of sight at top centre. The Orautoha Stream enters the river out of the picture at centre right.

FIGURE 5. The lower zone upstream from the river's confluence with the Wanganui River at bottom centre. The Huikumu valley is at centre right.

Volcanic activity has affected soil formation through most of the catchment. Soils near Mount Ruapehu are recent volcanic ash grading to yellow-brown pumice steepland soils, yellow-brown steepland earths, and yellow-brown loams, with increasing distance from the mountain (Soil Bureau 1968). The yellow-brown loams develop principally from volcanic materials, are found on flat to rolling country, and have a higher natural fertility than soils developed from sedimentary rocks. The steepland soils and yellow-brown earths develop from sedimentary rocks and have low to medium natural fertility and generally respond well to added fertiliser. They are frequently poor draining and susceptible to erosion (Soil Bureau 1968).

Pastoral areas in the middle zone show signs of slight to moderate sheet erosion and slumping on steep faces; areas which have been left undisturbed under indigenous vegetation show few signs of erosion. In neighbouring catchments to the north a recent study (Muirhead and Turner 1980) recorded accelerated erosion, beginning with European settlement and continuing because of subsequent farm practices and with heavy rainfall years. The present situation, after over 40 years' retirement from farming varies from negligible erosion on flat to rolling land, to moderate erosion on steep to very steep forest covered slopes.

4.4 Climate

Ohakune has the closest climatological station to the Manganuioteao catchment. Weather conditions there are generally moderate with equable temperatures, below average sunshine hours, fairly high rainfall, and predominantly northerly and westerly winds (New Zealand Meteorological Service 1983). The altitudinal range of the catchment extends from 46 m to over 2000 m a.s.l. and it is subjected to a corresponding range of weather conditions outlined in Table 1.

Average annual rainfall varies between 1400 mm in the lower zone to over 5000 mm in the subalpine zone where up to 40% of the precipitation is snow (Tonkin and Taylor 1978). The average annual catchment rainfall is about 2000 mm (Tonkin and Taylor 1978; Water and Soil Division, Ministry of Works 1981, Beable and McKerchar 1982).

Monthly averages from stations in and near to the Manganuioteao catchment (Fig. 6) indicate a generally even distribution of rainfall throughout the year with slightly higher levels in winter than in summer. Daily rainfall exceeding 100 mm is a 1 in 10 year event in the Wanganui catchment excepting the Tongariro National Park (which includes the subalpine zone of the Manganuioteao River) where it may be expected to happen annually (Tonkin and Taylor 1978).

Droughts are rare; in 1973 less than 3 mm of rain was recorded throughout most of the Wanganui catchment in 1 month (Tonkin and Taylor 1978) and in 1978 little rain fell on parts of the Manganuioteao catchment for two months (NZMS 1983).

Air temperatures vary with altitude, and the sheltered aspect of the Manganuioteao valley also produces local variations from those recorded at nearby climatological stations, with still, hot conditions on summer days and temperature inversions and morning mists in autumn-spring. The mean daily range of 12°C and 8°C in winter at Ohakune (NZMS 1983) is likely to be 1-2°C less than in the Manganuioteao valley.

TABLE 1. Average climate data observed in and near and the Manganuioteao catchment (New Zealand Meteorological Service 1983)

	Site:	Ohakune	Ohakune Junction	Raetihi	Orautoha	Chateau
	Elevation:	610 m	629 m	549 m	323 m	1119 m
	Years of record:	1962-74	1974-82	1895-82	1957-82	1930-82
Rainfall (mm)	Average annual	1 320	1 507	1 590	1 414	2 823
Air temperature (°C)	Average daily - max	15.1	14.6			11.5
	- mean	10.1	10.1			7.2
	- min	5.2	5.4			2.9
Relative humidity (%)	Average at 9.00 am	77	88			81
Ground frost (days)	Average/year	105.8				142.2
Snow (days)	Average/year	4.3	4.9			16.2
Sunshine (hours)	Average annual	1 799				
	% of possible	42				

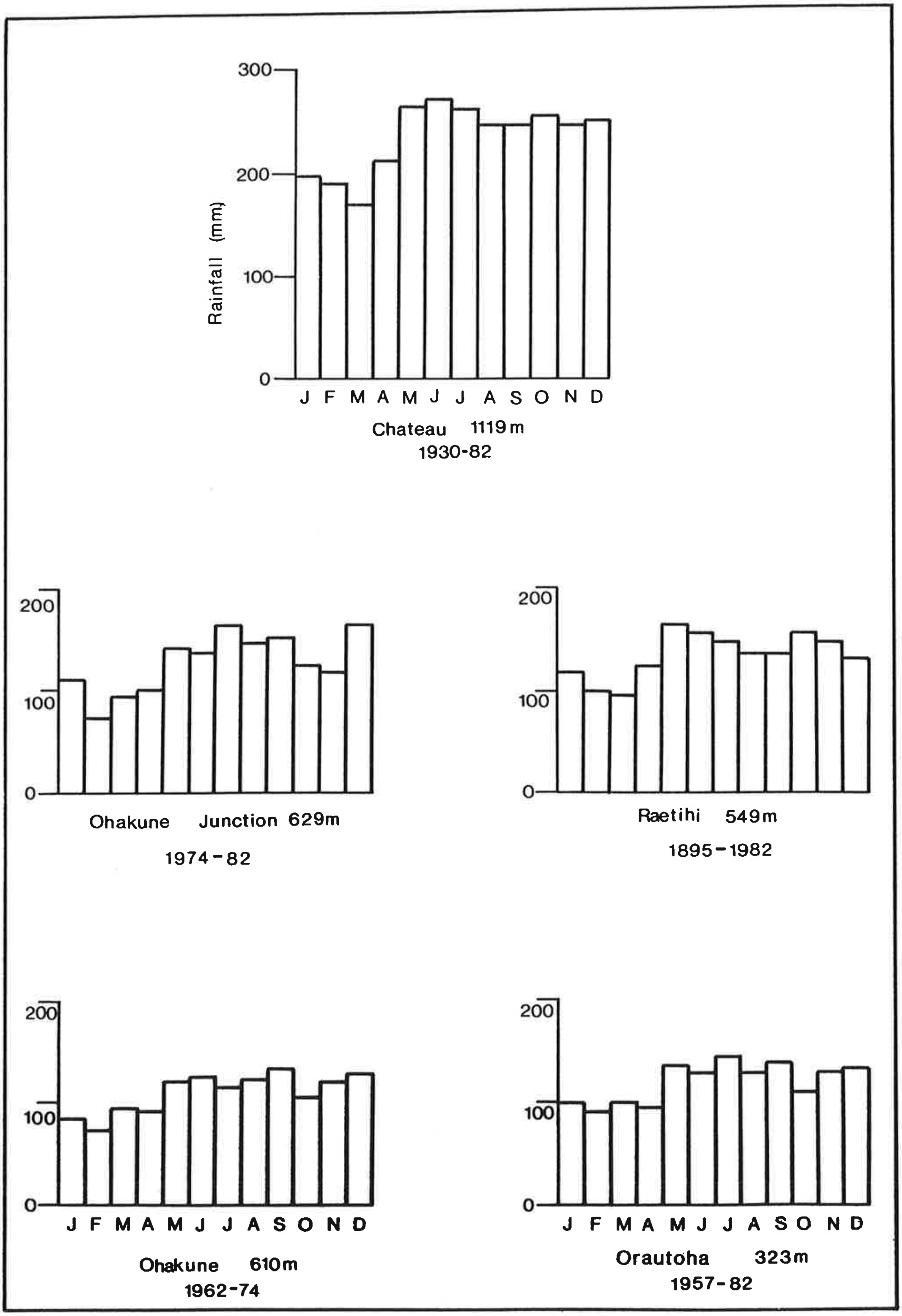

FIGURE 6. Mean monthly rainfall at stations in and near to Manganuioteao catchment.

The predominant wind flow is from the westerly to northerly sector (Tonkin and Taylor 1978). At Taumarunui, the closest station recording wind-run, the annual mean daily wind-run is 87 km and most wind occurs during the months of September to January inclusive (NZMS 1983).

4.5 Morphology

Over most of its course through the upper, middle, and lower zones the Manganuioteao River is confined within a narrow, incised channel between banks ranging from 3 to 30 m in height and from steep to sheer in slope. The channel is comparatively straight in the upper zone but becomes increasingly sinuous in the middle and lower zones (Table 2).

The predominant component of the channel substrate is large, rounded boulders of volcanic rock interspersed with finer materials. These extend to the river mouth and are supplemented with sedimentary rock and increasing fine material from about the Ruatiti Stream's confluence with the river. Outcrops of sedimentary rock in the river bed are common downstream from this area also. There is a tendency toward decreasing size of boulders and increasing presence of silt and sandbanks with distance downstream, but this is not evident in Table 2 because extremes were not measured and the sand-silt banks were usually associated with pools which again were not measured. The channel bed material estimates given in Table 2 are from boulder banks and runs and the size ranges of the components are given by Mosley (1982a). The composition does not change significantly in the three zones (Table 2), but Figures 7, 8, and 9 indicate the decrease in boulder size with distance downstream.

TABLE 2. Morphology of the Manganuioteao River

		Zone		
		Upper	Middle	Lower
Channel pattern		Straight	Irregular - tortuous meanders	Tortuous meanders
Sinuosity*		1.11	2.02	.07
Gradient		1:34	1:112	:291
Pools per km		7.0	4.2	.4
Pool depth† (m)	Max	6	7	
	Average max	2-3	4-5	-6
Channel bed material (%)	Boulders	81‡	84‡ 58.7§	0**
	Cobbles		29.8§	0**
	Gravel	12‡	8 9.9§	0**
	Sand	7‡	8 1.2§	0**
	Silt		0.4§	
Colour		Colourless	Light-brown	Brown
Clarity-vertical† (m)		3-5	2-3	0.5-2

Terminology after Mosley (1982a):

* Sinuosity is the ratio between distance in a straight line and river distance.
† Estimates made by divers - records from diving logs.
‡ Averages from New Zealand freshwater fish survey cards - various observers.
§ Averages of 510 1-m^2 quadrats in a 2000 m^2 area of river bed.
** Estimate measured from aerial photograph of 910 m^2 area of river bed.

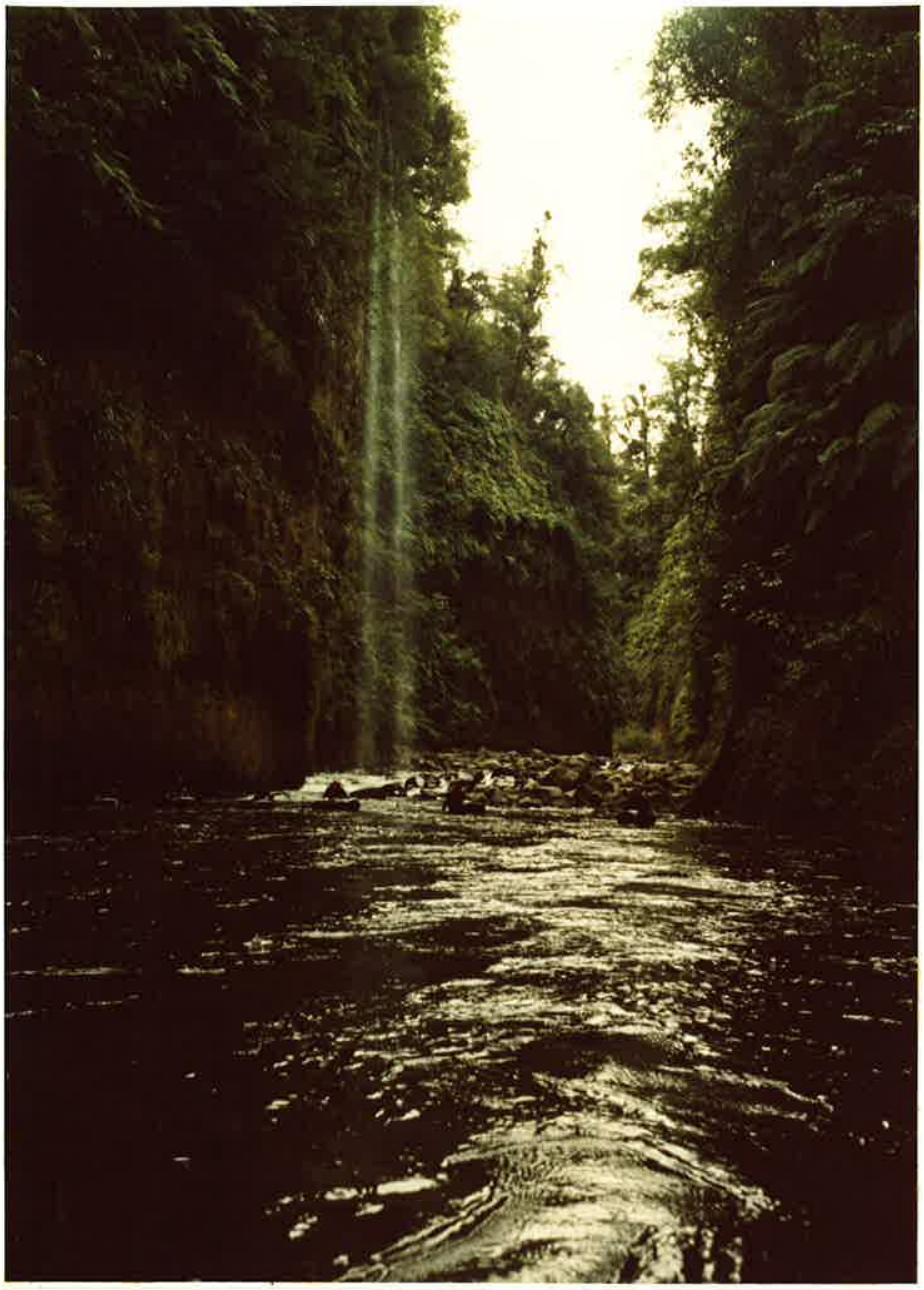

FIGURE 7. Pool 13 - characteristic of river morphology in the upper zone where pools are shorter and shallower than they are further downstream.

FIGURE 8. River morphology in the middle zone.

FIGURE 9. Pool 238 in the lower zone showing characteristic morphology in that area.

The gradient of the river is shown in Figure 10 and the average for each of the upper, middle, and lower zones is given in Table 2. The gradient is high in the first 30 km (the subalpine and upper zones in which the river falls 1680 m) and is moderate in the remaining 50 km (in which it falls 400 m). Between each of the upper, middle, and lower zones the gradient changes by a factor of three.

The appearance of the water also changes in a downstream direction from clear and colourless in the upper zone, to moderately turbid and brown under normal conditions in the lower zone, with intermediate values in the middle zone (Table 2).

Constrained by geology and landform, and by climatic and volcanic events, the Manganuioteao River has assumed a characteristic pool-rapid flow sequence in which a scour pool develops alongside a sheer bank and forms an outwash boulder bank over which the water tumbles to the next pool which is frequently against the opposite side of the channel (Fig. 8). This sequence results in the progressive increase in sinuosity in the middle and lower zones (Table 2 and Figs. 4 and 5).

There is evidently an ideal combination of gradient, water volume, and size of bed material which produces the pool-rapid sequence because it is not pronounced in the upper zone and the river channel is straighter there (Table 2 and Fig. 3). Above the Waimarino-Makatote confluence both the Manganuioteao and the Makatote rivers contain few pools and their flow is turbulent. Data for pools given in Table 2 refer to the area downstream from the Manganuioteao-Makatote-Waimarino confluence. Below this confluence, pools become noticeable features though they are characteristically short and shallow. The size and depth of the pools increases with distance downstream and the largest

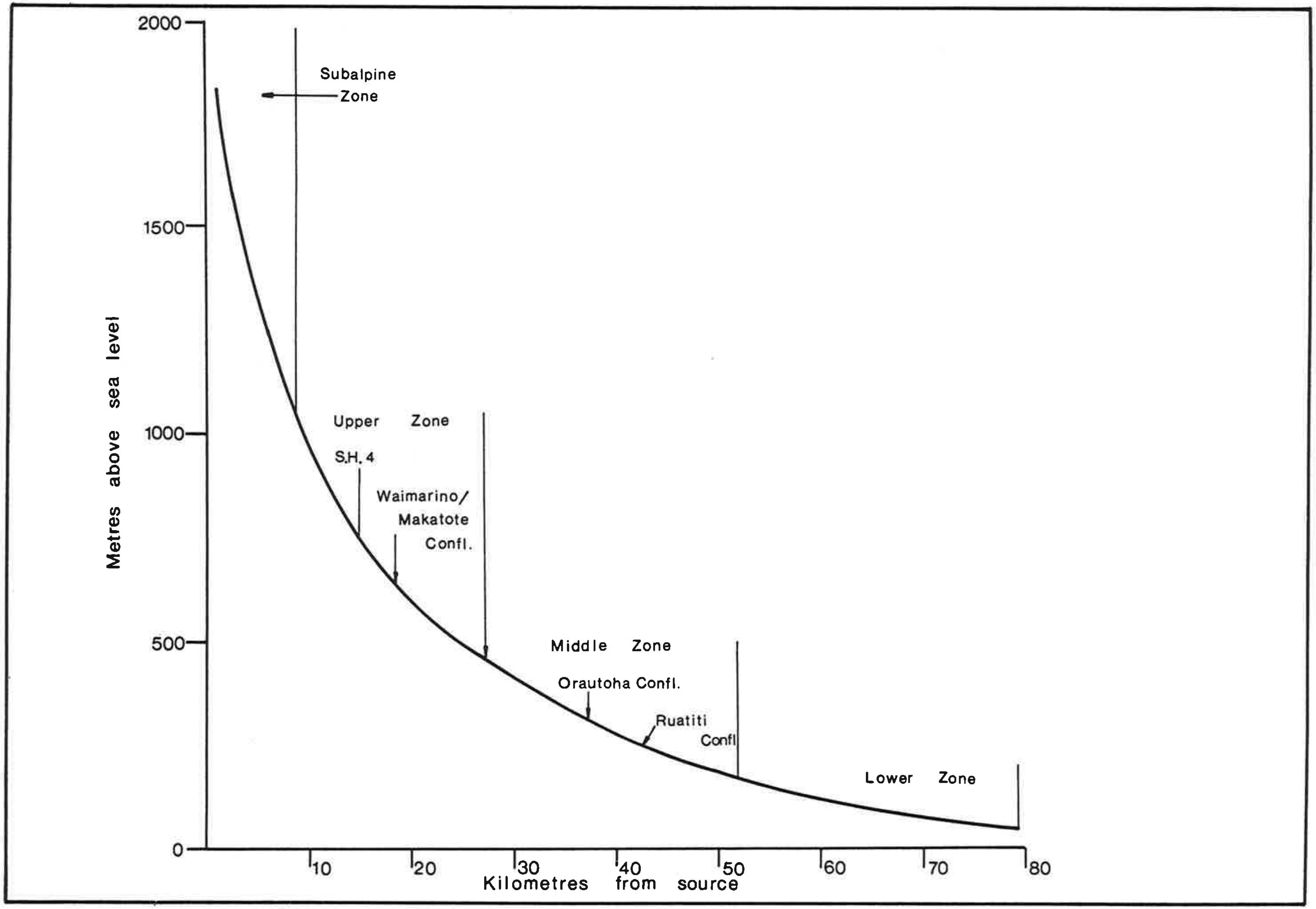

FIGURE 10. Gradient of the Manganuioteao River.

pools are in the lower zone. However, the deepest pools are frequently not the largest, this being dependent upon channel and flow configuration, and the average maximum depth of pools increases by only 1-2 m between zones.

The morphological stability of the Manganuioteao is an outstanding feature of the river. The boulders protect the river bed and make the pools and rapids semi-permanent fixtures. The annual identification of pools during the study period, despite 2-3 m high floods, proved the short-term morphological stability of the river and there are indications that few changes have taken place for a much longer time period. Figure 11 compares pool 240 in two photographs taken 90 years apart. Many severe floods occurred in that time including one which was the largest recorded in the Wanganui River and which had an estimated probability of occurring once in 100 years (Tonkin and Taylor 1978). In the Manganuioteao River this flood washed over the decking and removed one span of the bridge at Ashworth (H.H. Brown pers.comm). Its height on the present staff gauge, which only extends to 4 m, would have been 9 m, over 5 m higher than the maximum recorded during 1961-80 (MWD 1982). The two photographs show that pool 240 has undergone only minor changes. The appearance of the water surface indicates that it is shallower in the later photograph and measurements show that the water surface is slightly higher and wider. The far bank in the early photograph is where the shingle bar is in the later photograph. It seems that some infilling has taken place in pool 240 in the past 80-90 years, but it remains substantially unchanged. Sketches of the same area made by the missionary Richard Taylor in 1849 (Alexander Turnbull Library; references 50413½, 50564½ and 50409½) lack photographic detail, but

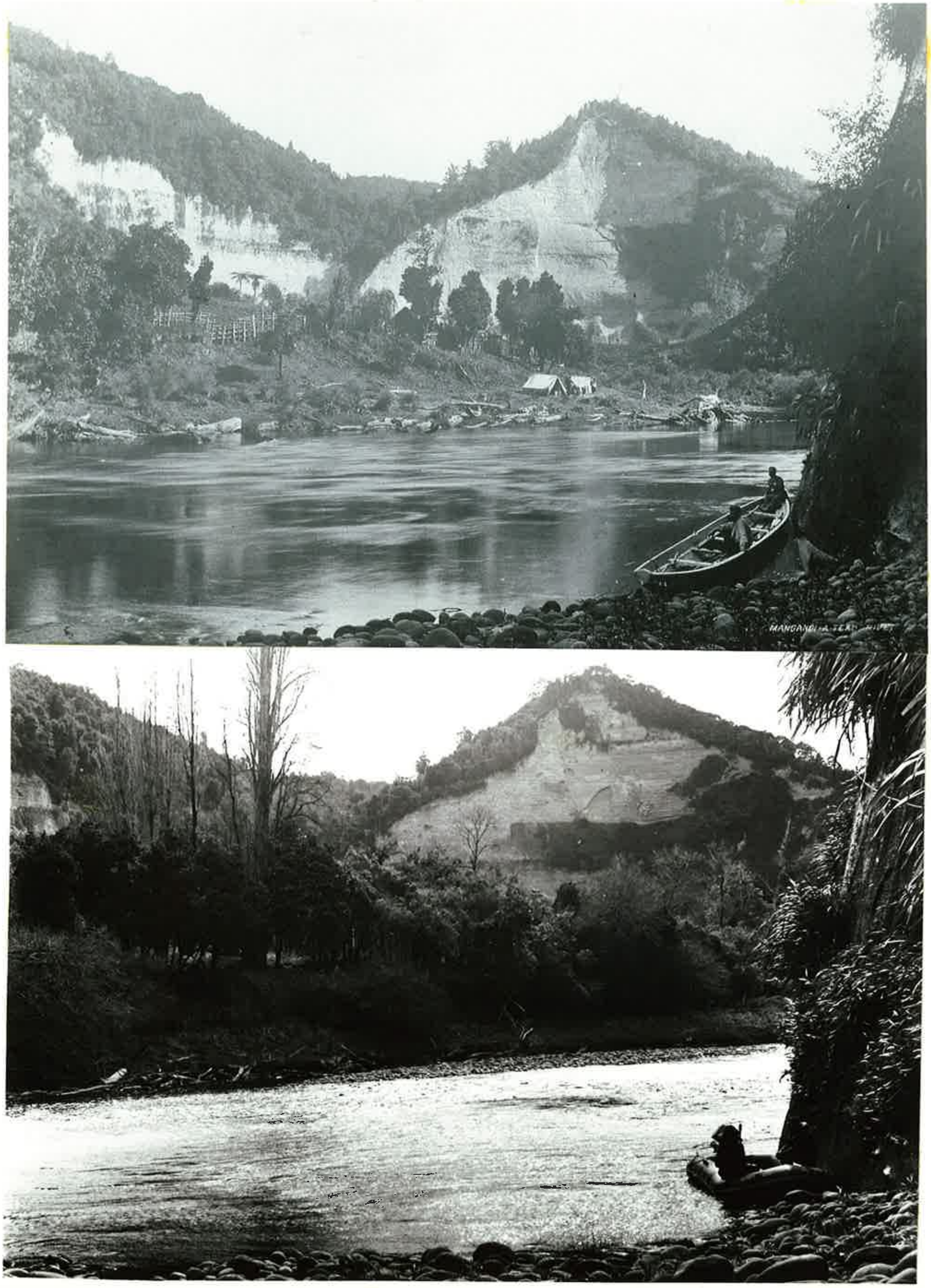

FIGURE 11. Pool 240 compared after 90 years. Above: ca. 1890 (Denton collection, Alexander Turnbull Library). Below: 1983. The shingle bank opposite is the river bank in the early photograph. The water level is now slightly higher and wider, but there is comparatively little change, despite many severe floods including a 1:100 year event.

may be compared with present day conditions and show that the general appearance of the river is unchanged - reinforcing the concept of long-term morphological stability.

4.6 Hydrology

4.6.1 Flow Characteristics

The Manganuioteao is the third largest Wanganui River tributary, contributing about 12% of the Wanganui River flow at Pipiriki. The flow at Ashworth represents 54% of the Manganuioteao catchment and reflects the rainfall recorded at nearby NZMS rain gauges at Orautoha, Waikune, and Raetihi. The remaining 46% of the catchment receives about 30% less rainfall than the upper catchment (Tonkin and Taylor 1978).

Table 3 summarises the hydrological data collected at Ashworth and the annual rainfall record at Orautoha which is significantly correlated with the annual mean flow of the river ($r = 0.89$).

River flows are maintained by the high rainfall of orographic nature which falls on or around the slopes of Mount Ruapehu. The variation of river flow has two main characteristics. The first is the fairly frequent short duration floods and freshes which indicated that run-off from rainfall events is fast. The second is the seasonal variation. Figure 12 shows that mean monthly flows in winter and spring (July and September) are more than twice the minimum mean monthly flows in summer and autumn (February and March). However, unusual climatic conditions may result in variation from this pattern as in 1979 when low flows were recorded in June and July (MWD 1982).

TABLE 3. Hydrological data - Manganuioteao River at Ashworth (Ministry of Works and Development 1982, Water and Soil Division 1981, Beable and McKerchar 1982, and New Zealand Meteorological Service 1983)

Mean annual discharge (1962-79) - 18.2 m^3/s
Maximum flow recorded (1964) - 463.0 m^3/s
Minimum flow recorded (1978) - 3.07 m^3/s
Mean annual flood (1962-79) - 321.0 m^3/s

Year	Maximum discharge (m^3/s)	Annual mean discharge (m^3/s)	Seven day minimum flow (m^3/s)	Annual rainfall at Orautoha (mm)
1962	315	22.6	5.48	1 727
1963	169	16.7	5.92	1 290
1964	463	23.6	5.17	1 703
1965	410	21.4	6.83	1 648
1966	295	16.9	5.50	1 416
1967	393	17.0	4.99	1 395
1968	378	18.8	3.79	1 465
1969	193	12.4	4.13	1 167
1970	279	17.3	3.41	1 417
1971	317	17.6	4.08	1 446
1972	267	17.5	4.92	1 292
1973	242	15.5	4.13	1 263
1974	365	17.3	3.78	1 368
1975	396	19.3	4.91	1 524
1976	332	20.0	3.75	1 585 (est)
1977	233	19.1	4.36	1 254
1978	358	14.9	3.25	1 191
1979	372	19.2	4.99	1 457
1980	-	-	6.59	1 568

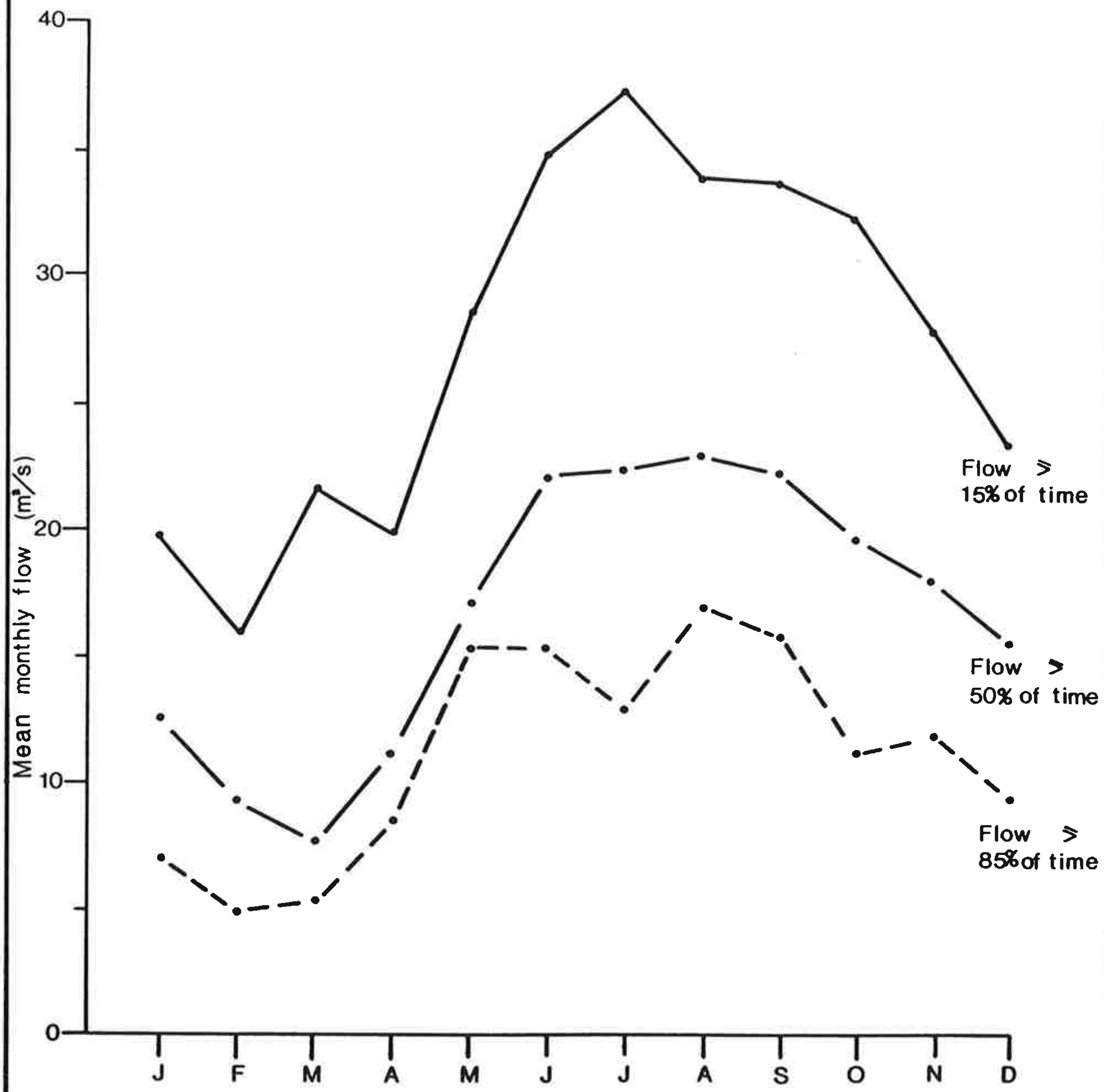

FIGURE 12. Seasonal variation of mean monthly flow at Ashworth.

The flow duration curve (Fig. 13) shows:

Minimum recorded flow - 3.07 m^3/s;

Flow exceeded 90% of the time - 5.0 m^3/s;

Flow exceeded 75% of the time - 7.5 m^3/s;

Flow exceeded 50% of the time - 11.2 m^3/s.

The ratio of mean to median flow of 1.6 indicates that the flow is fairly variable compared to other rivers around New Zealand (Table 4).

TABLE 4. Mean to median flow in some New Zealand rivers

River	Ratio of mean to median flow
Manganuioteao	1.6
Mohaka	1.3
Tutaekuri	1.5
Aorere	2.0
Motueka	1.7
Rangitikei	1.3
Patea	1.5
Waingongoro	1.5
Kakanui	1.8
Mataura	1.3
Waikaia	1.3
Ahuriri	1.3

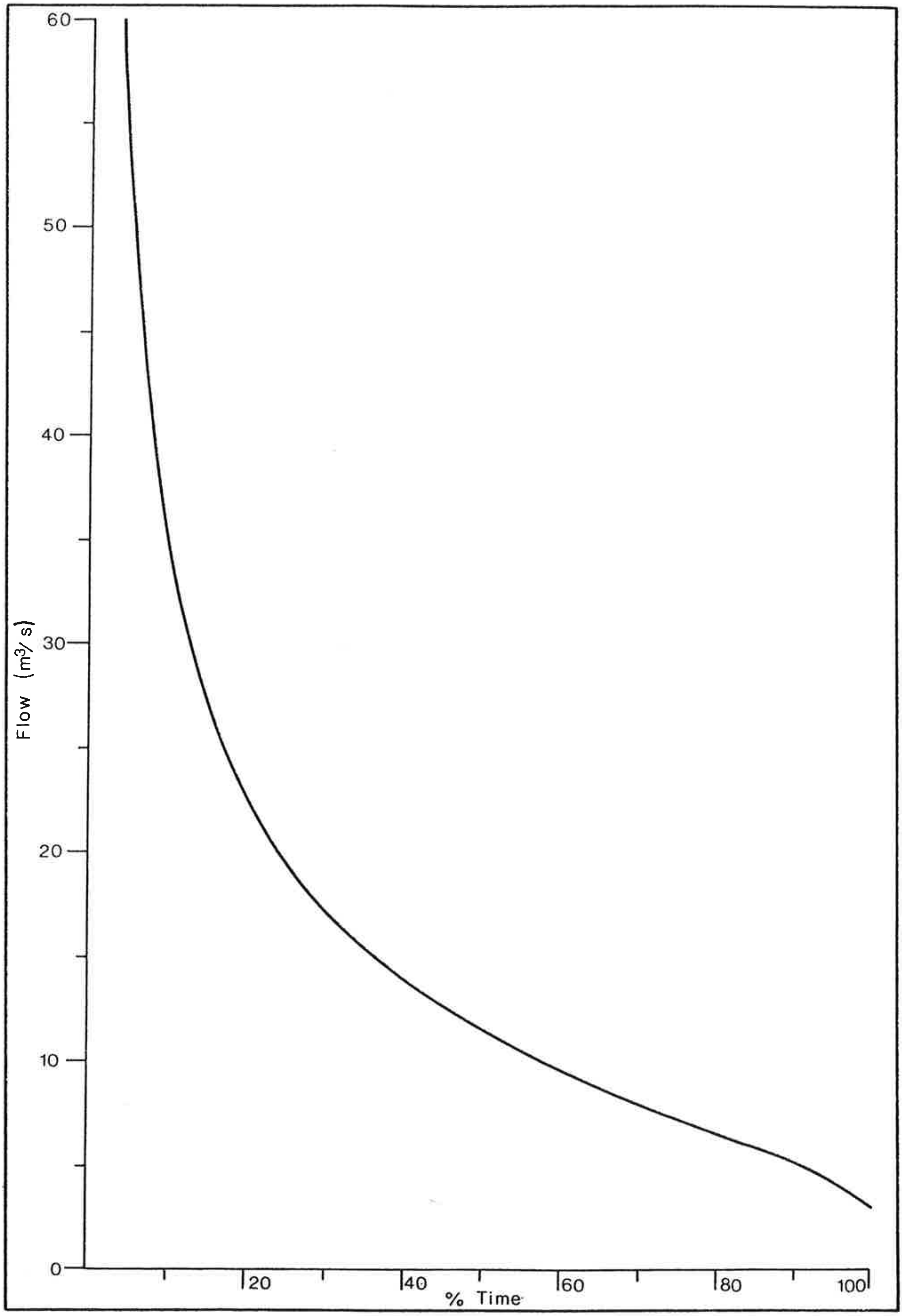

FIGURE 13. Duration of flows between 3 and 60 m^3/s at Ashworth.

4.6.2 Low Flows

Dry weather for periods of more than 1 month produces low flows in the Manganuioteao River. Tonkin and Taylor (1978) list four prolonged droughts recorded at Taumarunui between 1914 and 1977, two of which occurred while the water level recorder was operating. Rainfall records indicate that only one drought was experienced in Raetihi-Ohakune and it did not result in exceptionally low flows in the Manganuioteao. In 1978 a period of sustained low flow during March followed a dry, but not rainless period extending from January to the end of March. During this period the lowest ever flow of 3.07 m^3/s was recorded at Ashworth on 28 March with a mean flow for the day of 3.12 m^3/s. This is estimated to have a return period of 18 years.

Tonkin and Taylor (1978) compared the low flow characteristics of the Wanganui River tributaries and demonstrated the significance of Mount Ruapehu in attracting orographic precipitation and maintaining flows in the lower Wanganui during dry periods. The Manganuioteao is important in this respect as it is the largest tributary of the Wanganui draining from the slopes of Mount Ruapehu.

Figure 14 shows that the annual minimum daily mean flows conform closely to a log normal distribution which, when extrapolated shows that flows are unlikely to fall below 2.65 m^3/s more than once every 100 years. Table 5 lists the daily mean minimum flows for return periods of 2.33, 10, 50, and 100 years.

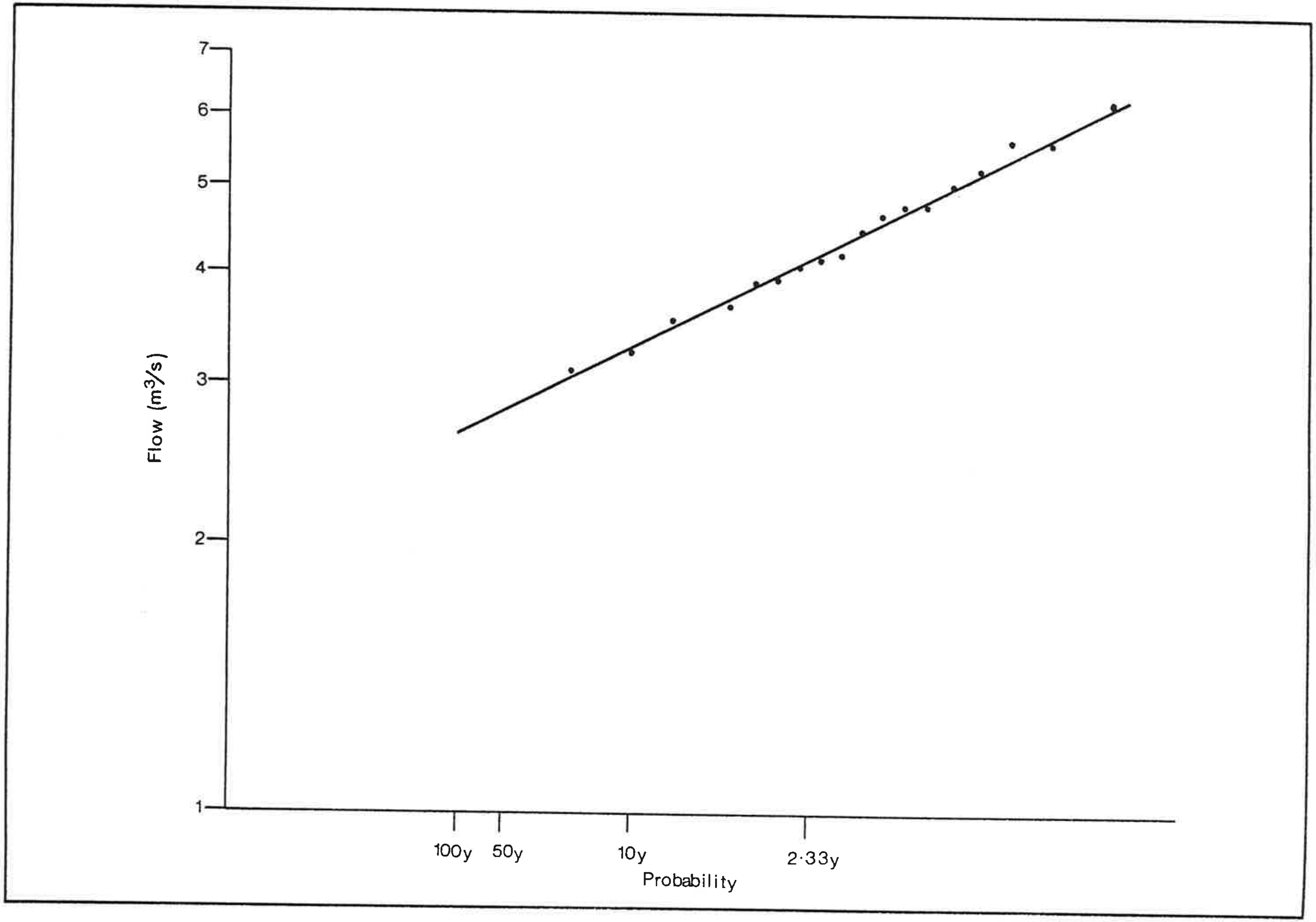

FIGURE 14. Annual daily minimum mean flows at Ashworth with frequency curve fitted.

