THE STATUS OF FISH IN HAMILTON LAKE (LAKE ROTOROA)

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Frontispiece: Fishing in Hamilton Lake (Lake Rotoroa).

Abstract

The size, population structure, relative fish abundance, diet and heavy metal concentrations of fish in Hamilton Lake (Lake Rotoroa) were examined. A combination of gill nets, fyke nets and minnow traps were used at each of 11 sampling sites located primarily at stormwater inflows around the lake. Sampling was undertaken between 9 December 1993 and 2 March 1994, with one overnight sampling occurring at each site.

A total of 1073 fish were captured, comprising nine different species: catfish (*Ictalurus nebulosus*), common bully (*Gobiomorphus cotidianus*), goldfish (*Carassius auratus*), longfinned eel (*Anguilla dieffenbachii*), perch (*Perca fluviatilis*), mosquitofish (*Gambusia affinis*), rudd (*Scardinius erythropthalmus*), shortfinned eel (*Anguilla australis*), and tench (*Tinca tinca*).

Abundance of rudd has declined since 1990, with a decline in catch rates of 67%. Conversely, perch abundance has increased since 1990, with catch rates increasing by 300%. During this period perch have surpassed rudd as the most abundant fish species. The declines in rudd abundance are probably associated with the disappearance of submerged aquatic macrophytes, largely *Egeria densa*, from Hamilton Lake during 1990.

Ages of rudd were determined using scales, while perch were aged using opercular bones. Back-calculation of fish length involved the use of both scale proportional (SPH), and body proportional hypotheses (BPH). Results from the SPH appeared more accurate, due to better compatibility with actual observed fish lengths. Sizes of one and two year old rudd appear to have declined over the past six years in Hamilton Lake. In 1987, the mean lengths of one and two year old rudd were 87 mm and 207 mm respectively, while in 1991 the same aged fish were 69 mm and 127 mm in length. Perch growth rates, however, do not appear to have changed. Poorly formed growth rings on both scales and operculum prevented tench from being aged.

Despite the total collapse of submerged aquatic macrophytes, which formed the bulk of the rudd diet (84% by volume), aquatic vegetation still remained the most important food item of adult rudd in the present study, although this now comprised entirely of emergent marginal vegetation. This suggests that rudd >200 mm in length are obligate herbivores. Perch fed largely on invertebrates, before a transition to a largely piscivorous diet at approximately 200 mm in length. Tench appeared to be specialist feeders on molluscs.

Concentrations of four heavy metals (arsenic, lead, copper, and zinc) in the white muscle of fish were examined. Concentrations of the majority of heavy metals analysed were well below maximum permitted levels. Arsenic concentrations were highest in bottom feeding fish, particularly catfish (mean=0.778 mg kg^{-1} wet weight, compared to the maximum permitted level of 2 mg kg^{-1} wet weight) due to high arsenic concentrations in the lake sediment resulting from sodium arsenate application for weed control in 1959. Arsenic in the present study was analysed using a dry ashing technique. Arsenic concentrations were higher than those of previous studies in the lake undertaken using a wet ashing technique, which fails to liberate all arsenic from the fish flesh.

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CHAPTER ONE:
Introduction

1.1 STUDY SITE

1.1.1 HAMILTON LAKE

Hamilton Lake (Lake Rotoroa) is a small (54 ha) eutrophic lake situated on the western side of Hamilton city (37°48' S, 175°16'30'' E). The lake formed between 15,000 and 19,000 years ago during the deposition of the Hinuera Formation in the Hamilton Basin (Green and Lowe 1994). Hamilton Lake has a maximum length and width of 1.5 km and 0.5 km respectively, and a maximum depth of approximately 6.5 m. The lake consists of two basins (northern and southern) linked by a central shallow area. Over 54% of the lake is less than 2 m deep and a further 25% is less than 1 m deep (Tanner et al. 1990). The surface temperature range is 9-25°C, with weak thermal stratification common over the summer period (Tanner et al. 1987).

Water enters the lake from a number of sources including discharge from 10 stormwater drains, direct rainfall, groundwater, and surface runoff (Hamilton City Council 1985). The 138 ha catchment area is made up of lake surface (40%), recreational reserve (35%), and residential housing (25%), (Edgar 1993). Hamilton Lake is an important part of the city's storm water system (Boswell et al. 1985). The main outflow of water from the lake is via a weir into an open drain, which leads to the Waikato River via the Waitewhiriwhiri Stream (Hamilton City Council 1985). Discharge from the lake is controlled by the Hamilton City Drainage Division. The lake has a low residence time of 2.4 years (Hamilton City Council 1985).

1.1.2 REVIEW OF AQUATIC WEED CONTROL IN HAMILTON LAKE

Prior to 1950 Lake Rotoroa was a moderately productive lake, with the bed colonised by extensive beds of charophytes and pondweed species. Phytoplankton populations were relatively sparse and lake water was comparatively clear (Coffey and Edgar 1993).

The need for management of the submerged vegetation arose with the establishment of the exotic oxygen weed *Lagarosiphon major* first recorded in the lake in 1953 (de Winton and Champion 1993). By the mid 1950s these tall growing weed beds developed to proportions which prevented recreational activities and decreased the lake's aesthetic appeal. At this time the first unsuccessful attempts were made to control weedbeds by mechanical harvesting (de Winton 1994).

In 1959 sodium arsenate was trialed as a means of controlling the growth of *L. major*. Due to the success of this trial 39 hectares were treated with 11,000 litres of sodium arsenate, supplying a total of over 5,500 kg of arsenic to the lake (Tanner and Clayton 1990). This treatment proved very successful, eliminating almost all *L. major* plants within eight weeks of spraying. However, sodium arsenate was not used again for aquatic weed control in New Zealand due to concerns regarding the toxicity and persistence of arsenic.

Recolonisation of the lake by submerged plants did not occur for approximately five years following sodium arsenate treatment. Native submerged species such as *Potamogeton cheesemanii, Nitella hookerii*, and *Chara corallina* were among the first plants to recolonise the lake bed. In December 1970 *L. major* re-established in the lake. Concern over the reappearance of native submerged plants and *L. major* led to application of the herbicide diquat to control growth.

The oxygen weed *Egeria densa* was first recorded in Hamilton Lake in 1977 and rapidly became abundant (Tanner et al. 1990). Diquat application continued, and large scale spraying was undertaken in the summer of 1978-79. Between 1982 and 1986 nuisance weedbeds were specifically targeted by applying a gel formulation of diquat. Experimental trials conducted with this gel in 1985 and 1986 targeted a widespread area of the lake, and were highly effective (Tanner et al. 1990).

Between 1988 and 1990 a dramatic decline in submerged aquatic vegetation was recorded in Hamilton Lake. No trace of submerged aquatic vegetation could be found after July 1990 (de Winton 1994).

1.1.3 WATER QUALITY

Following the decline of submerged aquatic macrophytes, Hamilton Lake became highly turbid (Coffey and Edgar 1993), with poor water clarity (Table 1.1). Water clarity in the lake appears to be influenced primarily by the concentration of suspended solids, of which phytoplankton biomass accounts for much of the organic portion (Edgar 1993). Evidence suggests that macrophyte beds may have been important in phytoplankton suppression, sediment stabilisation, and nutrient buffering (de Winton et al. 1991).

Table 1.1: Water quality characteristics of Hamilton Lake.

Water Quality Variable	Mean value[1] 1978-1979	Mean value[2] 1989	Mean value[2] 1992
Secchi depth (m)	-	1.3	0.81
Total suspended solids (g m^{-3})	5	9.04	14.90
Organic suspended solids (g m^{-3})	-	-	10.3
Inorganic suspended solids (g m^{-3})	-	-	4.6
Total nitrogen (g m^{-3})	0.716	0.832	-
Total phosphorous (g m^{-3})	0.025	0.027	0.040
Phytoplankton (cells ml^{-3})	95-650	2665	4510
Chlorophyll *a* (g m^{-3})	0.010	0.018	0.027

Sources: [1] Henriques (1979), [2] NIWA database. (Adapted from Coffey & Edgar 1993).

During 1994 water clarity was reported to improve slightly (Burns pers. comm., NIWA Hamilton 1995).

1.1.4 FLORA AND FAUNA OF HAMILTON LAKE

1.1.4.1 Fish

Hamilton Lake has a relatively diverse freshwater fish fauna by New Zealand standards, comprising six exotic fish species and four native fish species (Table 1.2, Plate 1).

Perch was the first exotic fish species to be introduced into the lake. After an unsuccessful attempt at introduction in 1885, a perch fishery was established in Hamilton Lake in approximately 1907 by the Waikato Angling Club (Hicks 1994). Mosquitofish and goldfish appear to have been present in the lake for some time, as they were well established by 1976 (Graynoth 1978); however the exact date of their introduction is unknown. Both rudd and catfish appeared in the lake in about 1977. Rudd were introduced illegally, while catfish appear to have spread from the Waikato River during the winter. Tench were released into the lake by the Auckland/Waikato Fish and Game Council to establish a new coarse fishery (Hicks 1994). The first liberation occurred on 4 February 1990, when 95 tench were released. Subsequent liberations occurred on 24 February 1991 and 23 February 1992, when 108 and 403 tench were released respectively (Wilson pers. comm., Auckland/Waikato Fish and Game Council 1995)

Table 1.2: Fish species found in Hamilton Lake.

Common name	Scientific name
Exotic:	
brown bullhead catfish	*Ictalurus nebulosus*
goldfish	*Carassius auratus*
mosquitofish	*Gambusia affinis*
perch	*Perca fluviatilis*
rudd	*Scardinius erythropthalmus*
tench	*Tinca tinca*
Native:	
common bully	*Gobiomorphus cotidianus*
common smelt	*Retropinna retropinna*
longfinned eel	*Anguilla dieffenbachii*
shortfinned eel	*Anguilla australis*

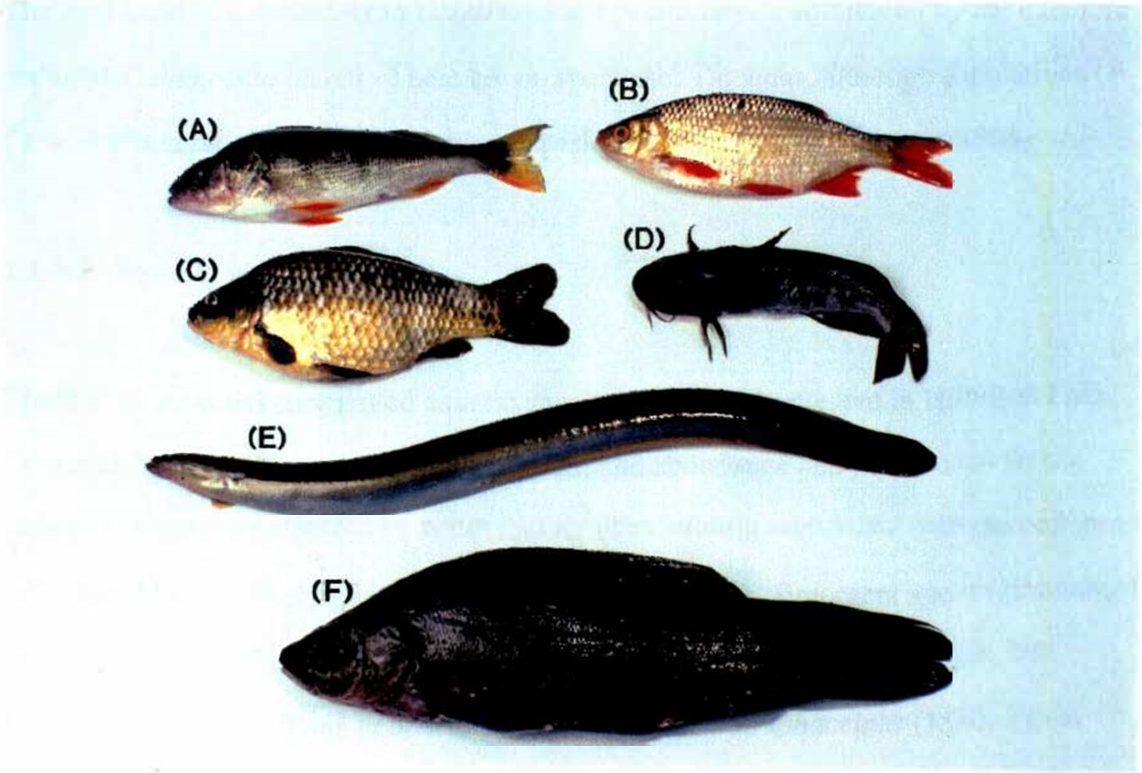


Plate 1: Six common fish species caught in Hamilton Lake. A=perch, B=rudd, c=goldfish, D=catfish, E=shortfinned eel, F=tench.

1.1.4.2 Plankton

Phytoplankton abundance is relatively high in Hamilton Lake, and the phytoplankton community has changed markedly in recent years (Coffey and Edgar 1993). Since late 1990 the large buoyant colonial green algae, *Botryococcus braunii* has dominated, forming over 90% of the total algal biomass (Edgar 1993).

The zooplankton community in Hamilton Lake is commonly dominated by the calanoid copepod *Calamoecia lucasi*. There are no species of *Daphnia*, although populations of *Ceriodaphnia pulchella* and *C. dubia* are periodically common (Chapman 1994).

1.1.4.3 Aquatic vegetation

There is no reported submerged aquatic vegetation currently present in Hamilton Lake. However, marginal vegetation is still present, and abundance and distribution do not appear to have been affected by water quality deterioration associated with the collapse of submerged aquatic macrophytes (Coffey and Edgar 1993). Emergent species dominate the marginal vegetation, which occupies approximately 50% of the lake. Of this, *Iris pseudacorus* (35%), *Baumea articulata* (22%), *Eleocharis sphacelata* (15%), *Typha orientalis* (14%), and *Nymphaea* cultivars (11%) are the most common species (Champion et al. 1993).

1.1.4.4 Benthic invertebrates

Hamilton Lake has a low diversity of benthic invertebrates, which Henriques (1979) attributed to consistently high arsenic concentrations in the sediments. Chironomids and oligochaetes appear to dominate the invertebrate fauna, although molluscs and insect larvae are also present.

1.2 RESEARCH OBJECTIVES

Previous studies have addressed aspects of fish biology in Hamilton Lake, such as growth, diet, and heavy metal accumulation (Graynoth 1978, Tanner and Clayton 1990, Wise 1990, Rajendram 1992, Totome, 1993). However, recent changes in the lake, particularly the collapse of submerged aquatic macrophyte beds, have dramatically altered the lake ecosystem. This study addresses some important areas of research into the fish biology of Hamilton Lake, focusing on the size, population structure, diet and heavy metal accumulation of fish populations, comparing results with those of previous studies.

The principle objectives of this study were to:

i) estimate relative fish abundance through catch per unit effort;

ii) determine fish sizes and distributions around the lake;

iii) determine growth rates of perch and rudd;

iv) determine fish diets;

v) determine the concentrations of arsenic, lead, copper, and zinc in the white muscle of fish.

CHAPTER TWO:

Abundance, Size, and Distribution of Native and Introduced Fish Species in Hamilton Lake

2.1 INTRODUCTION

The first major study of the biology of fish in Hamilton Lake was undertaken by Graynoth (1978), who assessed the potential of perch for angling purposes. Rudd and catfish have since been introduced into the lake, and Wise (1990) studied the biology of these three exotic fish species, finding rudd to be the most abundant. Since Wise's study, a number of changes have occurred in the lake. Juvenile tench were first introduced for angling purposes by the Auckland/Waikato Fish and Game Council in 1990. More significantly, the aquatic macrophyte beds collapsed in July 1990, which is likely to have significant impacts on the fish populations in Hamilton Lake.

Wise (1990) found that the diet of rudd comprised approximately 84% aquatic macrophytes, therefore the affect of the collapse of macrophytes on this species is liable to be pronounced. As bottom feeders, catfish are unlikely to be affected as greatly. However, the decline in water quality associated with the collapse is likely to affect perch, which rely on visual hunting strategies. Perch also consume invertebrates associated with the macrophyte beds, and their spawning may also be influenced.

Studies have been undertaken on aquatic vegetation and diets of selected fish since the decline in macrophytes. Edgar (1993) found that the lake vegetation had changed from being macrophyte-dominated to a state of stable dominance by the colonial green planktonic alga *Botryococcus braunii*. Totome (1993) studied the diets of rudd, perch, catfish, goldfish, and eel in Hamilton Lake, and found that rudd were still the most abundant of the fish sampled at that time.

The present study aims to assess the impacts of the recent changes in the lake on both native and exotic fish populations. The study assesses relative fish abundance, fish size, age and growth rates, and compares these with results of previous studies, specifically those of Wise (1990) and Graynoth (1978). The general biology of the fish is assessed. Gonad status was determined, enabling spawning periods of fish in the lake to be approximated. The condition of the fish was assessed through examination of length-weight relationships. Length-frequency distributions at different sampling sites around the lake were also examined to determine possible preferences of different fish species and sizes for specific habitats. This is the first study to address the biology and status of tench in Hamilton Lake since they were first introduced in 1990.

2.2 METHODS

2.2.1 FISH SAMPLING

Fish were sampled at the locations of stormwater inflows to Hamilton Lake. Sampling from sites close to inflows ensured that fish with potentially the highest concentrations of heavy metals accumulated in their flesh were obtained. There are ten stormwater inflows to the lake, but due to the close proximity of inflows 1, 9, and 10, a single sample was taken to combine these three sites (Figure 2.1). Additional sample sites were located in the northern, southern, and central basins.

Fish sampling was undertaken between December 9 1993 and February 2 1994 (Table 2.1). An additional sample was taken on March 2 1994 at site 4. Results from this netting will be used for the length-frequency analysis.

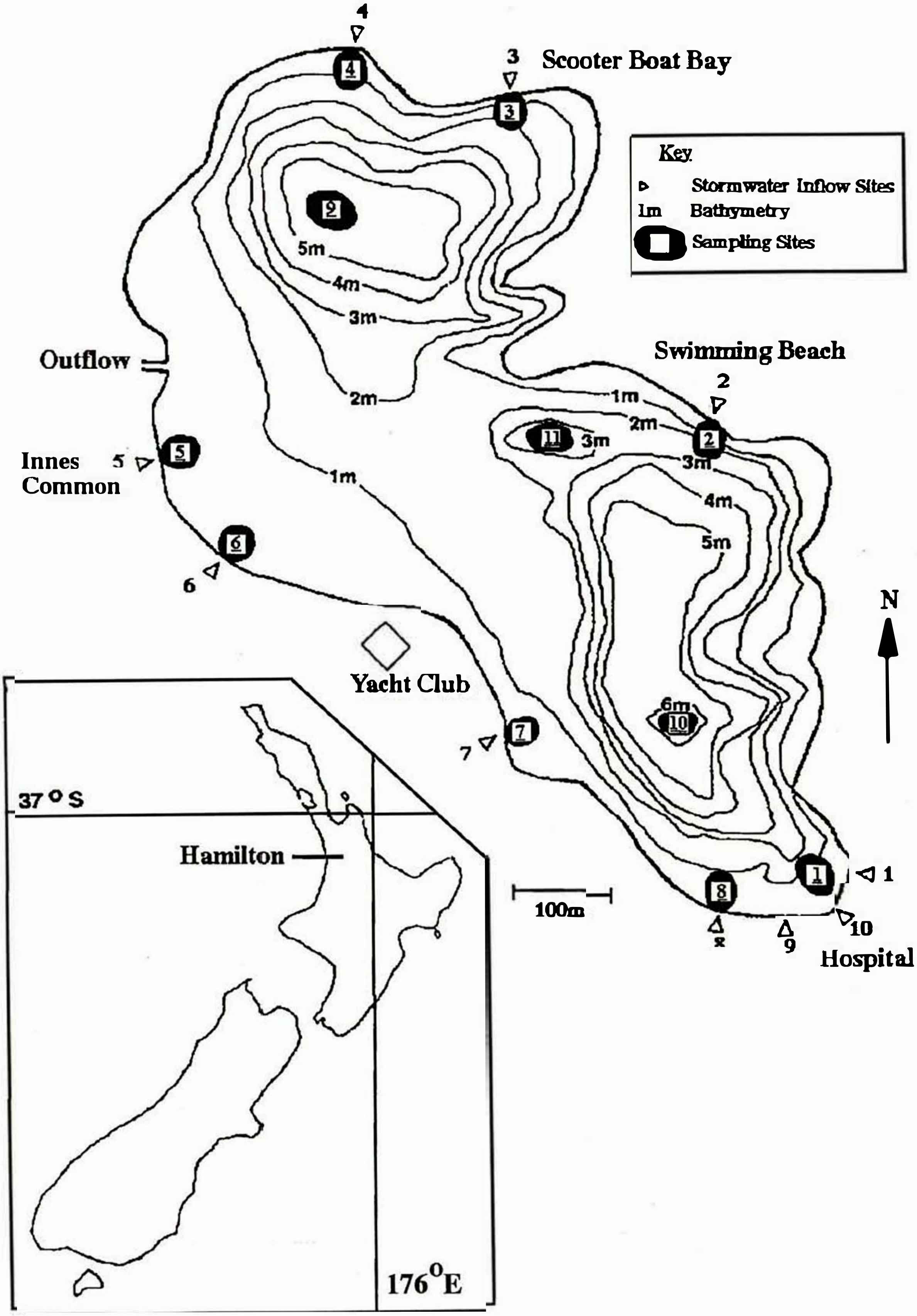


Figure 2.1: Bathymetric map of Hamilton Lake showing location of sampling sites (after Wise 1990).

Table 2.1: Dates on which fish were caught at sites near stormwater inflows to Hamilton Lake.

Sampling site	Date of setting
1	9 December 1993
6	14 December 1993
8	20 December 1993
4	10 January 1994
2	17 January 1994
9	19 January 1994
10	24 January 1994
11	25 January 1994
7	26 January 1994
5	31 January 1994
3	1 February 1994
4	2 February 1994

2.2.2 FISH CAPTURE

Sampling fish populations in the lake required the use of a variety of sampling techniques (Plate 2). Gill nets, fyke nets, and minnow traps were used at each sampling site to ensure that representatives of each fish species in the lake were obtained.

2.2.2.1 Gill net sampling

Three panel nets, each 40 m long and 2 m deep, were set at each site. The panel nets comprised five different mesh sizes (Table 2.2). The nets were set perpendicular to the shore, anchored down to the lake bottom with concrete blocks. The coarse meshes of the gill nets were set closest to the shore in the two outside nets, while the finer meshes were set closest to the shore in the middle net. In each case nets were set overnight (refer to Appendix 1 for individual netting times).

Plate 2: Fishing methods used for sampling the fish populations in Hamilton Lake (A=gill net, B=fyke net, C=minnow trap).

Table 2.2: Mesh sizes of gill nets used for sampling fish in Hamilton Lake.

Stretched mesh size (mm)	Stretched mesh size (inches)	Length of netting (m)
25	1.0	6
38	1.5	8
56	2.3	8
84	3.4	8
106	4.3	10
Total		40

2.2.2.2 Fyke net sampling

Three fyke nets were set at each sampling site. Each net consisted of three interconnected funnels, with a total net length of 6 m including a 4 m long wing extending from the net mouth to intercept and guide fish into the enclosure. The fyke nets comprised 25 mm diameter mesh.

2.2.2.3 Minnow trap sampling

Five fine-meshed (5 mm diameter), collapsible minnow traps were also used at each site. Minnow traps were set on the lake bottom, maintained in position with lead weights. Each minnow trap was 36 cm long, 15 cm in width and height, and square in cross section. Three traps had 55 mm diameter entrances, while two were 25 mm in diameter.

2.2.3 FISH PROCESSING

Fish were killed immediately following their removal from the nets, by either a sharp blow to the head or by the administration of a lethal dose of benzocaine. Fish were then placed in plastic bags labelled with net type, net number and mesh size, and then immediately placed in crushed ice. Upon reaching the laboratory the fish were weighed on an electronic balance, and fork-length was measured.

The visceral cavity of each fish was opened by making a mid-ventral incision from the anal pore forward. The stomach was then removed for the analysis of diet and preserved in a 10% formalin solution. The gonads were removed, weighed, and then used for sex determination. The fish were then placed in individually coded plastic bags and frozen. The appropriate structure for aging each species of fish was then removed when required.

2.2.4 FISH AGING

Age and growth rates were established for perch and rudd. Back-calculation of fish length involved the use of both the body proportional (BPH), and scale proportional (SPH) hypotheses (Francis 1990). Non-linear regression equations were used (due to the better r^2 fit to the data) for both perch and rudd.

The following equation was used for back-calculation:

$$L_i = (S_i/S_c)^v L_c$$

Where: S_c=scale radius (mm) at capture;

L_c=fork length (mm) at capture;

S_i=scale radius (mm) at the time of formation of the ith scale mark;

L_i=fork length (mm) at the time of formation of the ith scale mark; and

v=constant calculated from the scale/operculum-length relationship.

From Francis, 1990 (attributed to Monastyrsky 1930).

2.2.4.1 Rudd

Scales were used to establish rudd ages (Wise 1990). Scales were removed directly below the leading edge of the dorsal fin and above the lateral line (Figure 2.2). Replacement scales were discarded. At least eight scales were removed from each fish. Scales were cleaned with a damp tissue and then placed between two glass microscope slides and secured at each end with tape.

Scales were viewed on a microfiche projector (Minolta RP50 Microfilm Reader Printer) and prints of several scales for each fish were made. Measurements were made from the focus to the middle of the anterior edge of the scale margin, and the position of each consecutive annual check was noted (Plate 3). The average measurements of three scales were recorded for each fish.

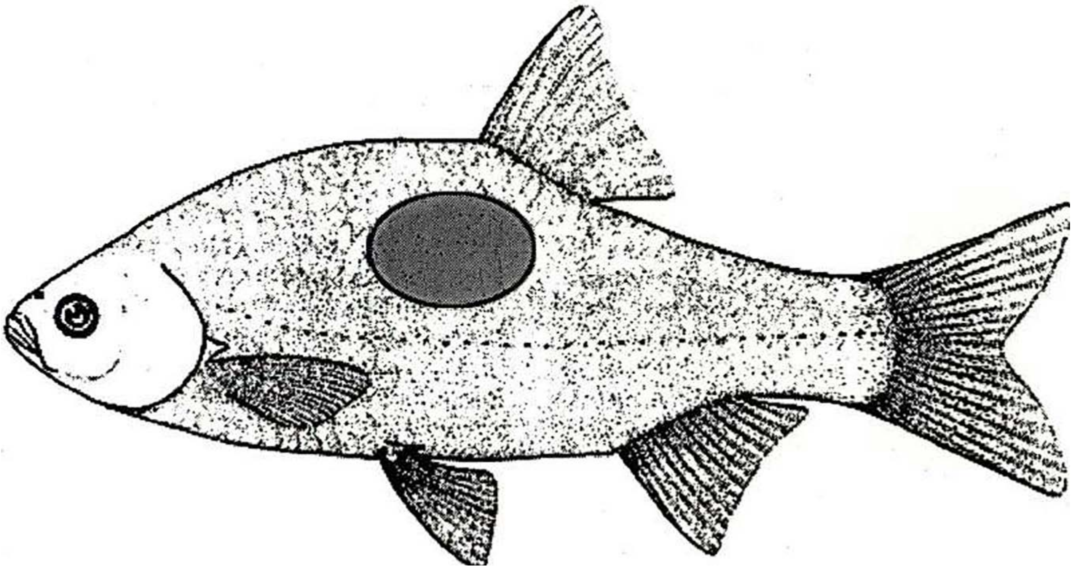


Figure 2.2: Position of scales removed for the aging of rudd (after McDowall 1990).

2.2.4.2 Perch

Opercular bones, which cover and protect the gills (Figure 2.3), were used for the aging of perch (established by Le Cren, 1947). The opercular bone is broad and flat and when dried usually shows clear growth rings.

The opercular bone was removed from both sides of the head by cutting along the anterior edge of the operculum with scissors and twisting the bone to remove it from its articulation with the skull (Le Cren 1947). The bones were placed in boiling water, and then cleaned with paper towels. The bones were then stored and allowed to dry, before viewing under a microfiche projector. Copies were made with this projector and measurements were made from the focus (point of greatest thickness) along a radius at a 30° angle to the opercular spine (Plate 4). If two opercular spines existed the outer-most spine was used.

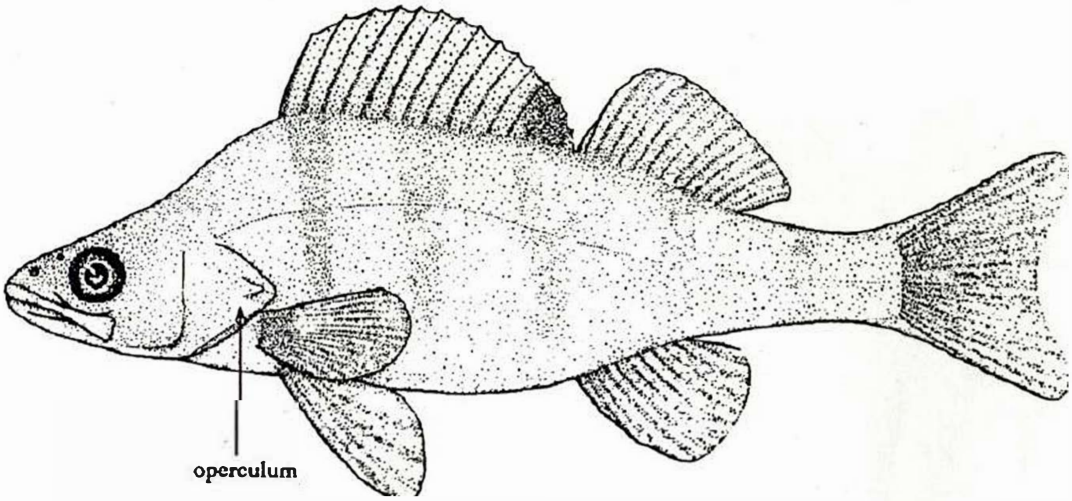


Figure 2.3: Perch showing position of the operculum removed for age determinations (after McDowall 1990).

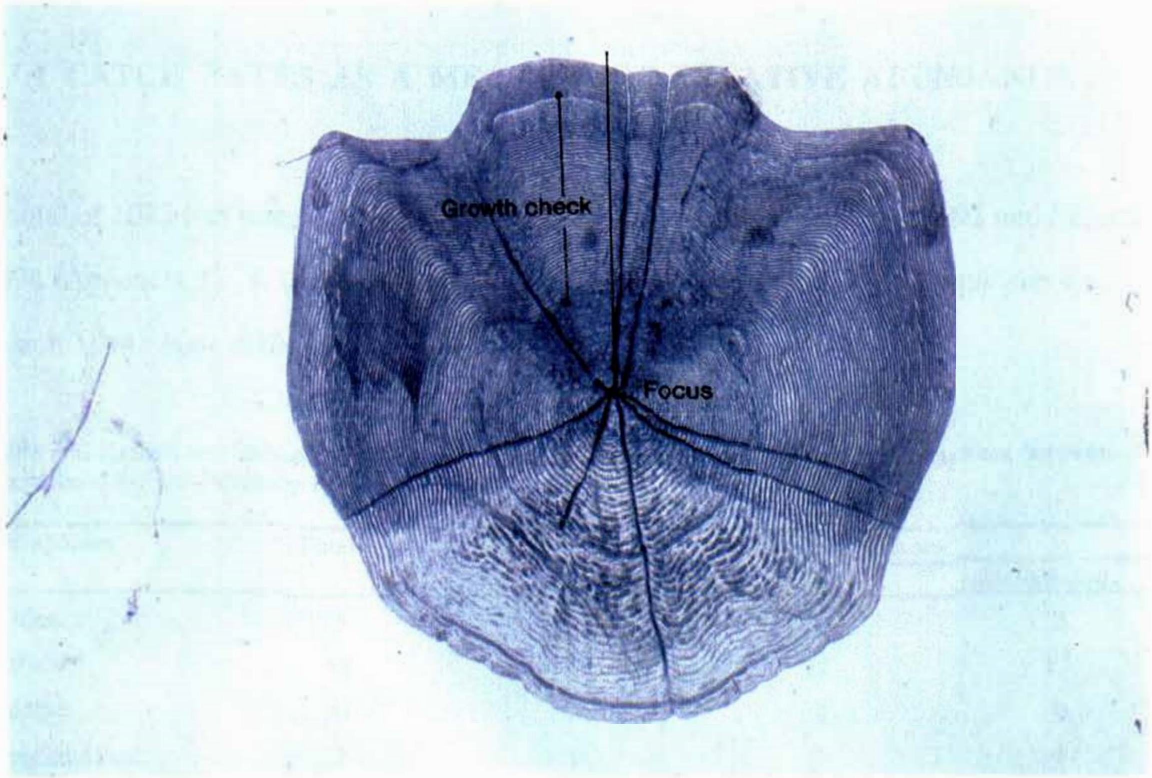


Plate 3: Diagram of a rudd scale, with the radius along which measurements were taken for back-calculation of length.