TABLE 5. Low flow frequency analysis, Manganuioteao River at Ashworth, 1961-80

Return period	Minimum flow (m^3/s) One day	Seven day
Mean annual (1:2.33 yr)	4.44	4.77
1:10 yr	3.30	3.50
1:50 yr	2.80	2.93
1:100 yr	2.65	2.75

4.6.3 Flood Flows

The Manganuioteao River responds rapidly to rainfall and the instream effect is accentuated by its confined channel.

During 1961-80 annual flood peaks ranged between 169 and 463 m^3/s (Table 3) and occurred mostly during winter (33%) and spring (39%) with fewer in autumn (22%) and summer (6%). However, very large floods are more likely to occur in summer when the potential for heavy rainall is greatest. This is illustrated by the Wanganui River where five of the highest historic flood levels at Paetawa occurred in February (Tonkin and Taylor 1978). The estimated return periods and magnitudes of floods are shown in Table 6.

TABLE 6. Flood frequency analysis, Manganuioteao River at Ashworth

Return period mean annual	Flow (m^3/s)	Stage height (m)
1:2.33 yr	335	2.94
1:10 yr	510	3.7
1:50 yr	680	4.4
1:100 yr	750	4.7*

* Measured stage height to old bridge deck 9 m. Rating curve and stage height are in doubt at >4 m.

Between 1961 and 1980 the largest recorded flood was 463 m^3/s which is lower than one would expect, from the flood frequency curve, in a 20-year period (Fig. 15).

The largest remembered flood since about 1930 occurred in February 1940 when the river washed over the decking and removed a span of the old road bridge at Ashworth (H.H. Brown pers. comm.). This corresponds with a staff gauge height of about 9 m. Extrapolation of the stage-discharge curve gives a flow of over 1700 m^3/s for this flood which gives it an exceptionally high return period and casts some doubt on the validity of the rating curve extrapolation. In the Wanganui River at Paetawa the same flood was the highest recorded in over 100 years. The river rose 18.25 m, and the flood's return period was estimated at 100 years (Tonkin and Taylor 1978). It is likely that the same flood in the Manganuioteao would have had a similar return period and, therefore, would have been about 750 m^3/s according to the rating curve. However, the gauge height is an observation whereas the estimated flow is based upon much lower flow records, thus there appears to be a discrepancy which would need to be reconciled by survey methods.

The largest flood during the period of record (463 m^3/s) reached 3.43 m on the staff gauge at Ashworth and the largest flood during the study period reached a little over 3 m on the staff gauge, but the water level recorder was not operating at the time.

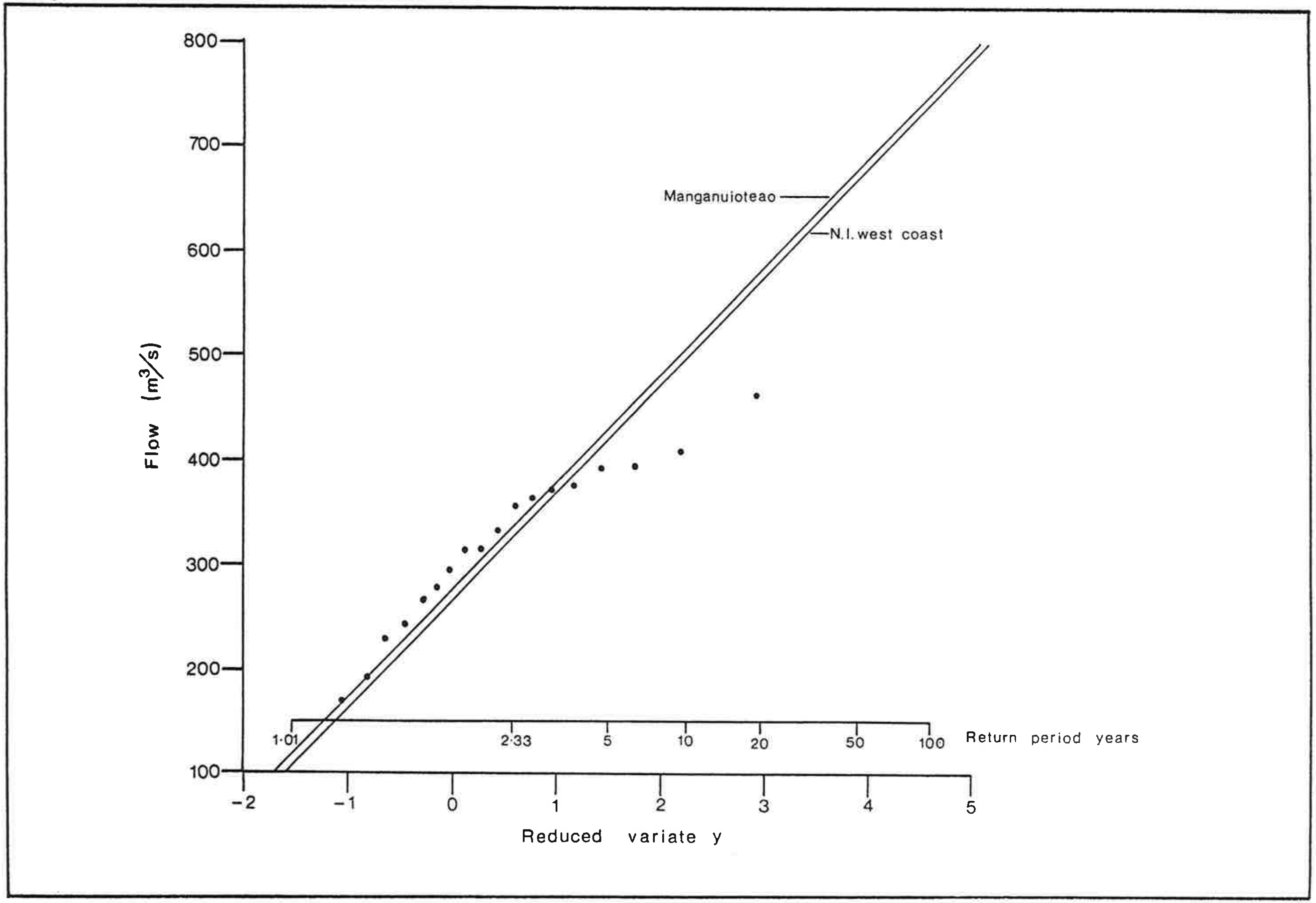

FIGURE 15. Maximum annual flows at Ashworth compared with frequency curve for North Island west coast (Beable and McKerchar 1982).

4.7 Water Quality

4.7.1 Chemistry

Generally, the Manganuioteao River has high quality water which reflects the catchment's geology and land use. Tonkin and Taylor (1978) presented water quality data for the Wanganui River system that showed that the Manganuioteao has some of the highest quality water, comparable with that of smaller streams with undeveloped bush catchments. The mean annual sediment discharge (58 t) is the lowest of the five largest Wanganui tributaries, and the median coliform level (70/100 ml) is the lowest of all the large tributaries below Taumarunui. Appendix I gives Manganuioteao water quality parameters from several sources and explanatory notes to the table give tolerances of aquatic life where applicable. Figure 16 shows the sampling stations.

The upper Manganuioteao and its tributaries contain extremely high quality water (stations 1, 2, 3, and 4 - Appendix I), but streams draining developed catchments (stations 7 and 9 - Appendix I) characteristically have higher sediment concentrations, wider pH ranges, and higher faecal coliform bacteria levels (Tonkin and Taylor 1978), all of which are indicative of increased run-off from pasture and cultivated land.

4.7.2 Temperature

The mean monthly water temperature at Ashworth (Table 7) parallels the mean monthly air temperature at Ohakune (Table 1) with a difference of about 1°C. Although the shelter afforded by the river valley often creates locally high air temperatures at times during summer, water

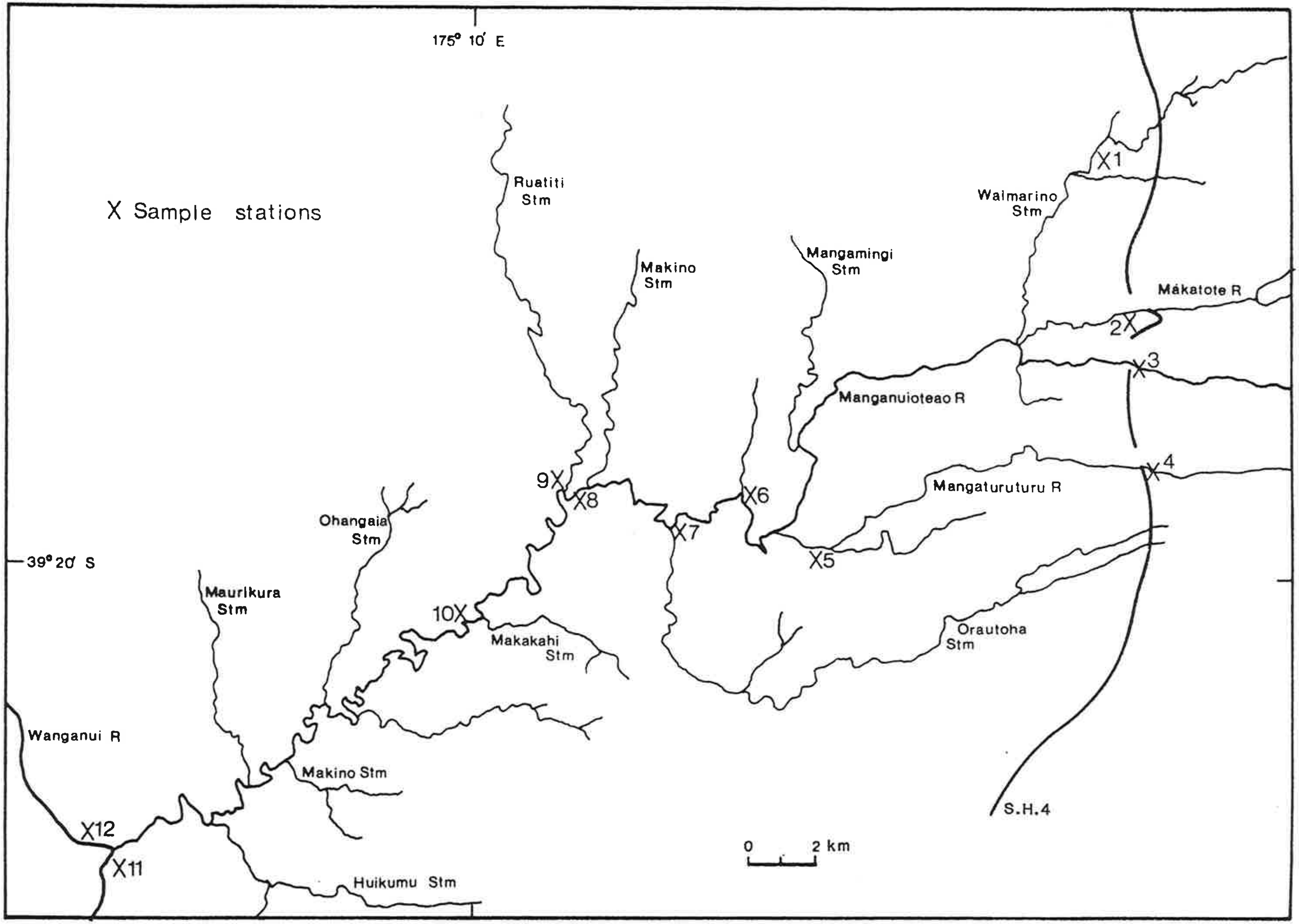

FIGURE 16. Water quality sample stations.

temperature does not reach extreme values. The maximum of 21.5°C (Table 7) was measured on a day when air temperature in the valley reached 27°C in the shade and though continuous records have not been collected it seems unlikely that water temperature at Ashworth would exceed 23°C under any conditions. Shading by high banks and vegetation, and water volume, velocity, and depth are important factors in maintaining equable temperatures under hot summer conditions. Jowett (1982) calculated a shade factor of 80% for the nearby Whakapapa River (Fig. 1) in predicting water temperature at Kakahi. The Whakapapa has a more open aspect and is generally shallower, especially in its lower reaches near Kakahi, than is the Manganuioteao. Continuous temperature recordings were kept by New Zealand Electricity Division of the Ministry of Energy in the Whakapapa River at Kakahi from 1973-82 during the months of December-February. These are summarised in Table 8. Temperatures measured in both rivers at comparable times, and comparison of the relevant monthly means (Tables 7 and 8), indicate that the Whakapapa at Kakahi is generally about 10% warmer than the Manganuioteao at Ashworth even though both sites are at similar altitudes.

TABLE 7. Mean monthly water temperature at Ashworth (Mosley 1982b)
Mean temp - 11.3°C SE 2.3°
Range - 5.8°-21.5°
(Tonkin and Taylor 1978, and personal records)

	J	F	M	A	M	J	J	A	S	O	N	D
(°C)	16	16	14	12.5	10	8	7	7	8	10.5	12	14.5

TABLE 8. Summer water temperature in the Whakapapa River at Kakahi (NZE recorder charts December 1973-February 1982)

	Dec	Jan	Feb
Maximum (°C)	23.1	25.0	24.5
Mean max (°C)	18.1	19.2	18.9
Minimum (°C)	10.0	11.0	11.4
Mean min (°C)	14.7	15.7	15.7
Difference - range (°C)		1.7-5.3	
- mean (°C)		3.3	
Mean (°C)	16.2	17.6	17.5
Mean hours per day >20°C (h)	4	7.3	6.0

Thus, the mean diurnal summer temperature range in the Manganuioteao River at Ashworth is likely to be 3°C and the time in excess of 20°C 3-6 hours on very hot days. In the upper and upper-middle zones temperatures exceeding 20°C have never been recorded; downstream from Ashworth peak temperatures are 1-3°C higher and conditions probably approach those recorded in the Whakapapa River at Kakahi (Table 8).

The 10-20°C temperature range is considered to be optimal for metabolic activity of most species of freshwater fishes in New Zealand (Morgan and Graynoth 1978, Richardson and Teirney 1982). At temperatures outside this range stressful effects become noticeable though tolerances vary among species.

The temperature regimes of rivers similar to the Manganuioteao are compared (Table 9) to see whether or not any distinct differences occur within New Zealand in large rivers which support premium fisheries. The 10 rivers compared are similar in that most support two species of large trout, they are large rivers, they are not lake fed, and their recorders are mostly 200-600 m a.s.l. Table 9 shows that all have similar temperature characteristics and that the Manganuioteao is close to average. Mean temperatures are within or close to the optimal range in all instances, and so the temperature regime is an important physical descriptor of a good trout fishery. This is reinforced by the fact that 6 of the 10 rivers in Table 9, including the Manganuioteao, are regarded as nationally important trout fisheries, and two as possibly of national importance using other criteria (Teirney, Unwin, Rowe, McDowall, and Graynoth 1982).

TABLE 9. Temperature characteristics of rivers similar to the Manganuioteao (Mosley 1982b, and Teirney *et al.* 1982)

Name	Location	$\overline{Q}$ (m^3/s)	Recel (m)	T max (°C)	$\overline{T}$ (°C)	T min (°C)	National importance
Manganuioteao	Ashworth	18.1	300	21.0	11.3	2.0*	yes
Taruarau	Taihape Road	6.2	582	22.2	11.2	2.8	yes
Ngaruroro	Kuripapongo	17.2	494	22.0	11.5	3.3	yes
Rangitikei	Springvale	21.9	561	19.0	11.0	5.0	yes
Mohaka	Glenfalls	35.2	311	22.2	12.1	2.0	yes
Rangitaiki	Murupara	22.3	201	18.6	12.7	6.7	yes
Wanganui	Piriaka	27.3	203	24.0	14.2	7.5	poss
Hakataramea	Above MHB	6.1	204	21.5	12.0	1.1	no
Ahuriri	South Diadem	22.3	610	17.0	9.1	0.6	yes
Mataura	Parawa	-	264	14.8	9.5	4.5	yes
Grey	Waipuna	49.2	171	20.0	10.4	4.5	poss
Range		6.1-49.2	171-610	14.8-24.0	9.1-14.2	0.6-7.5	
Mean				20.2	11.4	3.0	

$\overline{Q}$ - mean annual discharge.
Recel - recorder elevation.
T max - maximum temperature recorded.
$\overline{T}$ - mean temperature.
T min - minimum temperature recorded.
* 2°C appears to be aberrant both from the data presented by Mosley (1982b) and from the few records collected in the vicinity of Ashworth during the study period which indicate a minimum value of about 5°C.

4.7.3 Volcanic Effects

Mount Ruapehu is an active volcano and its Crater Lake contains acidic water which has a high chemical content and is toxic to aquatic life. The mountain has erupted many times in the past 120 years sometimes sending lahars (floods of water, mud, sand, and boulders) down streams which flow from glaciers adjacent to the crater.

Eruptions in 1969 and 1975 produced lahars which killed the fish and affected the benthic fauna in several tributaries of the Wanganui River, including the Manganuioteao. In 1977 a minor lahar flowed down the Whangaehu River after an eruption.

The Mangaturuturu River flows from a glacier adjacent to Crater Lake and is a continual source of volcanic contamination of the Manganuioteao River, but its most dramatic effects on the river occur after eruptions.

In 1975 the lahar frontwave reached S.H. 4 (16.4 km from Crater Lake) 30 minutes after the eruption of Mount Ruapehu and was followed 10 minutes later by the peak flow. The average velocity was estimated at 6.7 m/s and the flood surged violently from bank to bank, overtopping any banks less than 8 m high, and carrying boulders up to 1 m in diameter. An old concrete bridge pier weighing 90 t was carried 50 m downstream. At Ashworth on the Manganuioteao River (40.2 km from Crater Lake) the frontwave arrived 106 minutes after the eruption followed after 30 minutes by the peak flow. The average velocity was 4.9 m/s and the 3-m-deep pool by the recorder was filled with sand (Page and Paterson *in* Paterson 1976). In other parts of the river sand filled the bed to a depth of over 1 m and numerous dead trout and eels were found along the banks (H.H. Brown pers.comm).

Water quality also changed dramatically. The predominant effect was the lowering of the pH, but fluoride was present at a toxic concentration (Ellis 1975) and the suspended sediment concentration would have been sufficient to kill trout. Table 10 gives the concentration of various chemicals in samples collected up to 7.25 hours after the peak flow had passed.

Similar physical, chemical, and biological effects were noted after the 1969 eruption of Mount Ruapehu (Cudby 1969). After both eruptions a rise in pH to about 7 signalled a return to normal water quality and in some streams fish were recorded within a matter of weeks of this though populations took 3-4 years to regain their former density and diversity. Benthic fauna took up to a year to recover and in 1975 suffered continued after-effects of the eruption as material was flushed through streams and rivers during floods (Cudby 1976).

The Mangaturuturu River did not return to normal after the 1969 eruption and since that time it has been continually contaminated by volcanic effluent. At S.H. 4 its pH is 4-6, it has a bluish tinge, and deposits sinter. Trials with fingerling trout in 1970 resulted in all dying within 24 hours while those in a nearby unaffected stream remained alive (D.J.P. Turner pers.comm.). The benthic fauna consists only of occasional specimens of a resistant species. Gregg (1960) quoted several reports of the Mangaturuturu being alternately contaminated and clean during the past 100 years, and H.H. Brown (pers.comm.) stated that the river was contaminated prior to the 1945-46 eruptions of Mount Ruapehu. This was a major eruptive phase which took place over 10 months with frequent eruptions of ash and lava during which Crater Lake was displaced down its outlet, the Whangaehu River (Gregg 1960). During 1946-69, the Mangaturuturu was clean and trout were often observed near S.H. 4 during the spawning season (H.H. Brown pers.comm.).

TABLE 10. Water quality of 1975 lahar (Ellis 1975, and Freshwater Section, DSIR, Taupo pers. comm.)

	Time after peak (hrs-mins)	pH	SO_4	F	Cl	NO_3-N	NH_4-N	PO_4-P	Fe
			mg/m^3						
Mangaturuturu at S.H. 4	6-50	3.1	1900	23.1	492	-	-	-	-
Manganuioteao above its confluence with the Orautoha	7-17	3.2	390	4.7	100	35.0	371	32.6	1167

Notes:

SO_4 - sulphate radicle measured by Chemistry Division, DSIR, Lower Hutt.

F)
) - Fluoride and chloride concentrations calculated from proportion of sulphate compared with concentration in Wanganui River at Taumarunui (Ellis 1975).
Cl)

NO_3-N - nitrate nitrogen.

NH_4-N - ammoniacal nitrogen.

PO_4-P - phosphate phosphorus.

Fe - iron.

Near its confluence with the Manganuioteao, the Mangaturuturu now has a neutral pH and a normal assemblage of benthic invertebrates, the volcanic contamination having been buffered or diluted by tributaries entering it downstream from S.H.4. Tonkin and Taylor (1978) considered that the Mangaturuturu has a fairly small effect on the Manganuioteao under normal conditions, except for a small increase in dissolved salts, but Armstrong (1979) found that it makes a significant contribution to the suspended sediment load in the Manganuioteao during floods.

Upstream from its confluence with the Mangaturuturu the Manganuioteao River is not affected by lahars or volcanic chemicals. Ash from eruptions such as those which occurred during 1945-46 could find its way into the river there, but there is no record of this happening.

4.8 Tributaries

The tributaries of the Manganuioteao differ in character and quality depending upon their catchment geology and soils, vegetation, land-use, and gradient. The tributaries are shown in Figure 16 and their particulars are listed in Table 11. Water quality data for some are given in Appendix I.

4.8.1 Waimarino Stream

The Waimarino Stream drains tussock, bush, and an extensive swampy plain around Mount Hauhangatahi. It differs from the other upper zone tributaries of the Manganuioteao in having a lower gradient except in the last 3 km and its bed contains more gravel and sand. Its water exhibits a slight effect of run-off from developed land and a sewage

TABLE 11. Catchment area and discharge of the larger tributaries (Beca, Carter, Hollings, and Ferner 1979, and NZMS 1 Topographical Map series)

	Catchment area (km^2)	Mean annual flow (m^3/s)	Annual seven day low flow (m^3/s)	Annual mean as % of Ashworth flow	Catchment area as % of area at Ashworth	Catchment area as % of total
Waimarino Stm. S.H. 4	23.3	1.65	0.35	9	7.0	3.8
Makatote R. S.H. 4	36.1	2.88	0.71	16	10.9	5.8
Manganuioteao R. S.H. 4	0.5	1.53	0.44	8	6.2	3.3
Mangaturuturu R. S.H. 4	2.8	1.76	0.62	10	6.9	3.7
Mangaturuturu R. mouth	4.6	3.38	1.00	19	19.0	10.4
Orautoha Stm. mouth	55.3	2.06	0.33	11	16.7	8.9
Makino Stm. mouth	39.3	1.70	0.21	9	11.8	6.3
Ruatiti Stm. mouth	87.5	-	-	-	-	14.1
Tokitokirau Stm. mouth	8.3	-	-	-	-	3.0
Ohangaia Stm. mouth	29.2	-	-	-	-	4.7
Huikumu Stm. mouth	36.8	-	-	-	-	5.9

oxidation pond near S.H.4 (Appendix I). It is not entrenched except in the final part of its course and its catchment vegetation differs from that of the other upper zone tributaries (section 4.2).

4.8.2 Makatote River

The Makatote River is the largest of the upper zone tributaries. Its catchment lies between that of the Waimarino Stream and the Manganuioteao River on the slopes of Mount Hauhangatahi and is bush covered as described in section 4.2. The river channel is deeply incised in the lahar plain and it follows a direct line to its confluence with the Waimarino Stream and the Manganuioteao River which it meets at the scarp of the Raurimu fault (section 4.3). Cliffs of laharic material tower up to 100 m above the river at the S.H.4 crossing and there is a 25 m high waterfall 4 km upstream from S.H.4 (R.L. Scown pers.comm.). The gradient is high and the flow is turbulent. The bed is volcanic boulders with occasional patches of sand and gravel. Water quality is high, occasional releases of silty water or man-assisted slips contribute to the sediment load around S.H.4, but but there are no other sources of contamination.

4.8.3 Mangaturuturu River

The Mangaturuturu River begins at the base of the Mangaturuturu glacier on Mount Ruapehu and its course parallels those of the Manganuioteao and Makatote Rivers. Catchment vegetation, gradient, and bed materials are the same above S.H.4 as for the above two rivers, but its water quality differs and it is affected by eruptions of Mount Ruapehu which produce lahars (section 4.7.3). It has a wider, more open boulder bed in its upper reaches than do the above rivers, but it becomes progressively entrenched from about S.H.4. There are mudstone cliffs in many places below S.H.4 and the catchment vegetation there is mostly bush, some of which has been logged in the past. Parts of some tributaries below S.H.4 drain pasture land, and consequently the bacterial level at the river's mouth resembles that of the Waimarino Stream.

4.8.4 Orautoha Stream

The upper tributaries of the Orautoha begin in beech forest and scrubland near S.H.4, a little south of the Mangaturuturu River, but most of its tributaries drain pasture north of Raetihi (Figs. 16 and 2). The lower valley is large and open, about 2 km wide by 200 m high, with a fairly level bottom about 300 m wide. It enters the Manganuioteao valley from the south and both valleys are about the same size, but the stream has low banks and is not as entrenched as the Manganuioteao River. The valley appears to have been originally developed by a river larger than the present stream.

The Orautoha is one of the larger middle zone tributaries (Table 11). Since December 1917, its flow has been augmented by up to 312 ℓ/s (average 255 ℓ/s) from tributaries of the Makotuku Stream (Mangawhero River catchment) which are diverted through a hydro-electric power station into its middle reaches (WREPB pers.comm.). Observations near the mouth of the Orautoha during 1980 indicate that normal water level varies by about 20 cm between wet and dry periods and rises more than 1 m during moderate floods.

The water quality is lower than that of the Manganuioteao at their confluence and at times the effects of catchment development lower it further, for example, metal extraction in the upper reaches during 1966 covered the bed with 40-50 mm of silt and discoloured the Manganuioteao (Cudby 1966).

The stream bed consists of volcanic boulders and cobbles with patches of gravel and sand. The proportion of gravel increases in the upper reaches to 40% of the substrate in a 3 km reach (Tyson 1980). There are no waterfalls or obstructions and fish can move freely into the headwaters from the Manganuioteao River.

4.8.5 Makino Stream

The catchment is steep, sedimentary material, and the stream substrate is broken mudstone and a small amount of volcanic gravel. Vegetation is bush and scrub in the headwaters, manuka scrub and fern on higher slopes, and pasture elsewhere. The stream has an entrenched channel and enters the Manganuioteao on the right bank at Ashworth. It flows over a 2-m-high waterfall 800 m from its confluence with the Manganuioteao. Water quality has not been measured, but it can be assumed to be similar to that of the adjacent Ruatiti Stream.

4.8.6 Ruatiti Stream

The Ruatiti has the largest catchment of the Manganuioteao tributaries. Its mean annual flow has not been calculated. However, because the catchment is adjacent to the Makino flow characteristics are assumed to be similar, but of twice the magnitude (see Table 11). The upper catchment is bush and extensive areas of manuka scrub; the middle and lower catchments are mostly in pasture. The stream flows in an entrenched channel in its middle reaches, but its banks are lower in the upper reaches and in the final 1 km to its confluence with the Manganuioteao. The substrate is mostly solid mudstone, but there are a few volcanic boulders and cobbles and in the upper reaches a high proportion of gravel. There are several falls and shutes in the stream.

Water quality is lower than that of the Manganuioteao (Appendix I). Water temperature is generally higher and so are faecal coliform counts. Nutrient levels presented in Appendix I are low, similar to those recorded in the Manganuioteao itself, but both nutrients and suspended sediment would be expected to be higher in relation to the Manganuioteao during wet periods (McColl, White, and Gibson 1977, Tonkin and Taylor 1978). In the lower reaches the bottom is silty and the banks are muddy.

4.8.7 Tokitokirau Stream

The stream begins in bush country, but most of the catchment is manuka scrub with pasture on the valley floor. The stream is accessible in its upper reaches, but for most of its course it is hidden in a deep narrow gorge in sedimentary rock. There are a few volcanic stones in the substrate.

4.8.8 Ohangaia Stream

The Ohangaia is a right bank tributary which begins and ends in hilly pasture, but which drains an extensive bush catchment. The substrate is broken mudstone on a solid base and there are several waterfalls, one of which is 1 km upstream from the stream's confluence with the Manganuioteao and is 15 m high. A large earth-slump toward the stream is evident in this area as well.

4.8.9 Huikumu Stream

The Huikumu Stream is the largest tributary in the lower zone. The country it drains to the south of the Manganuioteao River was developed and farmed until the late 1970s, though much of the hill country had reverted to scrub and second growth bush by then. Beginning in the early 1980s this land has been progressively cleared by cutting and burning and has been planted with exotic trees, mainly the Monterey pine (*Pinus radiata*). Sheep and cattle are still grazed in the catchment and previously high populations of feral goats and pigs are controlled at low levels to aid the afforestation programme (T. Tapp pers.comm.). The Huikumu system contains numerous waterfalls and one of its tributaries, the Mangatawhero Stream, flows underground in a series of caverns for about 400 m. There is a 25-m-high waterfall in the Huikumu 3 km upstream from its confluence with the Manganuioteao River, and the stream is bounded by sheer mudstone cliffs and hills rising 300 m above it on each side. The valley widens a further 2 km upstream and pasture commences. Where the Huikumu traverses the Manganuioteao valley its substrate consists of volcanic boulders and cobbles on solid mudstone, but in its own catchment its substrate is mudstone boulders and cobbles and solid mudstone. The Huikumu carries a high silt load and the substrate is heavily silted. Its flow is generally turbulent, but there are calm, slow flowing areas in the middle reaches.

4.8.10 Makino Stream

A second Makino Stream enters on the left from a catchment adjacent to that of the Huikumu. At the mouth the stream is small and it resembles the Huikumu in both quality and substrate.

4.9 Land Use and Catchment Development

Sheep grazing is the principal agricultural activity in the Manganuioteao catchment. Cattle are grazed and crops are grown on easier slopes and valley bottoms. Some market gardening is practised in the catchment near Raetihi. Quarrying for road metal takes place periodically, sometimes on a large scale, adjacent to the river or its tributaries, and there is a small amount of exotic afforestation in the Waimarino Stream catchment. Land preparation for exotic planting encroaches into the Manganuioteao catchment over some southern hilltops and along several southern tributaries where indigenous forest and scrub have been clear felled and burned and a network of roads has been constructed. The WREPB has operated a small hydro-electric power station since 1917 in the Orautoha Stream catchment. This diverts an average of 255 ℓ/s from the Makotuku Stream, a tributary of the Mangawhero River.

The proposed development of the hydro-electric potential of the Manganuioteao is the most serious threat to the river. The large scale afforestation to the south of the lower zone is a lesser threat and can be minimised by careful practices and supervision. Diversification into different forms of agriculture and localised projects such as bridge works associated with the electrification of the North Island main trunk railway also have the potential to adversely affect the river, but can be controlled under existing systems.

4.9.1 Hydro-electric Development

In 1967 the Ministry of Works and Development produced a three stage scheme for electricity generation on the Manganuioteao River as part of their proposals to develop the hydro-electric potential of the Wanganui River (Beca, Carter, Hollings, and Ferner 1979). The Wanganui scheme was shelved after preliminary investigations and with it the Manganuioteao proposals, but in 1978 the WREPB began investigating power generation possibilities again and the Manganuioteao was reconsidered. Engineering consultants produced a feasibility report (Beca *et al.* 1979) describing a three stage development which would include the upper and middle zones of the Manganuioteao utilising 554 m of the 665 m hydraulic head available to produce 220 GWh annually from a total plant capacity of 55 MW (Fig. 17).

4.9.1.1 Erua Forest Scheme

Part of the flows from the Mangaturuturu and Manganuioteao Rivers would be diverted near S.H.4 and led by canals to a 15-m-high earth dam before discharging via a penstock to a 9 MW powerhouse in a small valley entering the Manganuioteao below its confluence with the Mangamingi Stream on the opposite side. The mean annual flows of the Manganuioteao and Mangaturuturu Rivers at S.H.4 are estimated at 1.53 m^3/s and 1.76 m^3/s respectively and 25-52% of the former and 65% of the latter would be diverted. The design flow for the power station is 4.6 m^3/s and the hydraulic head is 245 m.

4.9.1.2 Orautoha Scheme

A 43-m-high dam across the Manganuioteao River near its confluence with the Mangamingi Stream upstream from the Erua powerhouse, would enable water to be diverted into a 1700-m-long tunnel and, through a single penstock, to a generating station in the Hoihenga valley where it meets the Manganuioteao River. The scheme would have a hydraulic head

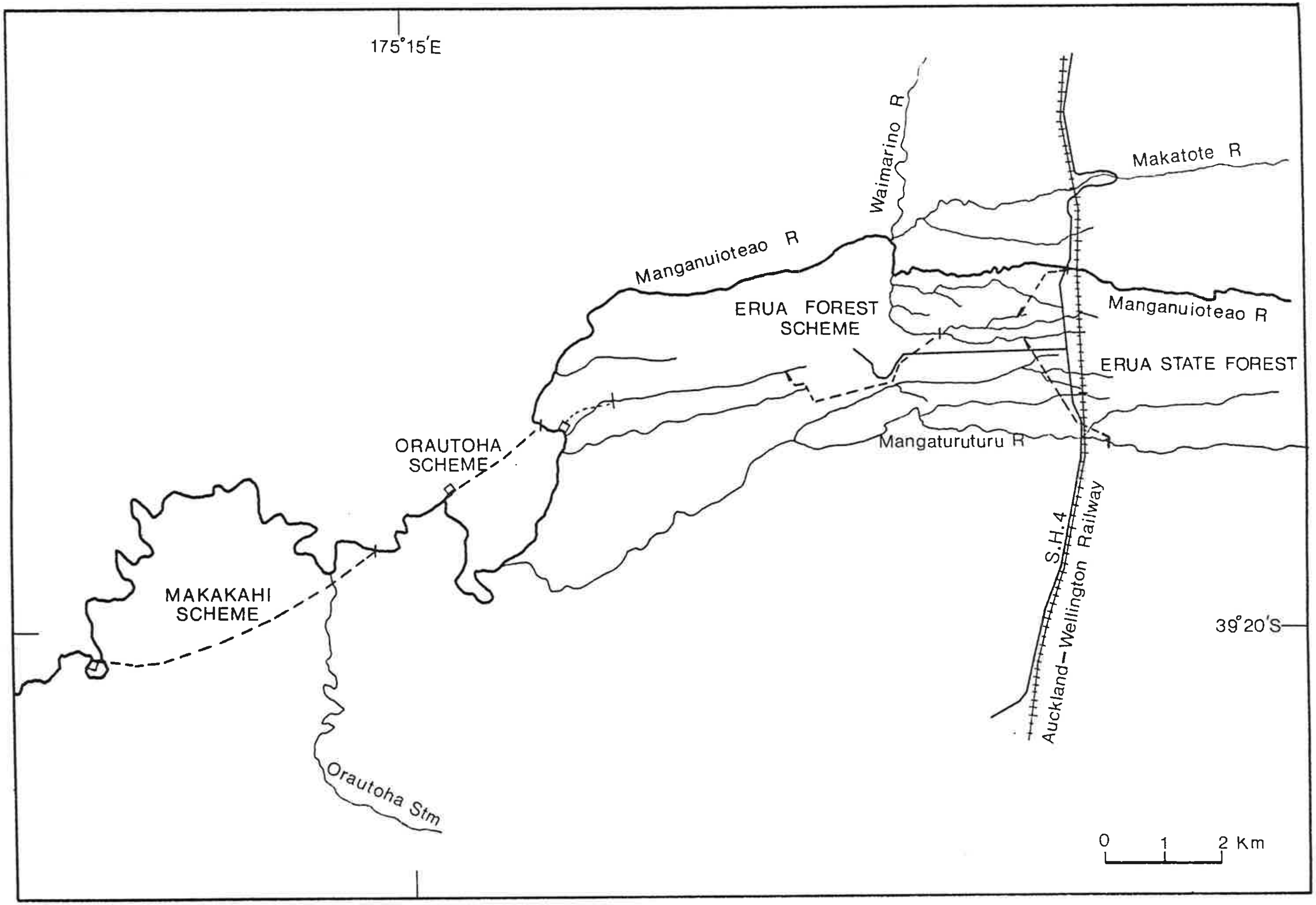

FIGURE 17. Proposed hydro-electric developments on the Manganuioteao River.

of 128 m, a maximum flow of 15.5 m^3/s, and a capacity of 15 MW. The reservoir formed behind the dam would extend 1200 m upstream.

4.9.1.3 Makakahi Scheme

A dam across the Manganuioteao valley 1.2 km upstream from the river's confluence with Orautoha Stream would form a 26-m-deep impoundment and enable water to be diverted into a 5.5-km-long tunnel crossing the Orautoha valley by an inverted siphon and leading to a powerhouse on the bank of the Manganuioteao River near its confluence with Makakahi Stream. The maximum diverted flow would be 28.8 m^3/s, the hydraulic head 161-181 m, and the capacity 35-40 MW depending upon the ultimate siting of the generating station.

These schemes would produce over 60% of the WREPB's 1977/78 electricity requirement and are considered attractive both economically and environmentally (WREPB 1978).

4.9.1.4 Impact

The ultimate siting and operation of the schemes will have some bearing on their impact on the river and its inhabitants, but generally there is a potential for serious damage. The Orautoha and Makakahi dams would be barriers to fish moving upstream and the stations would restrict downstream movements. In the 36.5 km of river between S.H.4 and the Makakahi powerhouse outfall, flows would be reduced and two reservoirs would flood over 2 km of river to form deep, steep sided pools with limited capacity either for water storage or for fish habitat. The remaining 29 km of the river would be subjected to fluctuating flows of two to three times normal, though sharp variations are unlikely (Beca *et al.* 1979). Depending upon their severity, flow fluctuations tend to destabilise biological systems in rivers and make them less productive. White, Hansen, and Alexander (1976) found that streams with the most stable flow generally support the most trout and Richardson and Teirney (1982) demonstrated a positive relationship between trout numbers and the amount and stability of discharge.

Mainstem water quality would change because a greater proportion of the water would come from lower quality tributaries draining pastoral land, and the temperature regime would change to one less equable.

The Whakapapa River bears many similarities to the Manganuioteao and the effects of the Tongariro power development diversion upon it give some insight into the effects which diversions and dams would have upon the Manganuioteao. The Whakapapa intake structure is a barrier to trout passing upstream and normally all but 0.6 m^3/s of the water is diverted through tunnels into the Lake Taupo catchment so it is also a barrier to most fish passing downstream.

Richardson and Teirney (1982) recorded the following effects in different sections of the river. Upstream from the intake there was a decline in the number of trout, elimination of a spawning run of trout, and non-recruitment from the area. Downstream from the intake, in the first 6.9 km to a sizeable tributary there was a reduction of flow from 14 m^3/s to less than 1 m^3/s, an estimated 90% reduction of medium and large fish, a substantial reduction in adult habitat, a decrease in habitat stability caused by the magnitude of flow fluctuations, and a probable reduction in benthos biomass caused by stranding and a build-up of fine sediment in pools. It was estimated that increasing the residual flow from 0.9 m^3/s to 5.2 m^3/s would increase adult trout habitat by 40%. In the next 5.7 km downstream the flow increased by 33% and the number of trout increased from 1.8 to 9.6 per kilometre. A second sizeable tributary draining pastoral and cut-over bushland then joins the Whakapapa and increases its flow by a further 33% in the remaining 16 km of river. In this section, numbers of trout per kilometre and the ratio of brown to rainbow trout were the same as those in a comparable reach of the Manganuioteao River which suggested that the tributary flows may have offset the effects of the diversion by about 12.6 km downstream from it. Other effects recorded were a decrease in water quality caused by a greater proportion of water originating from developed land, with increased summer temperatures and sediment deposition.

From the angling viewpoint the trout caught are now larger on average than before the diversion, but the catch rate has decreased and the river is no longer the most highly valued in the district, a description which now applies to the unmodified Manganuioteao River.

Development proposals for the Manganuioteao schemes include several flow options and configurations which would allow residual flows to be released, and the Erua scheme takes acidic water from the Mangaturuturu River and mixes it with the upper Manganuioteao which would probably neutralise its acidity (Cudby 1978a) and render most of the remaining Mangaturuturu River habitable to trout. However, the residual flows have a considerable influence upon the economic viability of the schemes and will be a continual source of contention. The establishment of a fishery in the lower Mangaturuturu would be negated by any redirection of acidic water during shut-downs, floods etc.

4.9.2 Forestry

Land development for forestry is a large scale operation requiring a network of roads and tracks; removal of existing vegetation by felling, dessicating, and burning; management during the growing phase; and finally felling and removal.

Morgan and Graynoth (1978) gave an extensive review of the effects of forestry practices upon streams and freshwater fishes. These include short- and long-term alterations to stream flows, increased sediment levels and bed-load movements, blockages and changes to stream morphology, temperature changes caused by increased or decreased shading, increases in some dissolved compounds and decreases in others, toxic levels of herbicides, insecticides, and fungicides, and enrichment by fertilisers.

South of the lower zone of the Manganuioteao River, bordering it in some places and including the catchments of southern tributaries from the Tokitokirau Stream downstream, Winstone Afforestation Limited have leased or bought 14 157 ha and since 1978 have proceeded with the establishment of the Waimarino Forest (Fig. 18). To December 1984, of a total 9017 ha considered plantable 4100 ha had been cleared and planted with *P. radiata* to supply pulpwood on a 10-15 year rotation and saw-logs in the longer term; 5140 ha of land considered unplantable is managed as reserves (35%) or left in its present state (65%). Planting of the remainder will terminate in 1988 (Fig. 18) (Winstone Afforestation Ltd 1984).

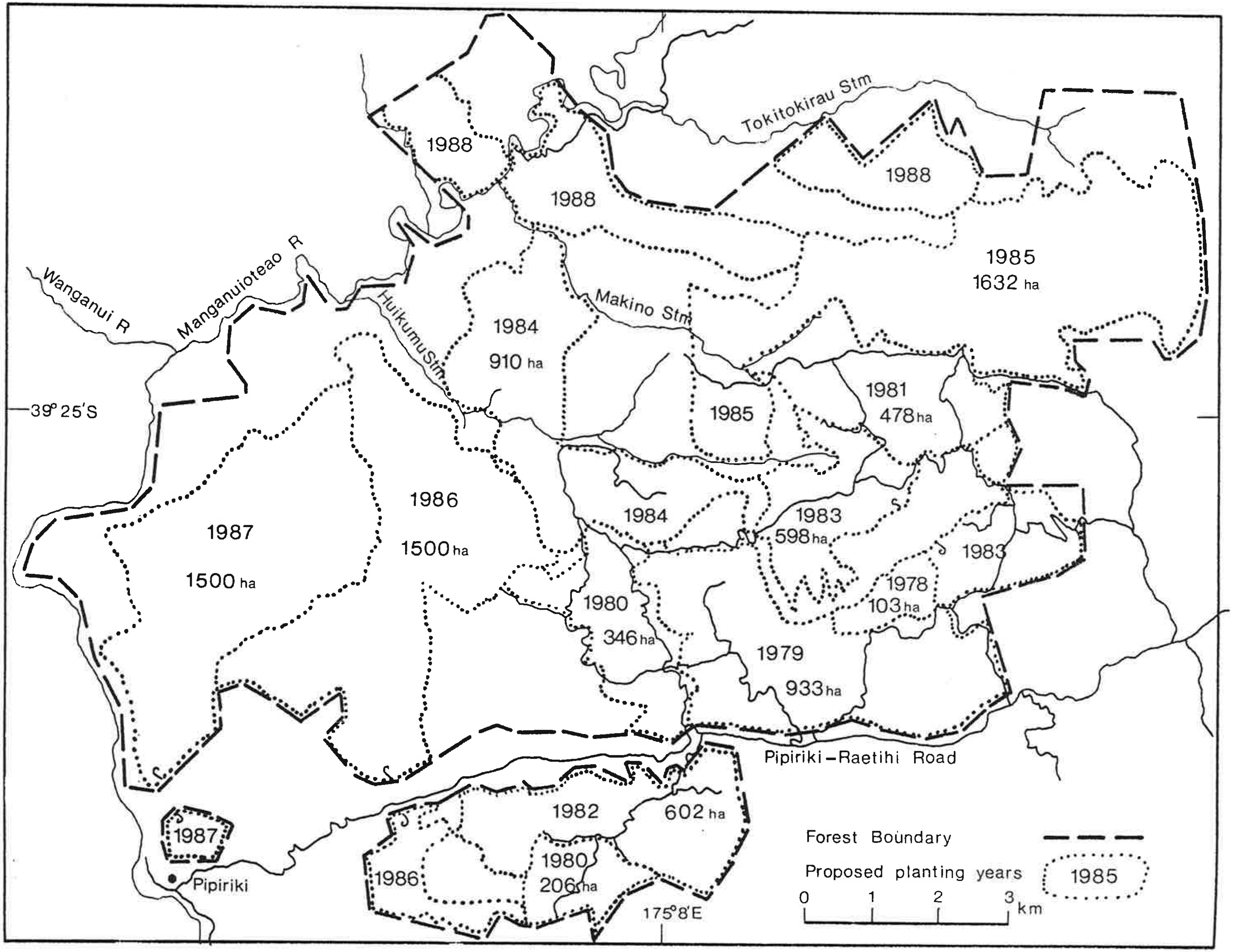

FIGURE 18. Waimarino Forest.

Winstone Afforestation Limited have stated land use policies. For protection of water-ways these are:

> Lakes and rivers - "A strip of land 50 m back from the ...... river bank or other practical point will be classified as permanent type. These may be cleared and grazed but will not be planted in production tree species."

> Streams - "In general, all streams large enough to support fishing, provide pools large enough for recreation use, or with some aesthetic value, should be bordered with a permanent type strip a minimum of 30 m wide on each side of the stream."

Erosion and the consequent sedimentation of streams seems inevitable when the ground cover is disturbed in steep country of this type (Muirhead and Turner 1980) and this is seen as the most serious threat of forestry operations to the Manganuioteao River. A certain amount of erosion occurred in the catchments of the Makino and Huikumu streams after road construction and vegetation clearance, and there were signs of periodic heavy sedimentation in both streams as a result. The effect upon the Manganuioteao River was not visually distinguishable from the sediment load from upstream sources, but the additive effect of all sources combines to downgrade the aquatic environment in the lower zone.

To have and maintain a healthy river which is attractive to migratory fishes and supports a good stock of trout, all land and water users must make an effective effort to reduce erosion and the sedimentation of streams.

5. NATIVE FISHES

5.1 Introduction

The Manganuioteao River is continuous with the Wanganui River for fish in the system which spend a part of their life cycle at sea. Without access to tributaries such as the Manganuioteao, or if modification of such a river rendered it unsuitable as habitat, many of these fish would be unable to complete their life cycle.

In the Manganuioteao River 11 species of native fish were found (Table 12) and all except Cran's bully have a marine stage in their life cycle. The first eight species listed in Table 12 have been in the past, and in most cases still are, the basis of fisheries in the Wanganui River.

TABLE 12. List of native fish found in the Manganuioteao River

Common name	Scientific name
Lamprey	*Geotria australis*
Long-finned eel	*Anguilla dieffenbachii*
Short-finned eel	*Anguilla australis*
Common smelt	*Retropinna retropinna*
Banded kokopu	*Galaxias fasciatus*
Short-jawed kokopu	*Galaxias postvectis*
Koaro	*Galaxias brevipinnis*
Torrentfish	*Cheimarrichthys fosteri*
Red-finned bully	*Gobiomorphus huttoni*
Common bully	*Gobiomorphus cotidianus*
Cran's bully	*Gobiomorphus basalis*

Investigations of native fish in the Manganuioteao were supplementary to trout studies and were aimed simply at finding out distributions. Hence the brevity of our results and the need for further investigation into all aspects of native fish in the Manganuioteao River and Wanganui River system.

5.2 Methods

Data on the distribution of native fish in the Manganuioteao River were obtained from electric fishing and observations made during various diving exercises (see section 6).

The principal method used was electric fishing which was done with a machine and methods described by Burnet (1959). Figure 19 shows the sites electric fished and the coverage of diving exercises. Most electric fishing sites were fished in 1979 and a further three added in each of the years 1980 and 1984. Records of several sites electric fished in 1965 and 1970 are also included.

Electric fishing was restricted to shallower margins in the main river, but almost complete coverage was obtained at sites in tributaries. Sampling distances ranged from 40 m to 150 m in the main river and 10 m to 200 m in tributaries. The sampling was strictly qualitative though numbers are mentioned for some species to indicate their apparent abundance.

Access difficulties restricted the various sampling activities, particularly the electric fishing, and this resulted in sampling gaps in the Manganuioteao's lower reaches and headwaters. Accordingly, our knowledge of the species present and their distribution in the Manganuioteao River is not exhaustive.

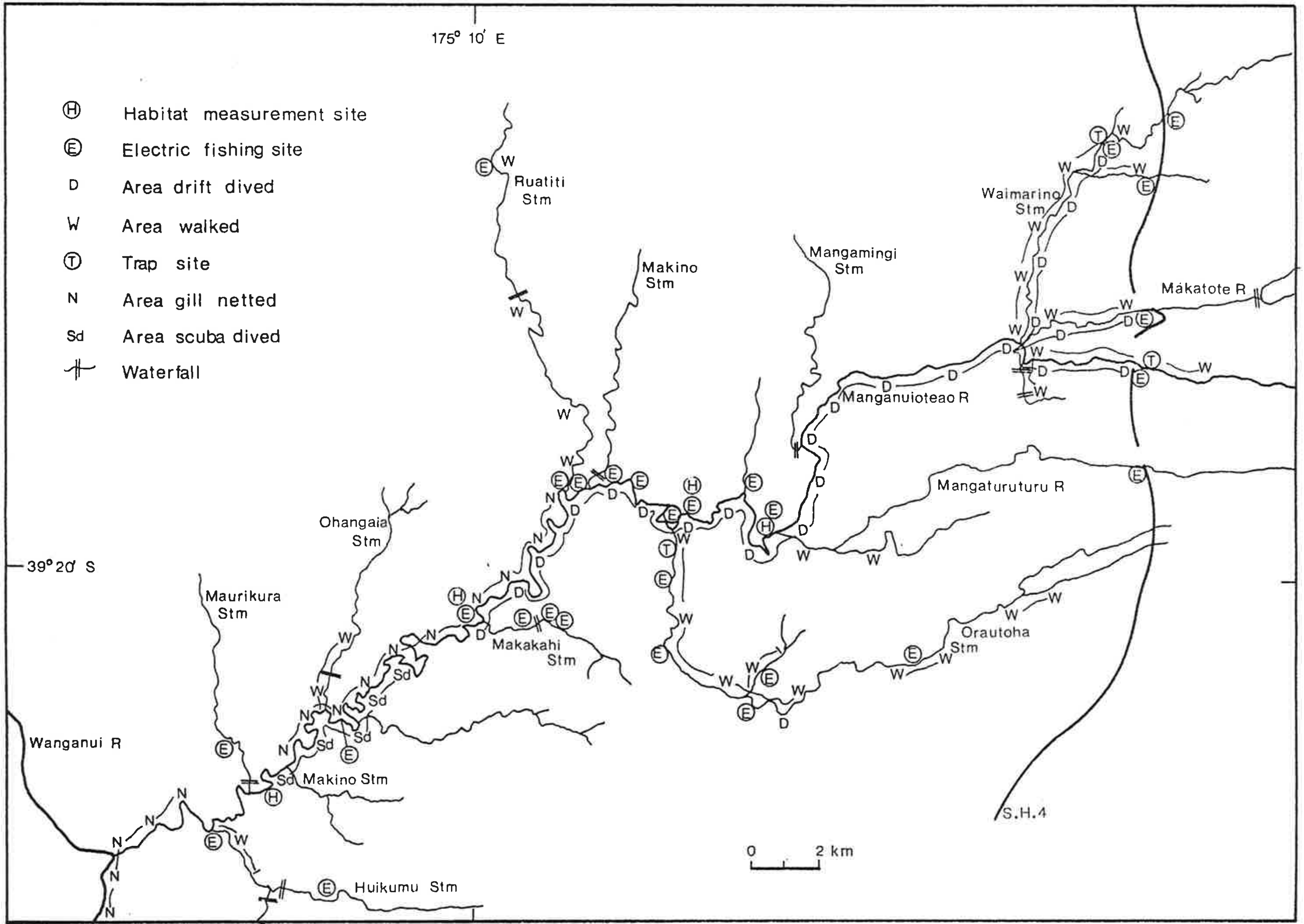

FIGURE 19. Areas sampled for fish distributions.

5.3 Results

5.3.1 Lamprey (*Geotria australis*)

Adult lampreys migrate from the sea into rivers such as the Manganuioteao during autumn freshes. This migration is associated with the breeding stage of the lamprey's life cycle, though documented knowledge of lampreys breeding in New Zealand and what happens to the adults afterwards is vague. However, juvenile lampreys can be found in the muddy-silt bottoms or sandy shallows of streams and they remain in this type of habitat up to 2 years before migrating out to sea (McDowall 1978). From observations of lamprey adults in bush streams in New Zealand and from details of the habitat utilised by spawning lampreys in Australia it has been inferred that in New Zealand lamprey spawning takes place in small bush streams with gravel substrates. Such substrates and conditions are available in the Manganuioteao River and its tributaries.

Lamprey fisheries based on the upstream migration of lamprey adults were, and in some places are still, important to Maoris. Although there is no evidence of a lamprey fishery in the Manganuioteao, 10 km downstream from its confluence with the Wanganui there is a lamprey fishery at Pipiriki. In former times considerable effort was put into lamprey fishing in the Wanganui River (section 3) which indicates that sizeable quantities of lampreys were caught as they migrated up river in search of suitable breeding areas. The continuation of lamprey fishing at Pipiriki indicates that significant numbers still migrate beyond this point in the Wanganui River. Todd (1979) reported that the total catch from one weir at Pipiriki may amount to several thousand a season.

Suitable lamprey breeding and rearing habitats have not been identified in the Wanganui system, but two ammocoetes, the lamprey's larval stage, were caught in the lower reaches of the Orautoha Stream in the Manganuioteao River system (Fig. 20). Typical ammocoete habitat, in which these two lampreys were found, was not sampled frequently in the Manganuioteao and so it is likely that more ammocoetes would have been found if these habitats had been more extensively sampled.

Most people involved in freshwater work have seen little of lampreys even in systems where lampreys are harvested in considerable numbers. If it were not for the Maori fisheries based on this species even less would be known of the lamprey's whereabouts. For these reasons the possible use of the Manganuioteao River by a large population of lampreys may also have gone undetected.

5.3.2 Long-finned Eel (*Anguilla dieffenbachii*)

Almost the entire life cycle of the long-finned eel is spent in freshwater, and it is only at the end of their life cycle that they migrate out of freshwater during autumn to spawn. The beginning of their life cycle is spent at sea and they enter freshwater as glass eels in the spring.

Recreational eeling takes place throughout the Wanganui River and in the middle reaches of the Manganuioteao River. Spears, gaffs, handlines, and hinakis are the methods most commonly used.

From the Wanganui area about 5 full-time and 25 part-time eelers are known to base their operations in the Wanganui River, but fishermen from other areas such as Auckland are also known to fish there occasionally. Up to 400 fyke nets can be found in use in the river at any one time when fishermen from outside the area are taken into consideration (I.C. Stoneman pers.comm.). As well as the Wanganui River, the mouth

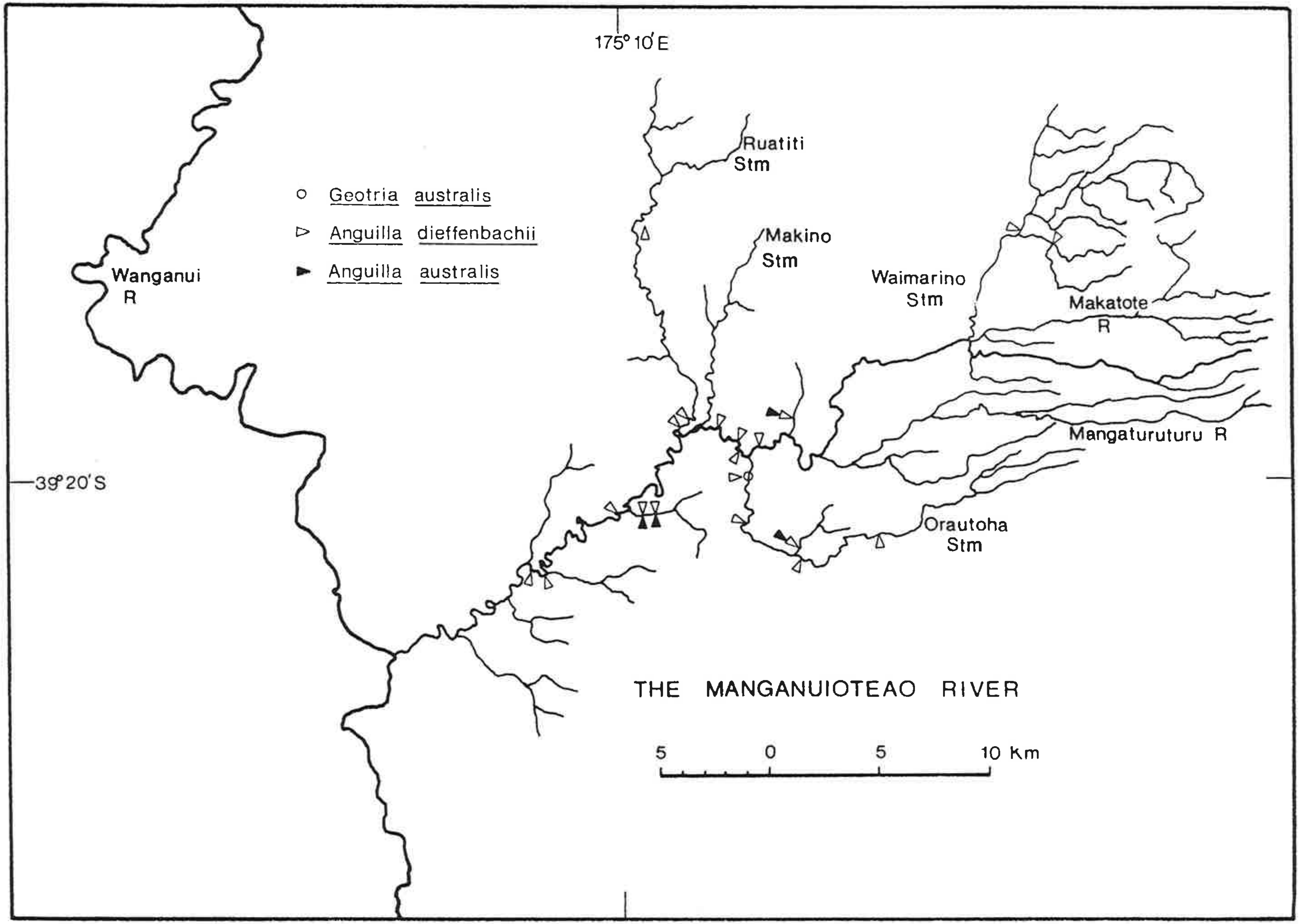

FIGURE 20. Distribution of *Geotria australis*, *Anguilla dieffenbachii*, and *Anguilla australis*.

and very lower reaches of the Manganuioteao are often fished by eelers who gain access by jet boat. In 1980, the four fishing areas in the Wanganui River area had an eel catch of 28 055 kg of which about 70% was longfins. It was not possible to get the exact catch or species composition for the Wanganui River, but it is probably predominantly longfins and in the upper regions entirely this species (P.R. Todd pers.comm.). Figure 20 shows that longfins were found throughout most areas of the Manganuioteao River that were sampled with the exception of the Mangaturuturu, and Makatote Rivers, and the Manganuioteao above its confluences with these rivers. Otherwise distribution gaps for longfins reflect areas not sampled and it is likely that the species is more widely distributed throughout the Manganuioteao river system than is shown.

Few records of longfin abundance were kept, but at electric fishing sites they were often recorded as "numerous" or "abundant". In the Orautoha Stream more than 100 were counted in the catch at one electric fishing site and at another site in the main river 52 were counted. During drift dives up to 32 longfins were counted between the "three rivers' confluence" and the Mangamingi. Below this section to the Mangaturuturu up to six longfins were counted, but below this drift divers have only ever counted one or two longfins. Most longfins seen by divers were large adult sized eels. River morphology (section 4.5) changes in the same area of the river as the dive counts of longfins decrease, but there is little to indicate whether this change affected longfin abundance or just reduced the opportunity to observe them. Also, observations of fish during drift diving concentrated more on trout.

In general longfins appeared to be widespread throughout the mainstem with a noticeable abundance of large longfins above the Mangamingi.

5.3.3 Short-finned eel (*Anguilla australis*)

The life history of the shortfin is essentially the same as that of the longfin though shortfin adults migrate to sea earlier than longfin adults (McDowall 1978).

Short-finned eels were only found during electric fishing in the Manganuioteao River and occurred at only five sites (Fig. 20). From these five sites less than 10 short-finned eels were caught. Short-finned eel distribution and numbers found in the Manganuioteao River indicate that few suitable habitats exist for shortfins within the areas sampled and that distribution is likely to be confined to the middle and lower reaches.

5.3.4 Banded Kokopu (*Galaxias fasciatus*)

Apart from a short period in the sea as juveniles, banded kokopu spend all their life cycle in freshwater. The upstream migration in spring of juvenile banded kokopu and other juvenile galaxiids makes up the New Zealand whitebait catch.

Recreational whitebaiting in the Wanganui system is mostly done in the lower reaches of the Wanganui River, and depending on conditions, tides, and weekends or holidays up to 100 people can be found whitebaiting at one time in this area (I.C. Stoneman pers.comm.).

In the Manganuioteao banded kokopu were found at two electric fishing sites (Fig. 21) and in each case only a single fish was caught.

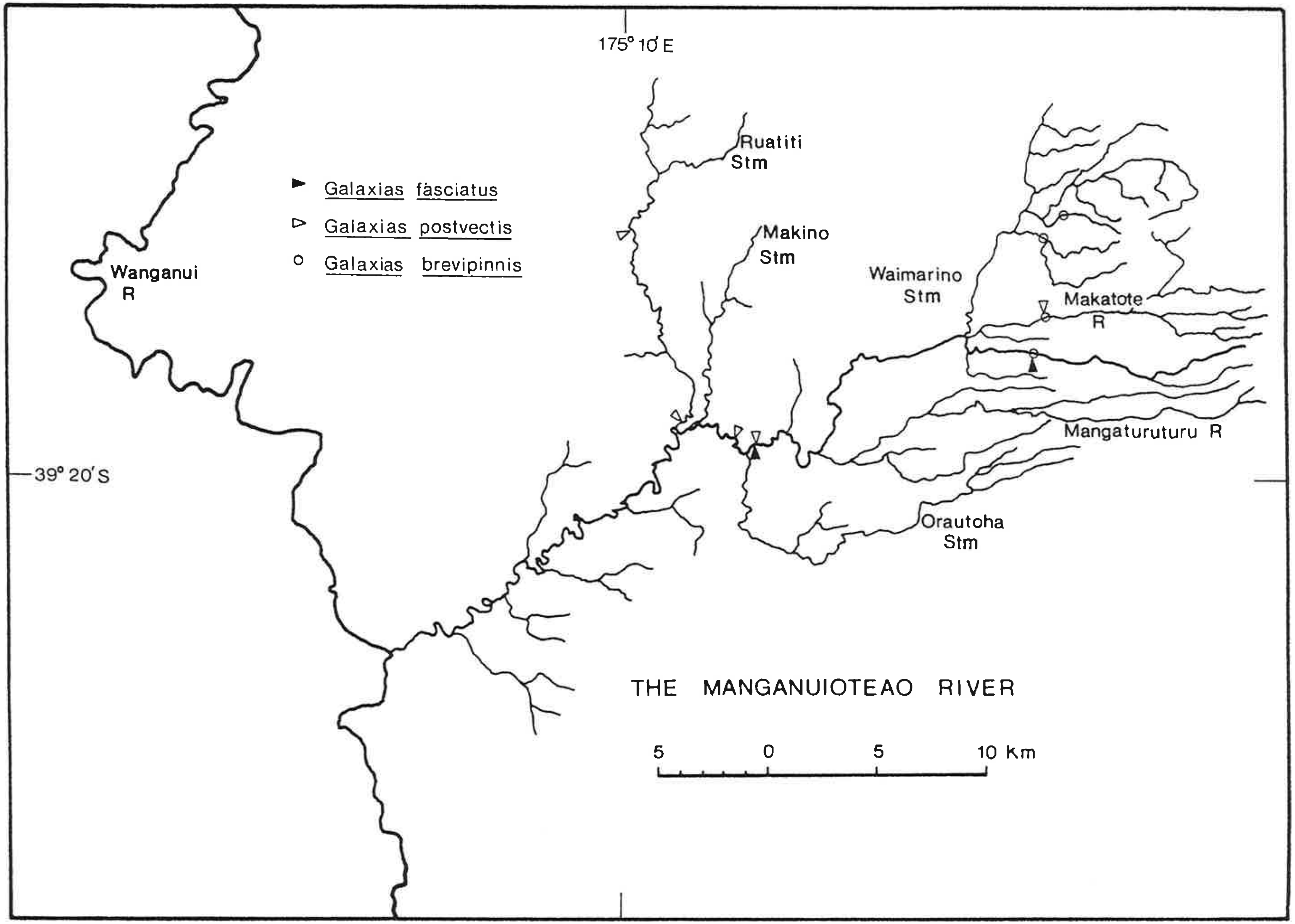

FIGURE 21. Distribution of *Galaxias fasciatus*, *Galaxias postvectis*, and *Galaxias brevipinnis*.

5.3.5 Short-jawed Kokopu (*Galaxias postvectis*)

The short-jawed kokopu is another galaxiid species whose juveniles form part of the New Zealand whitebait catch. The life cycle of the short-jawed kokopu is similar to that of the banded kokopu described above. McDowall (1978) described this species as rare, having been recorded from less than 20 places in New Zealand.

Short-jawed kokopu were the most widely distributed of the galaxiid species in the Manganuioteao River (Fig. 21). However, no more than two were found at any location. In the Ruatiti Stream short-jawed kokopu as well as long-finned eels were found above a shute which forms a barrier to upstream movement of trout. Short-jawed kokopu were only found when electric fishing, but an eeling party speared a large specimen (about 240 mm in length) at night in the lower Ruatiti Stream. Short-jawed and banded kokopu were found in similar habitats in the Manganuioteao River and these conformed to the habitat described for banded kokopu by McDowall (1978).

5.3.6 Koaro (*Galaxias brevipinnis*)

The koaro is another whitebait species with a similar life history to the two species described above and is the second most important species in the whitebait catch (McDowall 1978).

Koaro were found only in the headwater areas of the Manganuioteao River (Fig. 21). Single specimens were sampled at each of these sites except the northern-most site in the Waimarino Stream where seven were caught in March 1965. Among these seven some were noted as "ripe" and others as "spent" indicating that spawning may have been in progress in the vicinity at the time. All sites where koaro were found were consistent with known typical adult habitats, i.e., swift, bouldery rapids within an unmodified bush catchment (McDowall 1978).

5.3.7 Common Smelt (*Retropinna retropinna*)

Adult smelt migrate from the sea into freshwater to spawn from early spring until autumn. After hatching the larvae are swept out to sea and return about a year later often migrating considerable distances up some of the less turbulent and swiftly flowing large rivers (McDowall 1978).

In the Manganuioteao River during summer drift dives, smelt were seen as far upstream as the middle reaches (Fig. 22). Most sightings were of individuals, but a shoal of smelt was seen below the confluence of the Manganuioteao and Orautoha Stream. One small shoal and individuals were seen occasionally in the same reaches during May and July. These were adults and were seen in slow runs and tail-end sections of pools. Smelt were caught at two electric fishing sites, but notes made at the time mention that more were seen than were caught because of their apparent ability to avoid the electric field. These two sites were well below the Ruatiti-Manganuioteao confluence where pools and runs become longer and slower flowing (section 4.5). This indicates that smelt abundance is likely to increase in a downstream direction in the Manganuioteao.

The smelt fishery at Pipiriki (section 3.4) indicates that substantial numbers of smelt migrate above this point in the Wanganui River. Preservation of suitable river conditions and habitats for smelt upstream of Pipiriki is essential to maintain the smelt fishery at Pipiriki.

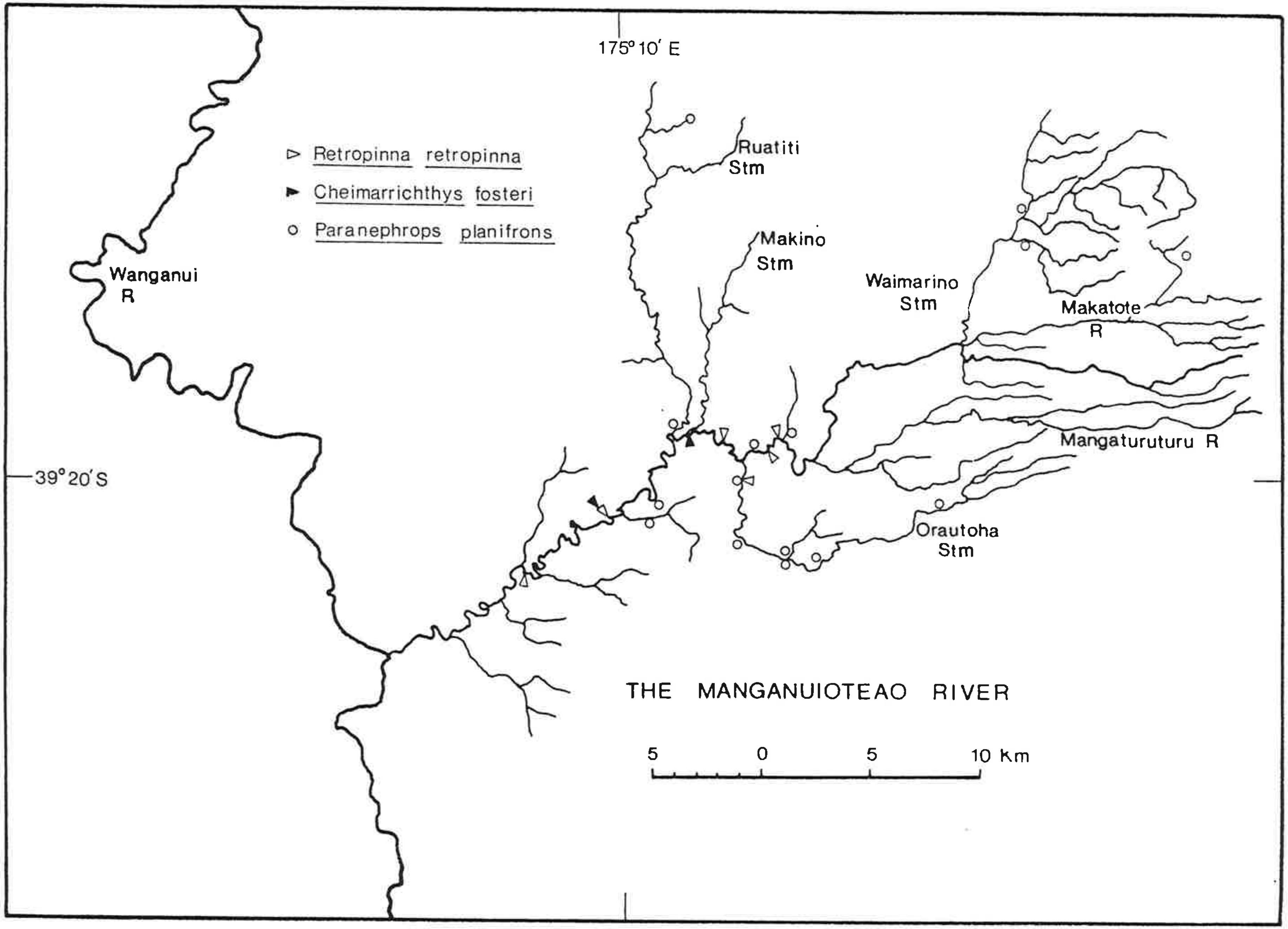

FIGURE 22. Distribution of *Retropinna retropinna*, *Cheimarrichthys fosteri*, and *Paranephrops planifrons*.

5.3.8 Torrentfish (*Cheimarrichthys fosteri*)

Little is known about the biology of torrentfish. Breeding seems to occur in the summer and early autumn, but nothing is known about spawning (McDowall 1978). Young torrentfish are found in the sea or estuaries and large torrentfish have been found as far upstream as the Whakapapa River's confluence with the Wanganui.

Torrentfish were recorded at three locations in the Manganuioteao River (Fig. 22). At the most downstream location torrentfish were noted as abundant, but at the next location upstream only four were caught and at the uppermost location only a single dead specimen was found during a drift dive.

In former times torrentfish in the Wanganui River were fished for by the Maoris (Mair 1880), but this practice appears to have been discontinued. No records could be found of the species having been fished for in the Manganuioteao though the fact that it may have been is not discounted.

5.3.9 Koura (*Paranephrops planifrons*)

Koura, being crustaceans, have been omitted from Table 12, but their distribution is shown in Figure 22 because they were noted as present during various surveys. Koura were found and seen throughout most of the Manganuioteao river system, but rarely was more than one recorded at any sample site with the exception of the top site in the Orautoha Stream where they were noted as "numerous and all sizes".

5.3.10 Red-finned and Common Bullies (*Gobiomorphus huttoni* and *G. cotidianus*)

The red-finned bully and common bully have similar life history patterns with spawning generally taking place from early spring to late summer. Newly hatched larvae go downstream into the sea where they spend several months growing to about 15-20 mm before returning upstream.

Distribution of both these species in the Manganuioteao River was confined to the middle and lower reaches (Fig. 23). The record of a common bully in the top reaches of the Orautoha Stream indicates that distribution of common bullies and possibly red-finned bullies may extend further upstream in the mainstem of the Manganuioteao River than the data show. Common bullies occurred at more electric fishing sites than red-finned bullies and were noted as "abundant" at sites in the lower Orautoha Stream. At sites where both species occurred they usually occurred in similar abundance.

5.3.11 Cran's Bully (*Gobiomorphus basalis*)

Cran's bully is the only native fish in the Manganuioteao whose life history does not depend on access to and from the sea. Instead the young hatch and live in marginal shallows during spring and summer months.

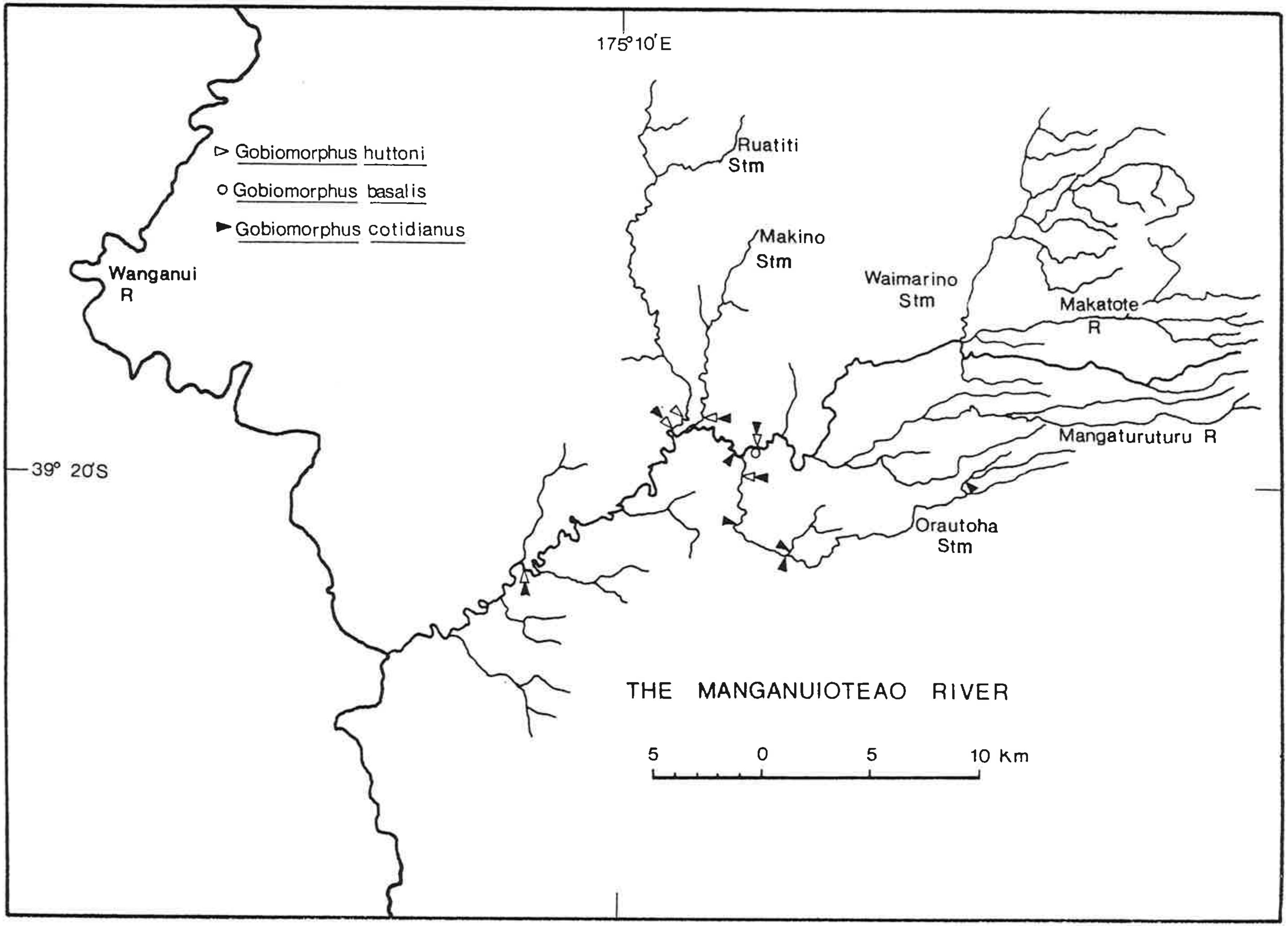

FIGURE 23. Distribution of *Gobiomorphus huttoni*, *Gobiomorphus basalis*, and *Gobiomorphus cotidianus*.

Distribution of Cran's bully in the Manganuioteao River appears restricted compared with the other two bully species as it occurred at a single electric fishing site just above the Orautoha Stream-Manganuioteao confluence (Fig. 23). Only two specimens were recorded at this site. At the same site both red-finned and common bullies were also recorded and this appears to be the upstream limit for the distribution of these three bully species.

5.4 Discussion

Broader data on native fish in the Manganuioteao River and Wanganui River system are required to properly assess their distribution, abundance, and role in the river's ecosystem and their importance as fisheries.

Since European settlement of New Zealand the Wanganui River system has undergone extensive modification to both the river and its catchment. Modification has included clearance of the natural catchment cover; diversion of headwaters out of the catchment; abstraction for water supply; additions of town sewerage and industrial waste discharge; farm and settlement run-off etc. During this time adjustment to the river system's ecological balance has changed the native fish composition, for example, the disappearance of the grayling (*Prototroctes oxyrhynchus*), and it has probably affected the abundance and distribution of many of the native fish. Added to the effects of the river modifications, exotic species have been introduced into the Wanganui, for example, trout, salmon, and catfish, all of which provide competition for native species. The commercial exploitation of eel stocks is also likely to have had an impact on the native species in the Wanganui system.

The Manganuioteao River in comparison with most other major tributaries of the Wanganui River has remained fairly unmodified. Eleven of the eighteen native fish species found in the Wanganui River have been found in the Manganuioteao and this is the greatest species diversity known from any of the Wanganui tributaries.

Tributaries such as the Manganuioteao River can be regarded as making a significant contribution to fisheries in the Wanganui. The placement of dams in the Manganuioteao River would affect all migratory fish, but for species with some climbing ability it may be possible for passes to be designed to allow fish passage upstream. However, apart from the physical obstruction which a dam would create it would also change features in the river's ecosystem which would have an effect on all native fish. Investigations into native fish requirements within the river would be necessary before assessing the degree of impact which dams would have on each species in the Manganuioteao River.