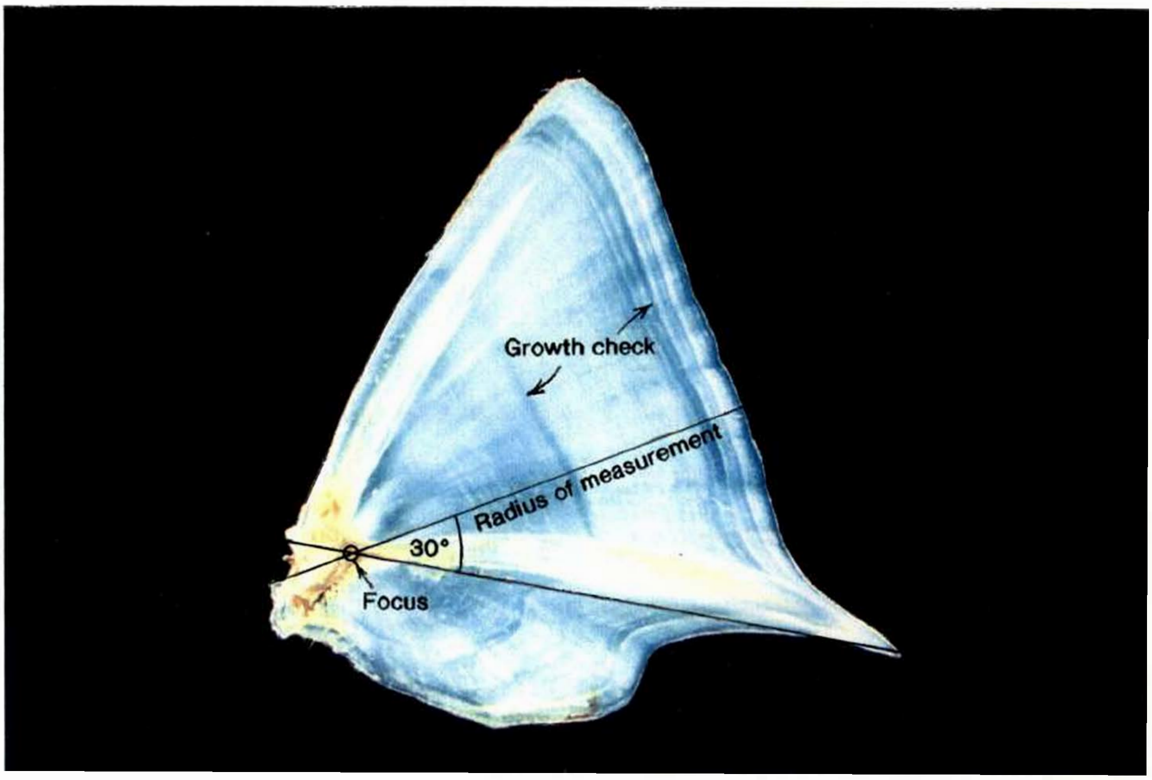


Plate 4: Diagram of a perch opercular bone, with the radius along which measurements were taken for back-calculation of length.

2.3. RESULTS

2.3.1 CATCH RATES AS A MEASURE OF RELATIVE ABUNDANCE

A total of 1073 fish were caught from 11 netting sites between December 1993 and February 1994 (Appendix 1). A further 69 fish were caught in a second setting at sample site 4 in March 1994. Nine different species of fish were caught (Table 2.3).

Table 2.3: Species and frequencies of fish caught in Hamilton Lake at the eleven sampling sites between December 1993 and February 1994.

Fish species	Total	Number of fish of each sex		
		female	male	undetermined
Bullies	3	0	0	3
Catfish	78	37	28	13
Goldfish	24	16	8	0
Longfinned eel	1	0	0	1
Mosquitofish	39	0	0	39
Perch	485	338	139	8
Rudd	308	154	151	3
Shortfinned eel	78	0	0	78
Tench	57	26	31	0
Total	1073	571	357	145

2.3.1.1 Gill net Catches

Three gill nets were set overnight at each of the 11 sampling sites between December 9 1993 and February 2 1994. A total of 120 m of gill net was set for an average of 15.6 hours per night, giving a total of 515.1 hours. Catch per unit effort (CPUE), expressed as number of fish caught per 100 metres of net per hour of fishing, is a measure of relative abundance of fish in the lake.

Catch rates were highest in 38 mm and 56 mm mesh sizes. Perch had the highest catch rate of any fish species caught in gill nets, followed by rudd. Catfish, tench, and goldfish had relatively low catch rates (Table 2.4).

Table 2.4: Catch rates for each fish species caught in Hamilton Lake between December 9 1993 and February 2 1994.

Mesh size (mm)	Catch per unit effort (fish h^{-1} 100 m^{-1} of net)					Total length of net (m)
	catfish	goldfish	perch	rudd	tench	
25	0.000	0.000	0.001	0.000	0.000	198
38	0.017	0.000	0.170	0.149	0.000	264
56	0.018	0.001	0.146	0.039	0.000	264
84	0.003	0.008	0.001	0.002	0.002	264
106	0.001	0.006	0.001	0.000	0.019	330
All sites combined	0.008	0.003	0.064	0.038	0.005	1320

Relative fish abundance showed considerable variation between sampling sites (Table 2.5 and Appendix 2). Few fish were caught at sampling sites 9, 10, and 11 (refer to Figure 2.1 for location of sites), probably due to oxygen limitations at the time of sampling (refer section 2.3.1.5). High catches of catfish and tench were recorded at site 7. Goldfish catches were low throughout the lake. Catches of perch and rudd were consistently high. Rudd were most abundant at sites 6 and 7, while perch were most abundant at sites 5 and 6. Results from CPUE analysis indicate that sampling sites on the western side of the lake (sites 5, 6, and 7) had the highest catch rates.

Table 2.5: Catch rate of fish caught in gill nets at 11 sampling sites in Hamilton Lake, between December 1993 and February 1994.

Sample site	Catch per unit effort (fish h^{-1} 100 m^{-1} of net)					
	catfish	goldfish	perch	rudd	tench	total
1	0.046	0.055	0.600	0.446	0.062	1.210
2	0.172	0.052	0.748	0.430	0.056	1.458
3	0.051	0.098	0.780	0.356	0.041	1.326
4	0.016	0.016	0.879	0.566	0.117	1.595
5	0.000	0.045	1.541	0.398	0.073	2.056
6	0.048	0.013	1.362	0.978	0.016	2.417
7	0.371	0.000	0.553	0.947	0.119	1.990
8	0.171	0.065	0.701	0.051	0.014	1.003
9	0.000	0.000	0.126	0.230	0.000	0.356
10	0.000	0.000	0.000	0.021	0.000	0.021
11	0.075	0.020	0.217	0.079	0.016	0.406

2.3.1.2 Fyke net catches

Three fyke nets were set overnight (averaging 16.2 h per night) at each of the 11 sampling sites, giving a total of 536.2 h. Fyke net CPUE is expressed as number of fish caught per hour per net.

Shortfinned eel had the highest catch rates of any fish species caught in fyke nets, followed by perch and rudd. Fyke nets also caught relatively high numbers of both catfish and tench. Goldfish and longfinned eel had low catch rates. Sampling site 7 had highest fyke net catch rates for catfish, rudd, and shortfinned eel. Perch and tench had highest fyke net catch rates at sampling site 4 (Table 2.6).

Table 2.6: Mean catch rate of fish caught in 3 fyke nets set at each of 11 sample sites in Hamilton Lake between December 1993 and February 1994.

Sampling site	Mean catch per unit effort (fish h^{-1} net^{-1})						
	catfish	goldfish	longfinned eel	perch	rudd	shortfinned eel	tench
1	0.035	0.000	0.000	0.035	0.018	0.053	0.018
2	0.024	0.000	0.000	0.192	0.072	0.048	0.000
3	0.038	0.000	0.000	0.038	0.038	0.056	0.094
4	0.093	0.000	0.000	0.241	0.111	0.093	0.185
5	0.039	0.000	0.000	0.078	0.020	0.176	0.020
6	0.036	0.000	0.000	0.198	0.126	0.126	0.000
7	0.247	0.000	0.000	0.123	0.432	0.782	0.082
8	0.000	0.019	0.019	0.039	0.097	0.097	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.025	0.000	0.099	0.000
All sites combined	0.048	0.002	0.002	0.091	0.086	0.142	0.039

2.3.1.3 Net selectivity

The majority of fish were caught in gill nets (Table 2.7). Gill nets were found to be effective for the capture of adult perch, rudd, catfish, and tench, with 90%, 84%, 67%, and 63% of the total catch respectively. Fyke nets were most successful in the capture of eels, but also caught relatively high numbers of both catfish (33%) and tench (37%). Fine-meshed minnow traps, set primarily for the capture of juvenile fish, proved to be relatively unsuccessful. A few mosquitofish and bullies were caught in these traps.

Table 2.7: Number of fish captured in nets of different types in Hamilton Lake between December 1993 and February 1994.

Fish species	Number of fish caught in each net type			
	Fyke	Gill	Minnow	Total
Bullies	0	0	3	3
Catfish	26	52	0	78
Goldfish	1	23	0	24
Longfinned eel	1	0	0	1
Mosquitofish	0	0	39	39
Perch	49	436	0	485
Rudd	46	259	3	308
Shortfinned eel	76	0	2	78
Tench	21	36	0	57
Total	220	806	47	1073

2.3.1.4 Mesh size selectivity of gill nets

There appears to be a linear relationship between gill net mesh size and mean fish size caught, with larger mesh sizes catching larger fish (Figure 2.4). The low catch rate of some species in certain mesh sizes is the most likely explanation for outlying values.

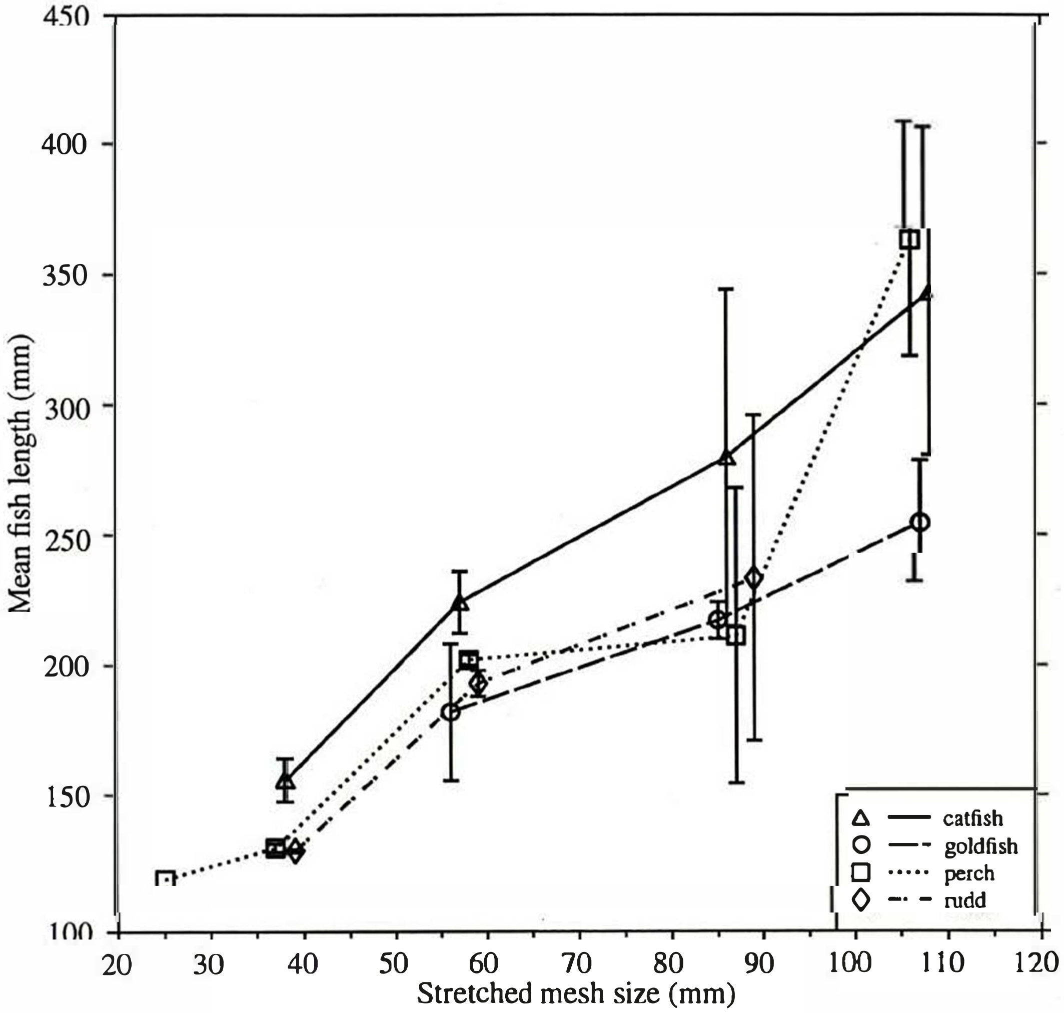


Figure 2.4: Selectivity of gill net mesh of different sizes, for the capture of catfish, goldfish, perch, and rudd in Hamilton Lake (error bars show 95% confidence intervals).

2.3.1.5 Water quality

During the period of fish sampling, the waters of Hamilton Lake showed thermal stratification (Figure 2.5). The deeper cooler waters were completely deoxygenated in places, and would most likely have limited the distributions of fish in the lake at the time of sampling.

2.3.2 FISH POPULATION CHARACTERISTICS

2.3.2.1 Length-frequency distributions

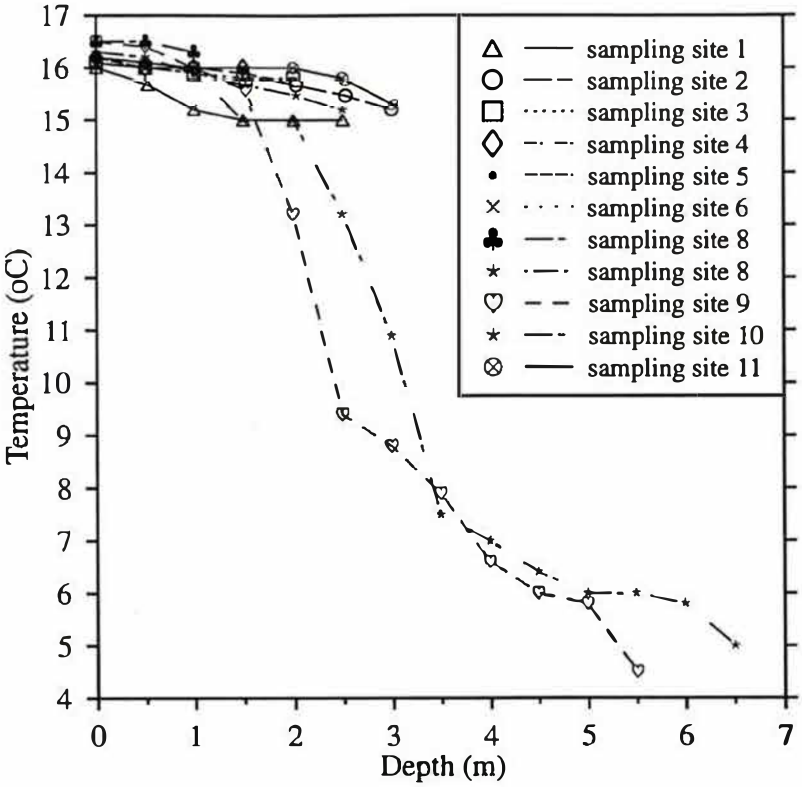
The length-frequency distributions of fish caught in the Hamilton Lake are shown in Figure 2.6. The length-frequency data shows the absence of juvenile fish (<100 mm in length) in all fish species illustrated. This is particularly obvious with tench where there is an absence of small fish with a fork length <310 mm.

High proportions of small perch were recorded at sampling sites 3, 4, and 6, with the latter having particularly high proportions (Figure 2.7). Larger sized perch were proportionally more abundant at sampling site 5.

Rudd show a relatively even length-frequency distribution between sampling sites (Figure 2.8), although a higher proportion of small length rudd were recorded at sampling site 6.

2.3.2.2 Sex ratios

For all sites combined, length frequencies of fish species for which sex could be determined showed that rudd had relatively equal numbers of both male and female, though the largest



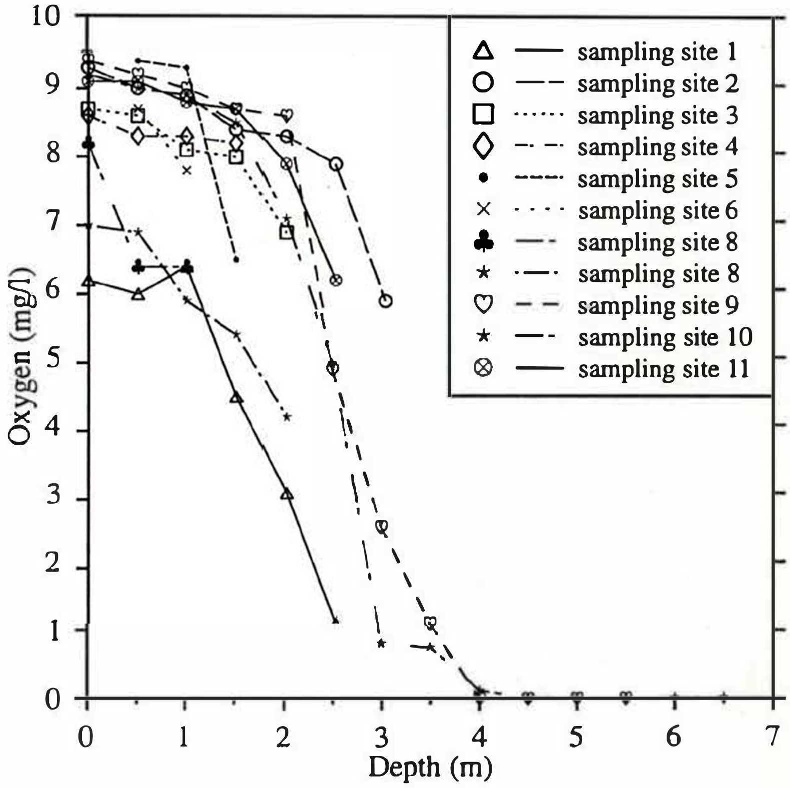


Figure 2.5: Oxygen depth and temperature depth profiles in Hamilton Lake (14 February 1994)

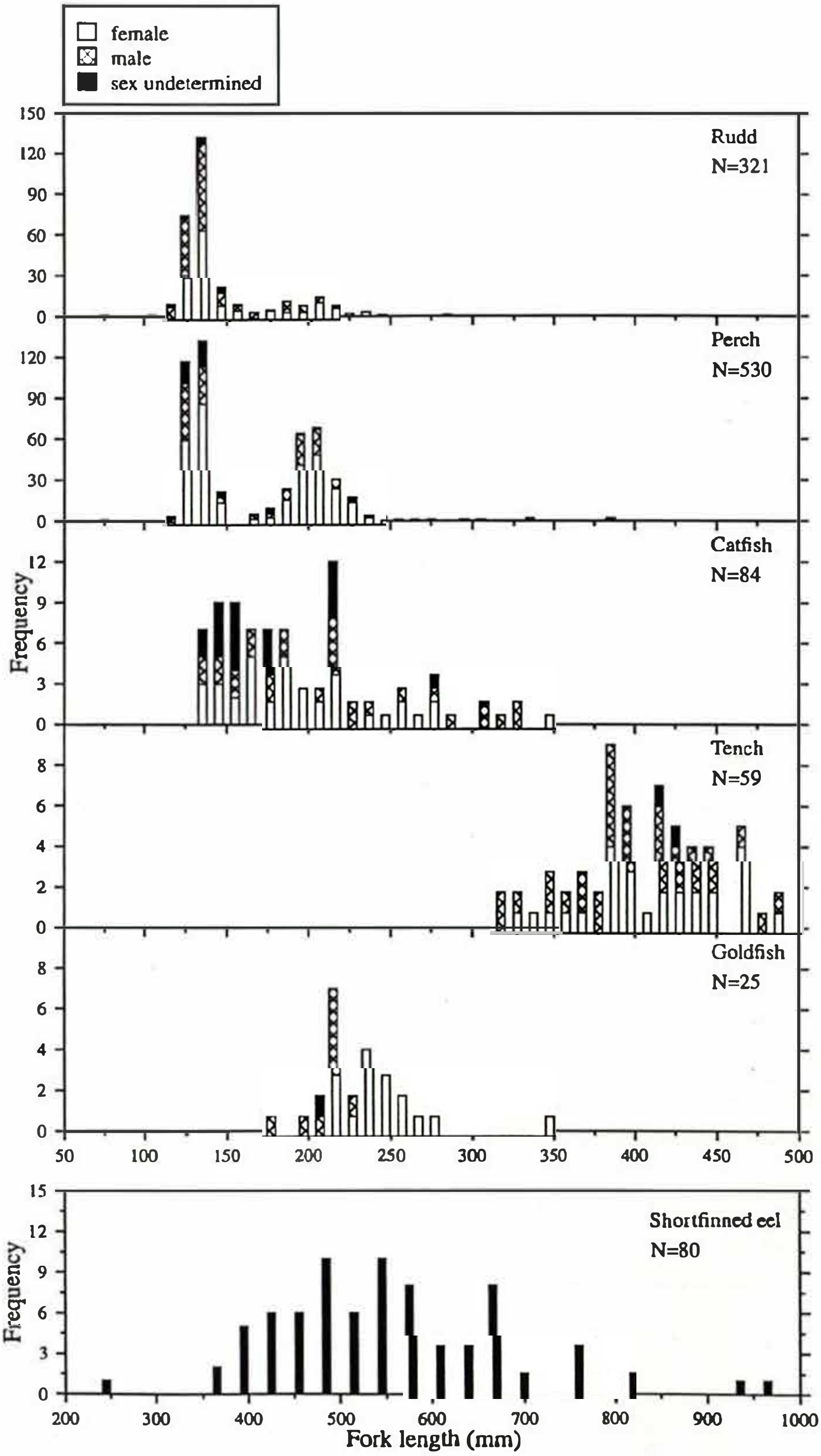


Figure 2.6: Length-frequency distribution of fish caught in Hamilton Lake between December 1993 and March 1994.

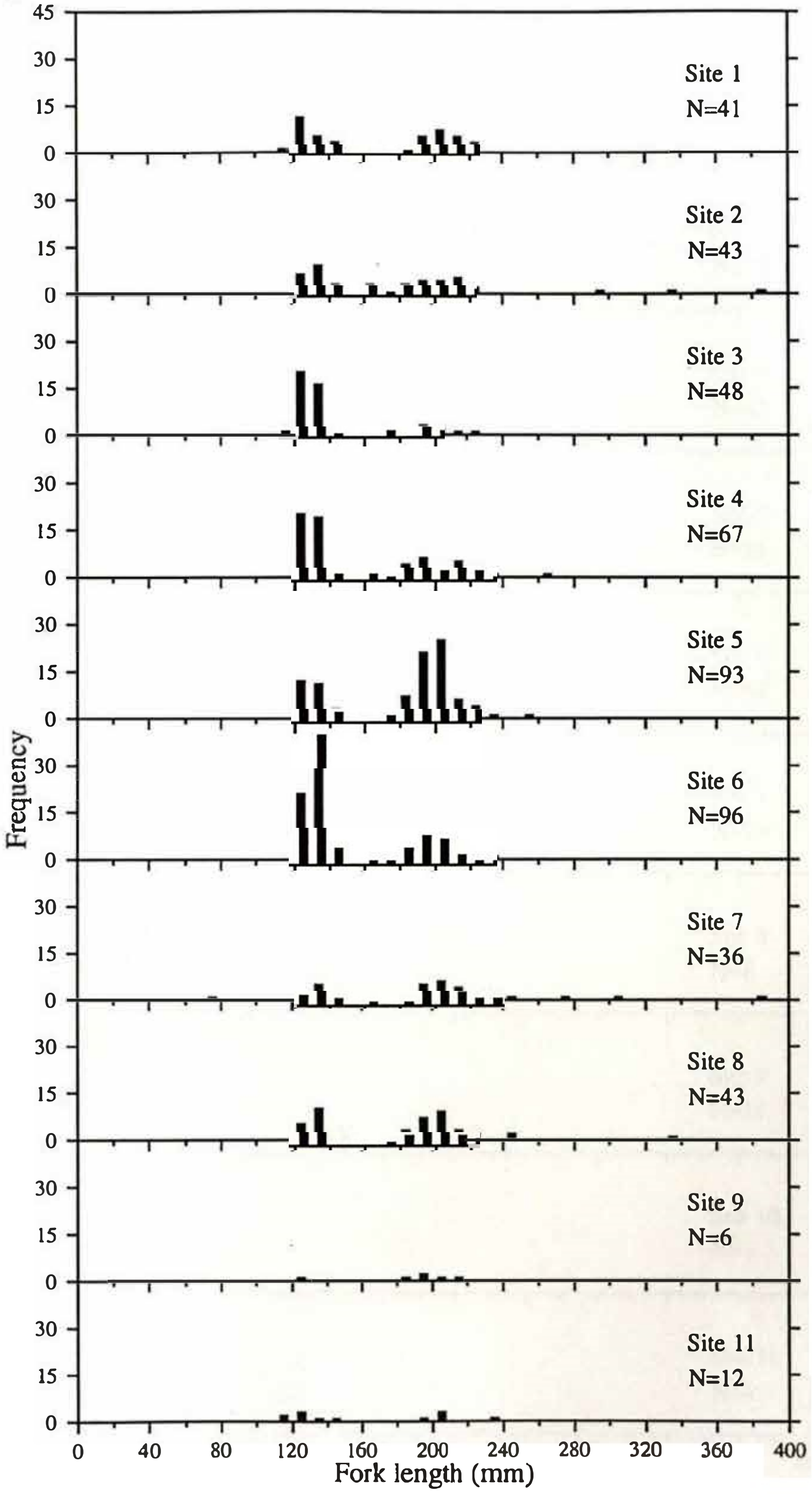


Figure 2.7: Length-frequency distribution of perch caught at different sampling sites in Hamilton Lake between December 1993 and March 1994.

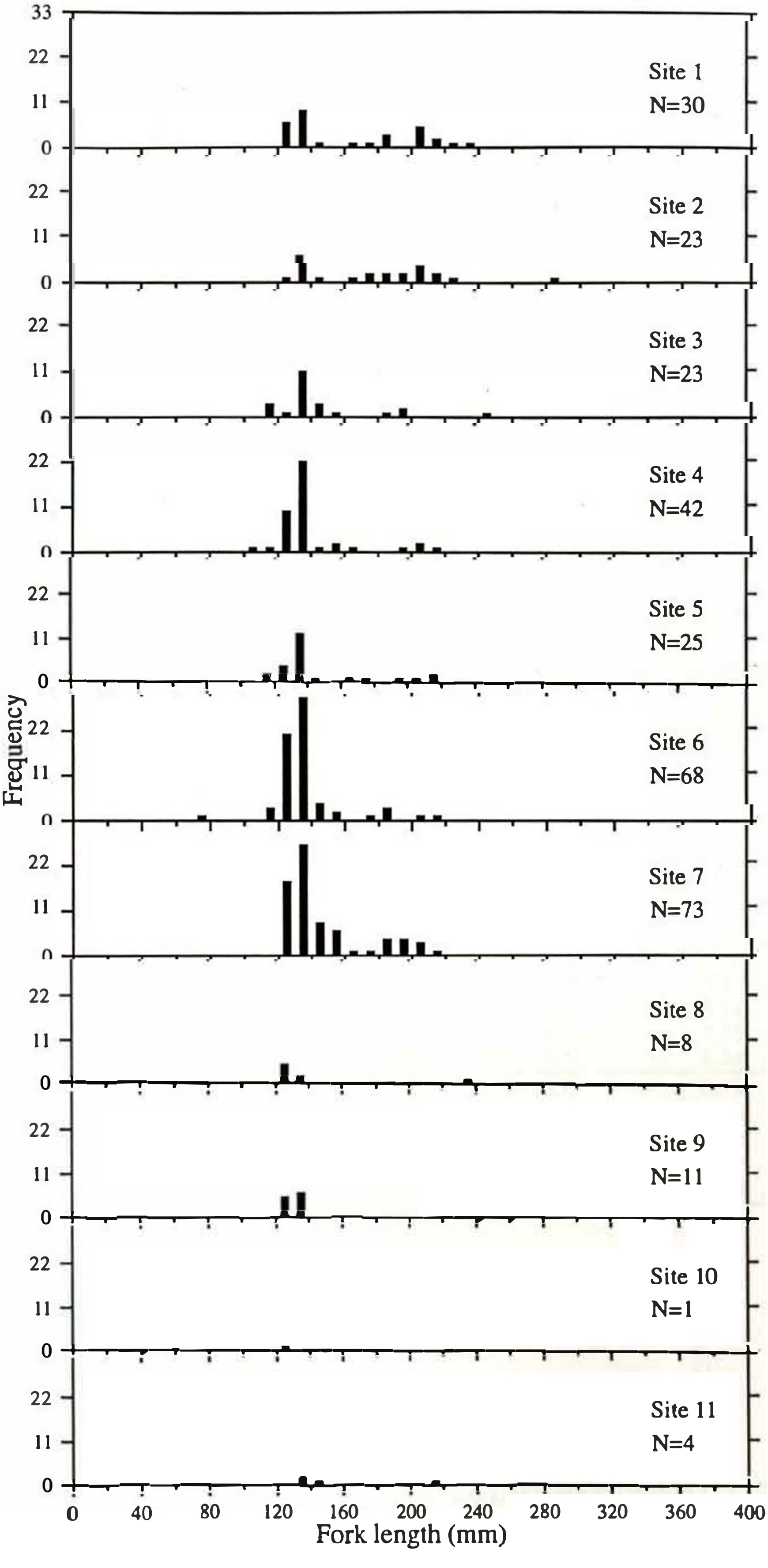


Figure 2.8: Length-frequency distribution of rudd caught at different sampling sites in Hamilton Lake between December 1993 and March 1994.

rudd were most commonly female (Table 2.3, Figure 2.6). Female perch were considerably more abundant than males with a ratio of 2.4:1. Female perch are most highly represented in the larger length classes. Goldfish females outnumber the males by a ratio of 2:1 with females comprising the largest fish. Catfish and tench both have relatively even distributions of both sexes.

2.3.2.3 Gonadosomatic index

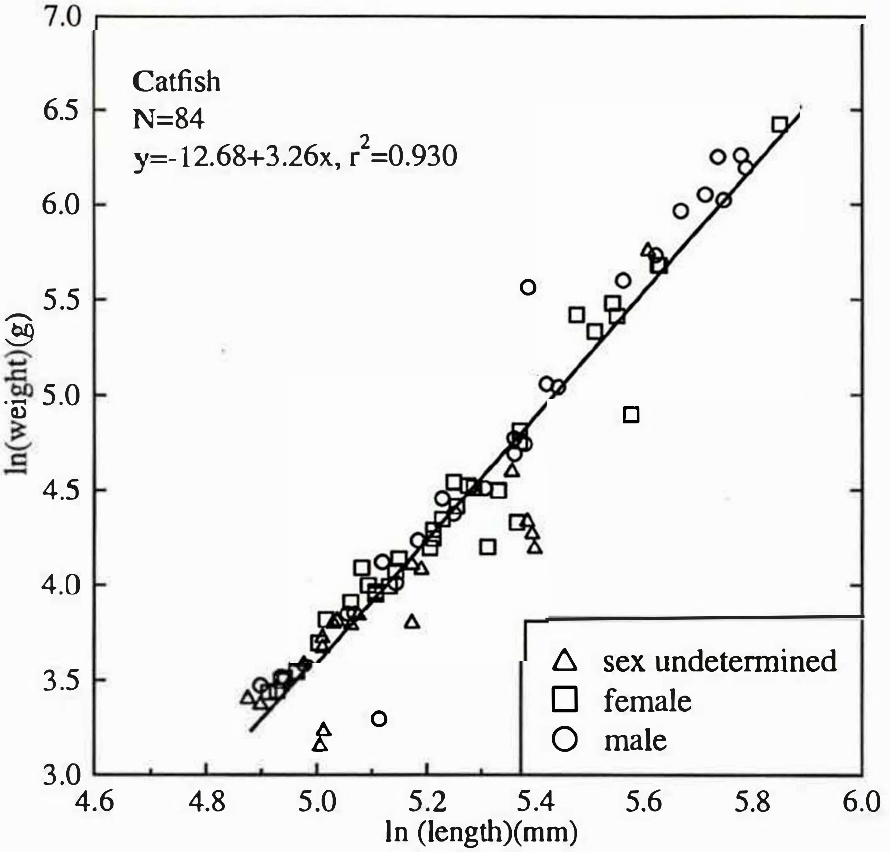
Gonad development was studied using the calculation of the gonadosomatic index (GSI) (Table 2.8), where gonad weight is expressed as a percentage of total body-weight (Jellyman 1980). GSI results indicate that the mean gonad size is larger in females than in males. This is particularly pronounced in goldfish where the mean GSI in females is more than three times that of males.