6. TROUT

6.1 Introduction

The high quality of angling in the Manganuioteao River can be inferred from comments in Annual Reports of the Waimarino Acclimatisation Society and in district summaries in angling magazines, but there are few records giving details of the fishery during the first half of this century. Even during more recent years detail is limited to analyses of a few anglers' diaries.

For the first 40-50 years after 1903, when angling began in the district, the fishery appears to have been largely of local importance.

Occasional notes on catches made by anglers appear in fishing magazines, for example, in 1928, 15 trout averaging 1.76 kg and ranging between 1.36-2.72 kg, were caught by one angler in a day (ACH 1928).

After World War II ended in 1945, travel became easier and the popularity of angling increased at a higher rate than the growth of population (Hobbs 1948). The need for sound management of the country's fisheries was recognised at this time also, and acclimatisation societies co-operated with government scientists by encouraging anglers to record their results in diaries and by providing collection points for the diaries. The resulting publication (Allen and Cunningham 1957) showed that the Manganuioteao River was one of the most important in the Waimarino Acclimatisation Society district. Graynoth (1973b) also used anglers' diaries to estimate the size, growth, distribution, and population size of trout stocks throughout the Waimarino district. He showed that the Manganuioteao is one of the most popular rivers in the district and its trout are among the largest caught by anglers.

Graynoth (1974c) later concluded that angling diary schemes could not be used to accurately monitor fish stocks, but in lieu of direct monitoring, anglers' records and observations are often the only method available. Such was the case with the Manganuioteao River when the WREPB hydro-electric proposals were circulated in 1978. It was known that the river was popular with anglers, that those who fished it regarded it highly, and that it contained large brown and rainbow trout. A few records existed of other fauna, mostly in the tributaries (Woods 1964, Cudby 1966 and 1976, and Turner, Allen, and Beam 1969). There was insufficient information available to make an assessment of the effects of the proposals, and because the same information was needed by the developers, the fishery managers, and FRD, a team representing each group was engaged to collect it during summer 1979; the resulting data was shared by each group and used in a report to WREPB by its environmental consultants (Armstrong 1979).

Further information about trout spawning, movements, and habitat requirements was considered necessary to support a growing conviction that any changes to the river would have a dramatic effect on its trout fishery, and FRD, supported by WS, embarked on a longer term study to examine these aspects. This report embodies the data collected between 1979-81.

6.2 Methods

Trout in large rivers such as the Manganuioteao are usually studied by indirect methods, (Ricker 1968, Graynoth 1974c, Kesner and Barnhart 1972). The aims of this investigation and initially the time available for it, called for more direct methods and extensive coverage, and underwater observations were among several methods which were discussed as possibilities. Divers have successfully counted fish in North American rivers (Keenleyside 1962, Northcote and Wilkie 1963) and the method has been tried in this country (Galloway and Cudby 1965, Cudby 1978b), but not on the scale necessary to provide adequate coverage of a river like the Manganuioteao. However, the method was considered to be the most appropriate one available at the time.

Techniques for counting fish were developed prior to the summer 1979 survey and subsequently were refined, and team drift diving became the principal means of data collection. However, it had shortcomings in that few fish could be handled, and both restricted visibility and large pools in the lower zone raised doubts about the accuracy of counts. As information accumulated and further questions were raised, the study was extended and other methods were adopted to catch fish for tagging, to study spawning characteristics and to follow the movements of trout within the system. These are described in the following sections and Figure 24 shows the sampling coverage.

6.2.1 Drift Diving

Two or more divers, wearing neoprene wet suits for protection and using snorkelling equipment (mask, snorkel, fins, and weight belt) for manoeuvrability, move downstream in line abreast formation, diving alternately when necessary to keep the river bottom in sight, to examine cover, and to identify and count fish which pass through the divers' zones of vision. The nature of the river and visibility range dictate the number of divers required and the areas which can be examined. Inflated tyre inner tubes were used for floatation and protection when traversing rapids.

Surveys in summer 1979 indicated that a team of six was necessary in the Manganuioteao and that best coverage could be attained in the 24 km length of river between the Makatote and the Ruatiti confluences with the Manganuioteao. This area was examined each summer from 1979 to 1981.

In July 1979, 9 km within this area was examined, and the summer 1979 survey covered a further 9 km beyond it as well as parts of the Waimarino Stream and the Makatote River. Areas drift dived are shown on Figure 24.

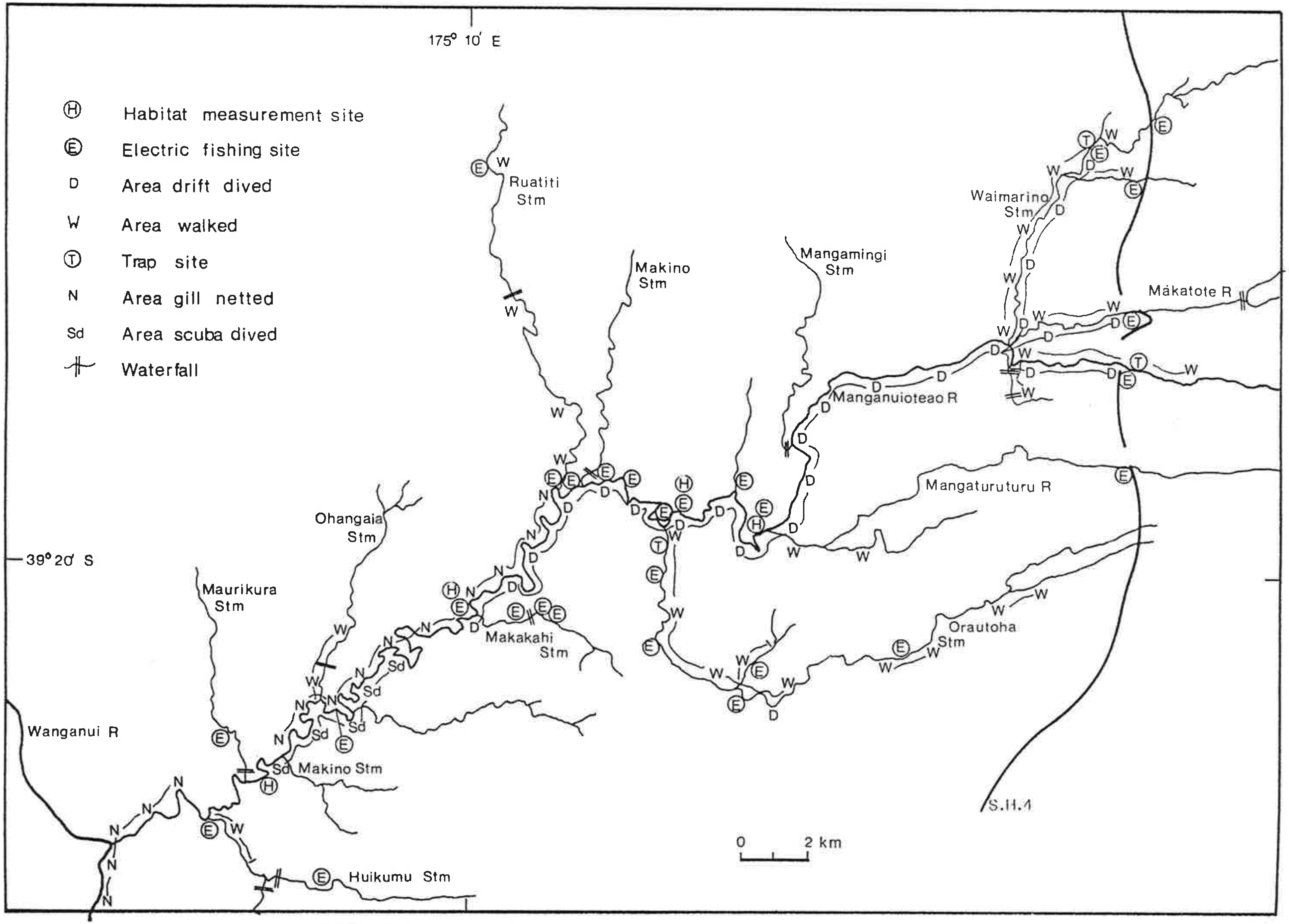

FIGURE 24. Sampling coverage of the Manganuioteao system.

Counts were made in pools because most large fish were found there and divers could neither maintain position nor count accurately in the turbulent areas between them. Pools were numbered within sections of river identified by access points or landmarks, and successive counts were compared.

Trout were identified as brown or rainbow, and as small (<20 cm), medium (20-40 cm) and large (>40 cm). The size ranges were based upon knowledge of the size of adult trout in the river (Graynoth 1973b) and approximations of the size of 1- and 2-year-old trout in populations with large (>40 cm) adults.

Some trout passed the divers too rapidly for them to gain more than an impression of size and were recorded as "unidentified". Other fish species (section 5) were identified to genus or species and counted; shoals of fish were counted as units.

The accuracy of the method for counting medium and large sized trout was tested in 1980 by recounting the trout in a 1-km-long section of river containing six pools, 4 days after the original count. The difference between the means of the two counts was not significant at $P = 0.01$ and the pool by pool correlation coefficient was high ($r = 0.87$). It was concluded that almost all of the medium and large trout not hidden under cover were being counted with acceptable accuracy and that counts repeated at longer intervals provide a useful index of these fish.

Visibility during drift diving counts varied between 2-5 m (Table 2), but was usually 2-3 m. The river flow at Ashworth ranged from 5 to 11 m^3/s (MWD 1983).

6.2.2 Crawl Diving

Clad as for drift diving, but without weight belts or swim fins, divers move upstream through bouldery, turbulent areas identifying and counting fish. This qualitative method was adopted during spring 1980 to carry out spot checks for juvenile trout (Fig. 24).

6.2.3 SCUBA Diving

The increasing length of pools and the reduced visibility below the confluence of the Ruatiti Stream and the Manganuioteao made snorkelling difficult and its accuracy doubtful during the 1979 visit, and netting parts of the river in April 1981 proved ineffective (section 6.2.5). SCUBA divers using a similar technique to snorkel drift diving teams (moving downstream along the river bed in line abreast, counting trout which passed beside or over them) were used in the parts of the river where netting had been unsuccessful. Five divers were in the team and a boatman followed closely in an inflatable raft to transport the divers over rapids and shallows.

SCUBA counts were carried out on 3 days during May 1981 and 35 pools were examined. Visibility varied between 1-2 m and the discharge at Ashworth was about 11 m^3/s (FRD records). During the same period two divers dived in two other pools by day and again at night to compare counts of size classes.

6.2.4 Fish Trapping

Traps were constructed in the headwaters of the Manganuioteao River, the Waimarino Stream, and the Orautoha Stream (Fig. 24) during May-August 1980 to catch trout migrating upstream to spawn. Large fish and signs of spawning activity had been observed in these areas during the previous winter, and also at this time drift diving counts from a 9 km length of the Manganuioteao indicated that there had been a migration away from it (section 6.3.4). Therefore, it was decided to find the main spawning tributaries, determine the number of fish using them, and mark trout for a subsequent study of migration within the system.

The traps each consisted of a wire mesh cage attached at one corner to of a mesh barrier which extended across the stream at a slight angle and prevented fish from passing. The cage contained a narrow "V" entrance facing downstream through which fish entered. The barrier was stapled to a log fastened to the stream bed and was supported at the top by a cable attached to a strainer post on one bank and to a winch on the other. To avoid damage during floods the barrier could be lowered by use of the winch. The traps were manned continually and kept from clogging with debris; fish were taken from the cage each morning. Trout were measured, tagged, and given an adipose fin clip before being released upstream of the trap. Trout moving downstream after having spawned were not trapped, but some were caught with a hand net and examined.

6.2.5 Gill Netting

Gill and trammel nets of 4-11 cm stretched mesh size were set in pools between the Ruatiti-Manganuioteao confluence and the mouth of the Manganuioteao (pools 140-248) during March-April 1981 to catch a sample of medium and large sized trout for measurement and examination.

The nets were set and retrieved from an inflatable boat and the operation was assisted by use of a helicopter to transport personnel, equipment, and catch to and from chosen locations. Fifteen nets could be managed in each set of about 18 hours. One end of each net was tied at the head of a pool and the other was left, with a buoy attached, to stream in mid current. One to two nets were set in each pool depending upon the size of the pool.

Eighty-eight pools were netted, but in 40 the catch was restricted by algae which clogged the nets. Most of these pools were subsequently examined by SCUBA divers (section 6.2.3).

6.2.6 Tagging

Forty-three trout were caught in hand nets and tagged during drift diving counts in 1979 and 1980; seven were caught, tagged, and released by anglers and three were tagged during electric fishing work in 1979. The 1980 fish trapping resulted in 300 trout being tagged.

The tags used were numbered, colour-coded "Floy" streamer tags attached to a plastic stalk with a "T-bar" at one end. The "T-bar" was inserted with a gun into the back of each trout below the dorsal fin; it was inserted at an acute angle and lodged behind the pterygiophores beneath the fin. Measurements of the fish and the tag particulars were recorded and the adipose fin was clipped to aid recognition.

Tagged trout were either sighted or recovered by drift diving, SCUBA diving, trapping, gill netting, and by anglers who recorded the particulars of the fish they caught and returned the data with the tag. A large proportion of the tags was lost by the fish. Close examination of 260 trout, by SCUBA divers and during netting, showed 13 (5%) trout which had been tagged at Orautoha trap almost 1 year previously. Ten (77%) of these trout had lost their tags. Tilzey (1977) also reported a high tag loss (50%) with the same type of tags used on brown trout in Australia.

6.2.7 Electric Fishing

The method is described in section 5.2; it provided an inventory of species present throughout the catchment and of juvenile trout in particular locations.

6.2.8 Walking Surveys

Observations, counts of fish and redds, and estimates of availability of spawning gravel suitable for trout were made by observers who walked and waded either upstream or downstream and who used either polaroid sunglasses or diving masks to aid vision into the water. Most tributaries were examined (Fig. 24) during 1979 and 1980 to identify spawning grounds and to try to assess numbers of fish using popular areas.

6.2.9 Angling

Angling results were collated from data collected by other workers and from anglers' diaries.

6.3 Results

A total of 2131 trout was sampled by diving, trapping, and netting during the study period and a further 708 were recorded by diarists during 1947-81 (Table 13). The results of analyses of these samples are set out in the succeeding sections of this chapter and discussed in section 6.4.

TABLE 13. Numbers of trout >20 cm sampled by different methods

Year	1979	1979	1980	1980	1981	1981	1981	1947-81
Season*	Su	W	Su	W	Su	A	A	-
Method†	DD	DD	DD	T	DD	N	S	An
River zones sampled‡	U,M	M	U,M	-	U,M	M,L	L	-
Distance (km)	32	11.5	24	-	24	37	10	-
Number of trout	494	67	416	297	590	180	87	708
% Unidentified	26	6	12	0	14	0	8	0

* Su = summer, A = autumn, W = winter.
† DD = drift diving, T = fish trapping, N = gill netting, S = SCUBA diving, An = angling (diaries).
‡ U = upper zone, M = middle zone, L = lower zone (section 2.3 and Fig. 2).

6.3.1 Population Composition

6.3.1.1 Species

The species composition of trout >20 cm was determined from samples obtained by drift diving during successive summers, gill netting, and SCUBA diving counts. Although bias may be introduced by pooling the results of different methods, the trout were caught or counted when they were naturally distributed during their feeding and growing season and the samples are sufficiently large to provide a good indication of the species composition throughout the river mainstem at this time. Table 14 shows the species composition in the three river zones. The trends shown reflect those observed in the field; both species were present in all zones, but rainbow trout were predominant in the upper zone and brown trout were predominant in the lower zone; both shared the middle zone though brown trout tended to dominate. The proportion of brown trout in the middle and upper zones increased during the study period and there was a distinct increase in the middle zone in 1981.

TABLE 14. Species composition of trout >20 cm in the upper, middle, and lower zones of the Manganuioteao River

	Upper zone (pools 1-60)			Middle zone (pools 61-160)			Lower zone (pools 161-248		
	% Brown	% Rainbow	*n*	% Brown	% Rainbow	*n*	% Brown	% Rainbow	*n*
1979	21	79	73	53	47	253	-	-	-
1980	23	77	115	57	43	251	-	-	-
1981	38	62	130	67	33	375	88	12	173

The annual increases in the total numbers counted (+12% in 1980 and +59% in 1981) and the increasing proportion of brown trout are clear in Table 15. If the unidentified group is divided (75% rainbow : 25% brown) and added to the other two species the annual changes become even clearer though the species ratios then become somewhat hypothetical. The reasons for assigning a higher proportion of the unidentified group to rainbow trout are their pelagic habit and greater mobility when disturbed; on many occasions divers felt strongly that fish which they had glimpsed were rainbow trout, but these were recorded as "unidentified" unless they were clearly seen. This was especially so in 1979 and the reduction in the proportion of "unidentified" in 1980 and 1981 no doubt reflects an improvement in the identification skills of the diving team. Therefore, the hypothetical species composition shown in Table 15 is quite realistic and close to that which actually occurred in the area examined by drift divers.

TABLE 15. Species composition of trout > 20 cm counted by divers in pools 1-140 in successive years with hypothetical composition when unidentified are assigned to species

Year	n	% Unidentified	% Brown	% Rainbow
1979	372	31	31	38
1980	416	12	41	47
1981	590	14	51	35
When unidentified = 75% rainbow:				
1979			39	61
1980			44	56
1981			54	46

6.3.1.2 Sex

Trout trapped in 1980 and netted in 1981 were used to determine the sex composition of medium and large trout in the Manganuioteao River (Table 16). Although the sex composition of both brown and rainbow trout from the 1981 netted sample is similar and close to 50:50 the spawning population is quite different as is clear from the 1980 figures. The proportions of males and females of both species of trout in spawning runs is usually 30-40% males and 60-70% females in New Zealand. Table 17 compares the Manganuioteao with a selection of data from spawning runs throughout New Zealand which demonstrate this trend. The slight difference between the Manganuioteao rainbow data and others can be explained by the fact that the trap sampled a non-representative portion of the rainbow spawners; more females ran later and were not caught when the trap was out of action (section 6.2.4).

TABLE 16. Sex composition of trout >20 cm in samples caught by trapping (1980) and by gill netting (1981)

	Brown			Rainbow		
	male (%)	female (%)	*n*	male (%)	female (%)	*n*
1980	35	65	152	42	58	64
1981	47	53	147	53	47	30

TABLE 17. Sex composition of trout in New Zealand spawning streams - the Manganuioteao (Orautoha) compared with three North Island and three South Island systems

Stream/system	Year	Brown trout male (%)	Brown trout female (%)	Brown trout *n*	Rainbow trout male (%)	Rainbow trout female (%)	Rainbow trout *n*
Orautoha/Manganuioteao	1980	35	65	152	42	58	64
Ngongotaha/Lake Rotorua	1958-59*	35	65	9 993	35	65	19 442
Wairehu/Lake Rotoaira	1974†				37	63	7 294
Tokaanu/Lake Taupo	1976-78‡				36	64	5 988
Waihukahuka/Lake Taupo	1976-78‡				33	67	6 944
Pigeon/Lake Brunner	1934§	34	66	314			
Pigeon/Lake Brunner	1959**	36	64	171			
Pigeon/Lake Brunner	1963††	34	66	199			
Orawia/Waiau	1964‡‡	35	65	1 022			
Scott, Muddy, Outlet/ Lake Alexandrina	1962§§	38	62	214	37	63	3 372

* Wildlife Service (Rotorua) records.

† MAF (Turangi) records.

‡ Wildlife Service (Turangi) records.

§ Hobbs 1937.

** Eldon n.d.

†† Cudby and Moore 1965.

‡‡ Galloway and Cudby 1965.

§§ Moore n.d.

6.3.1.3 Size

Trout for tagging, caught by divers and anglers in 1979 and 1980 and by trapping and netting in 1980 and 1981, were measured. The range of sizes and the mean length and weight of both species of trout are shown in Table 18. The sampling methods generally caught adult trout and varied in the time they were used to collect and the part of the population from which they drew. Because of this they have been analysed separately and compared by examining the difference between the mean of each sample and the overall mean (Table 18).

The 1979 tagging sample selected larger brown trout (difference significant at 95% confidence level), and the 1981 netting sample selected smaller rainbow trout (difference significant at 95% confidence level for length and 99% confidence level for weight). Deleting these data results in only a 3 mm decrease in the mean length of brown trout and a 14 mm and 0.3 kg increase in the means of rainbow trout. Therefore, they are included in the size analyses because neither constitutes an unduly large part of the total sample and the differences are fairly small.

The average size of both species is similar; the differences between means of length and of weight are not significant (Table 19). There are highly significant differences in the sizes of male and female brown trout; males are larger and heavier (Table 20). These differences are not as distinct in the rainbow trout; there is an indication that males are longer than females, but the average weights are similar and the differences are not significant.

TABLE 18. Length and weight of brown and rainbow trout and Student's t values comparing differences between the means of different sampling methods

		Brown trout					Rainbow trout			
		Total	Tagged 1979	Tagged 1980	Trapped 1980	Netted 1981	Total	Tagged 1980	Trapped 1980	Netted 1981
Length (mm)	Mean	505	540	529	498	502	495	509	509	462
	Range	305-720	390-710	305-720	337-655	306-660	235-692	465-560	383-640	235-692
	n	388	31	28	181	148	97	5	63	29
	t**	-	2.013*	1.196	1.558	0.530	-	0.836	1.935	1.961*
Weight (kg)	Mean	1.63			1.57	1.75	1.68		1.75	1.41
	Range	0.25-3.15			0.50-3.00	0.25-3.15	0.55-3.70		0.70-3.70	0.55-2.05
	n	226			151	75	79		62	17
	t**	-			1.386	1.708	-		1.000	2.618**

* Significant at P = 0.05.

** Significant at P = 0.01.

TABLE 19. Length and weight of Manganuioteao trout and Student's t values comparing differences between the means of species

		All trout	Brown	Rainbow
Length (mm)	Mean	503	505	495
	Standard error	3.3	3.7	7.3
	t**	-	0.536	1.101
Weight (kg)	Mean	1.64	1.63	1.68
	Standard error	0.033	0.038	0.063
	t**	-	0.263	0.635

** Significant at P = 0.01.

TABLE 20. Length and weight of male and female brown and rainbow trout and Student's t values comparing means of sexes in each species

		Brown trout		Rainbow trout	
		Male	Female	Male	Female
Length (mm)	Mean	537	485	507	484
	Range	360-710	337-720	370-692	235-640
	n	170	210	40	52
	t**	6.005**	4.477**	1.300	0.981
Weight (kg)	Mean	1.84	1.50		
	Range	0.45-3.15	0.25-3.00		
	n	88	138		
	t**	3.492**	2.717**		

** Significant at P = 0.01.

6.3.1.4 Growth

Ten tagged trout were recaptured and measured after periods ranging between 118 and 862 days (mean 286 days). Their lengths at first capture ranged between 430 and 640 mm (mean 522 mm) and their growth rate ranged between 0 and 83 mm/yr (mean 33 mm/yr).

6.3.2 Distribution

The river's mainstem supports both brown and rainbow trout. Both species were recorded in the Waimarino, and Orautoha Streams and in the Makatote River. Only rainbow trout were recorded in the Manganuioteao River above the Waimarino-Makatote confluence and only brown trout were recorded in the Ruatiti Stream (Fig. 25).

During the 1979 survey there was a tendency for rainbow trout to predominate in the upper zone and for brown trout to become more common with distance downstream. Therefore, results from the more extensive coverage of the system during 1981 by diving and netting were examined to determine the overall distribution of trout >20 cm. The presence or absence of trout of both species was recorded in each pool of the river from the Waimarino-Makatote confluence to the Wanganui River, and the frequencies were entered into a four-point contingency table. This method summarises the respective frequencies of both species, one or other, or neither one nor the other being found in pools, and the point correlation coefficient calculated from the table (rp = -10.212) indicates a tendency for rainbow trout and brown trout not to be found together. The chi-square probability of rp (P = 0.002) shows that the

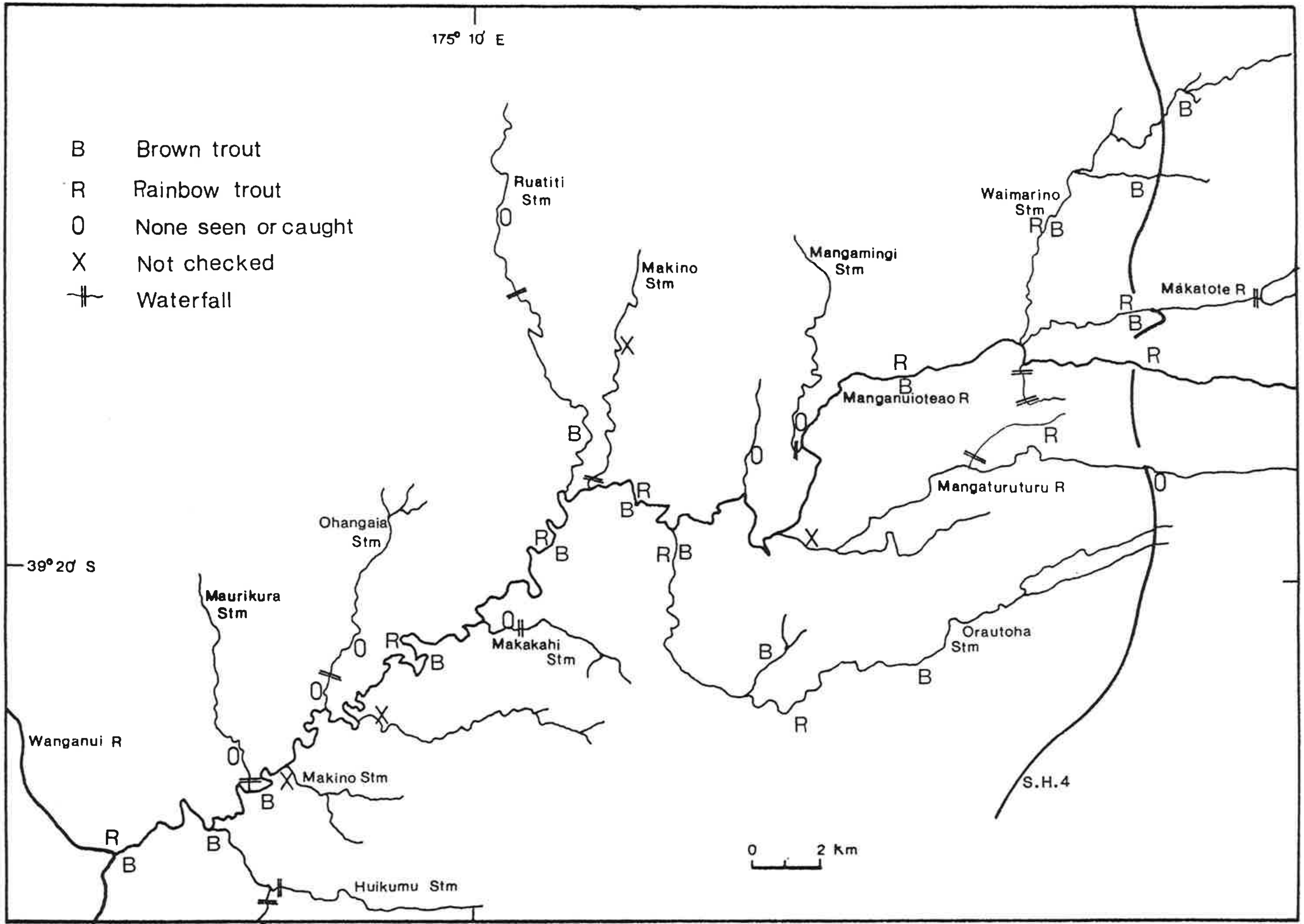

FIGURE 25. Distribution of trout in the Manganuioteao system.

result is significant. In Figure 26 the data are grouped for each 10 pools to show the distribution pattern within the system. Both species coexist in pools throughout the mainstem, but they are most commonly found together in the middle zone. Rainbow trout are most commonly the only species in pools in the upper and upper-middle zones (pools 1-80) and brown trout monopolise pools in the lower-middle and lower zones (pools 140-248). Pools which contained no trout in 1981 were mostly in the upper and lower zones. Only one pool held no trout in each year of the study period. Pool 54 is a long, deep and dark pool in a narrow gorge in which scour patterns indicated high velocities at above normal flows and where little shelter is available. It is evidently unattractive trout habitat.

Within a typical pool-rapid sequence large brown trout were usually found near the head of the pool where they lay on the bottom against the vertical channel side or against large boulders. Smaller brown trout (about 20-40 cm, the "medium" group) were found toward the tail of the pool sometimes sheltering behind boulders and sometimes swimming in mid water. Rainbow trout of all sizes were usually encountered in mid water from a little beyond the white water swirl at the head of a pool. When several fish were present they often formed a shoal. In rapids, juveniles and medium sized trout of both species sheltered behind boulders.

Pool 115 was examined at night by SCUBA divers using hand held torches after it had been examined 4 hours earlier during daylight. There was a six-fold increase in the number of trout counted at night and five eels were also seen where none had been seen during daylight (Table 21). The number of small and medium sized fish showed the greatest increase; it is likely that most of these would have moved into

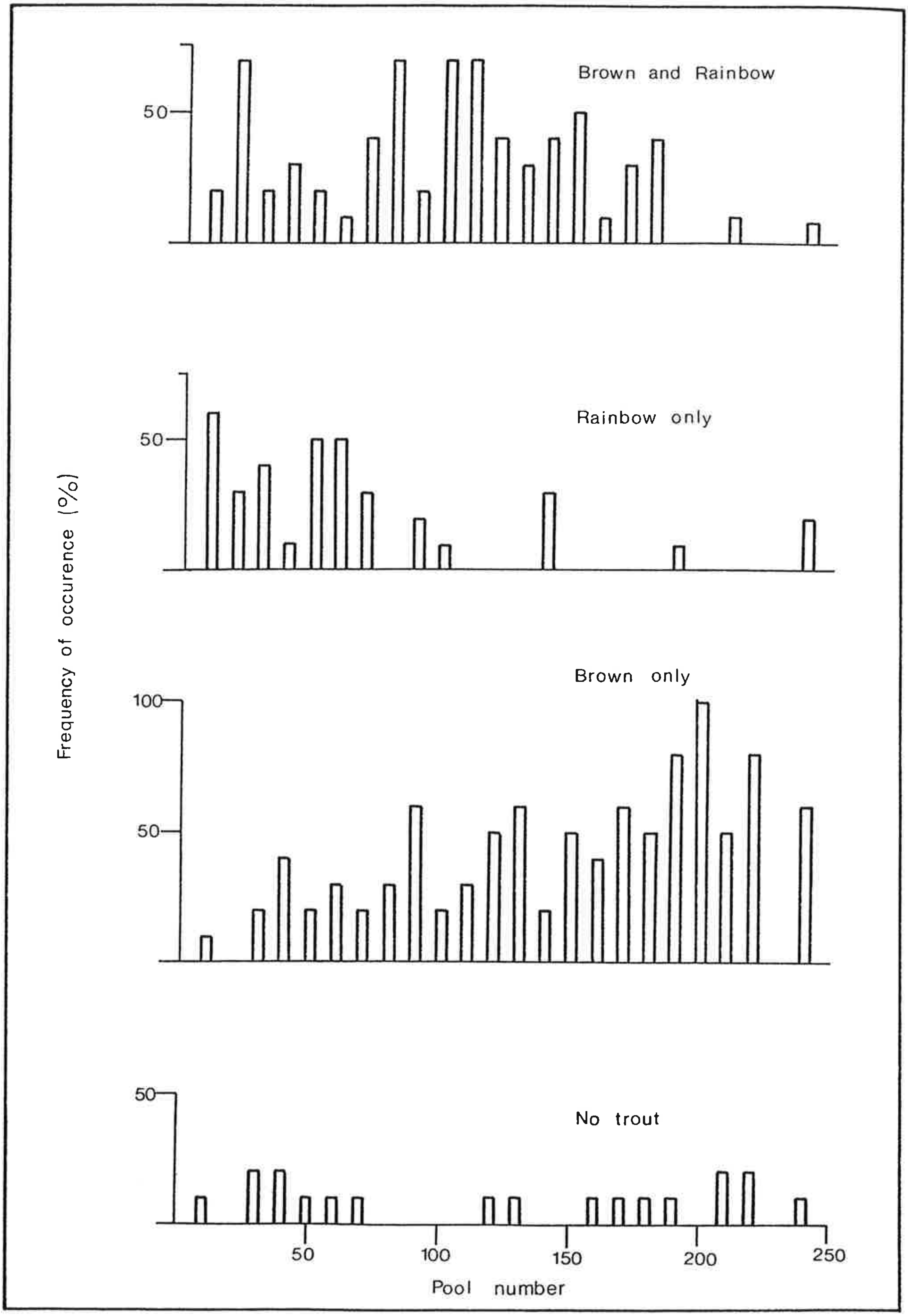

FIGURE 26. Distribution of brown and rainbow trout, 1981.

the pool from the fast water at either end, but that the large fish and eels had come out from cover within the pool.

TABLE 21. Numbers of trout counted by day and night in pool 115 (7 May 1981)

	Day			Night			
	Small	Medium	Large	Small	Medium	Large	
Brown trout	-	1	2	2	6	12	
Rainbow trout	-	-	-	1	-	-	
Unidentified trout	-	-	1	3	-	-	(5 eels)
Total		1	3	6	6	12	

Observations of trout distribution in one pool-rapid-boulder bank area during an annual cycle are shown in Figure 27. The observations were made using a variety of techniques at an area that is readily accessible and which was visited frequently. It is considered typical of most of the middle zone. Figure 27 shows the way in which the different life stages of trout are distributed within such a reach. It is obvious that repetitive diurnal and seasonal sampling is necessary to gain an understanding of the way in which salmonids are distributed within a system such as the Manganuioteao.

Juvenile trout are difficult to sample and observe in the Manganuioteao River. They are found seasonally in, or close to, heavy cover (Fig. 27) and day-night observations (Table 21) indicate that they also share the pools under the cover of darkness. Parr and older juveniles have been recorded throughout the mainstem during the study period and also in the Waimarino, Makatote, and Orautoha tributaries.

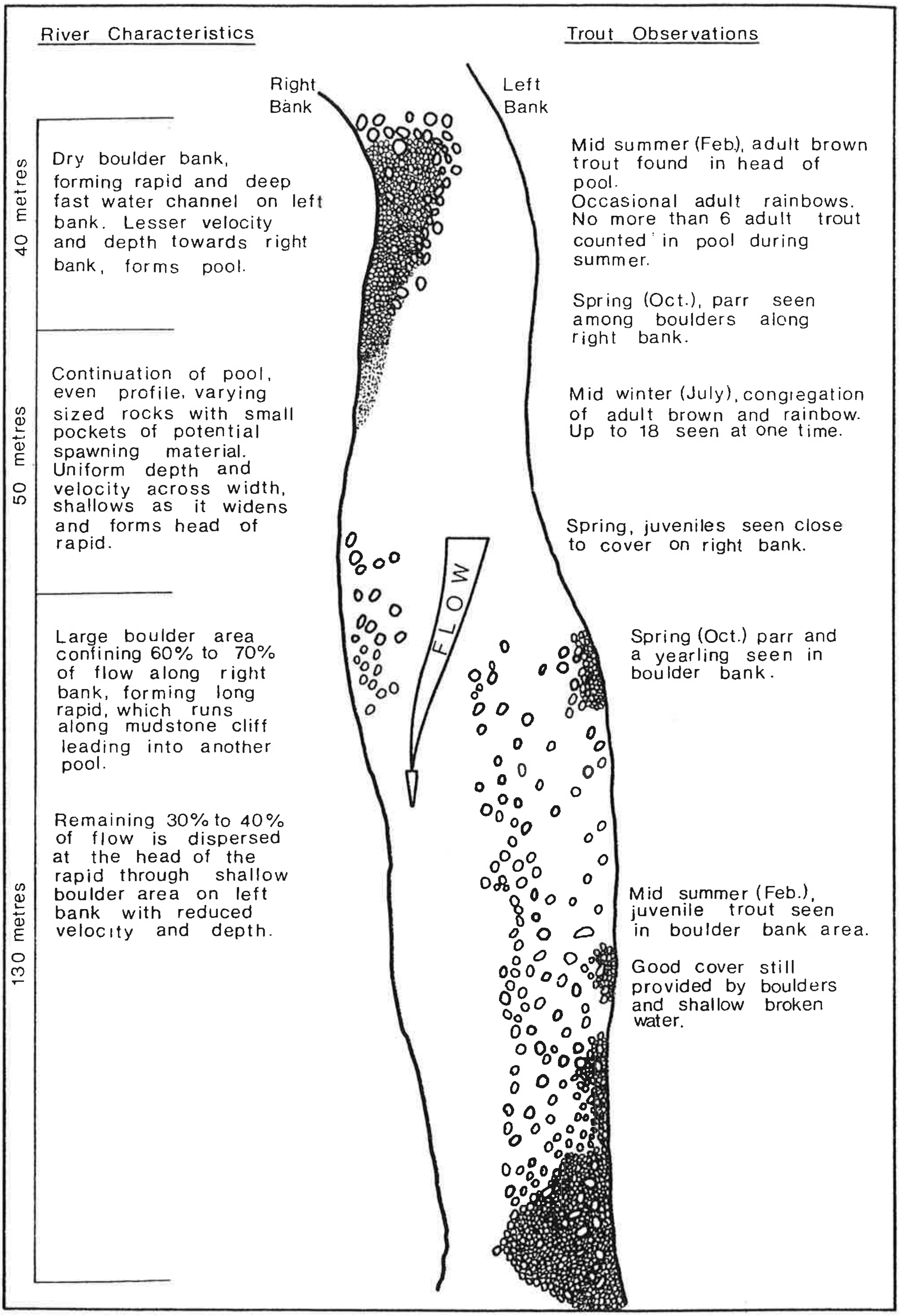

FIGURE 27. Sequence of river characteristics in a pool-rapid area of the middle zone showing the range of trout habitat offered and observations during one annual cycle.

Figure 28 shows the distribution of juvenile trout. Apart from in spring, when fry may be seen in pools during the initial dispersal from spawning sites. most juveniles in the mainstem are found in boulder banks and fast flowing areas where the interstices of boulders shelter and protect them.

6.3.3 Abundance

Numbers of trout >20 cm sampled by drift and SCUBA diving and by gill netting provide an indication of the abundance of both species. The drift diving data alone indicate changes in numbers during the study period and the combined data indicate abundance throughout the mainstem. Limitations inherent in each sampling method are acknowledged, but the combined data reflect observed trends.

The abundance of medium and large trout in summer-autumn is shown in Figure 29 expressed as trout per pool, and Table 22 gives the data in 50-pool sections expressed as fish per pool and fish per kilometre for comparison with other rivers where this presentation is used. In the Manganuioteao study, fish per pool is the most realistic expression of abundance because the counts were restricted to pools. However, because the bulk of the adult population is restricted to the pools and few large fish were observed in the rapids fish per kilometre is also valid as a general comparison with other rivers.

In the Manganuioteao River most adult trout live in the middle zone during the summer-autumn period and the upper and lower zones each have fewer fish per pool. In the upper zone the density distribution averages two fish per pool, it peaks at an average of five fish per pool in the middle zone and tails off to 1.5 fish per pool in lowest section (Table 22).