Table 2.8: Gonadosomatic Index (GSI) of fish caught in Hamilton Lake between December 1993 and February 1994.

Sex	Fish species	Number	Mean	Standard deviation	Maximum	Minimum
Male	catfish	28	0.16	0.12	0.48	0.03
	goldfish	8	3.34	1.59	6.61	0.87
	perch	139	0.76	0.78	7.14	0.04
	rudd	151	2.64	1.40	7.45	0.17
	tench	31	0.56	0.29	1.24	0.04
Female	catfish	37	0.30	0.17	0.72	0.04
	goldfish	16	11.32	5.89	22.23	3.81
	perch	338	0.98	0.75	6.53	0.04
	rudd	154	4.74	2.69	15.77	0.37
	tench	26	5.99	2.68	11.39	0.65

2.3.2.4 Length-weight relationships

Length-weight relationships of fish caught in the Hamilton Lake are illustrated in Figures 2.9-2.12. The coefficients of the linear equations for the length-weight relationships are shown in Table 2.9. Due to the low r^2 value for goldfish and the low catches of longfinned



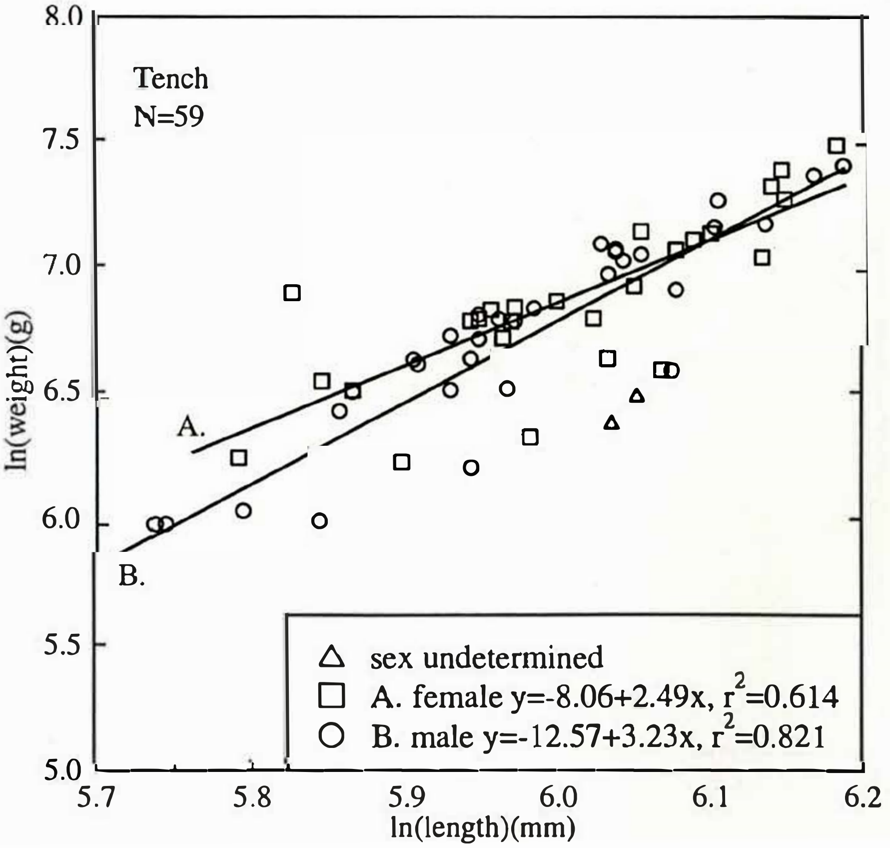
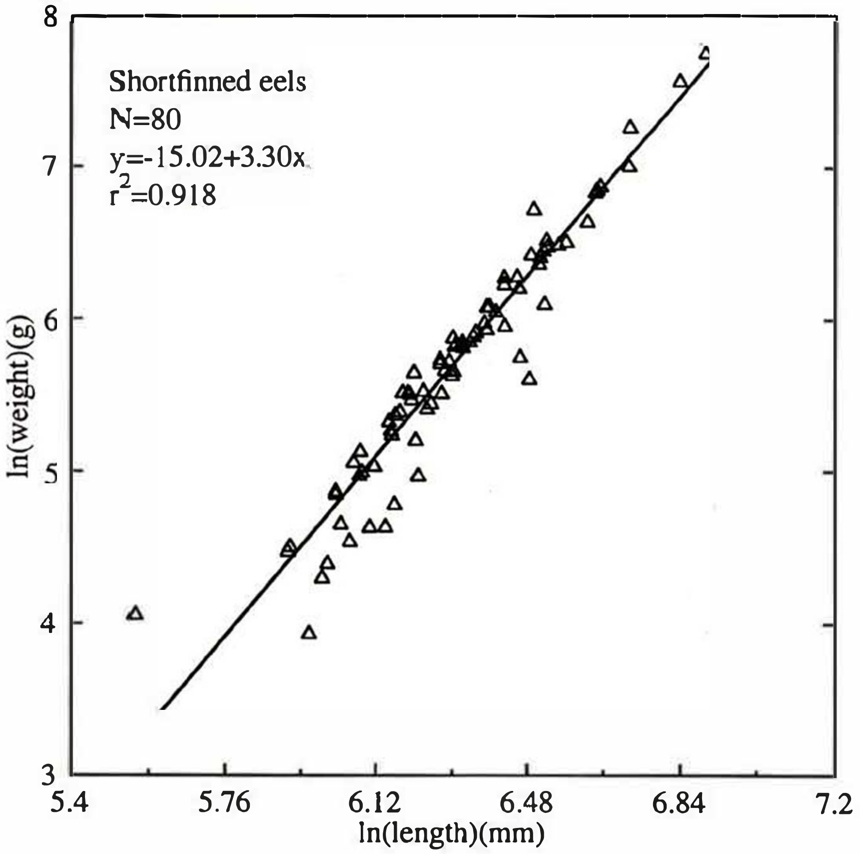


Figure 2.9: Length-weight relationships of catfish and tench caught in Hamilton Lake between December 1993 and March 1994.



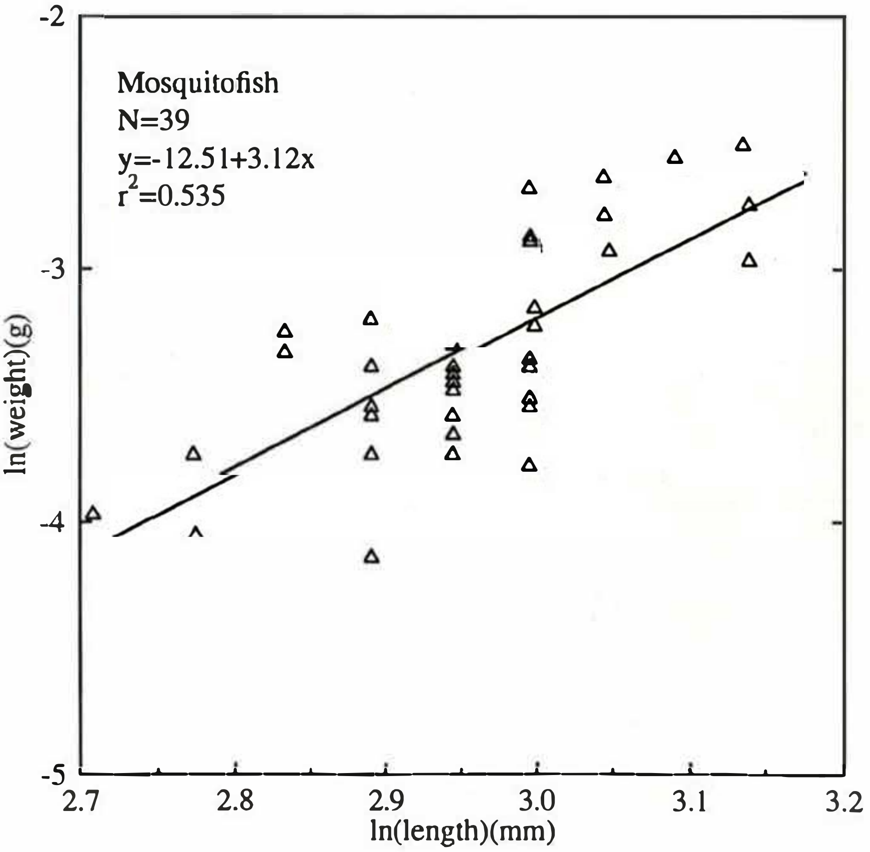


Figure 2.10: Length-weight relationships of shortfinned eel and mosquitofish caught in Hamilton Lake between December 1993 and March 1994.

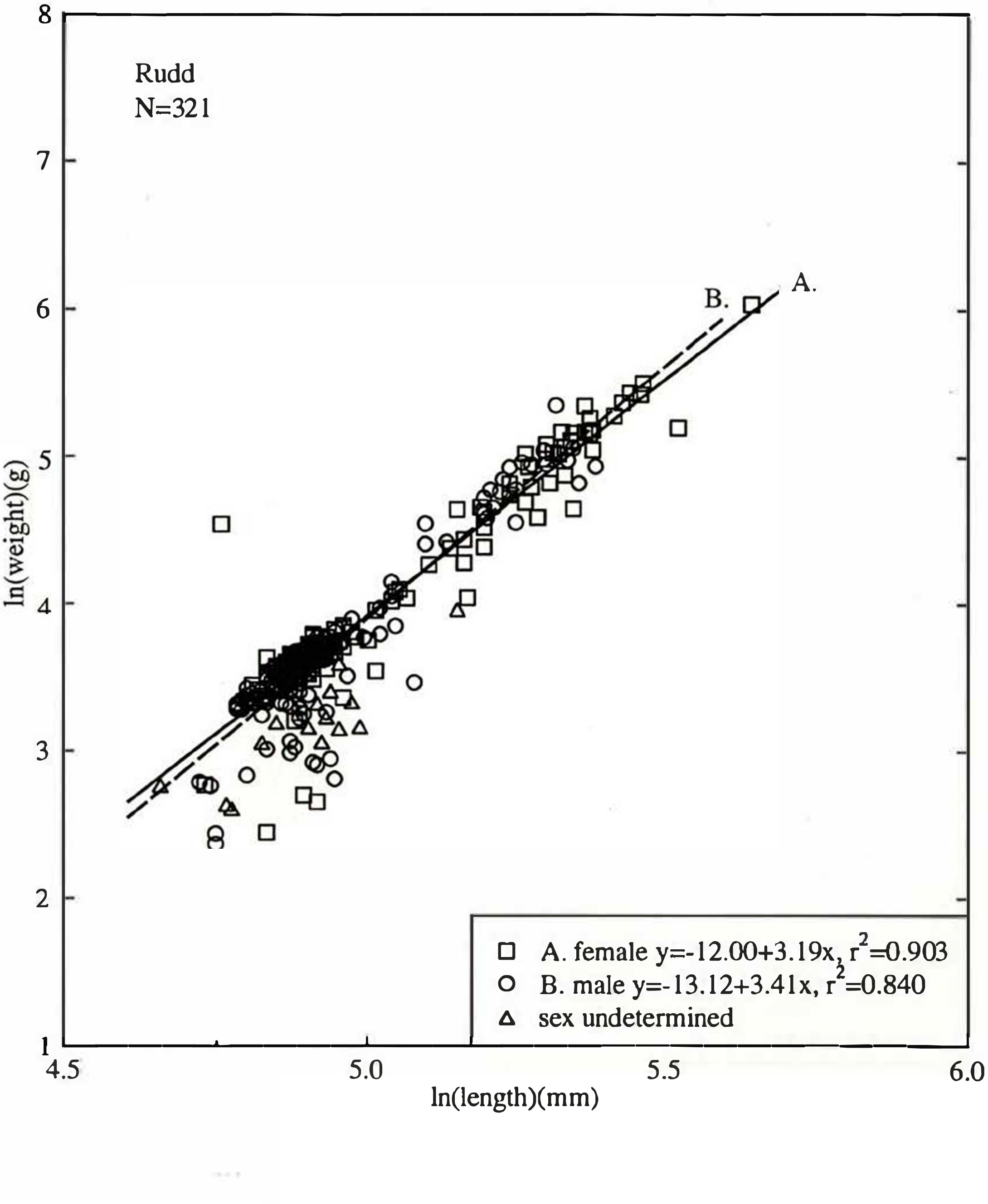


Figure 2.11: Length-weight relationships of rudd caught in Hamilton Lake between December 1993 and March 1994.

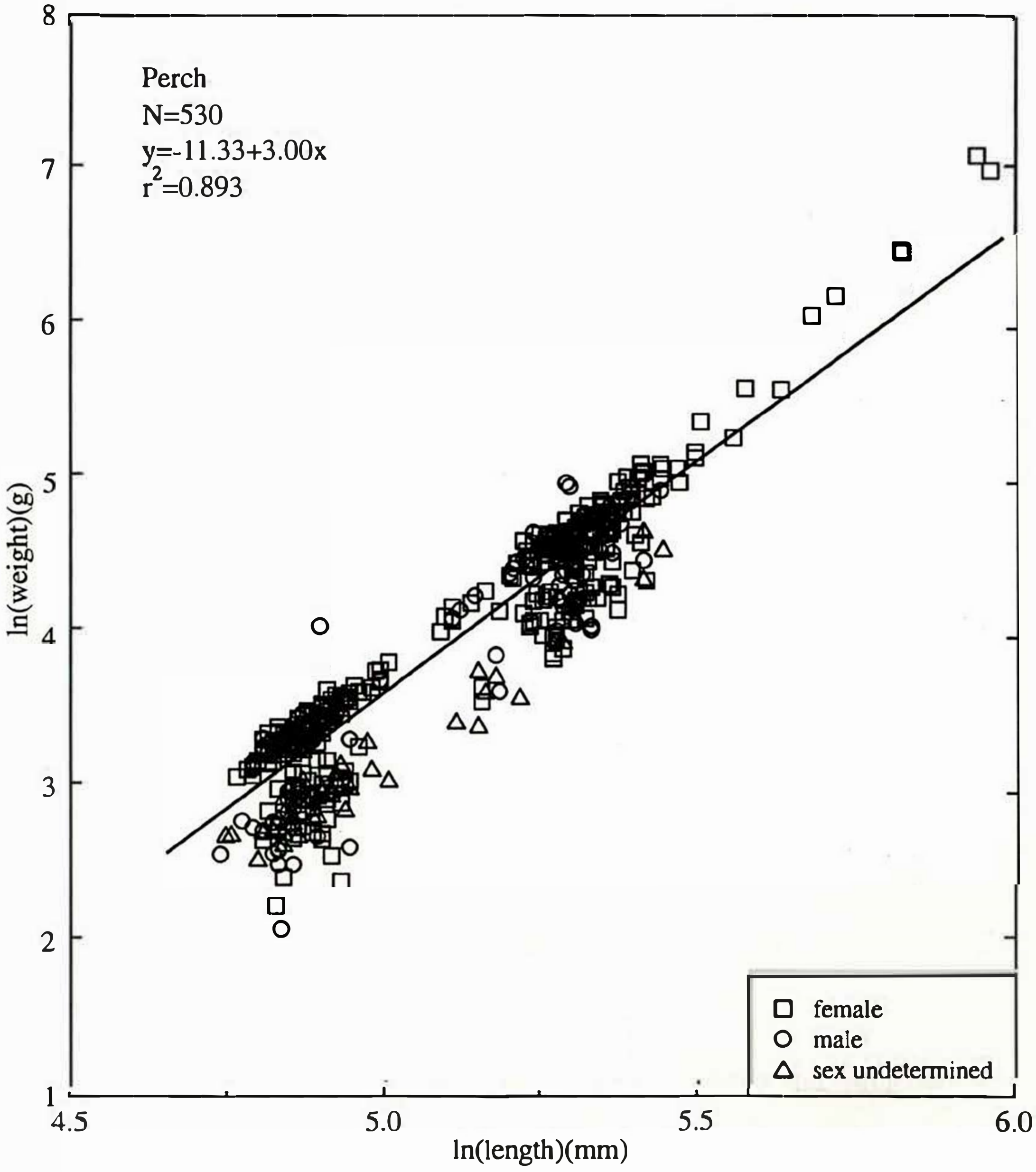


Figure 2.12: Length-weight relationships of perch caught in Hamilton Lake between December 1993 and March 1994.

eel and bullies, these species were excluded from this analysis. The results of the analysis of the length-weight data has shown that a significant difference ($p<0.05$) between males and females only existed in rudd and tench populations. In each case males were lighter than females for their length in early stages of life and became heavier for their length during latter stages.

The cause of the relatively low r^2 value for perch was investigated by plotting perch caught at each sampling site separately (Figure 2.13). When this series of regressions had been calculated, it was clear that in general the r^2 values were greater than for all sites combined.

Table 2.9: Coefficients of linear equations [Ln(weight in g)=a+b(Ln(length in mm))] for fish species caught in the Hamilton Lake between December 9 1993 and February 2 1994.

Species	No.	Sex combined			Female			Male		
		a	b	r^2	a	b	r^2	a	b	r^2
catfish	84	-12.68	3.26	0.930	-11.68	3.07	0.947	-13.48	3.42	0.956
mosquito-fish	39	-12.51	3.12	0.535						
perch	530	-11.33	3.00	0.893	-11.39	3.01	0.902	-11.11	2.95	0.862
rudd	321	-12.47	3.29	0.884	-12.00	3.19	0.903	-13.12	3.41	0.840
short-finned eel	80	-15.02	3.30	0.918						
tench	59	-10.76	2.93	0.739	-8.06	2.49	0.614	-12.57	3.23	0.821

2.3.2.5 Age and growth rate of rudd

For the age analysis of rudd, a relationship between scale radius and fish length was established. Measurements were taken from 52 rudd, and compared to 42 rudd obtained by Grundy (1993), in the winter of 1993 (Figures 2.14 and 2.15). The latter measurements were found to be significantly different at a 95% confidence interval from those collected during the present study in the summer of 1993/94. This indicates that the relationship between scale radius and fish length may change seasonally, and that a relationship should be determined in winter, at the time of annulus formation. For this reason the scale

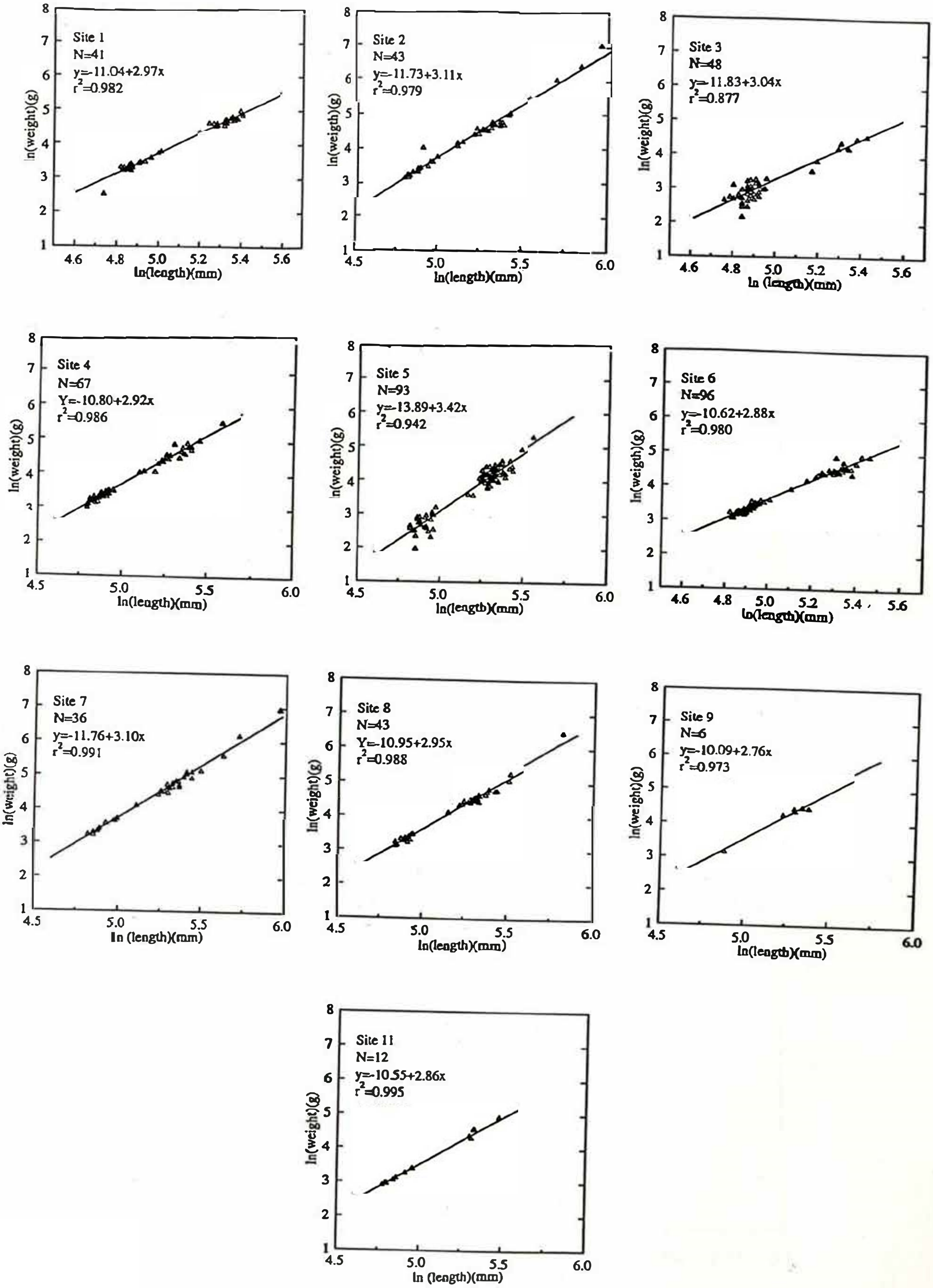


Figure 2.13: Length-weight relationships of perch caught at different sites in Hamilton Lake between December 1993 and March 1994.

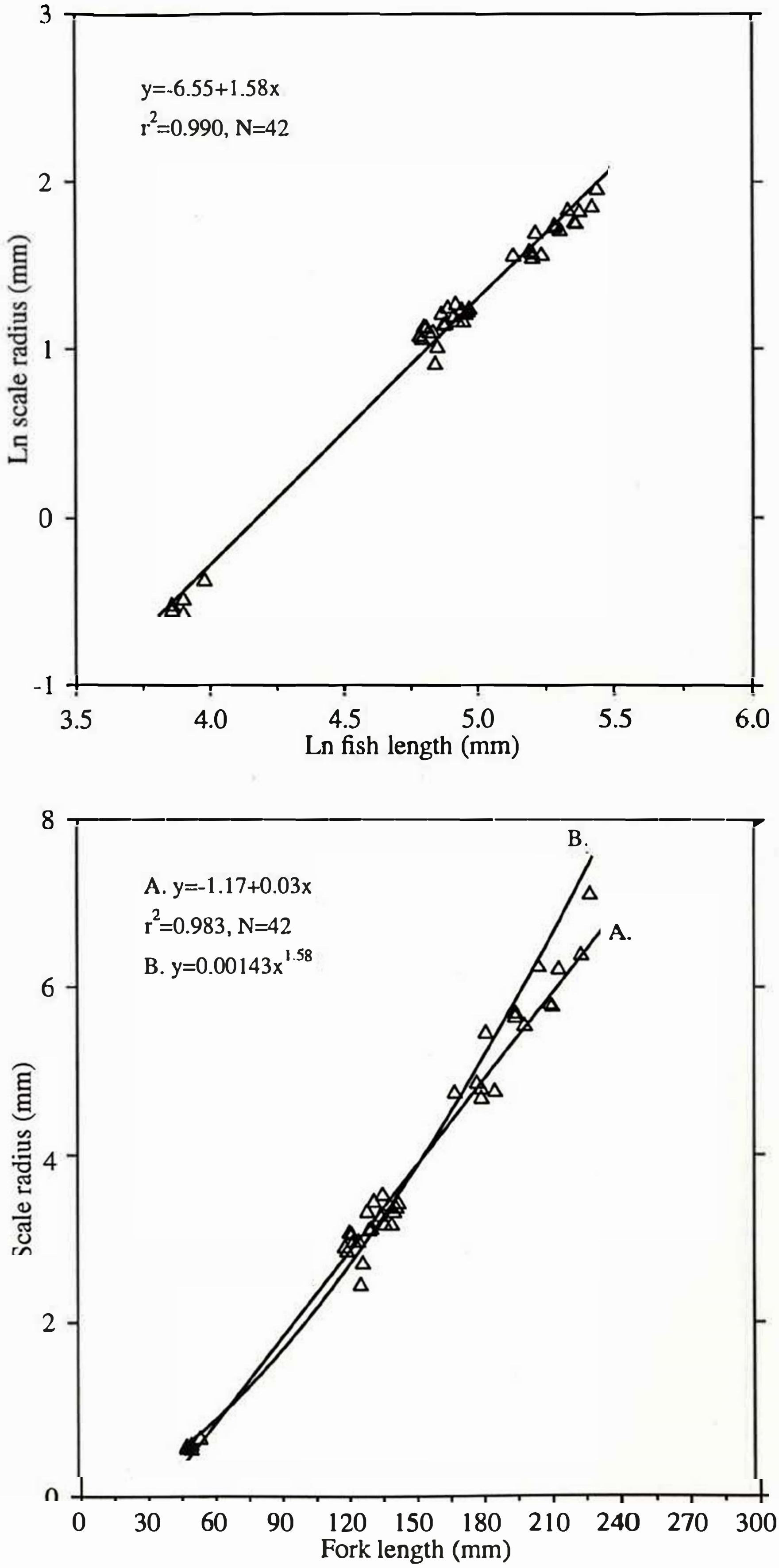
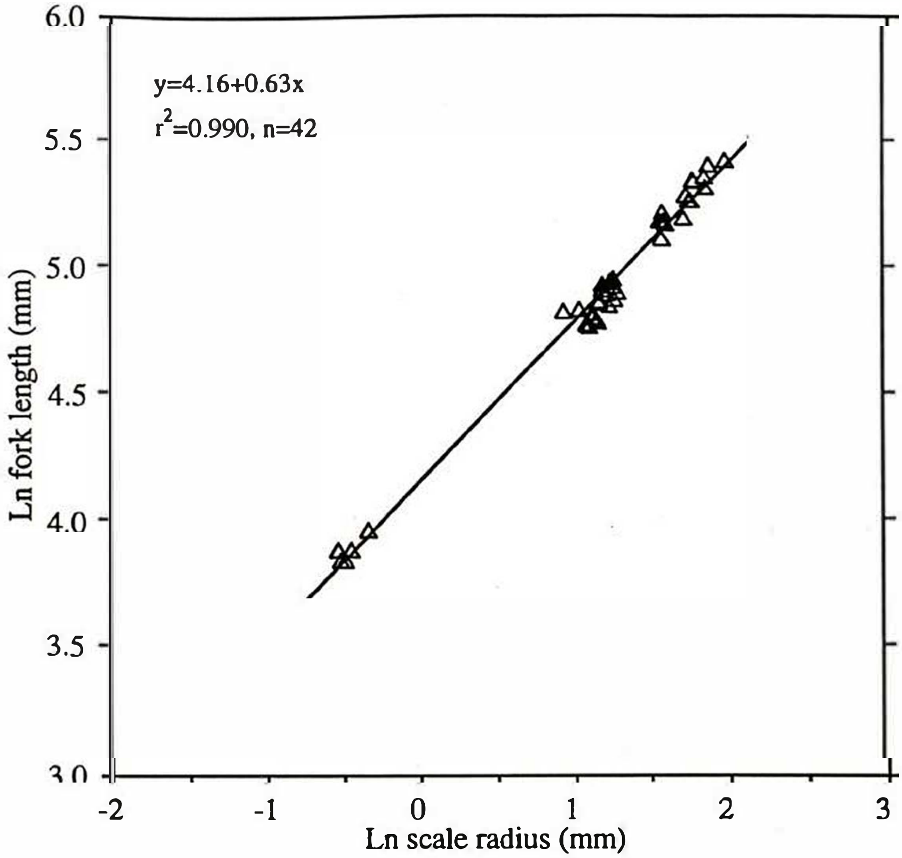


Figure 2.14: Relationship between scale radius and fork length of rudd caught in the winter of 1993 in Hamilton Lake (data from Grundy 1993), using the scale proportional hypothesis (SPH).



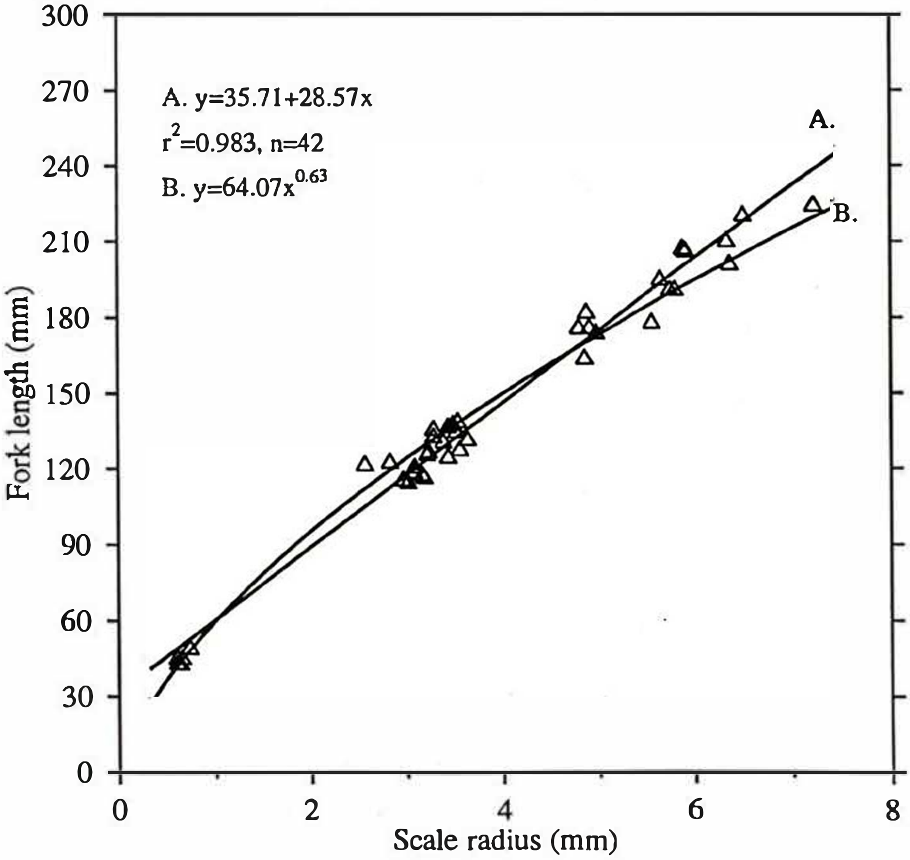


Figure 2.15: Relationship between scale radius and fork length of rudd caught in the winter of 1993 in Hamilton Lake (data from Grundy 1993), using the body proportional hypothesis (BPH).

radius/fish length relationship obtained by Grundy (1993) was used.

Results from both the SPH and BPH indicate the gradual decline in the growth rate of rudd in the Hamilton Lake, which occurred between 1987 and 1992 (Table 2.10). Declines in growth rates are most noticeable in cohorts greater than one year of age (Figures 2.16 and 2.17).