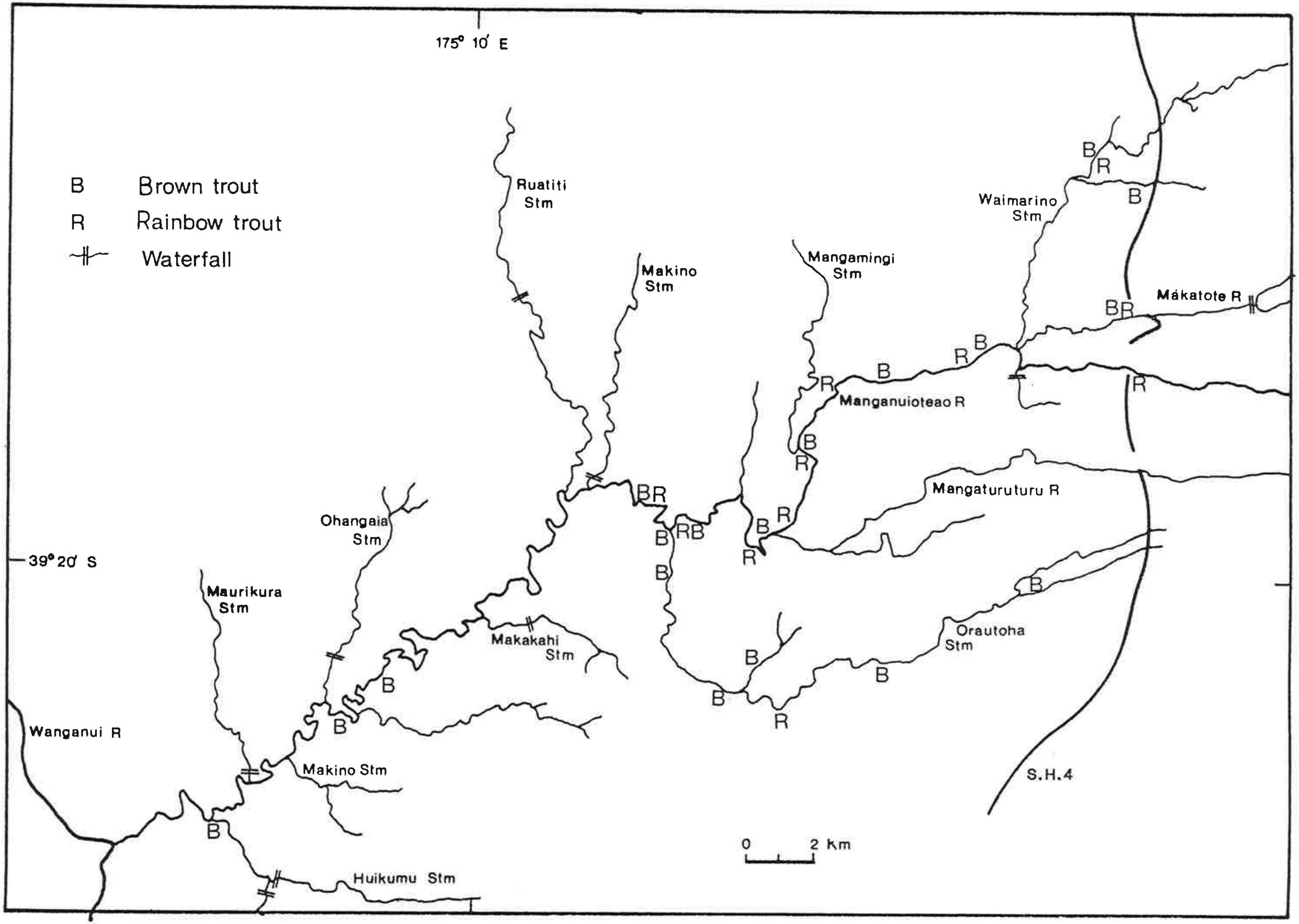

FIGURE 28. Distribution of juvenile trout, 1979-81.

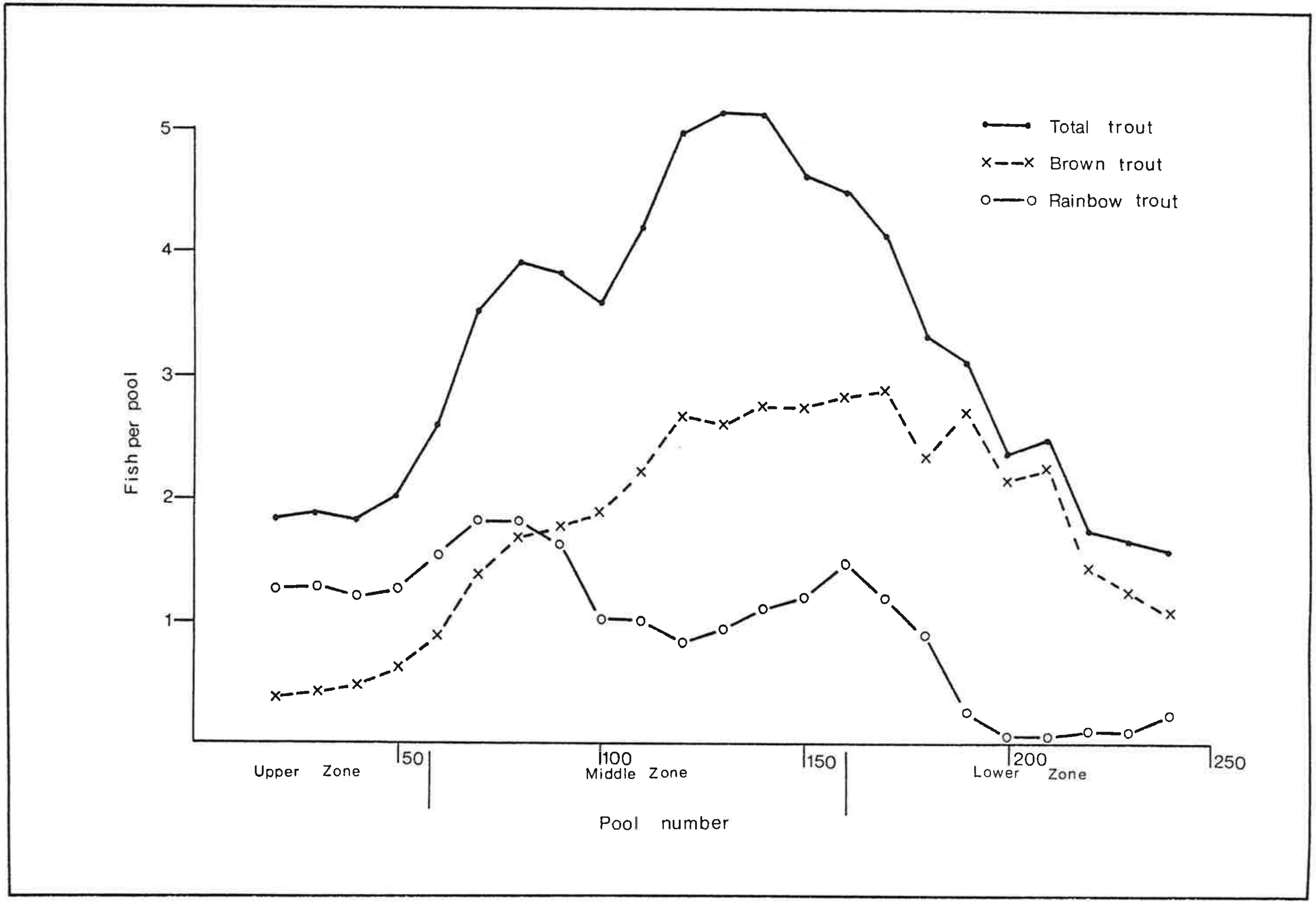

FIGURE 29. Abundance of medium and large trout, 1979-81 (order 3 moving average of summer-autumn counts).

TABLE 22. Abundance of trout >20 cm in the Manganuioteao River, 1979-81

		Pool				
Distance		1-50	51-100	101-150	151-200	201-250
Brown trout						
Range	per pool	0-3	0-10	0-14	0-16	0-5
	per km	1.7-4.6	2.0-13.8	4.5-29.0	1.2-14.8	2.9-6.2
Mean	per pool	0.4	1.5	2.6	2.2	1.3
	per km	3.2	7.7	11.4	4.4	4.2
S.D.*		0.30	0.81	1.19	1.11	0.28
Rainbow trout						
Range	per pool	0-9	0-15	0-5	0-3	0-3
	per km	6.7-10.6	6.0-20.0	0.6-8.9	0-10.8	0-1.5
Mean	per pool	1.3	1.7	0.9	0.7	0.3
	per km	9.1	9.1	4.0	3.1	0.9
S.D.*		0.57	0.86	0.73	0.87	0.23
Total						
Range	per pool	0-9	0-16	0-21	0-16	0-5
	per km	8.9-16.7	11.0-28.0	6.2-42.0	3.2-17.6	3.5-6.9
Mean	per pool	1.9	3.5	4.8	3.1	1.5
	per km	13.5	18.6	20.6	8.7	5.0
S.D.*		0.72	1.33	1.83	1.20	0.29

* Standard deviation of mean per pool.

There is a marked difference in the abundance of the two species. Rainbow trout are numerically dominant in the upper zone, but they decrease through the middle and lower zones whereas the trend in brown trout numbers is almost the opposite; from a low level in the upper zone they increase to dominate over rainbows in the middle and lower zones though their numbers also decrease in the lower zone.

Annual changes are apparent in the summer drift diving counts (Fig. 30). The "total trout" curve is similar in both 1979 and 1981 apart from an increase in its magnitude in 1981. In 1980 the changed shape of the curve is caused by greater numbers of rainbow trout in the first 100 pools though the total number counted remained similar in both 1979 and 1980. The most likely cause of this bunching effect is a flood which occurred 1 week before the 1980 count took place and which raised the river level 1.3 m at Ashworth (MWD 1982). The flood seems to have induced an upstream movement of rainbow trout because the "brown trout" curves remain similar each year. The reason for such a response is not clear.

The increase in the abundance of both species during the study period is shown in Table 23 which does not take account of the annual changes in the "unidentified" group (see Table 15 where this is done for species composition). Brown trout increased the most, particularly between 1980-81, whereas rainbow trout numbers increased slightly throughout. Although an improvement in the skill of the counting team at identifying trout is evident between 1979-80 it is unlikely that this improvement would have made any difference to the total numbers counted because coverage was the same each year and all fish seen were counted whether identified or not.

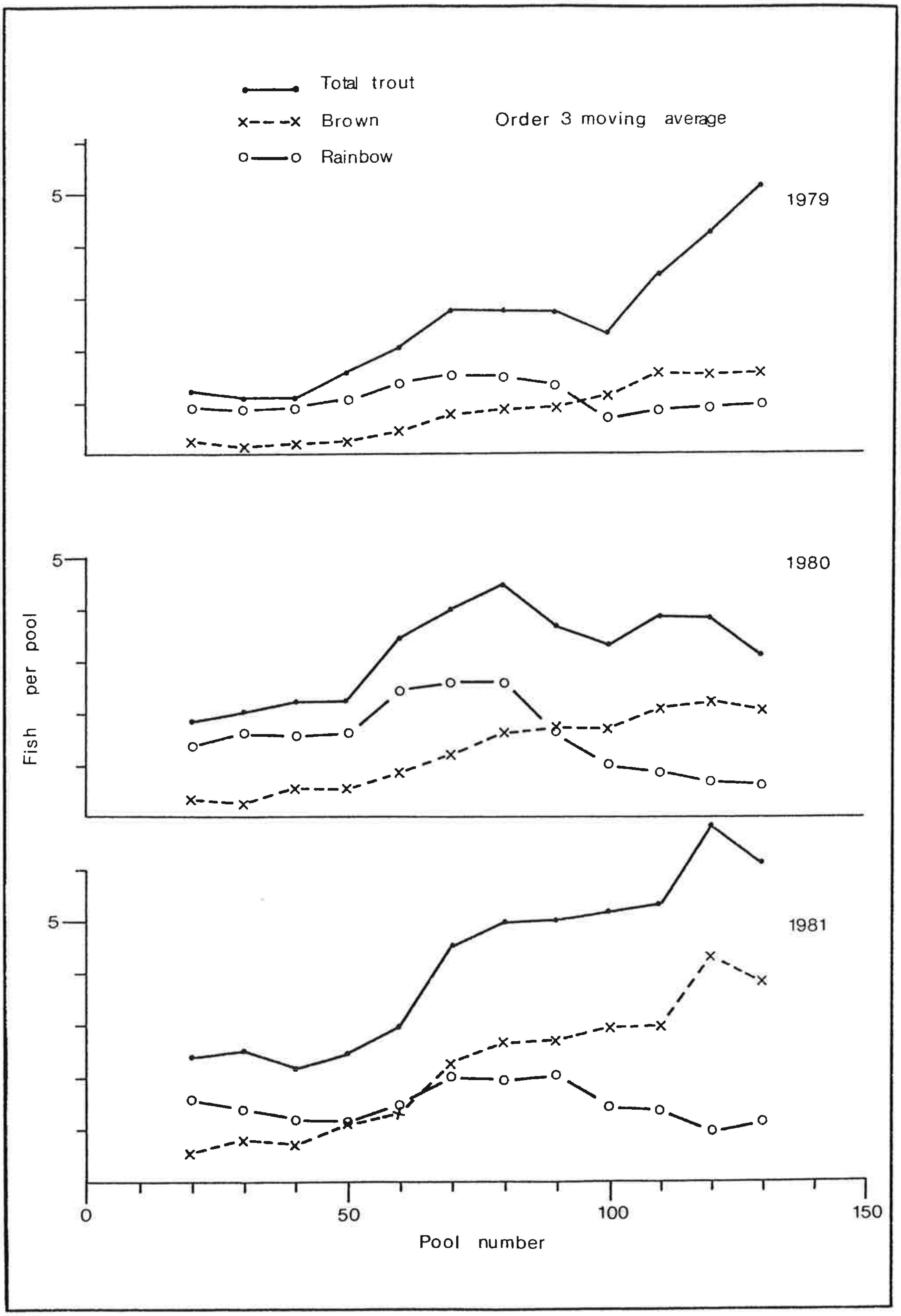

FIGURE 30. Summer abundance of trout > 20 cm in pools 1-140, 1979-81.

TABLE 23. Changes in abundance of trout >20 cm, pools 1-140, 1979-81

	1979	1980		1981		
			Increase on		Increase on	
	Number >20 cm	*n*	1979 %	*n*	1979 %	1980 %
Brown	114	170	49	300	163	76
Rainbow	141	196	39	205	45	5
Total	372	416	12	590	59	42

Seasonal changes in abundance are evident when the results of summer and winter (1979) drift diving counts in part of the middle zone are compared (Fig. 31). These distinct changes undoubtedly result from the movement of adult trout out of the area to spawn because surveys of spawning stocks (section 6.3.5) showed that these fish move into the Orautoha Stream and far up the Manganuioteao to spawn. The change in the relative abundance, from the summer maximum in the vicinity of pools 120-140 upstream to the vicinity of pool 80 where several redds were also observed is a further indication of this.

6.3.4 Movements

Knowledge of movement patterns of individual trout is based upon the recovery or observation of 41 tagged fish. Recaptures were by anglers, nets, and fish traps, and divers recorded tag colours (and occasionally numbers) on fish they observed.

One brown trout was recaptured by an angler in the Kaupokonui Stream, Taranaki after being at large for 125 days and having swum 112 km downriver and 118 km along the coast by the most direct route.

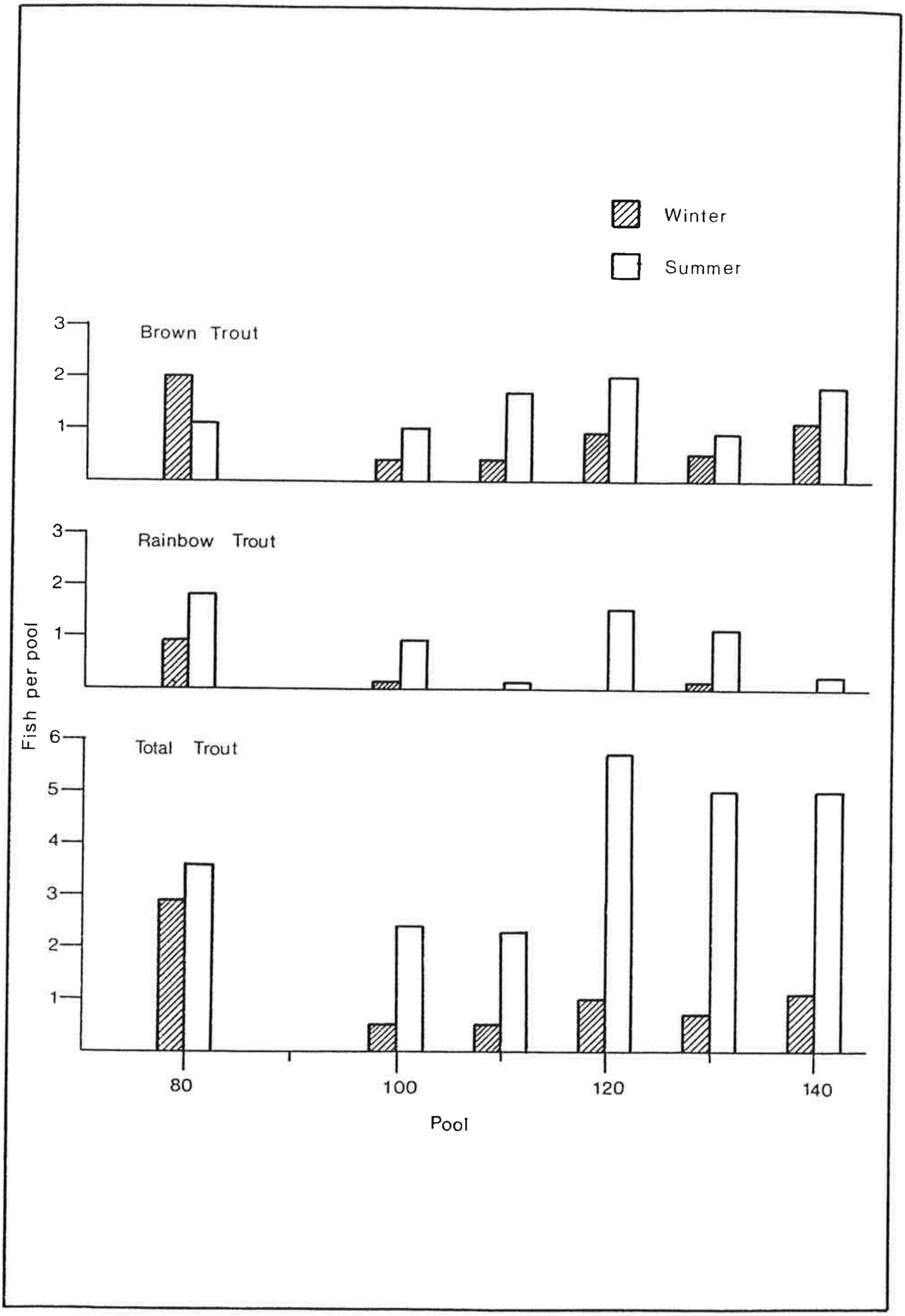

FIGURE 31. Abundance of trout > 20 cm in the middle zone, summer and winter 1979.

The remaining 40 recoveries were within the Manganuioteao system (Fig. 32). Distances travelled ranged between 0 km in 12 months and 38.4 km in 10 months (mean 9.3 km in 9.2 months). Poor access restricted both the tagging and subsequent recovery of fish in the upper zone of the Manganuioteao River though trout certainly move about within this area in relation to spawning activities (section 6.3.5). Two trout which had been tagged upstream from the Orautoha Stream-Manganuioteao confluence (8.7 km and 2.4 km respectively) were recovered 4-5 months later at the Orautoha fish trap, indicating that some trout must move downstream before entering this spawning tributary.

Detailed information about trout movements is constrained by the high tag loss (section 6.2.6). However, the tags recovered provide indications of extensive movements. The increase in numbers of adult brown trout in summer 1981 indicates movement from outside the Manganuioteao system since these fish were not apparent during the counts carried out in the previous summer.

Movements of juvenile trout were not studied, but implicit in the identification of spawning grounds (section 6.3.5) is the corollary that juveniles must disperse from them, generally in a downstream direction.

6.3.5 Spawning

Visual examinations from stream banks, winter drift diving, spring crawl diving, fish trapping, and electric fishing results provided information about spawning locations and in some cases an assessment of the numbers of trout using them.

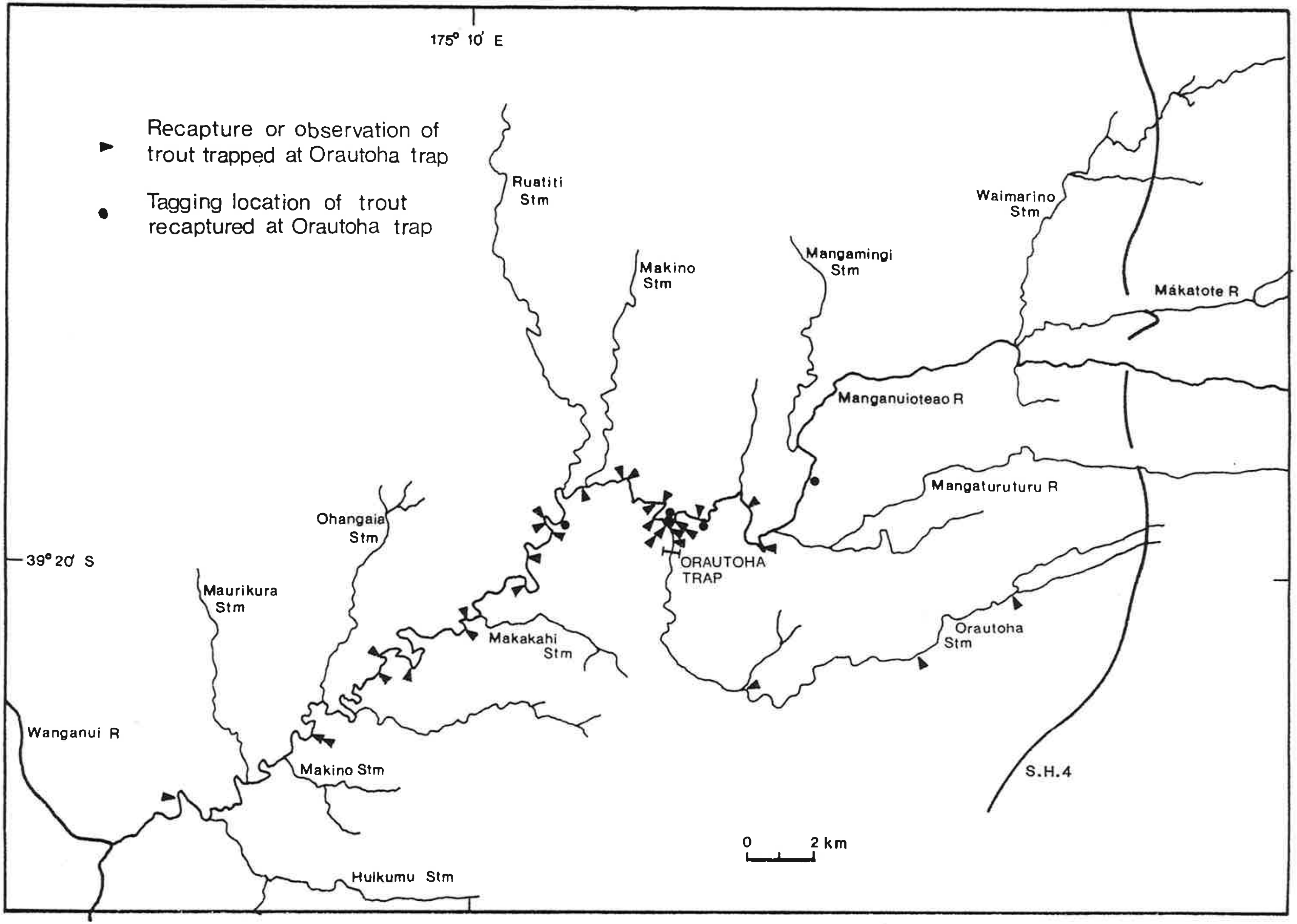

FIGURE 32. Movements of tagged trout within the Manganuioteao system.

An inconclusive attempt was made to identify spawning areas prior to the study period (Turner 1978), but the summer and winter drift diving counts in 1979 indicated that extensive spawning migration occurred. Accordingly traps were installed to catch trout moving upstream into areas that appeared to be used as spawning grounds during winter 1980 (see Fig. 24). Visual examinations were made of as many of the remaining tributaries as possible.

The numbers of trout trapped are set out in Table 24 and the results at each site are illustrated in Figure 33. The presence of rainbow trout in the Orautoha Stream and the poor catch in the Manganuioteao trap were unexpected results because the Orautoha had been regarded as a brown trout spawning stream from local reports and the summer's electric fishing results, whereas the previous winter's observations of redds and spawning rainbow trout had indicated that numerous fish spawned upstream from the Manganuioteao trap site.

TABLE 24. Numbers of upstream migrant trout caught in fish traps at three sites in the Manganuioteao system

Trap	Period	Brown trout	Rainbow trout	Total
Waimarino	13/6/80 to 25/8/80	48	2	50
Manganuioteao	3/6/80 to 26/8/80	-	9	9
Orautoha	29/5/80 to 27/8/80	151	64	215

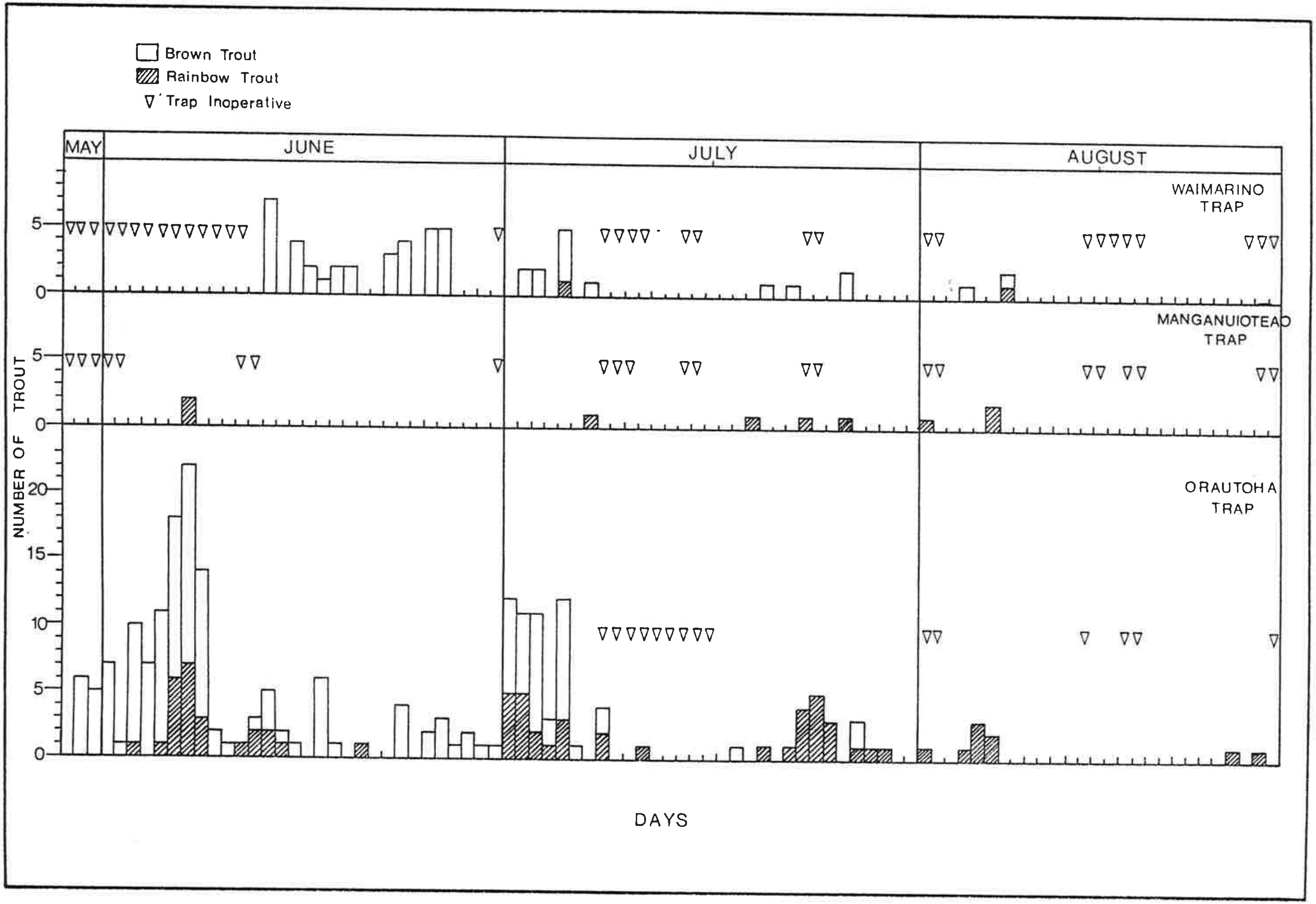

FIGURE 33. Frequency of upstream migrants at three trap sites during 1980.

Spawning migrations had begun in the Orautoha and Waimarino Streams before the traps were installed. This is indicated in Figure 33 and proven by the capture of 38 downstream migrants at Orautoha on 1 July 1980 after the trap had been in continuous operation since 29 May. Thirty (79%) of these fish had not passed through the trap on their way upstream and must have been in the stream before 29 May.

The timing of the spawning season in the Manganuioteao system may be inferred from divers' observations, and gill netting and trapping results. During March 1981 gill nets set in the lower zone, several kilometres downstream from the Orautoha Stream-Manganuioteao confluence, caught five times more trout in the same pools on a night in which rainfall caused the river to rise slightly than on the previous night which had been fine and clear. The tendency of trout to migrate toward spawning grounds during a fresh or flood has been noted by Hobbs (1937) and Frost and Brown (1967). In addition most of the trout examined while netting during March-April had well developed gonads; 24% (mostly brown trout) were considered to be within a few weeks of spawning.

Figure 33 shows the pattern of movement of spawners past the trap sites during winter 1980. The Orautoha trap data indicate that the bulk of the brown trout had passed upstream by mid June and that most of the rainbow trout passed the site during July, though an apparently discrete migration occurred in mid June as well.

In October 1980, trout parr (4-8 weeks old) were observed by divers in pools 58, 108, and 113 and also in the Orautoha Stream. This indicated that hatching had taken place during August-September and incubation during the previous 2 months.

Therefore, the general sequence begins in March-April with initial movements associated with spawning migration; brown trout move to their spawning grounds in May-June and rainbow trout in June-July. They spawn, and hatching begins by August-September after which the small trout begin to disperse.

The number of trout migrating into the Orautoha Stream to spawn can be assessed from the ratio of marked to unmarked trout in the 38 downstream migrants caught in July. This would mean that 520 trout were in the stream though only 138 had been caught in the trap until that time. If it is assumed that the trap caught half of the subsequent upstream migrants the spawning run would have totalled about 600-700 trout. Unfortunately this estimate cannot be verified, but a figure of this magnitude is not improbable when the estimates of abundance (Table 22) and the presence of trout from outside the Manganuioteao system (sections 6.3.1.1 and 6.3.4) are considered.

Expected migrations of trout into the headwaters of the Manganuioteao River and the Waimarino Stream did not eventuate. The fish trapped at Waimarino appear to be residents in the stream because they are generally larger than the Manganuioteao trout. The mean length and weight of Waimarino trout is significantly different from Orautoha trout at $P = 0.01$ ($t = 3.101$ (length); 3.617 (weight)), and when they are compared with all of the Manganuioteao brown trout the mean length is significantly different at $P = 0.05$ ($t = 2.544$) and the mean weight is significantly different at $P = 0.01$ ($t = 3.143$). Waimarino trout have consequently been excluded from calculations relating to the Manganuioteao trout population, as have the nine rainbow trout caught in the Manganuioteao trap. The latter did not differ significantly in size from other rainbow trout samples, but were excluded because the sample was too small.

Direct and indirect observations of spawning activities made by diving, walking surveys, and electric fishing during the study period are shown in Figure 34 and the comments on the spawning potential of tributaries which follow are drawn from records of our surveys, Armstrong (1979), and Turner, Allen, and Beam 1969.

The upper Manganuioteao River from the Makatote-Waimarino confluence for 6.5 km upstream has a substrate of rounded, andesite boulders with pockets of gravel, turbulent flow, and few pools. In 1980, gravels suitable for spawning were estimated to comprise 15% of the substrate in the 2.5 km downstream from S.H.4 and 1% in the 0.5 km upstream of S.H.4. Adult rainbow trout have been observed in the area during winter and redds have been counted there (25 in 1979). Juvenile rainbow trout have been caught in the vicinity of S.H.4 by electric fishing. A waterfall that is likely to be a barrier to trout exists upstream of S.H.4, but its exact location is not known: Mead (1979) records the death of a tramper who fell over it while travelling downstream. An unnamed stream which joins the Manganuioteao River from the south a short distance upstream from the Makatote confluence has a series of log jams and waterfalls throughout its course, beginning 100 m upstream from the mouth, and has very limited spawning facilities; nevertheless, adult rainbow trout have been seen near the mouth during winter (J. Barnett pers.comm.).

The Makatote River is similar to the upper Manganuioteao, but fewer adult trout or redds have been observed in it. Angling for large trout is reported to be rewarding during spring (D. Griffiths pers.comm.) and it is reasonable to assume that these fish spawn in the river during winter and gradually retire downstream in spring and early summer. Juvenile rainbow trout have been caught in the vicinity of S.H.4 and a

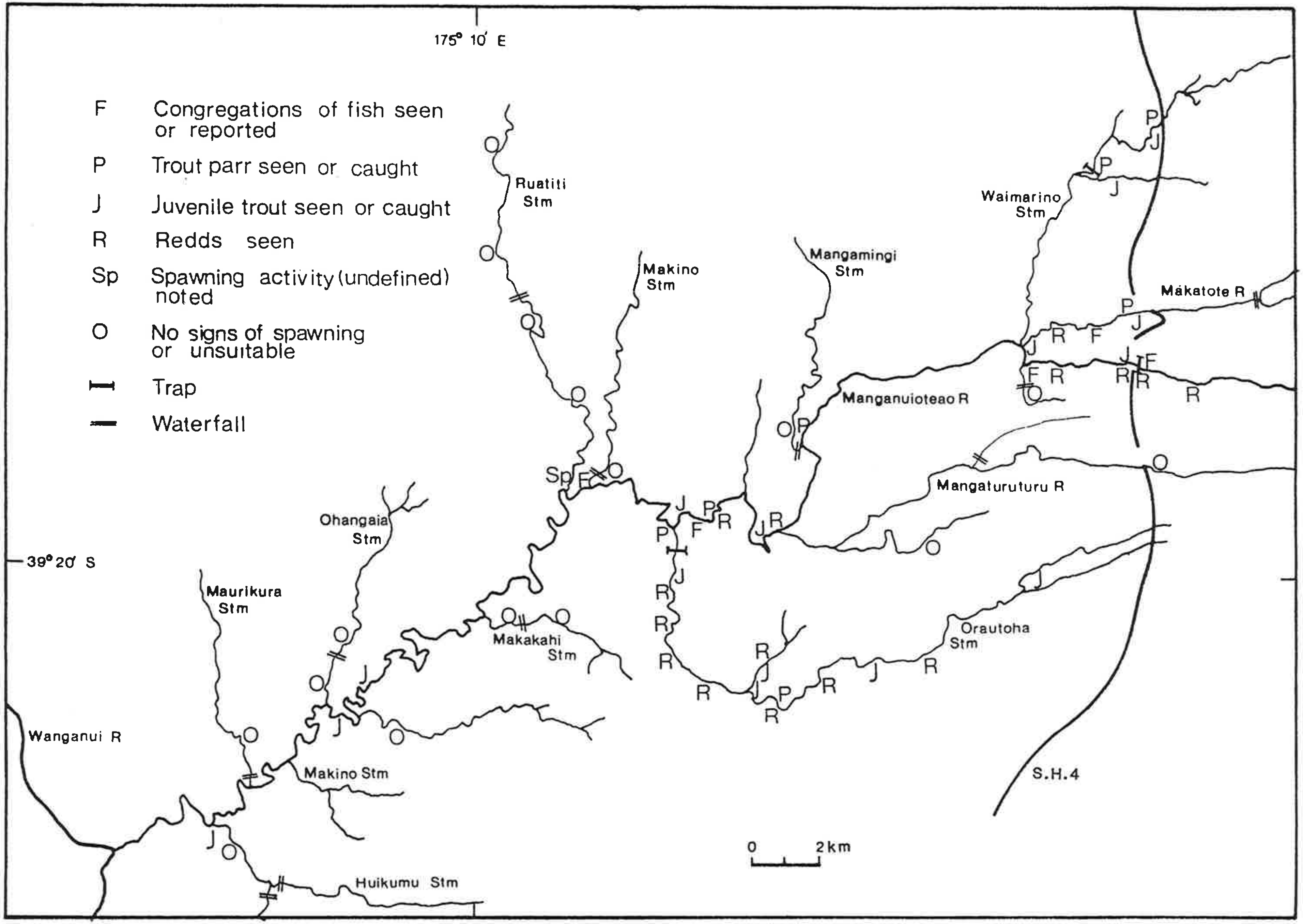

FIGURE 34. Trout spawning 1979-81.

single juvenile brown trout was seen near the confluence of the Waimarino Stream and the Makatote. In a 2-km-long stretch of river in the vicinity of S.H.4, gravels suitable for spawning exist in isolated pockets and comprise 5% of the substrate. A 25-m-high waterfall 4 km upstream from S.H.4 restricts trout to the 8.5 km of river between it and the Manganuioteao-Makatote confluence.

The Waimarino Stream appears to contain a trout population which is discrete from that of the Manganuioteao River. Access for trout from the Manganuioteao or Makatote Rivers is difficult in the lower 1 km (N. Ewing pers.comm.), but above this area of cascades and rapids there is good trout habitat in a 3-km-long reach near the fish trap. Trapping results indicate that a comparatively small spawning migration occurs, largely of resident trout. Redds have not been observed between the fish trap and S.H.4 despite favourable spawning conditions being available, and so it is likely that spawning occurs upstream of S.H.4. Juvenile brown and (one) rainbow trout have been caught in the stream and also in a tributary, the Makokomiko Stream, which appeared less favourable for spawning with only 5% suitable substrate.

The Mangaturuturu River was not examined because its waters are toxic to trout at S.H.4 and because the lower reaches, which may support trout, were inaccessible for walking surveys. Although trout are reported in an unnamed Mangaturuturu tributary which joins the river via a 30-m-high waterfall from the northern side between S.H.4 and the mouth (D. Griffiths pers.comm.), they are believed to be a restricted resident population. In the Makara Stream, a southern tributary of the Mangaturuturu River, a 2-km-long reach was examined. No fish or redds were seen and though 10% of the substrate was suitable for spawning, local residents reported never having seen trout in it.

The Mangamingi and Hoihenga Streams are two small Mangaturuturu tributaries which are considered unsuitable trout habitat. The former has a series of waterfalls near its mouth and the latter has a bed of mudstone, and few gravels; no trout were caught in it by means of electric fishing.

The Orautoha Stream is by reputation the most important spawning tributary of the Manganuioteao River, but sightings of trout and redds do not indicate a large migration into it. In July 1979, 54 redds and 8 trout were counted in the first 7 km of the stream and in July 1980 6 redds and 9 trout were seen in 9 of the next 12 km upstream. The trap installed in the Orautoha Stream during winter 1980 caught 215 upstream migrants and several hundreds more are estimated to have passed upstream while the trap was inoperative. This represents a substantial migration for a river dwelling trout population. Reasons for the difference between numbers trapped and the evidence from visual surveys no doubt include the size of the system (it contains up to 30 km of accessible water), the presence at any one time of only a small proportion of the total number of trout caught during the longer term of the spawning season, and the fact that spawning sites are not always readily identifiable in the river. The substrate of the Orautoha Stream resembles that of the Manganuioteao River in its middle reaches, that is, rounded andesite boulders with isolated patches of sand and gravel, but the Orautoha contains more sand and silt than the Manganuioteao. The following estimates were made of suitable spawning substrate (at distances upstream from mouth): 0-4 km, 5% suitable; 7-11 km, 1%; 13-15 km, 10%, and 18-21 km, 40%. Juvenile brown trout have been found in all parts of the stream and several rainbow parr were observed in spring 1980. The apparent absence of rainbow trout juveniles during summer may be caused by higher temperatures in the Orautoha Stream coupled with the tendency of these fish to be more pelagic and mobile than brown trout; rainbow juveniles tend to disperse downstream to the Manganuioteao at a faster rate.

Few signs of spawning activity were seen in 2.5 km upstream from the mouth in Papa Creek, a tributary of the Orautoha Stream. One dead fish was found and in 1979 juvenile trout were caught there so a limited amount of spawning evidently takes place in the creek. The substrate contained 2% gravel suitable for spawning.

The Makino Stream is reputed to contain a few trout during the spawning season, but access is blocked by a waterfall near the mouth (H.H. Brown pers.comm.). A little over 1 km was examined in August 1984 by walking and swimming upstream from the mouth. A 2-m-high waterfall 800 m from the mouth would stop fish passing at normal flows and below it the stream appeared unsuitable for spawning though there were patches of suitable gravel at the tails of pools. The stream channel is deeply entrenched and heavily shaded in a sheer sided gorge. The bed is mostly silt and mud and there are many logs embedded in it. It is evident that the stream carries a heavy silt load. It provides limited spawning, if any, and extremely limited rearing habitat for juveniles.