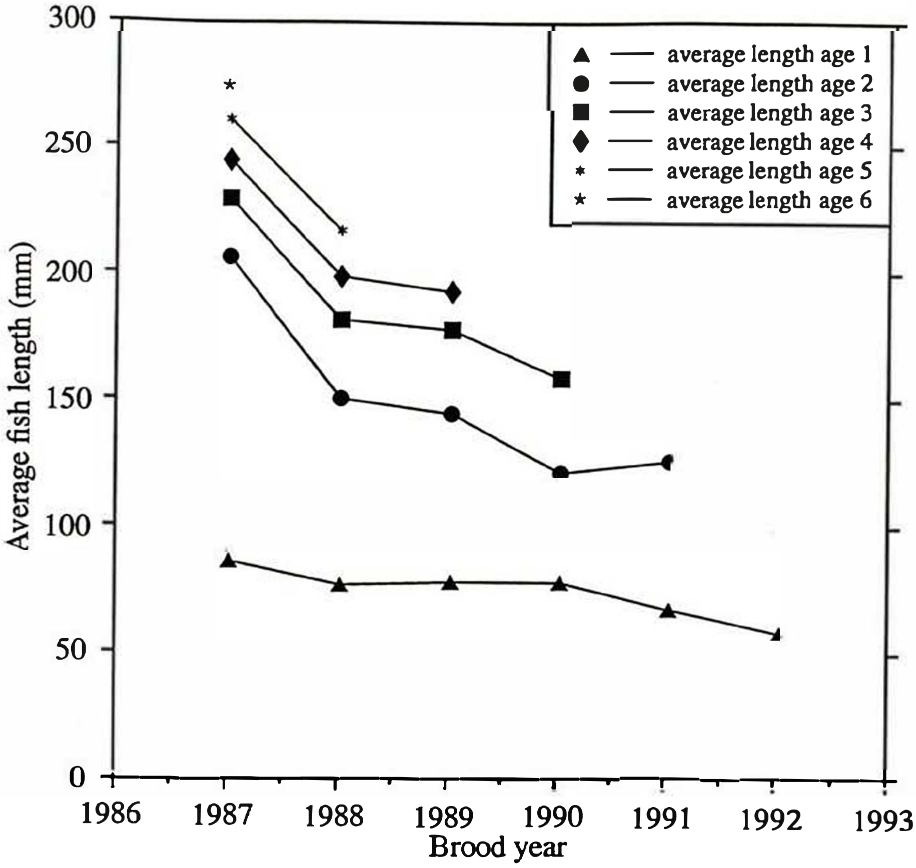
Table 2.10: Back-calculation of rudd lengths using A) the scale proportional hypothesis (SPH), and B) the body proportional hypothesis (BPH).

A)

Brood year	Age at capture	Number of fish	Mean length at age					
			Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
1987	6+	1	87	207	230	245	261	274
1988	5+	9	78	151	182	199	217	
1989	4+	8	79	145	178	193		
1990	3+	13	79	122	159			
1991	2+	15	69	127				
1992	1+	4	60					
Mean			74	135	173	199	221	274

B)

Brood year	Age at capture	Number of fish	Mean length at age					
			Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
1987	6+	1	106	224	243	255	266	276
1988	5+	9	89	165	191	205	219	
1989	4+	8	88	156	183	196		
1990	3+	13	83	129	161			
1991	2+	15	73	128				
1992	1+	4	60					
Mean			80	143	178	204	224	276



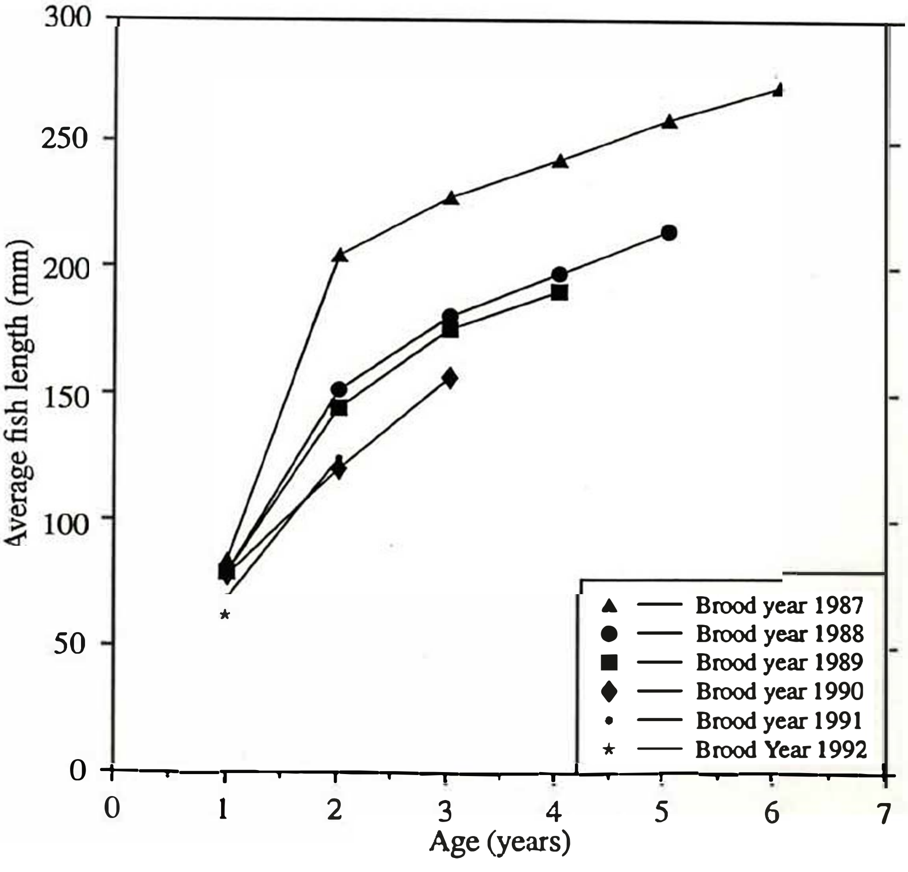
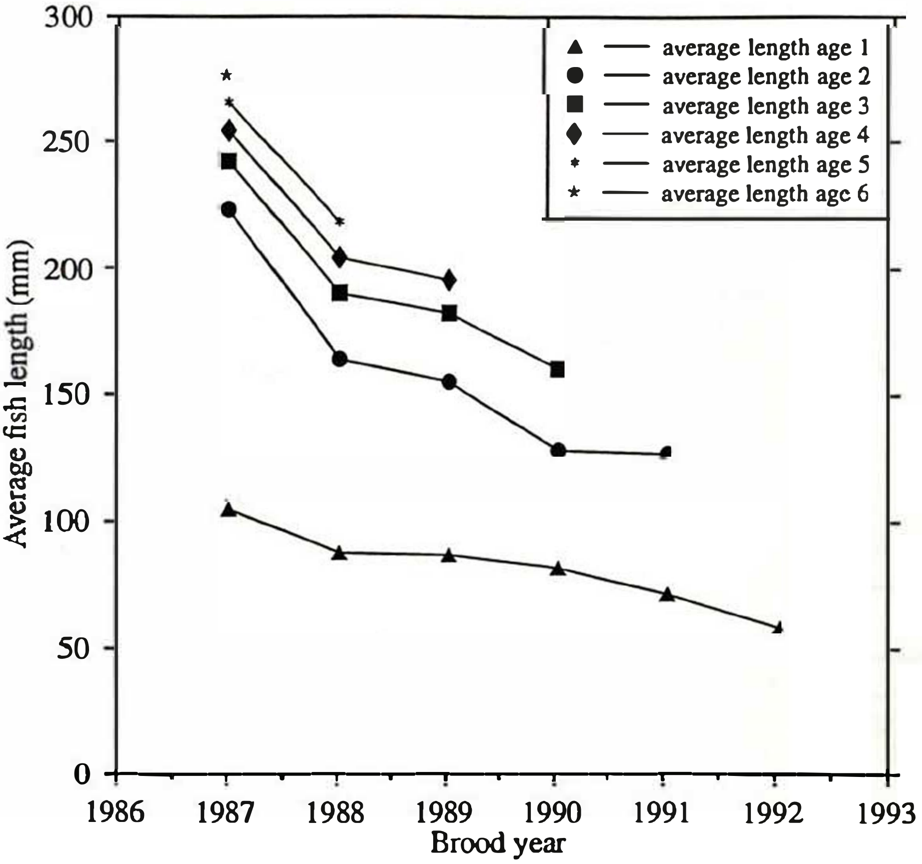


Figure 2.16: Changes in growth rates of rudd with brood year caught in Hamilton Lake using the scale proportional hypothesis (SPH).



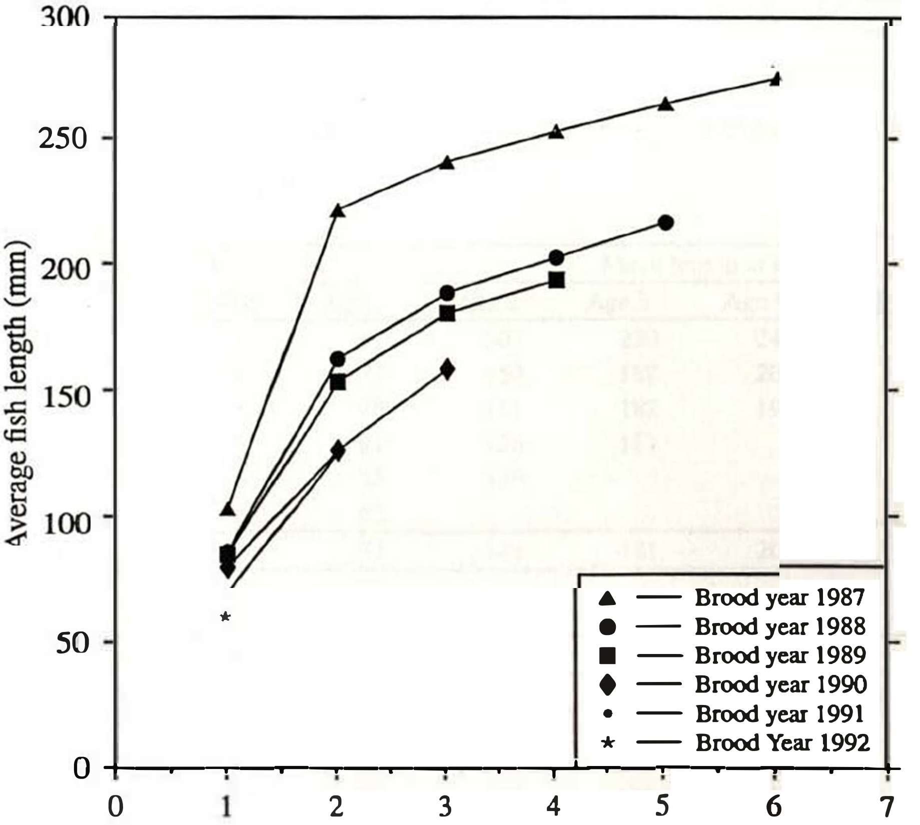


Figure 2.17: Changes in growth rates of rudd with brood year caught in Hamilton Lake using the body proportional hypothesis (BPH).

Both methods of back calculation indicate that growth is more rapid in female rudd than in males (Figure 2.18, Tables 2.11 and 2.12).

Table 2.11: Back-calculation of male rudd lengths using A) the scale proportional hypothesis (SPH), and B) the body proportional hypothesis (BPH).

A)

Brood year	Age at capture	Number of fish	Mean length at age Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
1988	5+	3	79	147	170	186	213	
1989	4+	3	80	137	170	184		
1990	3+	6	76	118	150			
1991	2+	9	66	126				
1992	1+	2	59					
Mean			71	128	160	185	213	

B)

Brood year	Age at capture	Number of fish	Mean length at age Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
1988	5+	3	92	159	180	191	203	
1989	4+	3	91	146	178	195		
1990	3+	6	75	122	153			
1991	2+	9	69	128				
1992	1+	2	56					
Mean			76	133	166	193	203	

Table 2.12: Back-calculation of female rudd lengths using A) the scale proportional hypothesis (SPH), and B) the body proportional hypothesis (BPH).

A)

Brood year	Age at capture	Number of fish	Mean length at age Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
1987	6+	1	87	207	230	245	261	274
1988	5+	6	77	154	188	206	219	
1989	4+	5	78	151	182	198		
1990	3+	7	81	126	167			
1991	2+	6	73	129				
1992	1+	2	62					
Mean			77	141	181	206	225	274

B)

Brood year	Age at capture	Number of fish	Mean length at age Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
1987	6+	1	106	224	243	255	266	276
1988	5+	6	87	168	197	212	227	
1989	4+	5	86	162	188	196		
1990	3+	7	90	134	168			
1991	2+	6	80	129				
1992	1+	2	63					
Mean			85	150	186	209	233	276

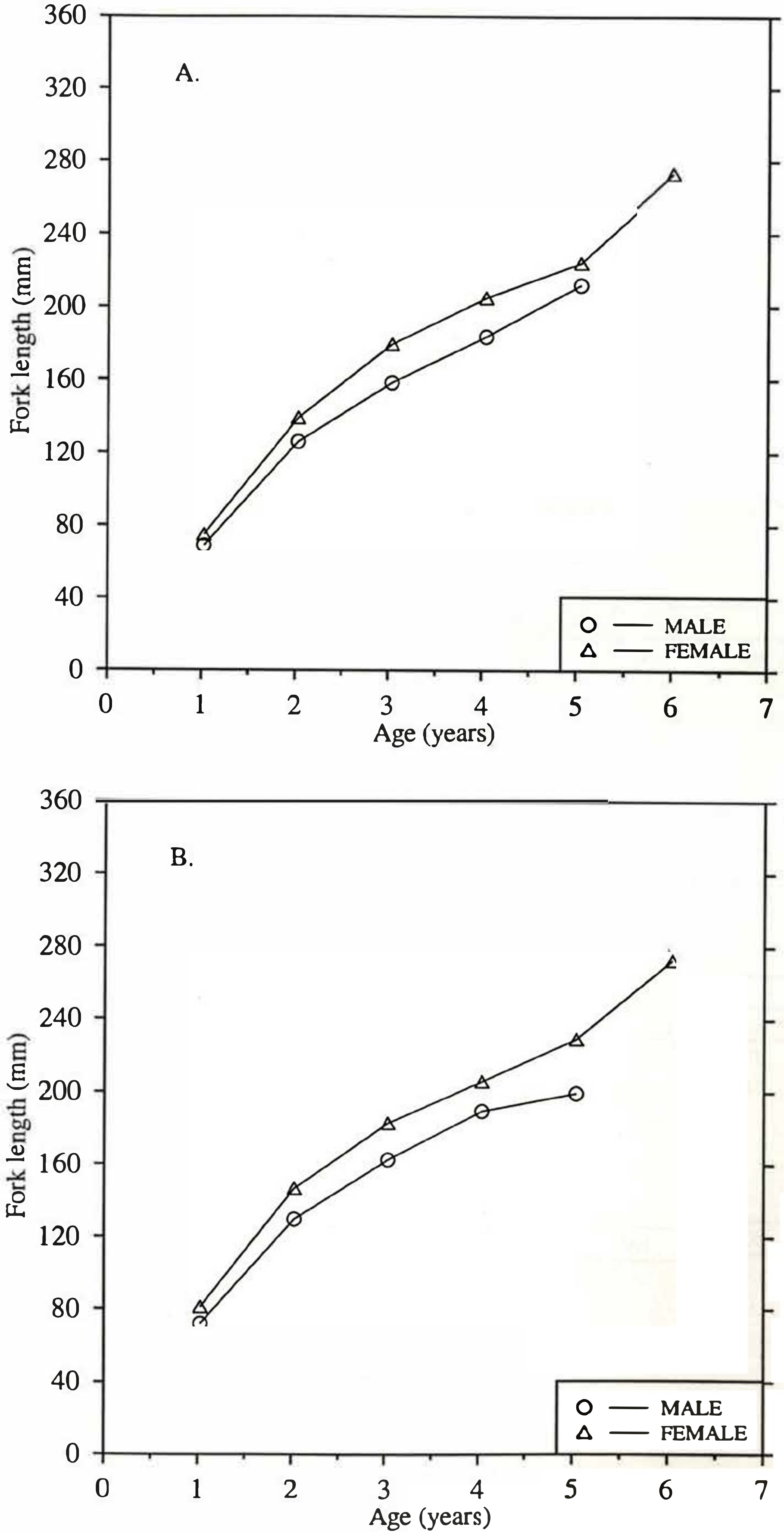


Figure 2.18: Mean fork length of rudd from Hamilton Lake, back calculated using A) the scale proportional hypothesis (SPH), and B) the body proportional hypothesis (BPH).

2.3.2.6 Age and growth of perch

A relationship between fish length and opercular radius was established for 44 perch caught in the Hamilton Lake (Figures 2.19 and 2.20). Fish length was then back-calculated using both BPH and SPH methods (Table 2.13). The two hypothesis produced significantly different results. Growth rates of perch were more consistent with Lee's phenomenon, as older, larger fish exhibited slow early growth when back-calculated (Figures 2.21 and 2.22).