The Ruatiti Stream was examined by spot checking accessible reaches within the first 20 km upstream from the mouth. A shute 10 km from the mouth would probably constitute a barrier to upstream movement and others could exist in gorges that were not examined. Armstrong (1979) reported spawning activity in the stream, and local residents report having seen trout only in the lower reaches (J. O'Neill and F. Bright pers.comms.). No trout were caught by electric fishing. In most places examined in the 10-km-stretch upstream from the mouth the substrate was unsuitable for spawning, but there were a few suitable patches of gravel. The Ruatiti, like the Makino in the adjacent catchment, evidently carries a heavy silt load at times and its spawning and rearing facilities for trout are limited.

The Makakahi Stream is unsuitable for trout. The mudstone substrate provides no spawning possibilities and access beyond 2 km from the mouth is barred by a 10-m-high series of waterfalls. No trout were caught by electric fishing downstream from the falls.

The Tokitokirau Stream is deeply entrenched in a narrow gorge in its lower reaches. From points where it could be viewed, the mudstone substrate appeared to be unsuitable for trout spawning.

The Ohangaia Stream has a 15-m-high waterfall 1 km from the mouth and the mudstone substrate is unsuitable for trout spawning. No fish were seen in 2 km of stream.

The Maurikura Stream is unsuitable for trout spawning. Two hundred metres from the mouth access is barred by two waterfalls 7-10-m and 12-15-m-high respectively in a narrow gorge, and below the falls the substrate is unsuitable.

The Huikumu Stream has a 25-m-high waterfall 3 km from the mouth. Below the fall the substrate is mudstone boulders and silt changing to andesite boulders and cobbles when it enters the Manganuioteao valley. In 1.5 km upstream from the mouth there were no suitable spawning gravels in the substrate. A juvenile trout was seen while electric fishing near the mouth and rainbow trout are reported to have escaped into the headwaters from a small man-made lake which was stocked with hatchery reared trout (T. Tapp pers.comm.). However, the stream does not appear to be suitable for trout spawning and it is unlikely to provide spawning habitat for Manganuioteao trout. In August 1984 it carried a heavy silt load resulting from afforestation activities in its catchment.

The mainstem of the Manganuioteao River contains isolated patches of suitable spawning gravels in the lower and middle zones which trout utilise though the number of fish involved is unknown. Redds have been observed between pools 69 and 115 with brown trout in the vicinity. Parr have been observed and caught between pools 58 and 113 and congregations of adult trout are sometimes seen in pools within this area during winter; these are all clear indications of spawning activity, but no attempt was made to assess the extent of spawning in the mainstem.

6.3.6 Angling

6.3.6.1 Introduction

On 18 January 1979, a gathering of Waimarino anglers provided a background to the angling characteristics of the Manganuioteao River: "fishing takes place between the top of Pukekaha Road and Pikes Flats (pools 58-178) and the area between the confluences of the Orautoha and Ruatiti Streams (pools 112-139) receives the most pressure. Most fish are caught between pools 106-178 and the early part of the season (October-December) provides the best fishing. Spoon fishermen usually concentrate on the lower part of the area and achieve good results there while nymph and dry-fly lures are more commonly used upstream from the Ruatiti confluence and are very effective in the evening".

A CNIWC licence is required to fish the Manganuioteao River and the season begins on 1 October and ends on the following 30 June. Spoon and artificial fly fishing methods are permitted and the bag limit is eight rainbow trout and unlimited brown trout per day. The minimum size takeable is 35 cm for both species.

Angling data have been extracted from past diary schemes summarised by Allen and Cunningham (1957) and Graynoth (1974c) from angler census data presented by Armstrong (1979) and Todd (1981) and from diaries on MAF file Tgi/1/2. The data used show historic and present day results and characteristics of the angling population and their catch.

6.3.6.2 Results

Table 25 summarises angling results between 1947 and 1981. There are three periods when the data are sufficient to allow comparisons to be made. They are 1947-52 and the 1962-63 and 1978-79 fishing seasons. The remaining data merely show the variability in the catch rate and the general size of fish caught, but the samples are too small for comparison. A slight decrease in average size is evident between 1962-63 and 1978-79 and the catch rate appears to have dropped between 1947-52 and 1962-63 to its present level of 0.3-0.5 fish per hour or 0.8-1 fish per visit. However, catch rate is extremely variable as is demonstrated by the individual results of 26 anglers (section 6.3.6.4) whose average catch rate was 0.36 fish per hour, but who ranged between 0 and 6 fish per hour individually. By selecting from the 26 anglers those who fished for more than 1 hour with some success, a rate (0.69 fish per hour) close to the 1947-52 figure is obtained.

TABLE 25. Angling results

Period	Visits	Hours fished	Fish kept	Takeable fish per hour	Takeable fish per visit	Mean length (mm)	(n)	Mean weight (kg)	(n)	Brown (%)	Rainbow (%)
1947-52[*]	321	796.0	564	0.71	1.8	478	(477)	-		21	79
1953-54[†]	-	10.5	5	0.48	-	-		-		-	-
1962-63[*]	35	108.3	36	0.33	1.1	478	(56)	-		50	50
1967-68[*]	2	3.3	3	1.00	1.5	549	(5)	-		67	33
1974-75[†]	4	13.0	11	0.85	2.6	475	(10)	1.42	(10)	-	-
1976-77[†]	6	15.0	3	0.20	0.5	538	(3)	1.93	(3)	-	100
1978-79[‡]	82	148.3	76	0.51	0.9	447	(78)	1.14	(81)	23	77
1980-81[†]	16	34.0	10	0.23	0.8	541	(8)	2.08	(9)	40	60

* Graynoth 1974c.

† Angling diaries and summaries, file Tgi/1/2.

‡ Armstrong 1979.

In addition three other anglers who voluntarily kept diaries during the 1978-79 season averaged 0.70 fish per hour, also close to the 1947-52 catch rate. Graynoth (1974c) found that anglers who returned diaries fished more frequently and were more successful than the average licence holder and so it appears from the above figures that the catch rate of anglers who keep diaries may not have changed since about 1950 and that catch rates calculated from these diaries are likely to be higher than average.

The proportions of the two species of trout in the catch are almost the same in both 1947-52 and 1978-79, but the difference in 1962-63 cannot be explained. The proportions of the two species caught by anglers and by sampling (Table 26) show that most fish caught by anglers are rainbow trout which were also the dominant species in the population of medium and large fish during that period. However, anglers caught a greater proportion of rainbow trout and a lesser proportion of brown trout than those recorded by divers in the same area.

TABLE 26. Comparison of the species composition of the anglers' catch, 1978-79, with trout sampled in the middle zone (pools 61-140) by drift diving and adjusted by adding "unidentified" at 75% Rainbow, and 25% Brown

Anglers' catch (n = 81)		Drift diving (n = 289)	
Brown %	Rainbow %	Brown %	Rainbow %
23	77	44	56

The size of the trout caught by anglers is significantly smaller than those sampled by netting and trapping (Table 27). A much higher proportion of the trout caught by anglers (33%) was less than 40 cm long compared with trout caught by other methods during this survey (9%). Table 27 shows that the size difference is due to the smaller size of rainbow trout caught by anglers. However, the proportion of each species <40 cm is about the same and so it is likely that a larger sample of brown trout caught by anglers would also be significantly smaller on average than those caught by netting and trapping.

TABLE 27. Comparison of the length and weight of trout caught by anglers, 1978-79, and sampled by trapping and netting, 1979-81

		All trout		Brown		Rainbow	
		Sample	Angler	Sample	Angler	Sample	Angler
Length (mm)	*n*	485	78	388	17	97	61
	Mean	503	447	505	463	495	442
	Range	235-720	330-686	305-720	350-686	235-692	330-572
	t		7.06**		1.91		6.64**
Weight (kg)	*n*	305	81	226	19	79	62
	Mean	1.64	1.14	1.63	1.28	1.68	1.08
	Range	0.25-3.70	0.50-2.38	0.25-3.15	0.57-2.38	0.55-3.70	0.50-2.04
	t		9.91**		2.57*		11.51**

* Significant at P = 0.05.
** Significant at P = 0.01.

The catch rates of four different angling methods are compared in Table 28. Nymph fishing is the most popular method used, but with the dry fly method it is the least successful. The most successful method is spoon fishing and this is borne out by comparing the season's results of two experienced anglers, one of whom used the spoon and caught fish at a rate averaging 1.5 fish per hour and another who used nymph and occasionally wet fly and caught fish at 0.41 fish per hour.

TABLE 28. Catch rates of different angling methods (1978-79 creel census data (Armstrong 1979))

Method	Hours fished	Fish kept	Catch rate (fish per hour)
Nymph	53.18	16	0.30
Spoon	15.91	9	0.57
Wet fly	6.70	3	0.45
Dry fly	7.00	2	0.29

Catch characteristics of the four methods are compared in Table 29. Larger fish and more brown trout were caught by nymph fishermen whereas spoon fishermen caught mostly rainbow trout and also the greatest proportion <40 cm. The numbers of fish returned to the water by anglers using spoon and nymph gives a further indication of the selective properties of each method. During 1978-79, spoon fishermen returned 14 undersized trout to the water whereas nymph fishermen returned 3 undersized and 2 takeable trout. The wet and dry fly methods produced small samples which could not be compared with the other two methods.

TABLE 29. Catch characteristics of different angling methods (1978-79 creel census and angling diaries (Armstrong 1979))

Method	Mean length (mm)	Mean weight (kg)	Species (%B,	%R)	<400 mm (%)
Nymph	459	1.22	35	65	17
Spoon	439	1.01	19	81	43
Wet fly	502	1.67	Small sample		
Dry fly	405	0.90	Small sample		

6.3.6.3 Influence of Hatchery Reared Trout

The numbers of rainbow trout ova, fry and yearlings released in the Manganuioteao system between 1965 and 1979 are given in Table 30. In each year except 1967 and 1970 the yearlings were marked by clipping a fin and some were tagged, but few have been recorded by anglers. During 1967-81 only one angler recorded a hatchery reared fish, an undersized one which was returned to the water. None of the 103 trout kept by anglers during that period was recorded as being marked, and of the 524 trout which were carefully examined during the study period only 5 had hatchery fin clips. These were yearlings which were caught while electric fishing near the S.H.4 crossing in the upper zone in January 1979; they had remained in the same location in which they were released 3-4 months previously. It is evident that hatchery reared trout have very little effect upon the adult trout population or upon the anglers' catch in the Manganuioteao River at the stocking levels shown in Table 30.

TABLE 30. Numbers of hatchery reared rainbow trout liberated in the Manganuioteao system, 1965-79 (Secretary, Waimarino Ward CNIWC)

Year	Ova	Fry	Yearlings
1965		15 000	8 400
1966	800		
1967		15 000	11 000
1968	3 200		1 200
1969	12 800	15 000	2 500
1970	3 600	18 000	4 500
1971		16 000	2 050
1972	10 000	3 700	4 800
1973	5 000	13 500	4 600
1974	8 000	16 000	2 500
1975	19 600	27 500	5 000
1976			3 400
1977			3 800
1978			2 000
1979			1 300

In contrast anglers caught 10 (3.3%) of the 307 trout tagged at the Orautoha trap and in the mainstem of the river during the study period despite the apparently high tag loss suffered by these fish. If the tag loss factor had been nil anglers would have recovered 10-12% of the tagged trout.

A qualification should be added to the statement that hatchery reared trout have little effect upon anglers' catch because it is evident that though tagged trout may be readily recognised most anglers fail to identify fin-clipped fish and this may have resulted in some not being reported. No fin-clipped fish without tags were reported by anglers during the study period, but an examination of the catches of several anglers in April 1981 revealed two such fish which had not been recognised by their captors despite familiarity with the tagging programme.

6.3.6.4 Angler Characteristics

The catch, time spent fishing, and methods used by 26 anglers who were interviewed during the peak holiday period in 1978-79 (Armstrong 1979) are set out in Table 31. More than half of the anglers (54%) spent almost one third (32%) of the total 83 hours fished and caught nothing, whereas two fishermen achieved unusually high catch rates in a short time evidently having both caught a fish and been interviewed within a short time of beginning. The wide variation in catch rates of the remaining successful anglers reflects differences in skill to some extent, but this is obscured by differences in the effectiveness of different methods (see Table 29).

TABLE 31. Angler success and catch rates from 1978-79 creel census (Armstrong 1979)

Angler	Hours fished	Fish caught (takeable)	Catch rate (fish per hour)	Fishing method
1	13	5	0.38	Nymph
2	6.25	5	0.80	Spoon
3	6.25	5	0.80	Nymph, Dry fly
4	14	4	0.29	Nymph, Wet fly
5	1.7	3	1.76	Wet fly
6	1.5	2	1.33	Spoon
7	0.5	1	2.00	Spoon
8	2	1	0.50	Spoon
9	5.25	1	0.19	Nymph, Dry fly
10	4.5	1	0.22	Nymph
11	0.17	1	5.88	Nymph
13-26	26.17	0	0	All
Total	82.79	30	0.36	-

A second survey of recreational users was conducted in 1980-81 over a comparable period to the 1978-79 survey (Todd 1981). Although anglers were recorded in this survey no census was taken of them, but some comparable information was collected on both occasions (Table 32).

TABLE 32. Numbers of anglers and distances travelled to reach the Manganuioteao River taken from two censuses during the peak holiday period (Armstrong 1979, and Todd 1981)

	24 December 1978 to 8 January 1979 (16 days)	27 December 1980 to 5 January 1981 (10 days)
Total no. anglers:	36	46
Total no. groups:	51	46
Total no. associated:	204	222
Distance from home (km)	Percentage of anglers	Percentage of anglers
0- 10	None recorded	9
11- 30	50	39
31-100	19	19
101-200	3	11
201-400	28	13
>400	-	2
Overseas	-	7

More anglers were recorded during the shorter 1980-81 survey than in 1978-79 and on both occasions most were associated with families or groups averaging 5-6 people who participated in activities other than angling. These activities were most commonly camping and picnicking; others included swimming, canoeing, rafting, and trail bike riding. Residents of the Waimarino district (0-30 km from the river) are the single most numerous group of anglers comprising about half of those checked on both surveys, but other visitors travel considerable distances to reach the area. The incidence of overseas visitors in 1980-81 is not a new development because one was encountered shortly after the 1978-79 survey ended and the comments of a professional fishing guide at that time also indicated that he brought overseas clients to the river (Cawthron Technical Group 1979). Many anglers return repeatedly to fish the river. Armstrong (1979) states that 75% of the anglers interviewed in 1978-79 estimated that they had visited the river 20 or more times and they listed a variety of reasons for their visits. The most common reasons related to the scenery and solitude, the high quality water, the varied, high quality angling available, the suitability of the area for a variety of family orientated activities, and the presence of blue ducks.

During non-peak periods the number of anglers using the river is estimated at 0-5 per day depending upon weather conditions; between 10 and 20 local anglers regularly fish the river (H.H. Brown *in* Armstrong 1979).

6.3.6.5 Angling Importance Grade

A National River Angling Survey was conducted in 1980-81 in which randomly selected samples of licence holders in each acclimatisation district were asked to indicate which rivers they fished, their reasons for doing so, their methods, usage, and results, and to assign a grade of importance to their rivers and to the particular attributes of each (Teirney 1980). Provisional data from the survey were used (Richardson and Teirney 1982) to show the relative use and value of Waimarino district rivers (Table 33). The Manganuioteao River and the Wanganui River upstream from Taumarunui both received the highest importance grades at the regional level.

TABLE 33. Angler use and importance grades of rivers in the Waimarino district (Richardson and Teirney 1982)

River	Number of respondents	Number of visits	Visits per angler	Importance grade*
Manganuioteao	23	217	9.4	5
Wanganui	22	268	12.2	5
Whakapapa	26	253	9.7	4
Mangawhero	17	298	17.5	4
Taonui	13	154	11.8	4
Retaruke	5	40	-	†
Orautoha	5	47	-	†

* 1 - not highly valued.
5 - very highly valued.
† - insufficient responses.

Teirney *et al.* (1982) assessed the National River Angling Survey data and produced a list of 9 North Island and 16 South Island rivers which were rated nationally important by consistently high anglers' scores for importance, usage, and distance travelled to reach them. The rivers are subdivided into three categories which take account of the relative degrees of accessibility, distance from centres of population, usage, methods applicable, catch, scenic beauty, solitude, associated activities, and catchment modifications. The three categories are wilderness, scenic, and recreational fisheries. The Manganuioteao River is classed as a scenic river fishery of national importance according to these criteria; it received exceptional ratings from over half of the survey respondents and was visited by anglers from 6 of the 13 North Island acclimatisation districts. Angling effort was limited by difficult access to some parts of the river, but peace and solitude were highly valued and scenic qualities were considered exceptional. Anglers used a variety of methods and reported a generally reasonable catch rate of large trout.

The Manganuioteao River is the only one in the Waimarino district which is rated as nationally important though there are several others nearby in the central North Island (Table 34).

6.4 Discussion

We have shown that a team of snorkel divers can count trout in pools of the upper and middle Manganuioteao River with acceptable accuracy and that methods such as gill netting and SCUBA diving give an indication of the nature and extent of the trout population in the lower river, but it is clear from the difference between day and night counts in one pool (Table 21) and from observations by individual divers of trout hidden amongst boulders and logs in the stream that none of the methods used sampled all of the fish present.

TABLE 34. North Island nationally important angling rivers (Teirney *et al.* 1982)

River	Region of river (and NMNS 1 map reference)	Category
Manganuioteao	Source to confluence with Wanganui River (N121/571505)	Scenic
Tongariro	Poutu intake (N112/304840) to Lake Taupo (N102/264070)	Recreational/scenic
Tauranga-Taupo	Source to Lake Taupo (N102/380107)	Recreational
Waitahanui	Source to Lake Taupo (N103/547257)	Recreational
Tarawera	Lake Tarawera outlet (N77/957984) to Tarawera Falls (N77/977009)	Scenic
Ruakituri	Source to road access (N96/741405)	Wilderness
	Road access to Erepiti Road bridge (N105/763279)	Scenic
Mohaka	Confluence of Oamaru and Kaipo rivers (N113/728907) to Willow Flat (N115/371983)	Recreational/scenic
Ngaruroro	Source to Whanawhana (N133/845315)	Wilderness
Rangitikei	Source to Napier-Taihape Road bridge (N123/502404)	Wilderness
	Napier-Taihape Road bridge to the sea (N148/741448)	Recreational/scenic

Northcote and Wilkie (1963) investigated the accuracy of diver counts in a North American river of 8.4 m^3/s (7 m visibility, gravel and boulder substrate) by carrying out 12 replicate counts of a 100 m section blocked off with seine nets and then poisoning the section and recovering dead fish. Diver counts of rainbow trout ranged between 36% and 85% of the fish subsequently recovered (mean 59%) and repeated counts of several other species of fish were "reasonably homogenous". On this basis trout counts in the Manganuioteao could be expected to underestimate the number of medium and large trout present by a similar amount. However, the method is standardised and repeatable so if it is assumed that the miss rate is reasonably constant, as is indicated by the results of repeated counts, then the results of diver counts provide a good comparison between sections of the river, seasons, and years, and also between other rivers where the same method has been used. Similarly the gill net sample is unlikely to have caught all of the fish present, but bearing in mind that more fish are present in pools at night than during the day and that the nets were set overnight, it can be assumed that a high proportion of the fish which were active in each pool would have been caught.

For the above reasons it is misleading to express the numbers counted as a measure of density when in reality relative abundance has been measured, but for the sake of simplicity and for comparisons numbers are often expressed as densities. Comparisons of fish density measures should only be made when the same methods have been used in each study.

The overall species composition of medium and large trout in the Manganuioteao River in summer 1981 was 67% brown trout and 33% rainbow trout. These values are so close to those of trout caught at Orautoha trap during the previous winter (70% brown trout) that there can be little doubt that both fairly represent the adult trout population at that time. Richardson and Teirney (1982) using the same method found 75% brown trout in the neighbouring Whakapapa River in 1980 and 1981, Hicks (1982) recorded 34% brown trout in the middle reaches of the nearby Rangitikei River in 1979 and Jellyman, Davis, Wing, and Teirney

(1982) recorded 42% brown trout in the South Island's Ahuriri River in 1982.

In summer the distribution of the two species of trout throughout the Manganuioteao system gives an indication of their preferences for different habitat features. Rainbow trout are predominant in the faster water and smaller pools of the upper zone whereas brown trout are more tolerant of conditions in the slower flowing, larger pools of the lower zone and are dominant there. Both species share the middle zone though brown trout tend to be dominant. A similar pattern was found in the Whakapapa River (Richardson and Teirney 1982) and in the Rangitikei River (Hicks 1982) though rainbow trout were predominant in the middle reaches there. Woods (1964) found the same pattern when electric fishing in 28 trout streams flowing from the central North Island volcanoes and noted it as a feature of the area. This pattern does not apply to all rivers containing two species of trout, for example, brown trout predominate in the upper reaches and rainbow trout in the middle and lower reaches of both the Ahuriri River (Jellyman *et al.* 1982) and the Mohaka River which flows eastward from the central North Island and was electric fished extensively in 1983 (Strickland 1985). In a study of the relationship between fish populations and physical parameters of pools in Montana, U.S.A., Lewis (1969) found that during summer cover was the most important factor influencing brown trout distribution and density whereas current velocity was most important to rainbow trout. If this is also true for the Manganuioteao River then the optimum combination of all factors is found where both species are most abundant, that is, in the middle zone (pools 61-161), and both co-exist there because each uses different parts of the habitat at different times and because there is sufficient space for them to do this.

In the Manganuioteao the summer distribution changes in winter in the middle zone when most of the rainbow trout move out of the area and it becomes dominated by brown trout, though in lower numbers than during summer. Hicks (1982) found the same pattern in the Rangitikei River. During an annual period the pattern was both cyclical and seasonal. In both rivers these changes were undoubtedly due to spawning migrations and subsequent dispersal. Tagged fish returns show that not all trout move upstream to spawn and downstream afterward; some fish moved downstream and into the Orautoha tributary to spawn and others moved up the Manganuioteao River after spawning in the Orautoha Stream.

The three summer drift dive surveys showed that a change from rainbow to brown trout domination took place between 1979 and 1980 and became strong in 1981, apparently caused by the entry of several brown trout from outside the Manganuioteao system during winter 1980. Armstrong (1979) suggested that fish stocks had not fully recovered in 1979 from the effects of the 1975 lahar and this is supported by the opinion of Whakapapa anglers. They felt that that river had just recovered from the effects of the 1969 lahar when the 1975 one affected it (Cudby 1976), which may account for the changes during our study period. Also, it is impossible to ignore the conclusions of Burnet (1981) that the so-called "balance of nature" is a dynamic one and that though most biological functions have an annual cycle, most animals have a life cycle lasting several years and very considerable short-term fluctuations can be expected in such studies as this. Thus the composition and abundance of the Manganuioteao trout stocks will vary naturally and our extended study merely gives an indication of the extent of this variation.

The origin of the brown trout which are thought to have entered the Manganuioteao from elsewhere during the 1980 spawning season cannot be stated with certainty, but there are indications that they come from sea-run or estuarine stocks. There is ample evidence that some New Zealand brown trout go to sea and often move considerable distances around the coast, for example, Hobbs (1948), Burnet, Cranfield, and Benzie (1969) and Rowe (1980). McDowall (1984) poses a likely scenario of trout migrations between fresh and salt water and also gives evidence of natural restocking by brown trout of a tributary of a large Canterbury river after each spawning season.

Although only one Manganuioteao trout was recovered after a known sea journey the likelihood is raised here that there were other sea-run trout in the system. The tagged fish (566 mm) was part of a group of larger than average fish which formed a distinct peak (545-575 mm) in the length-frequency distribution of brown trout in the Orautoha Stream spawning run (Fig. 35). It seems likely that these larger males and females were of sea-run or estuarine origin. In August 1983 the senior author recorded a 54-cm-long immature male brown trout and sighted an identical one which was caught in an adjoining pool in the lower zone of the Manganuioteao River. Both bore the "lake" colouration (McDowall 1978) and were pale sided, indicative that they were sea-run. The scales of the author's fish exhibited an initial period of slow growth followed by zones of alternating fast and slow growth and ending with an extended period of slow growth. Within the fast and slow zones other zones showing seasonal patterns could be identified. The scales were interpreted as showing an initial spring, summer, and winter in freshwater, 2 summers and a winter in the sea and the final autumn-winter in freshwater, which meant that the fish was entering its fourth year. Sea-run trout are not unknown in the Wanganui River estuary. The Wanganui Herald (1976) showed a 61 cm, 1.6 kg brown trout

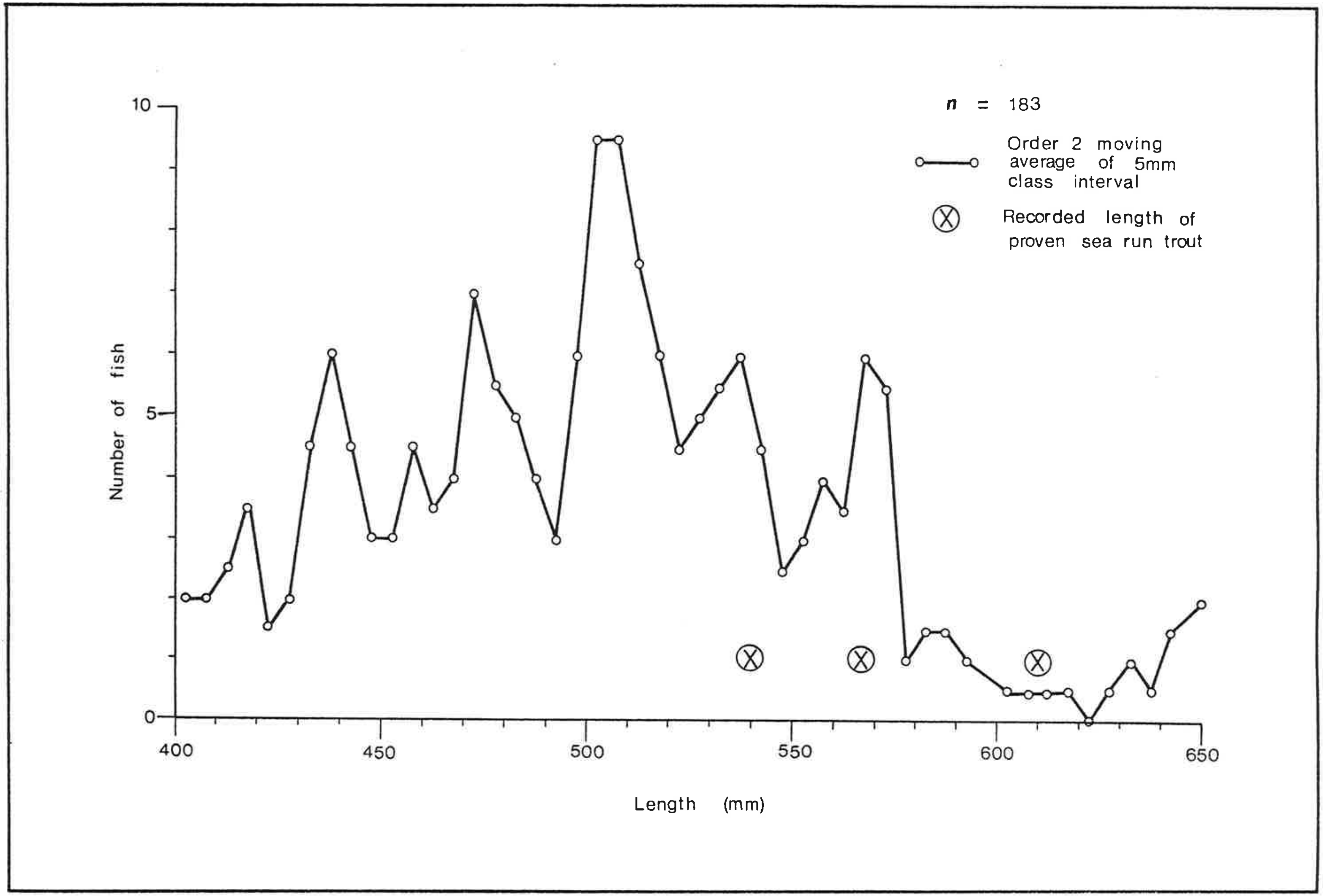

FIGURE 35. Length-frequency distribution of brown trout 400-600 mm at Orautoha trap, 1980.

(mistakenly labelled "rainbow") which was caught near the river mouth. The lengths of both this fish and the author's trout are close to those of the group of larger fish which are thought to be sea-run or estuarine (Fig. 35). Thus, evidence that the 1981 increase in large brown trout in the Manganuioteao River was largely due to an invasion by fish from the Wanganui River, or further afield, which did not disperse completely after spawning in winter 1980, though limited, is nevertheless compelling.

The average size of adult trout in the Manganuioteao is virtually the same in both trapped and netted samples, though rainbow trout netted in the lower zone are significantly smaller than those trapped. The average size of both species was about 50 cm (brown trout 505 mm, rainbow trout 495 mm). This is large by any standard and compares favourably with the average size of trout in similar rivers sampled at the same time and by the same means, for example, the Tukituki River in Hawke's Bay and the Rangitikei in the central and southern North Island (Table 35). The average sizes of the males of both species are also larger than those of the females in each of the rivers.

The average growth rate of 10 adult trout (33 mm per year) in the Mangauioteao tallied closely with that reported by Jellyman *et al.* (1982) for 6 brown trout in the same size range in the Ahuriri River (35 mm per year). Based upon the growth rates of seven younger rainbow trout, Jellyman *et al.* (loc. cit.) estimated that rainbow trout in the Ahuriri grow at up to 20 cm per year for the first 2 years; the rate then declines with the onset of spawning activity to that measured in the adult fish. Allen (1951) measured similar growth rates for brown trout during their first 2 years in the lower reaches of the Horokiwi Stream in the southern North Island. Once again there are too few data relating to Manganuioteao trout, but the data available suggest that growth rates are similar to those measured in younger trout from both the Horokiwi and Ahuriri and in adult fish from the Ahuriri.

TABLE 35. Comparison of size of trout trapped during spawning runs in Manganuioteao River (1980), Tukituki River (1980 and 1981) and Rangitikei River (1983)

Species	River system	*n*	Mean length (mm)	Mean weight (kg)
Brown trout	Manganuioteao	181	498	1.57
	Tukituki*	47	567	2.70
	Rangitikei†	206	566	2.22
Rainbow trout	Manganuioteao	63	509	1.75
	Tukituki*	215	482	1.42
	Rangitikei†	179	489	1.50

* L.W. Spooner pers. comm.
† Cook 1983.

During the study period the abundance of medium and large trout ranged between 0 and 21 fish per pool (3.2-42.0/km) and averaged 3 fish per pool (12/km), but it varied considerably throughout the system (Fig. 29, Table 23) and within the study period (Fig. 30). In the area drift dived the average number of trout per pool changed from 2.7 (15.4/km) in 1979 to 3.0 (17.3/km) in 1980 and 4.3 (24.5/km) in 1981. Within the system the 1979-81 average of 4.8 trout per pool (20.6/km) in the middle zone (pools 101-150) diminished in both upstream and downstream directions to between 1-2 trout per pool (13.5/km upstream and 5.0/km downstream).

Comparable counts have been carried out in some central North Island rivers and in the South Island's Ahuriri River. Richardson and Teirney

(1982) have compared the Manganuioteao and Whakapapa Rivers; they used slightly different zones than ours and found averages of counts to be virtually the same where the effects of diminished flows in the Whakapapa are offset by extra water from its tributaries (23 trout per kilometre in each river). In the Rangitikei River Hicks (pers.comm.) recorded averages of 18.3/km in the headwaters and 29.5-34.4/km in the middle reaches from 1979-80 counts of fish >12 cm. Counts of fish >20 cm in three short headwater sections of the Rangitikei in 1983-84 gave a range of 1.2-32 trout per kilometre (mean 16.9/km) (author's unpublished records) which is similar to Hicks' average allowing for his inclusion of smaller fish. In contrast the Manganuioteao average in the upper zone was a little lower (13.5/km), but the 1981 count (16.6/km) approached that of the Rangitikei River.

Jellyman *et al.* (1982) record 36.5 trout per kilometre in 16 km of the lower Ahuriri River in 1982 and 14/km from two 500-m sections in the upper river. The Ahuriri discharges into Lake Benmore and differs from the Rangitikei and Manganuioteao Rivers in that rainbow trout periodically move upstream from the lake and greater numbers of trout are consequently found in the lower reaches at times. However, the numbers per kilometre are similar in each of the rivers throughout the range of values when these differences in distribution within each system are ignored.

The most important spawning tributary of the Manganuioteao River is the Orautoha Stream, but it appears to be less important as a rearing area because only a few juvenile brown trout are found in it during summer. The reasons for this are not clear. An obvious cause would be poor water quality from higher summer temperatures, enrichment, and consequent diurnal variation in the dissolved oxygen level. However, though extreme values have not been investigated in the stream, from consideration of measured values (Appendix I and Table 8) the extremes are not expected to be unduly severe. Other streams in the district have similar catchment characteristics and support good trout populations. Some, such as the Mangawhero River and its tributary the Makotuku, run through urban areas and are subjected to periodic pollution-enrichment problems. Turner, Allen, and Beam (1969) report a particularly bad incidence in the Makotuku Stream, but they still found 10-25 cm trout present. It is unlikely that the lower water quality of the Orautoha Stream (when compared with the Manganuioteao River) is a significant factor in the dispersal of juveniles.

Although other workers have demonstrated various habitat preferences of juvenile salmonids these almost always relate to induced changes in depth, velocity, substrate, or water quality - none of which can be seen as a major contributing factor to the early dispersal of juveniles from the Orautoha Stream when the variety of habitat and conditions within the catchment are considered. Hopkins (1970) records a downstream movement of fry in a Wairarapa brown trout nursery stream between December and February which he attributes to displacement in the competition for living space. In the Orautoha Stream in summer the amount of living space does not appear to be limiting and it is difficult to envisage such an effect even during spring when many juveniles are present, because there are extensive bouldery areas within the system which provide shelter. Tilzey (1977) found that lake-living brown trout repeatedly homed to specific tributaries of Lake Eucumbene (N.S.W., Australia) and that lake-living rainbow trout did not, but moved into various other tributaries to spawn. He showed that racially distinct populations of brown trout have developed in the system and that a resident population in a tributary stream provided a navigational cue to the migratory population. The lack of homing behaviour amongst rainbow trout was attributed to the very early age at which their juveniles vacated their natal streams and to the absence of a resident population in them. Similar circumstances may exist in the Manganuioteao system and would explain the dispersal of juveniles from the Orautoha Stream. That is, the young of migratory fish disperse because they have innate migratory tendencies and they complete their development amongst the boulders of rapids and runs of the middle and lower zones of the Manganuioteao River. There is probably a high mortality amongst these early out-migrants and this, combined with the abundant cover for small fish in the Manganuioteao mainstem, would explain why few were seen or caught during this study compared with the numbers commonly observed in other rivers. For example Hopkins (1970) estimated 60-70% mortality amongst his juveniles between October-February while Flain (1982) estimated that 94% of out-migrant quinnat salmon fry (*Oncorhynchus tshawytcha*) in the Rakaia river system were lost.

The Manganuioteao mainstem is likely to be more important for spawning than it appears to be from the data presented and it is the principal juvenile rearing area. Brown trout have been observed near redds in the river, but the upper zone is likely to be an important spawning area for rainbow trout. Signs that this is so are the predominance of rainbow trout adults, observations of a concentration of rainbow trout in the vicinity of S.H.4 in winter 1979, and comments by a local angler that good fishing for large rainbow trout is the norm during October-December (that is, immediately after the spawning season) in the vicinity of the Manganuioteao-Makatote-Waimarino confluence. The reason for the absence of numbers of spawning trout near S.H.4 after 1979 is not clear; there may have been insufficient inducement, such as freshes, at the right time, or the runs may be somehow related to releases of hatchery reared rainbow trout at the S.H.4 crossing. Releases were discontinued after 1979 (H.H. Brown pers.comm.).

It seems unlikely that the spawning run of trout trapped in the Waimarino Stream came from the Manganuioteao River because access is difficult and because all but two of the fish trapped were brown trout which were significantly larger than those in the Manganuioteao, indicating that they were from a separate population. This makes the Waimarino Stream unusual amongst others in the system in that it is an upper zone tributary which has a population of predominantly brown trout. The predominance of brown trout in it adds to the argument that Manganuioteao trout do not enter the Waimarino Stream because rainbow trout are able to live in the Waimarino and it would seem logical for them to predominate there as they do in the Manganuioteao and Makatote Rivers if they had easy access. Instead, spawning grounds are under-utilised and few rainbow trout are present. The contribution of the Waimarino to the Manganuioteao trout populations is unknown, but it is probable that there is an out-migration of small trout. A single juvenile brown trout was observed near the Makatote-Waimarino confluence and adults are present in small numbers from the Manganuioteao-Makatote confluence downstream. Burstall (1975) notes that Lake Waikaremoana is stocked with brown trout which originate from fish residing in the upper reaches of tributary streams separated from lake populations by waterfalls.

Physical barriers, poor water quality, and unsuitable substrates make all of the remaining Manganuioteao tributaries unsuitable for trout spawning and rearing, but the conditions available in the Orautoha Stream, the Manganuioteao mainstem, and the upper tributaries are evidently sufficient to maintain trout populations without the addition of hatchery reared juveniles because no hatchery reared fish were present amongst those sampled and few have been reported by anglers. Although there may be a valid case for the release of these fish to restore or enhance the population after a natural disaster such as a lahar it is clear from the examination of the numbers released (Table 30) and the numbers recovered, and also from Hobbs (1948) and Allen (1952), that an extremely large number of juveniles would need to be released to have any effect upon the Manganuioteao trout populations.

We contend that the boulder banks and rapids, with their protection of large, rounded stones piled upon each other and jammed together by the force of water, are the principal rearing areas for Manganuioteao juveniles because, apart from during spring, these are the areas where juvenile fish are found. The fact that few juveniles have been found when searching some of these areas in comparison to the numbers seen or caught in other rivers (for example, Richardson and Teirney 1982) is probably more indicative of the protection afforded the fish than of the numbers present.

Most anglers fish in the middle zone of the Manganuioteao (pools 61-161) where the best access coincides with the greatest numbers of trout. However, the trout caught by anglers differ from those we have sampled by being generally smaller (average 1947-81 = 476 mm) and containing a greater proportion of rainbow trout (Table 26). These characteristics appear to be typical of comparable rivers such as the Tukituki and Rangitikei, though angling data given by Graynoth (1974c) are not contemporary with those in Table 35. In the Waiau River

(Southland) Galloway and Cudby (1965) compared the average sizes of spawning trout caught in two tributary traps with those of trout caught by anglers during the previous season and found that brown trout caught by anglers were 30 mm smaller in the lower river and 40 mm smaller in the middle reaches and rainbow trout caught by anglers were 92 mm smaller on average in the middle reaches (none were trapped in the tributary feeding the lower reaches).

A comparison of the species composition of anglers' trout with those counted by drift divers is made in Table 36. The Manganuioteao and the Whakapapa rivers are both similar in having a smaller proportion of brown trout in the anglers' catch than is present in the river and they also resemble many lake fisheries in this respect, for example, Taupo and Rotorua (Burstall 1975) and Benmore (Bloomberg, Stancliff, and Thornton 1983). The Ahuriri River differs from all of the above in having a higher proportion of brown trout in the anglers' catch than what appears to be present in the river, but the divers' count here is apt to be biassed by the time of year in which it was carried out and the limited area which was covered. In Lake Benmore, into which the Ahuriri discharges, fewer brown trout are caught than are present and Jellyman *et al.* (1982) also thought that brown trout constituted a greater proportion of the resident population throughout the river.

Historically there appears to be little change in the average size of trout caught by anglers, or in the catch rate and these both compare favourably with other well known New Zealand rivers (Table 37) giving the lie to the often heard comment "but she's nothing like she was in the old days". There are of course differences between seasons as is evident from comments in annual reports of the Waimarino Acclimatisation Society (1941-76) and also in comparing the two largest seasonal samples

TABLE 36. Species composition of trout kept by anglers compared with medium and large trout counted by divers during the same season(s)

		Angler			Drift dive		
River	Year	*n*	Brown %	Rainbow %	*n*	Brown %	Rainbow %
Manganuioteao	1979	76	23	77	372	39	61
	1981	10	40	60	590	54	46
Whakapapa*	1980 & 1981	162	28	72	469	75	25
Ahuriri†	1981 & 1982	85	67	33	584	42	58

* Richardson and Teirney (1982).
† Jellyman *et al.* (1982).

TABLE 37. Average sizes of both species of trout caught by anglers, and catch rates in New Zealand river fisheries

		Brown trout			Rainbow trout			
		n	%	Mean length (mm)	n	%	Mean length (mm)	Catch rate (fish per hour)
Manganuioteao	1978-79	17	23	463	61	77	442	0.51
Whakapapa*	1979-81	43	28	515	118	72	494	0.35 & 0.50
Mohaka†	1947-73	-	-	530	-	-	414	0.16
Ahuriri‡	1962-82	289	64	472	137	36	426	0.31
Hakataramea§	1957-67	214	71	462	87	29	460	0.47-0.74
Waiau** (Southland)	1967-68	143			132	48	394	0.54

* Richardson and Teirney (1982).
† Graynoth (1973b).
‡ Jellyman *et al.* (1982).
§ Graynoth (1973a).
** Graynoth (1974a).

in Table 25 (1962-63 and 1978-79), but there are too few data to show distinct annual changes. For example the comparatively short-term effects of the devastation caused by volcanic lahars in 1975 and 1969 and the ash eruptions during 1945-46 do not show in the angling record, though various annual reports attribute poor seasons to them. Nor do these apppear to have had any lasting effect because the present day record is shown to be very similar to that of 30 years ago (section 6.3.6.2). In contrast, the Whakapapa River was affected by the same volcanic events and the diversion of 80% of its mean annual flow in the upper reaches (Tonkin and Taylor 1978); there has been a demonstrable change in the post-volcanic/water diversion period to a larger average size of trout and a decrease in catch rate (Richardson and Teirney 1982). Because there is no such change evident in the Manganuioteao it would seem most likely that the Whakapapa change was caused by the diversion of water from the upper Whakapapa, but the mechanism (change in biomass or change in numbers) cannot be determined.

Although Allen and Cunningham (1957) proved that no particular angling method was consistently more successful than another in their national study of angling results they conceded that under different weather or water conditions some were more effective and so investigators of individual fisheries consistently find distinct differences between the results of different angling methods. In the Manganuioteao the spoon is the most successful method and the nymph is least successful, though it is the most popular. Nymph fishermen caught larger fish and more brown trout than spoon fishermen. Comparatively few anglers used the wet fly and dry fly methods, probably because nymph fishing is fashionable, but even if these three methods are combined under the term "fly fishing" the above comparisons with the spoon method remain true.

Graynoth (1974b) also found that fly fishermen caught larger trout than spoon fishermen in seven rivers in the Wellington district, but Bloomberg *et al* (1983) found fly fishing to be more effective than spoon (and worm) fishing in Lake Benmore and the Ahuriri River in 1980-81. In 1981-82 Jellyman *et al.* (1982) found that the most popular and effective method used in the Ahuriri was again fly fishing, but in 1982-83 this changed dramatically and spoon fishing became the most popular method and also the most effective, giving a higher catch rate than fly fishing (Jellyman 1984).

A wide variation in individual angling success and hence skill, is demonstrated in the 1978-79 sample of holiday anglers on the Manganuioteao where 54% of anglers spent 32% of the time and caught nothing whereas 46% were successful in 68% of the time spent fishing. This type of sample can be biassed if the total fishing effort is not recorded; for example, the highest catch rate of an angler was from one who was both interviewed and caught a fish within 10 minutes of starting to fish (Table 31). If the average catch of those who fished with success for longer than 1 hour is compared with 1947-52 angling results (that is, those of skilled anglers) there is little apparent change.

Visitors travel long distances to reach the Manganuioteao River during the holiday period. At that time about half of the anglers are visitors, but a higher proportion of local anglers can be expected during the rest of the fishing season. Most anglers are associated with groups, often families, who engage in other activities, most of which involve some use of the river, and its popularity reflects this multi-use, family aspect as well as its angling qualities.

As a scenic river fishery the Manganuioteao is important both regionally and nationally. It compares favourably with every other highly regarded river fishery with which it can be compared and it has been rated as exceptional by more than half of the people who were surveyed in the National River Angling Survey (Teirney *et al.* 1982).

7. HABITAT STUDIES

7.1 Introduction

Bouldery edge zones and side channels adjacent to the main flow of the Manganuioteo River were identified as nursery areas for juvenile trout (Armstrong 1979). These boulder banks did not support high numbers of trout juveniles, but they were the only places in the main river where juveniles were found. The proportion of boulder bank areas in the Manganuioteao and the amount of physical habitat which they provided for juvenile trout was small compared with the amount of adult trout habitat. The lack of juvenile habitat suggested that few adult trout would be found in the river, but this was not so (section 6). The low numbers of trout juveniles, but abundance of adults was assumed to be related to the availability of more adult trout habitat than juvenile trout habitat. This indicated that the existing fishery, if it is dependent on natural replenishment of fish stocks, was reliant on very low numbers of trout juveniles for this purpose and further indicated that reduction of habitat for trout juveniles could result in a serious impact on a finely balanced fishery. To estimate changes which might occur to the available physical habitat for trout juveniles if flows were to be reduced below existing natural flows, several boulder bank habitats were selected to measure and predict habitat change at various flows. Measurements were made on the ground and from aerial photographs. Habitat referred to in this section is simply the physical habitat available for juvenile trout based on water depth and velocity. In actual fact much of the habitat suitable in these terms alone may never be utilised by juvenile trout because of unsuitable cover and temperature or unavailability of food. Even when all the above physical requirements are available competition for these requirements dictates the rearing capacity of the habitat.

7.2 Methods

7.2.1 Ground Measurements

A boulder bank area about 300 m below the proposed Makakahi dam site was chosen for habitat studies because it would obviously dry up during low flows.

Twenty transects were established across the width of the river at site 2 to cover all of the boulder bank. These were marked on both banks of the river by numbered iron standards set 6 m apart and numbered in sequence downstream.

Transect 1 was positioned for flow measurements about 15 m upstream of transect 2 in the tail of the pool above the boulder bank. A staff gauge was attached to the left bank at this transect and water levels were read periodically from February 1981 to October 1982 (see Table 38). River discharge was calculated from measurements made at five different water levels.

In February 1981 depth and velocity measurements were made at 1-m intervals along each transect except in the main channel of the river. In August 1981 depths were recorded at 1-m intervals on transects 2-15, but velocity measurements were only done at transects 4 and 8.

A rating table for the flows at the five different water levels was calculated and computer analysis of the transect depths and velocities was carried out by I.G. Jowett of Ministry of Works and Development (see Table 39).

7.2.2 Substrate Profiles

During the August 1981 measurements, profiles of the substrate were drawn for the 14 transects measured at site 2 (Fig. 36). This was done using the water level along each transect as a base line and measuring the depth or height of the substrate below and above the base line (Fig. 36). These measurements were taken at 0.5-m intervals and plotted on graph paper. The profile drawing was completed in the field by joining the plotted points by eye. Where an unusual or confusing configuration of the substrate appeared, depth or height measurements of the substrate were made at random through the configuration in order to complete the profile drawing as accurately as possible. Base marks defining the water level were chiselled on prominent rocks along each transect so that subsequent and different water levels could be related to the profiles. The method assumed that water level along each transect was horizontal, but of course this was not so as some drainage from the sides of the boulder bank area into the main channel occurred. In such instances the profile would have been biassed towards the surface base measurements. This error was ignored because it was considered that its effect on the profile would have been minimal and that the profile as such appeared sufficient to indicate the effect on water depth and surface coverage that various river discharges would have on the boulder bank. In addition to photographs the profiles allowed accurate documentation of the substrate size and composition

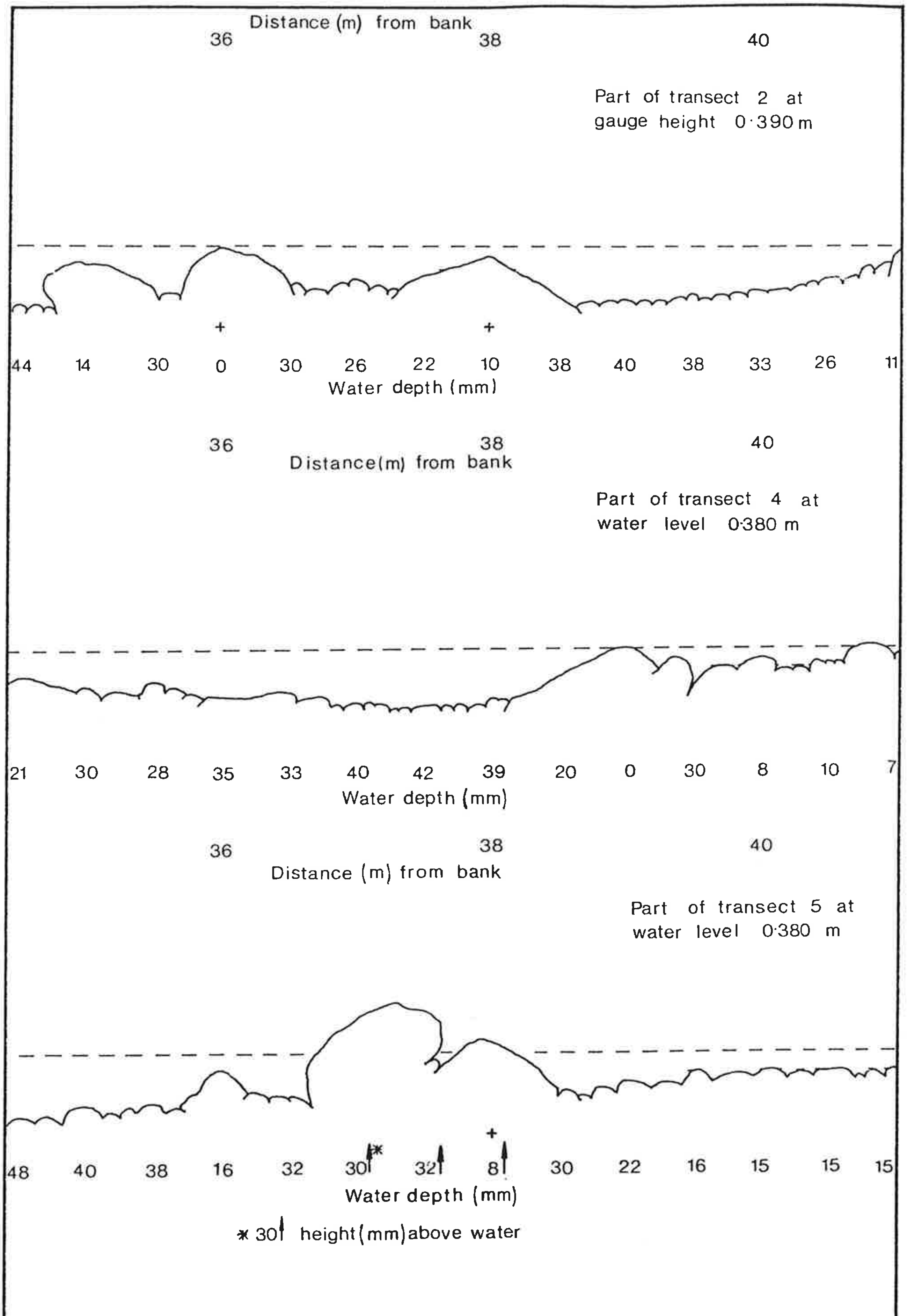

FIGURE 36. Example of profile drawings at transect sample in the Manganuioteao River.

throughout the boulder bank area which, if needed, would have served well as a monitor of any changes after flood events or over a long time period.

7.2.3 Aerial Measurements

Four boulder bank areas including the transect sample site were selected at various locations throughout the Manganuioteao River (Fig. 25) to assess the area of water coverage amongst boulder bank areas during various river flows. Aerial photographs were taken at these four sites during March and August 1981. Photography was done by R.W. Bedingfield, Wildlife Service, from a Bell Jetranger helicopter.

The camera used was a hand-held 500 EL "Hasselblad" with 150 mm lens and using 400 ASA "Fujicolor" colour print film.

Photographs were shot at various altitudes ranging from 1000 feet to 1900 feet a.s.l. Ground markers 10 m apart were spray painted on dry rocks within the boulder banks at each of the four sites. Prints were enlarged to 190 mm x 190 mm for ease of interpretation and a sample area was marked out over the boulder bank on each photograph using points which could be identified in subsequent photo-runs. The four sites are shown in Figure 37 and sample areas used to calculate water surface area are marked. Dot grid overlays comprising 25 dots per 20.25 mm^2 grid were used to calculate areas on each of the photo enlargements by use of the following formula:

$$\frac{\text{Total number of dots x area represented by one dot}}{\text{Number of mm}^2 \text{ on the photo representing 1 m}^2 \text{ on the ground}}$$

Site 1. N121/777604

Site 2. N121/753612

Site 3. N121/683578

Site 4. N121/617526

FIGURE 37. Aerial photograph sites of boulder banks in the Manganuioteao. (Location of each site shown by NZMS 1 map co-ordinates below each photograph.

At site 2, where both aerial and ground measurements were carried out, area calculations from aerial photographs were in an area approximately covered by the 24-42-m marks of transects 7-14. Comparison of aerial and ground calculations were, therefore, carried out using only ground measurements within transects 7-14.

Water surface areas for aerial and ground comparison were calculated with a constant for each method as follows (adapted from a method described by I.G. Jowett (pers. comm.)):

$$\text{Constant} = \frac{\underline{\%\ \text{water surface area}}}{\overline{m^3/s}}$$

Flows (m^3/sec) were derived from the rating table (see below) using the water level measured at the time a particular calculation of water surface took place:

$$\text{Water surface area} = \text{constant} \times \overline{m^3/s}$$

7.3 Results

A summary of the readings made at the water levels gauge at site 2 is shown in Table 38.

The rating table calculated for the river discharge at site 2 is shown in Table 39.

During the period in which these levels were recorded the lowest levels in each year were .205 m (1981) and .170 m (1982). The rating table (Table 39) shows that at these levels flows at site 2 would have been 3.64 m^3/s (1981) and 3.00 m^3/s (1982). Based on the percentage difference of the mean annual flow at site 2 and the Ashworth gauge site

TABLE 38. A summary of the water level recordings at site 2 from February 1981 to October 1982 (0.000 m)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	Minimum	-	.205	.225	-	.250	.476	.320	.370	-	-	-	-
	Maximum	-	-	-	-	.400	.508	-	.460	-	-	-	-
1982	Minimum	.260	.210	.170	.180	-	.360	.210	.290	.320	.50	-	-
	Maximum	-	-	.290	.190	-	-	.600	.670	Above staff	-	-	-

as derived from Beca *et al.* (1979), these flows would be equivalent to 4.58 m^3/s (1981) and 3.77 m^3/s (1982) at the Ashworth site. The lowest flow recorded at Ashworth was 3.07 m^3/s in 1978. This would have been 2.44 m^3/s at site 2. The lowest flows occurring during the year as measured at Ashworth are shown in Table 3 in the column for 7 day minimum flow. Table 40 also shows these flows and includes the annual 7 day low flow which would occur at site 2 based on the percentage difference of the average annual 7 day low flow for both sites as derived from Beca *et al.* (1979). As expected the lowest annual 7 day low flow recorded at site 2 was in 1978 at 2.81 m^3/s.

TABLE 39. Rating table for gauging station at site 2

Water level (m)	0	10	20	30	40	50	60	Discharge 70	80	(ℓ/s) 90
0	-40	178	391	598	800	997	•	•	•	•
	Multiply following by 10									
0	•	•	•	•	•	•	118	137	155	173
.100	190	206	222	237	252	267	283	300	318	336
.200	355	374	395	416	437	460	483	507	531	557
.300	583	609	637	665	695	725	755	786	818	851
.400	885	918	953	988	•	•	•	•	•	•
	Multiply following by 100									
.400	•	•	•	•	102	106	109	113	117	121
.500	125	•	•	•	•	•	•	•	•	•

Tideda 7.9.82

TABLE 40. Annual seven day low flows recorded at the Ashworth gauge site and calculated for site 2

Year	Seven day low flow at Ashworth (m^3/s)	Seven day low flow at site 2 (m^3/s)
1962	5.48	4.74
1963	5.92	5.12
1964	5.17	4.47
1965	6.83	5.91
1966	5.50	4.76
1967	4.99	4.32
1968	3.79	3.28
1969	4.13	3.57
1970	3.41	2.95
1971	4.08	3.53
1972	4.92	4.26
1973	4.13	3.57
1974	3.78	3.27
1975	4.91	4.25
1976	3.75	3.24
1977	4.36	3.77
1978	3.25	2.81
1979	4.99	4.32
1980	6.59	5.70

However, for more than 50% of the flow recording period the annual 7 day low flows were in excess of the average annual 7 day low flow of 4.1 m^3/sec, and Figure 12 indicates that this flow is normally equalled or exceeded 85% of the time.

To calculate the area of water which would cover the boulder bank area at site 2 during various flows several methods were investigated. The profile drawings gave an accurate account of the water coverage along each transect, but compared with aerial photographs, which covered about the same total area, they had less sample points (144 compared with 5529).

However, both methods did provide similar water surface area results for flows less than two cumecs (Fig. 38).

To test which of the two methods gave the most accurate results the transect profiles were used to measure the water level at which entire water coverage of the sample area would occur. A staff gauge water level of 0.82 m would have given 90-100% coverage where only the tops of about three boulders would be visible above the surface. At this level the river flow at site 2 would have been about 20 m^3/s. Also from the transect profiles it was indicated that the flow at which the boulder bank would be reduced to a few puddle patches was 0.178 m^3/s. In Figure 38 the curve best fitting these maximum and minimum flows was that derived from aerial photograph interpretation.

Curves showing the percentage of water surface area at different flows for all four sites have been drawn by use of the measurements derived from aerial photographs (Fig. 39).

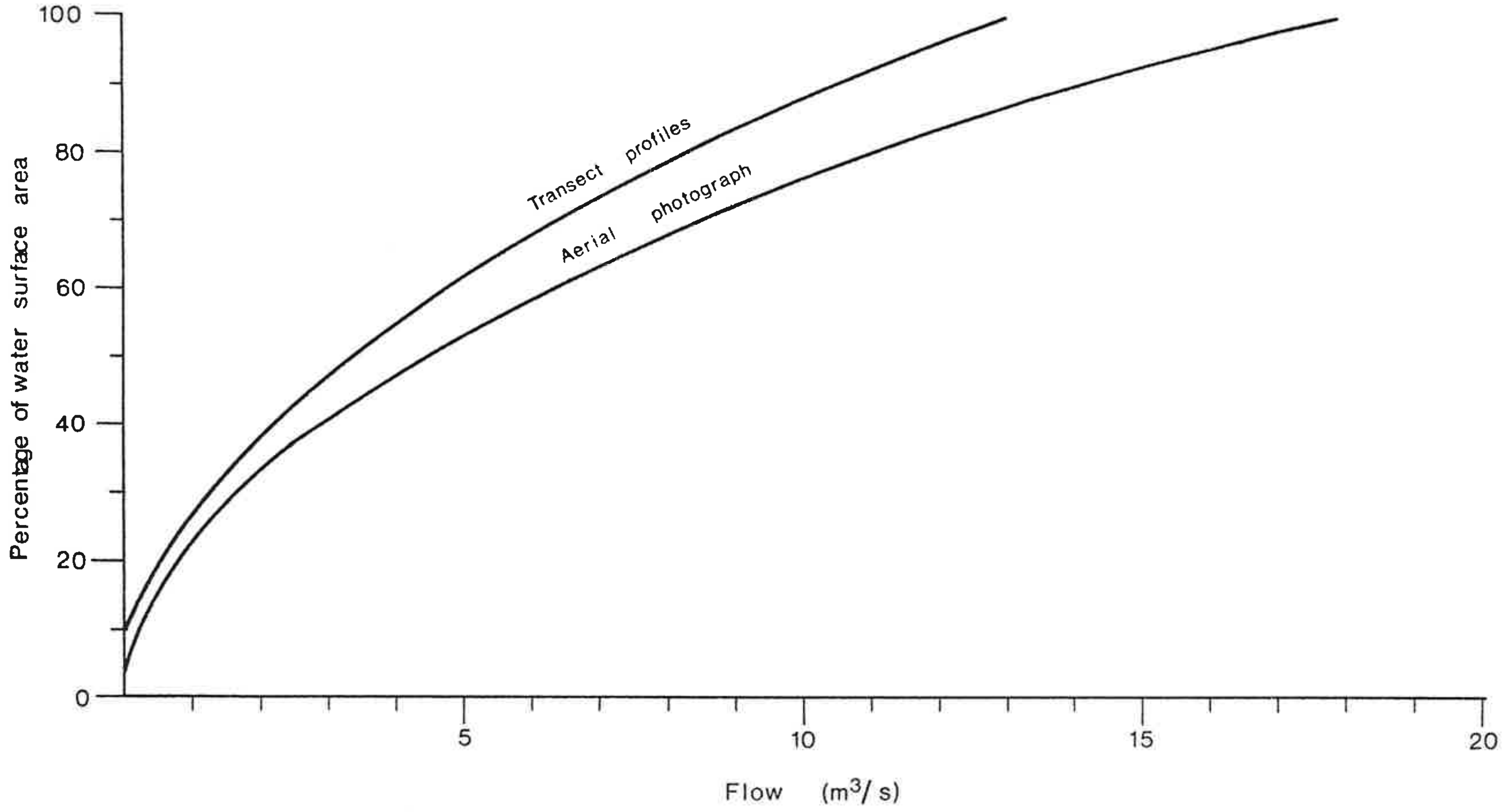

FIGURE 38. Comparison of two methods used to calculate the water surface area in the boulder bank at site 2.

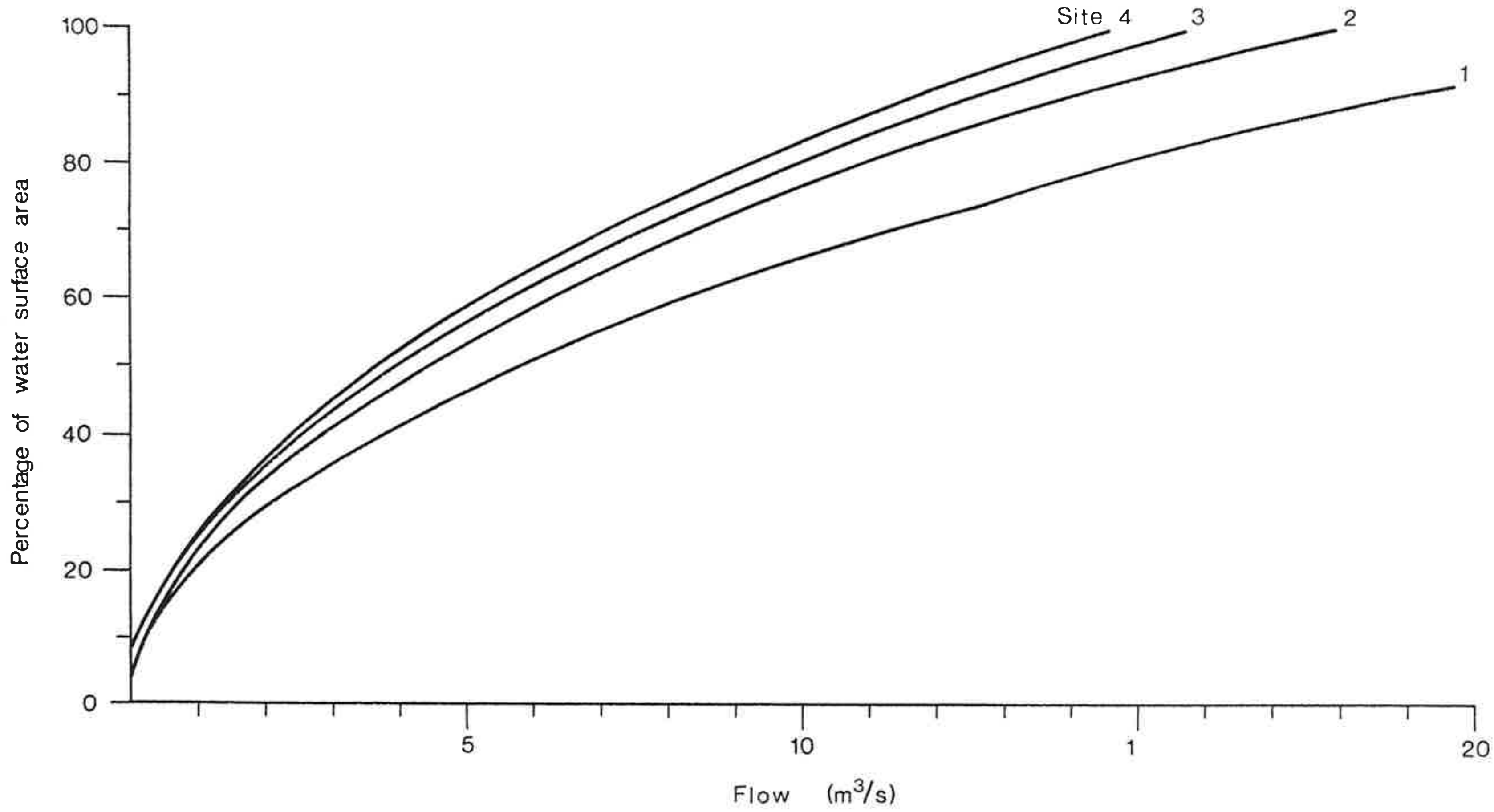

FIGURE 39. Percentage of water surface area at different flows at four sites measured from aerial photographs.

Juvenile trout were caught and seen in the boulder bank area at site 2. In February 1980, 3 rainbow trout juveniles were seen and caught and in October 1980 6 brown trout juveniles were positively identified out of 11 trout juveniles seen. Most of these juveniles were inhabiting a small portion of the boulder bank shaded by overhanging bank vegetation. On other occasions small fish, most likely to have been juvenile trout, were seen briefly as they darted amongst boulders.

7.4 Discussion

The upper and lower reaches of the Manganuioteao's channel are dominated by pools and deep runs, but the open nature of the middle reaches provide more riffles and shallow runs. However, even in the middle reaches about 60% of the channel length consists of pools and deep runs. Within the remaining 40% of the river more than half is made up of rapids and shallow sluggish areas. What is left of the river by way of shallow riffle areas makes up less than 20% of the river. It is this limited area of river that provides habitat for juvenile trout. The boulder bank studied at site 2 was among the largest of this habitat type found along the river.

Measurements of physical habitat alone are insufficient for predicting how many juvenile trout the river has the capacity to rear. In addition to suitable physical habitat many other requirements determine the all-round suitability of habitat for juvenile trout. For example, juvenile trout within the boulder bank at site 2 were scarce and appeared restricted to a small portion of the boulder bank shaded by overhanging vegetation. Even though this was an area where the largest number of juvenile trout were found in the mainstem, only a small fraction of the apparently large area of suitable habitat was actually being used by juvenile trout. This indicates that the remainder of the main stem of the river is very limited in rearing area for juvenile trout.

From conclusions made by Jowett (Appendix II), slightly less than 4 m^3/s at site 2 would provide optimum habitat for brown trout juveniles. At flows between 4 and 9 m^3/s, suitable habitat for rainbow trout juveniles stays about the same, but declines below 4 m^3/s. Therefore, an average annual 7 day low flow of 4.1 m^3/s should provide close to the optimum depth and velocity in the boulder bank at site 2 for a mixed population of both species of juvenile trout.

It could be detrimental for juvenile trout habitat, particularly rainbow trout, in existing boulder bank areas if flows were to be reduced to less than 4 m^3/s at site 2 (5.03 m^3/s at Ashworth).

At a flow of 4 m^3/s the percentage of water surface area created in the boulder bank at site 2 as calculated from aerial photographs would have been 48% (Fig. 39). If it is assumed that boulder banks at sites 1, 3, and 4 had similar juvenile trout rearing habitat values as those described by Jowett (Appendix II) for the boulder bank at site 2 then each of these habitats should provide close to their optimum juvenile trout rearing habitat at a flow which would create a 48% water surface area. Figure 39 shows that the flows required for this would be: site 1 - 5.3 m^3/s, site 2 - 4.0 m^3/s, site 3 - 3.6 m^3/s, and site 4 - 3.3 m^3/s. Thus, there is not a lot of difference in the flows required to maintain the boulder banks at sites 2, 3, and 4 with a 48% water surface area. Flows between 3.0 m^3/s and 4.0 m^3/s would maintain close to the optimum rearing habitat for juvenile trout at sites 2, 3, and 4. Even at site 1, where a more obvious difference between the four sites occurs, the difference becomes less obvious and probably less significant below 5 m^3/s (Fig. 39). For example, 4 m^3/s would provide a 48% water surface area in the boulder bank at site 2 and 42% in the boulder bank at site 1.

Jowett (Appendix II) indicates that optimum rearing habitat for juvenile rainbow trout, based on depth and velocity, would favour a flow of more than 4.0 m^3/s and optimum conditions for juvenile brown trout somewhere below 4.0 m^3/s. The different flows at site 2 and the consequent difference in water surface area from one site to another tends to provide more favourable habitat for either one trout species or the other. For example, a flow of 3.3 m^3/s at site 2 which would create a water surface area of 48% and close to optimum rearing habitat for both species at site 4 would result in a reduction of water surface area at site 2 to 43% (Fig. 39) and thus provide more suitable rearing habitat for juvenile brown trout than for juvenile rainbow trout. Obviously flow extremes will affect both species, but unfortunately these extremes are not known.

Jowett shows that the flows measured at site 2 provide a larger percentage area of suitable habitat for juvenile brown trout than for juvenile rainbow trout (Appendix II, Table 2). Between 63 and 96% of the time the flow measured at Ashworth is 9 and 4 m^3/s respectively (Fig. 3). Therefore, it can be assumed that the Manganuioteao River generally provides more suitable rearing habitat for brown trout than rainbow trout. This is supported by the fact that the adult trout population in this river is dominated by brown trout (section 6.3.3).

Although habitat predictions have been made from measurements at several different flows, actual presence and numbers of juvenile trout were not accounted for at these times so the reality of habitat predictions in the Manganuioteao are untested.

8. CONCLUSION

The call to preserve the Manganuioteao River in its natural state for all time is made with good reason whether from the viewpoint of the public's recreation, for wildlife habitat, or simply because it is the last major central North Island river which has not been modified and used to produce electricity. The river provides water for recreation, agriculture, and forestry and it serves as a stock barrier and a property boundary. It supports 11 indigenous and 2 exotic species of fish together with the common species of waterfowl and a comparatively large population of blue ducks, and it is a source of high quality water to the Wanganui River. Its value to all of its users appreciates as development projects modify other catchments, rivers, and lakes and as both recreational usage of water and the demand for export oriented primary and secondary products which require its use, increase.

The river is a product of the geology, pedology, meteorology, and vegetation of its catchment and factors of each interact to form the special features which many people value and seek to conserve and which make it a favoured place for its inhabitants. These features are: the high quality water with variable flows, but with a high baseflow component (>11 m^3/s for 50% of the time; >5 m^3/s for 90% of the time); the bouldery, stable bed which provides its inhabitants with cover, protection during floods, and a large surface area for production of the small plants and animals which are the basic links in the aquatic food chain; and the river channel, deeply entrenched for most of its length, with steep banks, meanders, and vegetation which buffers much of the water course from direct effects of run-off. The channel and the river also connect the bushland of the Tongariro National Park and Erua Forest with an area of the Wanganui River for which National Park status is being sought.

The animal inhabitants of the river are also some of its special features. The rare blue ducks, which seem to have similar riverine preferences to many of the native fish, are the subject of separate studies (M. Williams pers.comm.). The native fish contribute to recreational and traditional fisheries in the Wanganui River during their migrations and they are of scientific and general interest. The Manganuioteao River supports the greatest number of species of native fish of all of the Wanganui River tributaries so far investigated and 10 of the 11 species found in it require access to the sea to complete their life cycles. The rare short-jawed kokopu and two other galaxiids depend upon the shelter and equable conditions offered by native forest catchments because these fish are typically found in streams within, or close to, undisturbed native forest (McDowall 1978). The proportion of native forest in the catchment, the comparatively unmodified state of a large part of the river and its environs, its water quality, size, and proximity to the sea are undoubtedly reasons for the large number of native species in the Manganuioteao and its importance in the Wanganui system. However, the full contribution of the Manganuioteao River to Wanganui River fisheries is unknown and requires further investigation.

The trout fishery is an important feature of the river and it is the underlying reason for the desire to protect it. The fish and the fishing compare favourably with other highly regarded New Zealand rivers and their quality is dependent upon the habitat which the river provides in its natural state. Favourable habitat, the combination and interaction of the physical, chemical, and biological elements, is, therefore, a common denominator for all of the riverine fauna.

Threats to the natural state of the river are hydro-electric development, forestry, and any other land uses which remove ground cover and lead to erosion in catchments and sedimentation in waterways. Hydro-electric development is the most serious threat to the river because it could result in the greatest environmental changes. The best indication of what could be expected to happen to the Manganuioteao trout fishery as a result of hydro-electric development is given by the effects of the Whakapapa intake upon that river.

The Whakapapa River is an upper Wanganui tributary whose catchment adjoins that of the Manganuioteao. Beginning in late 1972, a dam-like intake structure in the Whakapapa's upper reaches has diverted 80% of the mean annual flow of the river out of the catchment leaving the river to regenerate from tributaries carrying lower quality water. A residual flow of 0.6 m^3/s is released below the intake to maintain the fishery and this may be augmented from time to time by compensatory flows for a hydro-electric station in the Wanganui River below its confluence with the Whakapapa, or for fish preservation (when the water temperature in the lower reaches exceeds 25°C), or by flood peaks.

Richardson and Teirney (1982) have demonstrated that the residual flow is insufficient to maintain desirable trout habitat and stocks in the first 6.9 km below the intake. At that point a tributary increases the river flow by 33% and trout abundance also begins to increase. At 12.6 km from the intake a tributary increases the river flow by 66% and trout numbers increase further, becoming comparable with a similar section of the Manganuioteao River and indicating a direct relationship between trout abundance and the volume and stability of discharge. Other effects documented by Richardson and Teirney (1982) are:

1. Elimination of a spawning migration above the intake;

2. Elimination of recruitment from above the intake;

3. Reduction of medium and large trout by an estimated 90% in the first 6.9 km below the intake;

4. Loss of adult habitat;

5. Reduction of habitat stability;

6. Reduction in the biomass of trout food organisms in the first 6.9 km;

7. Increased sedimentation from lower quality tributaries;

8. Increased summer water temperature;

9. Improved access for angling;

10. Decreased catch rate of trout by anglers;

11. Increased average size of trout caught by anglers;

12. Decreased perception of the river's value to anglers.

The series of dams and diversions proposed on the Manganuioteao River would affect most of the system (Fig. 40). In some places, notably the middle zone (the area most popular with anglers and other visitors) the effects would be serious in view of the changes which the Whakapapa River has incurred.

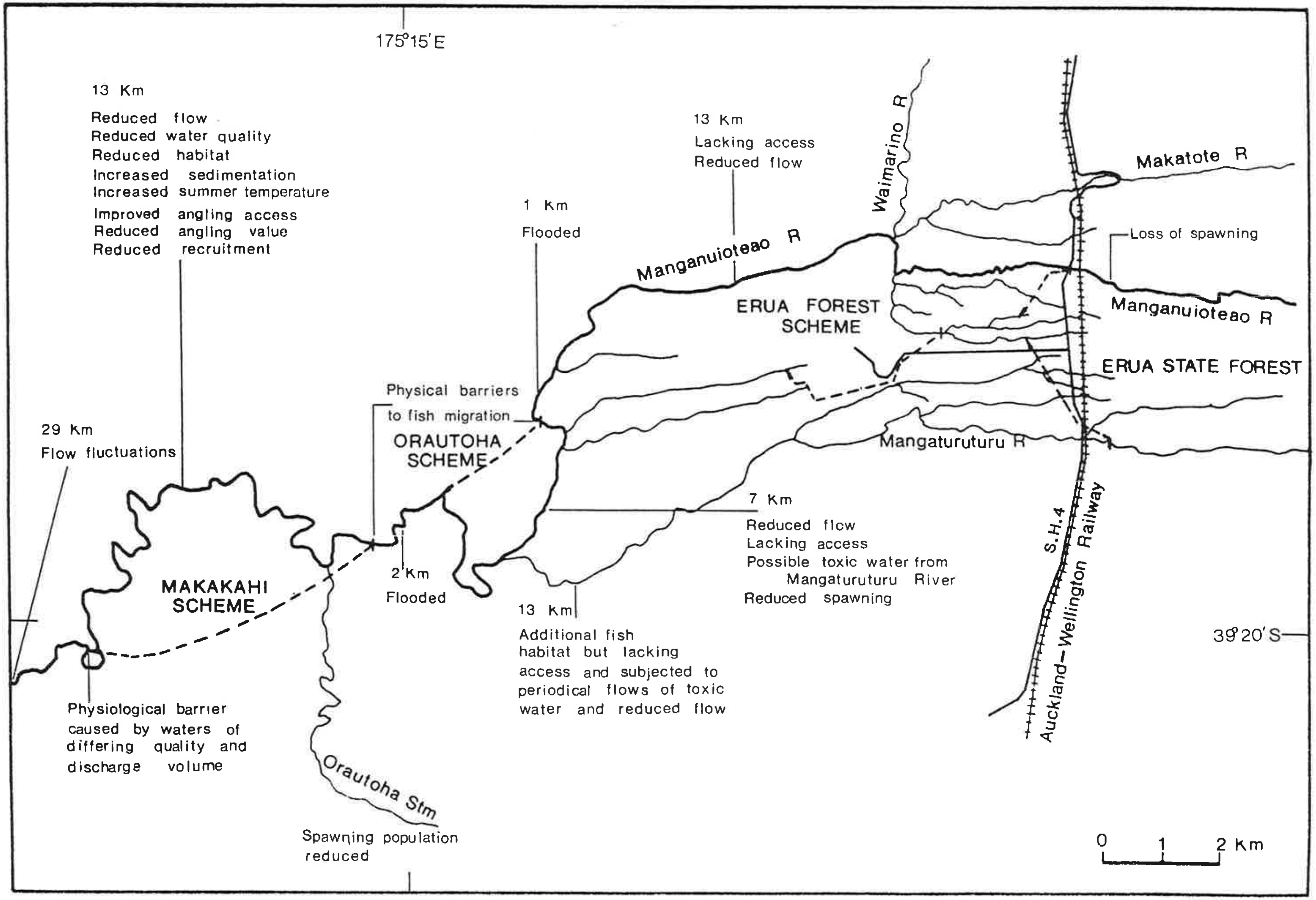

FIGURE 40. Effects of proposed hydro-electric development upon the Manganuioteao River.

Migratory fishes, both native and introduced, have been found throughout the Manganuioteao system and the ability to migrate must play an important part in the maintenance of the river's populations because so many of the species present possess it. If hydro-electric development proceeded as proposed the part of the river which would retain any semblance of its original character would be the 29 km downstream from the Makakahi powerhouse where periodic flow fluctuations may have some effect. This area supports a fairly low trout population where brown trout predominate and it suffers worst from the effects of catchment development because the gradient is lower and the pools are larger there. It would not replace the loss of habitat from the next 20 km upstream which is the most productive part of this fishery. Major changes in the distribution of native fishes would be expected; some sensitive species such as the galaxiids would probably disappear from present locations and the trout populations would change as well because partitioning of the river would favour the development of non-migratory species.

Although predictions indicate a net gain in juvenile trout habitat at reduced flows, which implies that there would be a consequent improvement in juvenile production, it must be remembered that the adult trout population is the most important feature of the river to anglers and that present juvenile production is sufficient to maintain it.

Loss of adult habitat was an important factor affecting the Whakapapa River fishery. Trout populations were reduced by up to 90% and the river required more than 12 km of travel and the addition of two sizeable tributaries to regain a semblance of its previous capacity. Figure 40 shows that the distances between diversion structures in the Manganuioteao are similar in two reaches and much less in one to the

12 km worst affected by the Whakapapa diversion. Therefore, the inference is that the three reaches in the Manganuioteao mainstem would not regain sufficient water to support resident fishes at acceptable levels, though measurements could not be made of adult habitat at different flows to support this. Measurements which were made indicated that a volume equivalent to the annual 7 day minimum flow would preserve sufficient juvenile habitat in the Manganuioteao. Richardson and Teirney (1982) showed that an increase in the residual flow below the Whakapapa intake to 5.2 m^3/s increased available habitat by 40%. The pre-diversion annual 7 day minimum flow in the Whakapapa River at the intake was 8.4 m^3/s (Tonkin and Taylor 1978). In the Manganuioteao, flows equivalent to the annual 7 day minimum tend to render hydro-electric proposals uneconomic. For example, Beca *et al.* (1980) state that development of the Orautoha scheme is economic with a residual flow of up to 2.0 m^3/s; they calculate the annual 7 day minimum flow as 2.4 m^3/s at the site. Power generation and fisheries interests would, therefore, need to bargain for their requirements; an unequal contest, from past experience, because it is easier to quantify a volume of water for power generation in dollar terms.

The Manganuioteao River is worthy of protection in its present state to preserve its fishery values. It is obvious that any hydro-electric development would alter fish migrations and that no compensatory measures would alleviate that. Residual flows necessary to maintain modified trout populations for angling would be difficult to justify in economic terms and could in any case be wasted if anglers regarded the loss of present aesthetic and angling qualities as a deterrent to visiting the river. The angling qualities of the river are comparable with other New Zealand rivers which anglers regard highly, but they are not the only reasons for wanting to protect it. The Manganuioteao remains in its original, primitive state for much of its length. Its connection with the Tongariro National Park and Erua Forest is directly responsible for this and the effect carries through into the middle zone of this study (between the mouths of the Mangamingi and Makakahi streams). This state and the diverse, high quality habitat it provides are responsible for the high count of native species and for the continued existence of many of them despite the presence of introduced trout.

Another very good reason for wanting to protect the river in its natural state is the presence of a large population of blue ducks. Although we have not studied these birds, observations were noted during our study and the distribution pattern clearly follows the least modified part of the river; the furthest downstream sighting was at pool 143. Early European travellers recorded the birds in the lower zone and so they were probably found throughout the river 100-150 years ago.

The birds, fishes, and recreationists have all found something in this river which satisfies their needs, something which is irrefutably connected with the unmodified part of the river and which, because it is the last unmodified section in the Wanganui catchment, has achieved incalculable value. The needs of the above groups and the wishes of those who signed a petition, if only to preserve in its natural state a part of the country they or their children might like to visit someday, can be met by affording the river protection against any future development which would alter its course or volume or adversely affect its water quality.

9. THE FUTURE

The following recommendations are ones which would improve knowledge and assist the management of the fishery. It is recognised that a wider viewpoint needs to be considered for the river itself to be preserved and managed effectively in the future, but this can only happen if 1 and 2 below are realised. The remainder of our recommendations may then form part of a more comprehensive management plan.

1. Future protection of the river in its natural state must be assured.

2. A management group should be formed which will plan and regulate the future use of the river. The constitution of the group would depend upon the means of protection afforded under 1.

3. Retain present usage of the river, but refrain from "opening it up" by improving or increasing facilities or tracks. Present access points could be indicated with the agreement of respective landowners, but wilderness areas, such as those in the now inaccessible parts of the upper and lower zones, should be preserved as areas of sanctuary.

4. Aim to improve water quality by education, regulation, and supervision in developed parts of the catchment.

5. Detailed studies should be carried out of indigenous fish distribution throughout the Wanganui system, and the relative importance of the Manganuioteao and its contribution to Wanganui fisheries should be assessed.

6. The effects and effectiveness of hatchery reared rainbow trout released in upper zone tributaries needs to be studied. Although

it is obvious that the Manganuioteao trout populations can maintain themselves naturally, there are suggestions that hatchery reared rainbow trout may have some influence upon spawning runs in the upper zone and the proportion of the species found further downstream. Also, because they are caught more readily by anglers, it may become necessary to monitor their relative abundance and manage them more intensively in the future.

7. Sea-run brown trout should be studied with a view toward enhancement. There is no detailed knowledge of these fish; it is not clear whether their diadromous habit is obligate or facultative and they are an excellent angling proposition. Improved understanding of them could lead to greater numbers in the Manganuioteao and also on a wider scale.

8. If future monitoring of the trout stocks becomes necessary, this should be carried out in the middle zone where the best indication of any changes can be gained. The drift diving method described in this report can be repeated fairly simply and gives results that can be easily compared. The best area to carry out a representative count is between the Mangamingi and Ruatiti Stream confluences (82 pools; 16 km) which can be covered in 10-12 hours diving by a practised team. A shorter, but less representative area, is that from Meyer's Bridge, above the Orautoha mouth, to the Ruatiti (30 pools; 6.5 km; 5-6 hours diving).

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11. LITERATURE CITED

ACH 1928. Reports from local correspondents. *In*: *The New Zealand Fishing Gazette. Volume 1 No 6.* 2 April 1928.

Alexander Turnbull Library. References 50413½, Manganui-a-te-ao, Wanganui. 50564½ Te Arero, Manganui-a-te-ao June 14 1849. 50401½ Te Arero, Manganui-a-te-ao June 14 1948. *In*: Taylor R. 1805-73. Sketchbook 1839-65.

Allen, G.F. 1894. Willis's guide book of new route for tourists. Willis, Wanganui. 200 p.

Allen, G.F. 1902. Supplementary edition of Willis's guide book of new route for tourists. Willis, Wanganui. 240 p.

Allen, K.R. 1951. The Horokiwi Stream: a study of a trout population. *N.Z. Marine Department, Fisheries Bulletin No.10*. 238 p.

Allen, K.R. 1952. A New Zealand trout stream. Some facts and figures. *N.Z. Marine Department, Wellington, Fisheries Bulletin No. 10A*. 70 p.

Allen, K.R., and Cunningham, B.T. 1957. New Zealand angling 1947-1952: results of the diary scheme. *N.Z. Marine Department Fisheries Bulletin No. 12*. 153 p.

Allen, P.J. 1971. A brief electric fishing survey of selected Waimarino streams. North Island Electric Fishing Service. *N.Z. Marine Department Investigation Report*. 4 p.

Armstrong, W.J. 1979. Manganui-a-te-Ao hydro-electric power development. Part II. Ecological considerations. Cawthron Technical Group Report commissioned by Wanganui-Rangitikei Electric Power Board. 210 p.

Arthur, W. 1881. History of fish culture in New Zealand. *Transactions and Proceedings of the New Zealand Institute 14*: 180-211.

Ashby, C.R. 1967. The centenary history of the Auckland Acclimatisation Society 1867-1967. Auckland Star Commercial Printers. 143 p.

Barton, C.J. n.d. Memoirs of Mr C.J. Barton. 17 p typescript.

Bates, A.P. 1981. The bridge to nowhere. The ill-fated Mangapurua settlement. 2nd edition 1982. Wanganui Newspapers Ltd. 167 p.

Beable, M.E., and McKerchar A.I. 1982. Regional flood estimation in New Zealand. *Water and Soil Technical Publication No. 20.* 132 p.

Beca, Carter, Hollings, and Ferner 1980. Manganui-a-te-Ao River hydro-electric development. Initial report on feasibility. Report prepared for the Wanganui-Rangitikei Electric Power Board. December 1979, revised August 1980. 102 p.

Bell, M.C. 1973. Fisheries handbook of engineering requirements and biological criteria. Fisheries Engineering Research Program. Corps of Engineers. North Pacific Division, Portland, Oregon.

Best, E. 1929. Fishing methods and devices of the Maori. *Bulletin of the Dominion Museum, Wellington 12*: 230 p.

Bloomberg, S., Stancliff A.G., and Thornton B.K. 1983. Angling in the upper Waitaki catchment, 1980-81 season. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No.18*: 17 p.

Bogle, A.H. 1975. Links in the chain. Field Survey in N.Z. 1975. N.Z. Institute of Surveyors. 86 p.

Bovee, K.D. 1978a. The incremental method of assessing habitat potential for coolwater species with management implicatons. *American Fisheries Society Special Publication 11*: 340-346.

Bovee, K.D. 1978b. Probability of use criteria for the family Salmonidae. Instream Flow Information Paper No. 4. Co-operative Instream Flow Service Group, US Fish and Wildlife Service.

Brandon, E.S. 1975. Re: stocking of Wanganui River. Letter dated 3 July 1975. Wanganui Acclimatisation Society.

Brewer, 1880. Letter to W. Arthur. May 1880. *In*: Arthur, W. 1881. History of fish culture in New Zealand. *Transactions and Proceedings of the New Zealand Institute 14*: 180-211.

Bullock, M. 1899. Wonderland. A glimpse of the marvels and beauties of the Taupo volcanic zone, New Zealand. Government Printer, Wellington.

Burnet, A.M.R. 1959. Electric fishing with pulsatory direct current. *N.Z. Journal of Science 2(1)*: 46-56.

Burnet, A.M.R. 1981. Research and management. *Freshwater Catch No 10*: 6.

Burnet, A.M.R., Cranfield, J.H., and Benzie, V.L. 1969. The freshwater fishes. pp. 498-508. *In*: Knox, G.A. (Ed.). "The Natural History of Canterbury." Reed, Wellington.

Burstall, P.J. 1975. Sport fisheries. pp. 308-318. *In*: Jolly, V.H., and Brown, J.M.A. (Eds.). "New Zealand Lakes." Auckland University Press, Auckland. 388 p.

Cawthron Technical Group 1979. Manganui-a-te-ao hydro-electric power development. Part I. Social and economic considerations. Cawthron Institute, Nelson, New Zealand. 136 p.

Cockayne, L. 1967. "New Zealand plants and their story." 4th edition. R.E. Owen, Wellington. 269 p.

Cooper, B. n.d. Te mata o Tauponui a Tia. The head of the lake. A history. Turangi and District Historical Society Inc. 32 p.

Cook, M. 1983. Report on Rangitikei River fish trap. Unpublished report to Director, Wildlife Service dated 20 June 1983. Ministry of Agriculture and Fisheries. File Tgi/4/1. 5 p.

Cowan, J. 1927. "The Tongariro National Park." Ferguson and Osborn, Wellington. 156 p.

Cudby, E.J. 1966. Pollution of Orautoha Stream by metal extraction operations. Unpublished report to Secretary for Marine, N.Z. Marine Department, Turangi. 12 September 1966. 12 p.

Cudby, E.J. 1969. Some effects of the Mount Ruapehu eruption of June 1969 on aquatic life. Unpublished report. N.Z. Marine Department, Turangi. 13 p.

Cudby, E.J. 1976. Effects of Mount Ruapehu lahars on aquatic life. Appendix 2. *In*: Paterson, B.R. 1976. The effects of lahars of the 1975 April Mount Ruapehu eruption and the threat of future eruptions on Tongariro power development. Unpublished report EG230, January 1976, New Zealand Geological Survey. 57 p.

Cudby, E.J. 1978a. Wahianoa River toxicity testing. Unpublished report. Fisheries Management Division, N.Z. Ministry of Agriculture and Fisheries. 17 p.

Cudby, E.J. 1978b. The Moawhango River fishery. Evidence in the case for a water concession. Unpublished report. Fisheries Research Division, N.Z. Ministry of Agriculture and Fisheries. 42 p.

Cudby, E.J. 1981. A submission on the minimum acceptable flow in the Manganui-a-te-ao River. Submission and letter dated 17 June 1981 to Rangitikei-Wanganui Catchment Board. N.Z. Ministry of Agriculture and Fisheries, Turangi. File Tgi/6/2/1. 7 p.

Cudby, E., and Moore, E. 1965. Spawning survey of Lake Brunner streams. *N.Z. Marine Department, Freshwater Fisheries Advisory Service Investigation Report 59*: 24 p.

Daly, G.T. 1979. Vegetation. pp. 164-177. *In*: Armstrong, W.J. 1979. Manganui-a-te-Ao hydro-electric power development. Part II. Ecological considerations. Cawthron Technical Group Report commissioned by Wanganui-Rangitikei Electric Power Board.

Darby, d'E.C. 1978. Some environmental aspects of the Orautoha and Makakahi power schemes on the Manganui-a-te-Ao River. Report to the Wanganui-Rangitikei Electric Power Board. March 1978. 15 p.

Denton, F.J. n.d. Collection in Alexander Turnbull Library, Wellington. Reference 23306 1/1.

Dobson, J.G. 1979. Save the Manganui-a-te-ao River petition. Petition to Parliament signed by J.G. Dobson and 5433 others. 26 September 1979.

Downes, T.W. 1918. Notes on eels and eel weirs (tuna and pa-tuna). *Transactions and Proceedings of the New Zealand Institute 50*: 296-316.

Downes, T.W. 1921. "History of and guide to the Wanganui River." Wanganui Herald Newspaper Co Ltd. 106 p.

Eldon, G.A. n.d. Investigation of the trout population and condition in Lake Brunner streams. *N.Z. Marine Department, Fisheries Advisory Service, Investigation Report 14*. 14 p.

Ellis, A.J. 1975. Effect of Mount Ruapehu eruptions on the composition of nearby waters. Unpublished report. Department of Scientific and Industrial Research. Chemistry Division, Petone. 21 August 1975. 10 p.

Falla, R.A., Sibson, R.B., and Turbott, E.G. 1966. A field guide to the birds of New Zealand. Collins, London. 256 p.

Flain, M. 1982. Quinnat salmon runs 1965-78 in the Glenariffe Stream, Rakaia River, New Zealand. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication No. 28.* 22 p.

Fordham, R.A., Kelton, S.D., Leersnyder, H., and Lo, P.L. 1979. Subalpine koura *Paranephrops planifrons* (Decapoda) in Tongariro National Park : Zoogeographic implications. *N.Z. Journal of Marine and Freshwater Research 1979 13(3)*: 443-446.

Frost, W.E., and Brown, M.E. 1967. "The trout." Collins, London. 286 p.

Galloway, J.R., and Cudby, E.J. 1965. Spawning survey of the Waiau River and tributaries. *N.Z. Marine Department, Freshwater Fisheries Advisory Service Investigation Report 61.* 32 p.

Grace, J. Te H. 1959. "Tuwharetoa. A history of the Maori people of the Taupo district." A.H. and A.W. Reed. 567 p.

Graynoth, E. 1973a. The Waitaki Valley trout and salmon fishery. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Technical Report No. 100.* 36 p.

Graynoth, E. 1973b. The Waimarino trout fishery. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Technical Report No. 102.* 38 p.

Graynoth, E. 1973c. The Hawke's Bay trout fishery. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Technical Report No. 114.* 45 p.

Graynoth, E. 1974a. The Southland trout fishery. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Technical Report No. 99.* 24 p.

Graynoth, E. 1974b. The Wellington trout fishery. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Technical Report No. 115.* 39 p.

Graynoth, E. 1974c. New Zealand angling 1947-68: an assessment of the national angling diary and postal questionnaire schemes. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Technical Report* No. 135. 70 p.

Gregg, D.R. 1960. The geology of the Tongariro subdivision. *Department of Scientific and Industrial Research, New Zealand Geological Survey Bulletin new series No. 40.* 152 p.

Hamilton, G.D. 1904. Trout fishing and sport in Maoriland. Government Printing Office, Wellington.

Hay, R.F. 1967. Sheet 7, Taranaki. Geological map of New Zealand. 1:250,000. Department of Scientific and Industrial Research, Wellington.

Healy, J. 1954. Origin of flood. pp. 6-8. *In*: Tangiwai Railway Disaster. Report of Board of Inquiry. Government Printer, Wellington.

Healy, J., Vucetich, C.G., and Pullar, W.A. 1964. Stratigraphy and chronology of late quarternary volcanic ash in Taupo, Rotorua and Gisborne districts. *Department of Scientific and Industrial Research, New Zealand Geological Survey Bulletin new series No. 73.*

Hicks, B.J. 1982. Rangitikei River survey update. *Freshwater Catch No* 14: 8

Hobbs, D.F. 1937. Natural reproduction of quinnat salmon, brown and rainbow trout in certain New Zealand waters. *N.Z. Marine Department, Fisheries Bulletin No. 6.* 104 p.

Hobbs, D.F. 1948. Trout fisheries in New Zealand: their development and management. *N.Z. Marine Department, Fisheries Bulletin No. 9.* 175 p.

Hogg, J.T. 1981. Manganui-a-te-Ao River. Minimum acceptable flows. Letter dated 24 August 1981. Chief Executive Officer, Rangitikei-Wanganui Catchment Board. 2 p.

Hopkins, C.L. 1970. Some aspects of the bionomics of fish in a brown trout nursery stream. *N.Z. Marine Department, Fisheries Research Division, Fisheries Research Bulletin No. 4.* 38 p.

Hubbard, N. 1979. The Wanganui smelt fishery. *Freshwater Catch No 4*: 10.

Jellyman, D.J. 1984. Recreational use of the Ahuriri River 1982/83. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No. 41.* 47 p.

Jellyman, D.J., Davis S.F., Wing, S.J., and Teirney, L.D. 1982. Fish stocks and fisheries of the Ahuriri river system. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No. 26*: 84 p.

Jowett, I.G. 1982. Whakapapa River. Water temperature modelling. Unpublished report. Power Division, Ministry of Works and Development. November 1982. 17 p.

Keenleyside, M.H.A. 1962. Skindiving observations of Atlantic salmon and brook trout in the Miramichi River, New Brunswick. *Journal of the Fisheries Research Board of Canada 19(4)*: 625-634.

Kesner, W.D., and Barnhart, R.A. 1972. Characteristics of the fall-run steelhead trout (*Salmo gairdnerii*) of the Klamath river system with emphasis on the half pounder. *California Fish and Game 58(3)*: 204-220.

Kerry-Nichols, J.H. 1884. "The King Country or explorations in New Zealand: a narrative of 600 miles of travel through Maoriland." Sampson, Low, Marston, Searle and Rivington. London. 379 p.

Koha, 1982. Television programme about Maori culture, broadcast by New Zealand Broadcasting Corporation, channel 1, on Monday 23 August 1982. Producer, R Waru; Director, M Evans.

Lewis, S.L. 1969. Physical factors influencing fish populations in pools of a trout stream. *Transactions of the American Fisheries Society 198*: 14-19.

Mair, G. 1880. Notes on fishes in the upper Wanganui River. *Transactions and Proceedings of the New Zealand Institute 61*: 315-316.

McColl, R.H.S., White, E., and Gibson, A.R. 1977. Phosphorus and nitrate run-off in hill pasture and forest catchments, Taita, New Zealand. *N.Z. New Zealand Journal of Marine and Freshwater Research 11(4)*: 729-744.

McDowall, R.M. 1978. "New Zealand freshwater fishes: a guide and natural history." Heineman, Auckland. 230 p.

McDowall, R.M. 1984. "Trout in New Zealand waters." Wetland Press, Wellington. 120 p.

Mead, W.P. 1979. Memories of a mountain and a river. Wanganui Newspapers Ltd. 79 p.

Ministry of Works and Development 1982. Tideda processes dated 18 February 1982.

Moore, E. n.d. Spawning survey of Lake Alexandrina and adjacent waters. *N.Z. Marine Department, Freshwater Fisheries Advisory Service Marine Department. Investigation Report 40.* 38 p.

Morgan, D.R., and Graynoth, E. 1978. The influence of forestry practices on the ecology on freshwater fish in New Zealand. An introduction to the literature. *N.Z. Ministry of Agriculture and Fisheries, Research Division Occasional Publication No. 14.* 36 p.

Mosley, M.P. 1982a. A procedure for characterising river channels. *Water and Soil Division, Ministry of Works and Development, Water and Soil Miscellaneous Publication No. 32.* 67 p.

Mosley, M.P. 1982b. New Zealand river temperature regimes. *Water and Soil Division, Ministry of Works and Development, Water and Soil Miscellaneous Publication No 36.* 86 p.

Muirhead, F.G.J., and Turner, G.A. (Chairman and Convenor) 1980. Mangapurua and Mangatiti valleys. Land use study. *Department of Lands and Survey, Land Use Series No. 6.* 59 p. and 8 appendices, 7 maps.

N.Z. Meteorlogical Service 1983. Summary of climatological observations. Monthly summaries of rainfall, temperature, climate, sunshine and windrun for specified stations. New Zealand Meteorological Service. File 23/2/6.

N.Z. Official Yearbook 1983. 88th annual edition. Department of Statistics, Wellington. 1038 p.

Northcote, T.G., and Wilkie, D.W. 1963. Underwater census of stream fish populations. *Transactions of the American Fisheries Society 92(2)*: 146-151.

Ombler, K.A., and Ombler, J.S. n.d. The Wanganui River. A scenic historic and wilderness experience. Wanganui River Reserves Board. 112 p.

Order in Council 1903a. Fishing in the Orautoha Stream, county of Waimarino, prohibited. Regulations under the Fisheries Conservation Act 1884. 18 September 1903. 1 p.

Order in Council 1903b. Regulations for trout fishing, Waimarino acclimatisation district. Regulations under the Fisheries Conservation Act 1884. 28 September 1903. 1 p.

Paterson, B.R. 1976. The effects of lahars from the 1975 April Mount Ruapehu eruption and the threat of future eruptions on Tongariro power development. New Zealand Geological Survey. Unpublished engineering geology report EG 230. 57 p.

Reed, A.W. 1961. "A dictionary of Maori place names." A.H. and A.W. Reed, Wellington.

Richardson, J., and Teirney, L.D. 1982. The Whakapapa River: a study of a trout fishery under a modified flow regime. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No. 22*. 71 p.

Ricker, W.E. (Ed.) 1968. Methods for assessment of fish production in freshwaters. IBP Handbook No 3. Blackwell Scientific Publications, Oxford and Edinburgh. 313 p.

Rowe, D. 1980. North Island sea-run salmonids. *Freshwater Catch No.9*: 6.

Smart, M.J.G., and Bates, A.P. 1972. "The Wanganui Story." 1973 edition. Wanganui Newspapers Ltd. 318 p.

Soil Bureau 1968. Soils of New Zealand. Part I. *Soil Bureau Bulletin 26(1)*. Government Printer, Wellington.

Strickland, R.R. 1985. Distribution and habitats of fishes in the Mohaka River. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No. 55*. 86 p.

Taylor, R. 1846-52. Journal of Richard Taylor. Volumes 4-7. Alexander Turnbull Library, Wellington.

Taylor, R. 1855. "Te Ika a Maui or New Zealand and its inhabitants." Werteim and Mackintosh, London. 490 p.

Teirney, L.D. 1979. Manganui-a-te-ao petition. Letter dated 7 November 1979 with submission in support of Manganuioteao petition. MAF file Tgi/6/2/1. 4 p.

Teirney, L.D. 1980. The National Angler Survey. *Freshwater Catch 8*: 17-18.

Teirney, L.D., Unwin, M.J., Rowe, D.K., McDowall, R.M., and Graynoth, E. 1982. Submission on the draft inventory of wild and scenic rivers of national importance. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No. 28*. 122 p.

Tilzey, R.D.J. 1977. Repeat homing of brown trout (*Salmo trutta*) in Lake Eucumbene, New South Wales, Australia. *Journal of the Fisheries Research Board of Canada 34(10)*: 1085-1094.

Todd, L.R. 1981. Submission of the Waimarino Ward, Central North Island Conservancy to the Rangitikei-Wanganui Catchment Board. 10 June 1981. 10 p.

Todd, P.R. 1979. Wanganui lamprey fishery. *Catch '79 No. 2, March. Freshwater Supplement.*

Tonkin and Taylor, 1978. Water resources of the Wanganui River. Report prepared for the Rangitikei-Wanganui Catchment Board, Marton. December 1978. 167 p.

Turner, D.J.P. 1975. Eruption of Mount Ruapehu. April 24 1975. Unpublished report to Director of Fisheries Management. Ministry of Agriculture and Fisheries, Turangi. File Tgi/6/2. 2 p.

Turner, D.J.P. 1978. Manganui-a-te-ao hydro development investigations. Unpublished report. New Zealand Ministry of Agriculture and fisheries. Fisheries Research Division, Turangi. File Tgi/6/2. 2 p.

Turner, D.J.P., and Allen, P.J. 1970. Electric fishing of the Makatote, Manganui-a-te-ao and Waione streams to establish the necessity for continued stocking of these streams with fingerling trout and fry. *N.Z. Marine Department, North Island Electric Fishing Services, Investigation Report 4, May 1970.* 3 p.

Turner, D.J.P., Allen, P.J., and Beam, M.G. 1969. A supplement to the Mangawhero River survey. *N.Z. Marine Department, North Island Electric Fishing Service, Investigation Report.* 4 p.

Tyson, P.J. 1980. Manganui-a-te-ao River. 1980 fish trapping and spawning investigation. Unpublished report. Ministry of

Agriculture and Fisheries. Fisheries Research Division, Turangi. File Tgi/6/2/1. 21 p.

Voelkerling, A. 1980. Some historical notes on the Manganui-a-te-Ao. Unpublished manuscript. June 1980. 3 p.

Waimarino Acclimatisation Society 1941-76. Annual Reports of the Waimarino Acclimatisation Society Nos. 38-73.

Wakefield, E.J. 1845. Adventure in New Zealand from 1839 to 1844. Volume II. John Murray, London. Facsimile edition Wilson and Horton Ltd, Auckland, New Zealand.

Wanganui Herald 1976. Unusual catch. The Wanganui Herald. Volume 109, No 33 (341). 2 November 1976.

Wanganui-Rangitikei Electric Power Board 1978. Manganui-a-te-ao hydro-electric development. Brief description of schemes. Wanganui-Rangitikei Electric Power Board brochure issued to interested parties. August 1978. 21 p.

Water and Soil Division, Ministry of Works and Development 1981. Catchment register for New Zealand. Volume I. *Water and Soil Division, Ministry of Works and Development, Water and Soil Miscellaneous Publication No. 12.* 238 p.

Waters, B.F. 1976. A methodology for evaluating the effects of different streamflows on salmonid habitat. *In*: Osborn J.F., and Allmon, C.H. (Eds.). Proceedings of the symposium and specialty conference on instream flow needs. Volume 2. American Fisheries Society: 254-266.

Wellington Acclimatisation Society 1883-1909. Annual Reports of the Wellington and Wairarapa Acclimatisation Society 1883-1909. (Bound volume containing 27 reports.)

White, R.J., Hansen, E.A., and Alexander, G.R. 1976. Relationship of trout abundance to streamflow in midwestern streams. *In*: Instream Flow Needs. Volume II. American Fisheries Society: 597-615.

Wilkinson, G.B. 1978. Biological investigations. Manganui-a-te-ao hydro project. Letter to Fisheries Research Division, Wellington. 3 November 1978. 4 p.

Winstone Afforestation Ltd. 1984. Forest fact sheet 31-3-84.

Woods, C.S. 1964. Fisheries aspects of the Tongariro power development projects. *Fisheries Technical Report, N.Z. Marine Department, No. 10*. 214 p.

APPENDIX I. Water quality (Tonkin and Taylor (1978), Armstrong (1979), and personal records)

River	Site	Temp. (°C)	DO (g/m^3)	BOD	pH	Alk. (g/m^3)	Cl (g/m^3)	SO_4 (g/m^3)	F (g/m^3)	Ca (g/m^3)	Mg (g/m^3)	N NH_4 (g/m^3)	NO_3 (g/m^3)	P PO_4 (g/m^3)	S-P (g/m^3)	T-P (g/m^3)	Conduct. (μmho)	Tot. hard. (g/m^3)	Absorbance (350 μm)			Faec. coli. (/100 ml)		
Range of parameters measured																								
Waimarino	1 S.H.4	3.4-16.5	9.5-12.6	X	7.0-7.9	36	2-5	2	< 0.1	X	X	X	X	X	X	X	30-125	14-49	nil	0.015	0.05	2	24	32
Makatote	2 S.H.4	2.9-16.0	9.5-12.8	X	7.1-8.0	30	2-5	12	0.1	X	X	X	X	X	X	X	40-155	16-54	nil	0.01	0.025	nil	12	18
Mangaturuturu	4 S.H.4	1.5-19.0	8.6-12.3	X	4.6-6.2	1	5-40	57	0.3	X	X	X	X	X	X	X	140-360	18-24	nil	0.005	0.02	nil	nil	nil
"	5 Mouth	3.6-17.5	9.5-12.6	X	6.7-7.2	11	10-23	40	0.2	X	X	X	X	X	X	X	115-255	46-85	nil	0.01	0.035	4	24	28
Orautoha	7 Mouth	3.0-2.40	9.4-11.9	X	7.2-8.3	38	6-8	5	< 0.1	X	X	X	0.063	X	0.016	0.039	75-155	22-53	0.02	0.04	0.055	30	160	1190
Ruatiti	9 Mouth	5.5-22.3	8.2-11.9	X	7.3-7.9	X	5-7	X	X	X	X	X	0.005	X	0.006	0.023	70-205	28-68	0.04	0.04	0.11	42	55	648
Manganuioteao	3 S.H.4	2.6-15.1	9.5-12.6	X	7.1-7.7	23	3-8	10	0.2	X	X	X	X	X	X	X	40-120	13-40	nil	0.01	0.04	nil	6	10
"	6 Hoihenga	5.4-18.2	9.4-12.9	X	7.2-7.7	X	5-13	X	X	X	X	X	X	X	X	X	80-185	28-59	nil	0.015	0.03	8	18	126
"	8 Ashworth	5.8-21.5	9.4-12.3	X	7.1-8.0	X	5-12	X	X	X	X	X	0.02	X	0.007	0.021	70-185	28-58	nil	0.02	0.185	12	34	228
"	10 Makakahi	6.0-22.5	9.1-12.7	X	7.4-8.5	X	5-12	X	X	X	X	X	X	X	X	X	80-190	25-60	0.01	0.02	0.05	10	70	468
Low flow survey - 15-16 February 1978 (early to mid-afternoon)																								
Manganuioteao	11 Mouth	22.0	9.5	1.0	8.7	42	12	X	X	24	30	nil	X	nil			160	54			0.02			24
Wanganui	12 ab Manganuioteao	23.6	8.7	2.0	8.7	56	12	X	X	30	22	< 0.10	X	nil			145	52			0.04			340
"	14 Upokongaro	24.2	7.7	1.8	8.3	58	14	X	X	34	24	nil	X	nil			175	58			0.04			42

Suspended sediment

River	Site	Mean annual discharge (t/day)	Mean annual discharge ($t/km^2/yr$)	Mean annual discharge ($m^3/km^2/yr$)
Manganuioteao	8 Ashworth	58	64	32
Wanganui	13 Paetawa	8846	486	243

APPENDIX I. Water quality: explanatory notes and tolerances for aquatic life.

Site no.: See Figure 16 - water quality sample stations.

Temp.: Water temperature in degrees celsius. Bell (1973) gives the following limits for trout:

	Optimum	Lethal
Brown trout	4-21	2*-29
Rainbow trout	12-19	0-29

* Brown trout have been known to survive at 1°C (personal records).

DO: The concentration of oxygen dissolved in the water. For most aquatic life concentrations above 6 g/m^3 are adequate.

BOD: The biochemical oxygen demand. A measure of the capacity of biological and chemical systems in the water to use dissolved oxygen; an indicator of organic pollution, for example, effluent from sewage plants and meat works can vary between 150-800 g/m^3.

pH: The acidity-alkalinity equilibrium expressed on a logarithmic scale of 0.0-14.0; 7.0 is neutral and values below 7 are increasingly acidic and those above 7 are increasingly alkaline. pH affects the solubility and toxicity of many chemicals. Optimum limits for most aquatic animals are between 6.0-9.0.

Alk.: Total alkalinity is a measure of the salts of weak acids; carbonate alkalinity given here is part of the system; it reflects the buffering activity of calcium carbonate.

Cl: SO_4: F: Chlorides, sulphates, and fluorides; the ionic concentration of the salts of strong acids. These often reflect land use patterns, but they can also reflect geological factors, for example, Crater Lake, Mount Ruapehu (Fig. 1) contains high concentrations of these anions and Ellis (1975) has shown that the sulphate concentration in streams draining from Ruapehu can be used as an estimator of the degre of contamination by volcanic effluent (see Mangaturuturu figures in table: 1.5 g/m^3 is lethal to most aquatic animals (Bell 1973)).

Ca: Mg: Calcium and magnesium are two of the most common cations present in water. They form salts with anions, particularly carbonates, and are important to biological processes. They are not directly lethal at normal concentrations and are a means of characterising different waters.

N - NH_4:	Ammonium	Nitrogen and phosphorus compounds are plant nutrients and components of living matter. They give an indication of the eutrophic potential of the water. Algal blooms and massive weed growths are possible at nitrate concentrations in excess of 0.5 g/m^3 and heavy algal blooms occur when phosphate concentrations exceed 0.03 g/m^3 (Bell 1973).
NO_3:	Nitrate	
P - PO_4:	Reactive phosphate	
S-P:	Soluble phosphorus	
T-P:	Total phosphorus	

Conduct.:	Conductivity in reciprocal micro-ohms per centimetre (= micro-siemens per centimetre); an indication of the total ionic concentration.
Tot. hard.:	Total hardness is an indication of the level of dissolved solids. These may be calcium-magnesium compounds - as is likely here because the magnesium concentration has been calculated by subtracting calcium from total hardness - or sulphates and chlorides.
Absorbance:	Light absorbance at a wavelength of 350 mu; an estimate of organic carbon content.
Faec. coli.:	Faecal coliform bacteria as number of cells per 100 ml. An indication of contamination by warm blooded animals and hence pathogenic organisms. Extreme levels in sewage effluent may contain 10^5 cells/100 ml, but good quality natural waters usually average less than 10^2 cells/100 ml.
Susp. sed.:	Suspended sediment discharge. 58 t/d is equivalent to an average concentration of 37 g/m^3 which is excessive as a continuous level; most of the time the concentration would be close to zero. In a tribunal hearing on gravel washing discharges which changed the river from clear to turbid (>15 g/m^3) were unacceptable, and Morgan and Graynoth (1978) quote harmful effects to salmonid ova and fry at 20 g/m^3, though most aquatic life can withstand short-term exposure to high concentrations.

During floods many of the parameters in Appendix I can increase dramatically, for example, in a 2-year-study of four experimental catchments with different vegetation McColl *et al.* (1977) found that nitrate and phosphorus run-off was spasmodic; up to 70% of phosphorus losses occurred during floods and less than 20% during low flows. Corresponding figures for nitrate losses were <83% and <1%. The greatest variation is generally found in streams draining developed land.

APPENDIX II. Extract from Manganuioteao trout fry and juvenile habitat survey by I.G. Jowett, Power Division, Ministry of Works and Development.

Habitat Quality

The most important factors influencing fry and juvenile habitat are substrate, depth and velocity. In the Manganuioteao the substrate was good - large relatively clean boulders with cobbles and gravel between them. Bovee (1978) indicates that rainbow fry and juveniles prefer gravel substrate whereas brown trout have less definite preference but generally tend to prefer the larger cobble substrate.

The range of suitable depths and velocities have been described for both rainbow and brown trout by Bovee. Basically brown trout fry prefer a velocity of between zero and 0.36 m/s whereas rainbow fry have narrower tolerances showing a definite preference for a velocity of 0.36 m/s but will accept velocities between zero and 1 m/s. Brown trout fry prefer slightly shallower water than rainbow, the former preferring 0.25 to 0.55 metres and the latter preferring water of 0.55 metres or deeper.

Juvenile brown trout prefer similar velocities and depths to the fry although generally the trend is towards slower and deeper water. Juvenile rainbow trout exhibit a definite preference for water 0.3 m deep and velocities between 0.2 and 0.43 m/s.

The suitability of physical habitat for fry and juvenile trout in the boulder reach can be evaluated using these criteria and assigning a "measure" to the suitability. This measure is the weighted usable area where a habitat factor is assigned a weight of between zero and one, zero meaning totally unsuitable and one meaning ideal. The product of the weights for substrate, velocity and depth give the measure of how suitable the measured point is for the habitat function and this can be expressed as an area by mulitplying the weight by the area (or river width) the measurement point represents.

First Survey

The first survey of fry and juvenile habitat was made on a falling stage on 2 February and 5 February 1981. The flow on the 2nd was 4.8 m^3/s and fell to 4.2 m^3/s on the 5th.

Nineteen transects were spaced at six metres and depths and velocities measured every metre.

The total area of river surveyed was 3738 m^2 and a boulder bank formed 53% of this area with the main river channel occupying the remainder.

Second Survey

The second survey was made on 6 August 1982 with a flow of 8.2 m^3/s. Depth measurements were made at 14 transects but velocities were only measured at two of them.

This is not a large sample but the agreement between the suitable habitat in these two sections in the first survey and the average amount of habitat in the 19 transects indicates that they are fairly representative.

Discussion

The variation of trout fry and juvenile habitat available in the Manganuioteao cannot be defined by the measurements taken for flows as low as those suggested as residual flows although some indication of the direction can be gained from a knowledge of habitat preferences and hydraulics.

The two surveys, the second at twice the flow of the first, indicate that there is little variation in usable habitat for between 4 and 9 m^3/s, particularly for rainbow trout. As would be expected from habitat preferences there is a slight increase in usable habitat for brown trout with a decrease in flow from 9 to 4 m^3/s. Extrapolating this to even lower flows one would expect juvenile brown trout habitat to reach an optimum at a flow lower than 4 m^3/s and then to decline rapidly as the flow to the boulder bank cut off. Rainbow trout habitat would probably continue to decline below about 4 m^3/s and drop sharply at some flow lower than this.

The percentage of river area with usable habitat can be compared to some other rivers surveyed to give some idea of its "quality". Unfortunately the other rivers surveyed in this manner have quite different characters and may not be comparable. However, in all cases the prime rearing habitat in the river systems are compared. In the Waitaki the area surveyed was a system of stable braids used as spawning and rearing areas and in the Clutha a side braid which provided spawning and rearing habitat was surveyed.

When flows in the Manganuioteao were between 4 and 9 m^3/s the potential rearing habitat was in the boulder bank but with further reduction of flow, possibly to quite low flows, suitable habitat will probably occur in areas of the main river and other boulder banks will develop which are at present unsuitable habitat.

This, however, may not be so desirable as these areas will be swept by higher velocity flood flows reasonably frequently and a percentage of the young fish will be swept further downstream and there will be increased mortality which would not occur if the areas of rearing habitat were less subject to velocity and depth changes as they are on the present boulder banks. Thus, while rearing potential would probably be optimum at quite low flows the impact of flow changes on the suitable areas could increase fry and juvenile mortality. The low flow which may be optimum for rearing would certainly not be suitable for adult fish and would promote a change from a mixed rainbow/brown population to conditions favouring a brown trout fishery.

Conclusions

a) The usable rearing habitat in the boulder bank was higher than in rearing areas surveyed in the Waitaki, Clutha and Tekapo Rivers.

b) For brown trout the rearing area slowly increases with a decrease in flow between the 4 and 9 m^3/s surveyed. Below this there will be some flow at which water supply to the boulder bank is cut off and available rearing habitat would reduce sharply at this point. Generally, in the river, one would expect a quite low flow to give an optimum area of rearing habitat.

c) For rainbow trout the rearing area stays about the same while the flow varies between 4 and 9 m^3/s. Below this there will be a point where the usable rearing habitat drops sharply as velocities become too low. Generally, in the river, one would expect the flow giving an optimum area of rearing habitat to be higher than that for brown trout.

d) While the rearing area available at a low residual flow is probably quite high this area will be situated in parts of the channel which are subjected to high velocities during the relatively frequent spill flows.

e) Any reduction in flow will create conditions more favourable to brown trout (fry, juveniles and adults) than rainbow.

TABLE 1. Percentage of area suitable habitat

	Brown trout		Rainbow trout	
	Fry	Juvenile	Fry	Juvenile
Whole river	32	29	16	15
Boulder bank alone	61	55	30	27

TABLE 2. Percentage of area of suitable habitat in boulder bank at two transects (4 and 8)

	Brown trout		Rainbow trout	
	Fry	Juvenile	Fry	Juvenile
First survey (flow approx 4 m^3/s)	68	61	34	32
Second survey (flow approx 9 m^3/s)	58	49	35	33

TABLE 3. Percentage of rearing area with suitable habitat

	Brown trout		Rainbow trout		Salmonid rearing waters (1976) criteria
River system	Fry	Juvenile	Fry	Juvenile	
Manganuioteao boulder bank	61	55	30	27	29
Waitaki stable side braids	21	20	7	13	15
Upper Clutha side braid	-	-	-	-	23
Tekapo	-	-	-	-	21