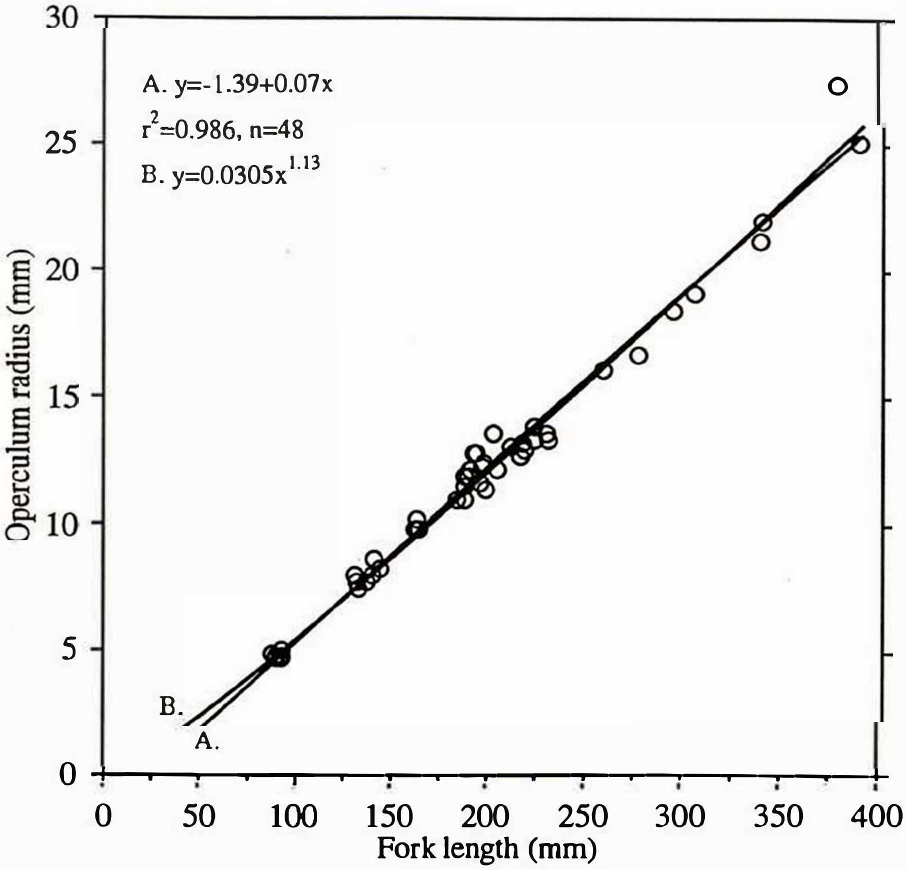
Table 2.13: Back-calculation of perch lengths using A) the scale proportional hypothesis (SPH), and B) the body proportional hypothesis (BPH).

A)

Brood	Age at	Number	Mean length at age					
year	capture	of fish	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
1987	6+	1	74	135	193	250	262	310
1988	5+	3	78	141	189	230	296	
1989	4+	2	84	151	191	236		
1990	3+	5	112	166	213			
1991	2+	22	101	174				
1992	1+	7	108					
Mean			100	167	201	235	288	310

B)

Brood	Age at	Number	Mean length at age					
year	capture	of fish	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
1987	6+	1	106	167	219	269	278	316
1988	5+	3	115	181	224	256	311	
1989	4+	2	119	183	226	265		
1990	3+	5	133	181	218			
1991	2+	22	118	178				
1992	1+	7	114					
Mean			119	179	221	261	303	316



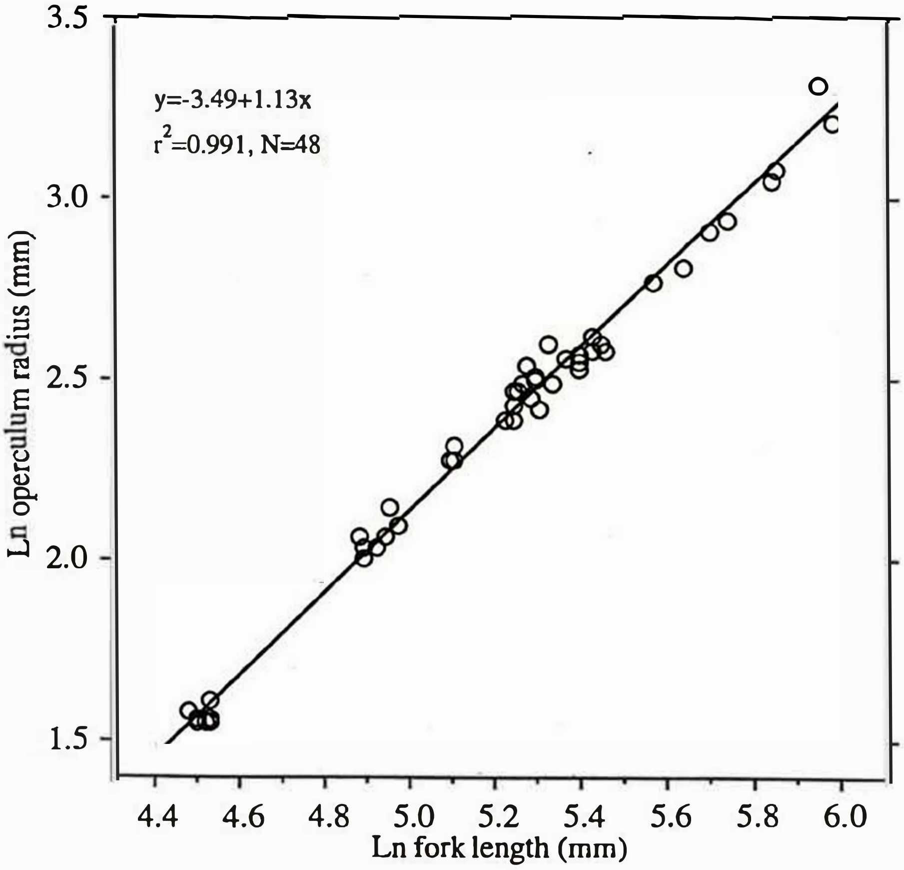
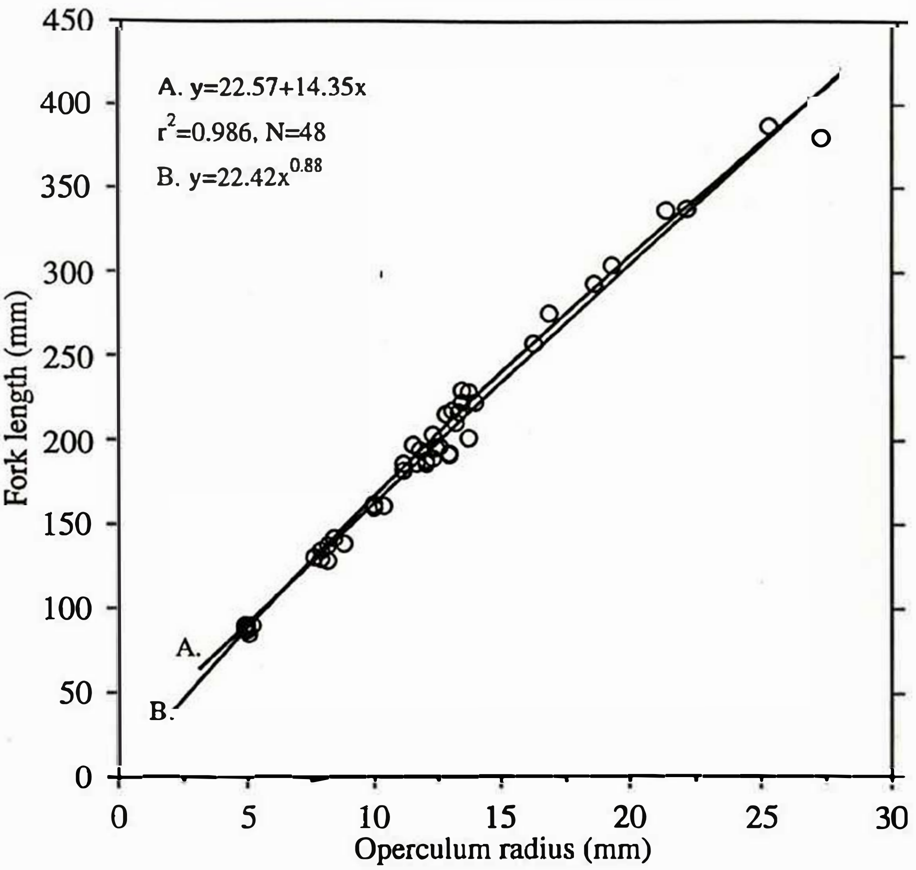


Figure 2.19: Relationship between operculum radius and fork length of perch caught in Hamilton Lake using the scale proportional hypothesis (SPH).



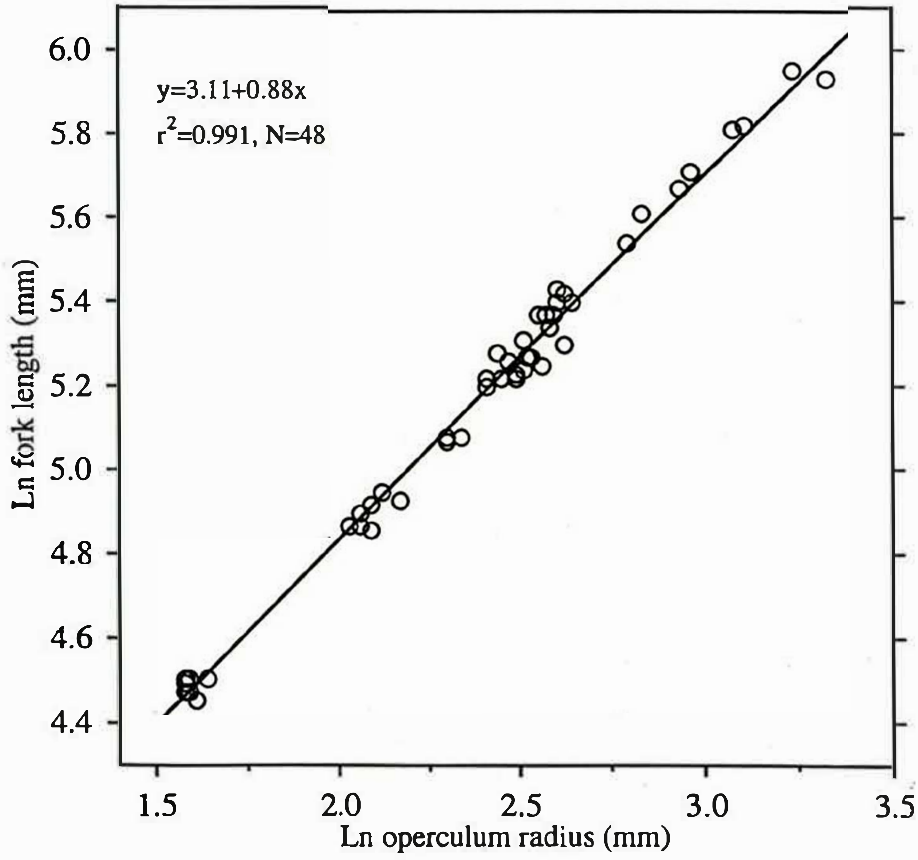
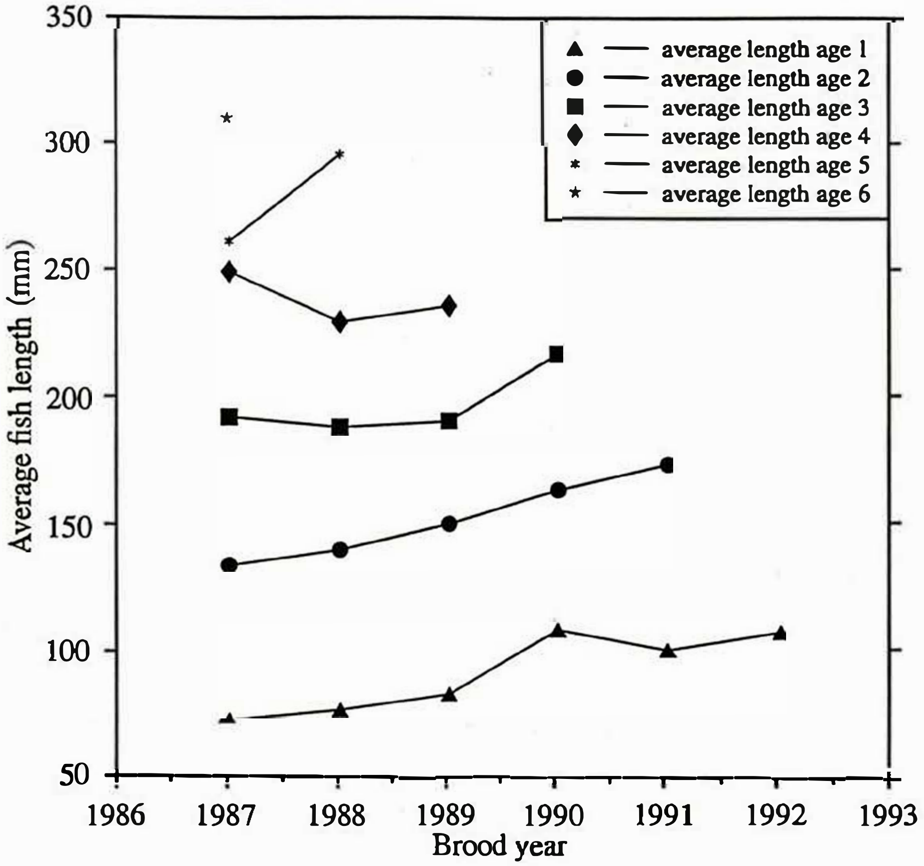


Figure 2.20: Relationship between operculum radius and fork length of perch caught in Hamilton Lake using the body proportional hypothesis (BPH).



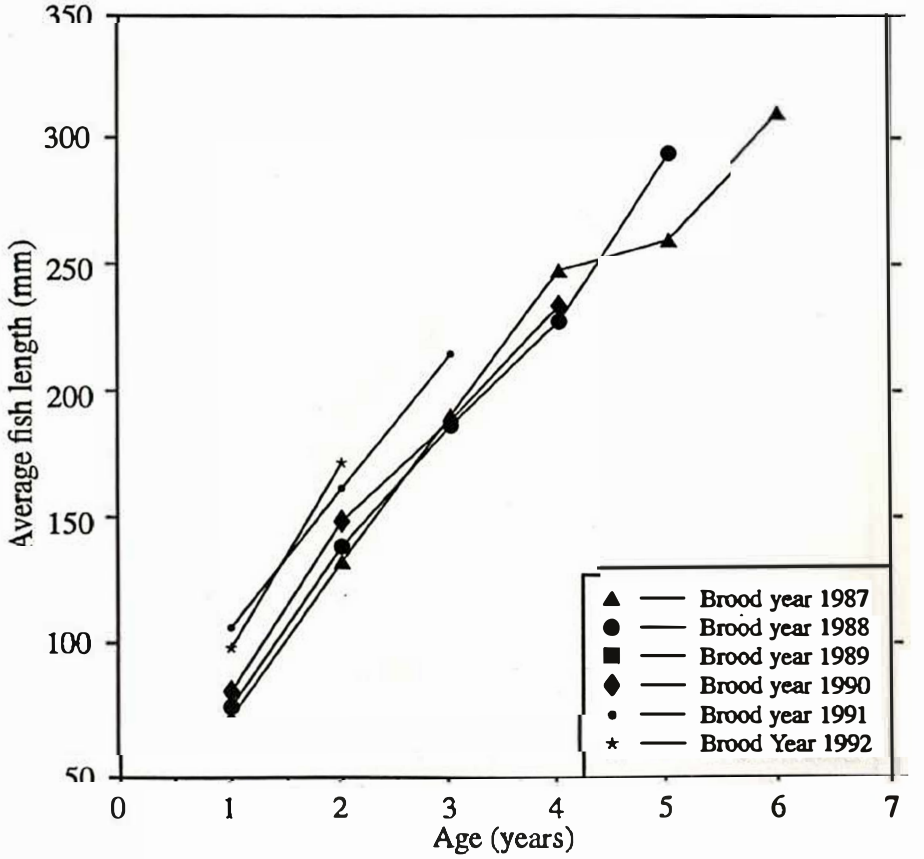


Figure 2.21: Changes in growth rates of perch with brood year caught in Hamilton Lake using the scale proportional hypothesis (SPH).

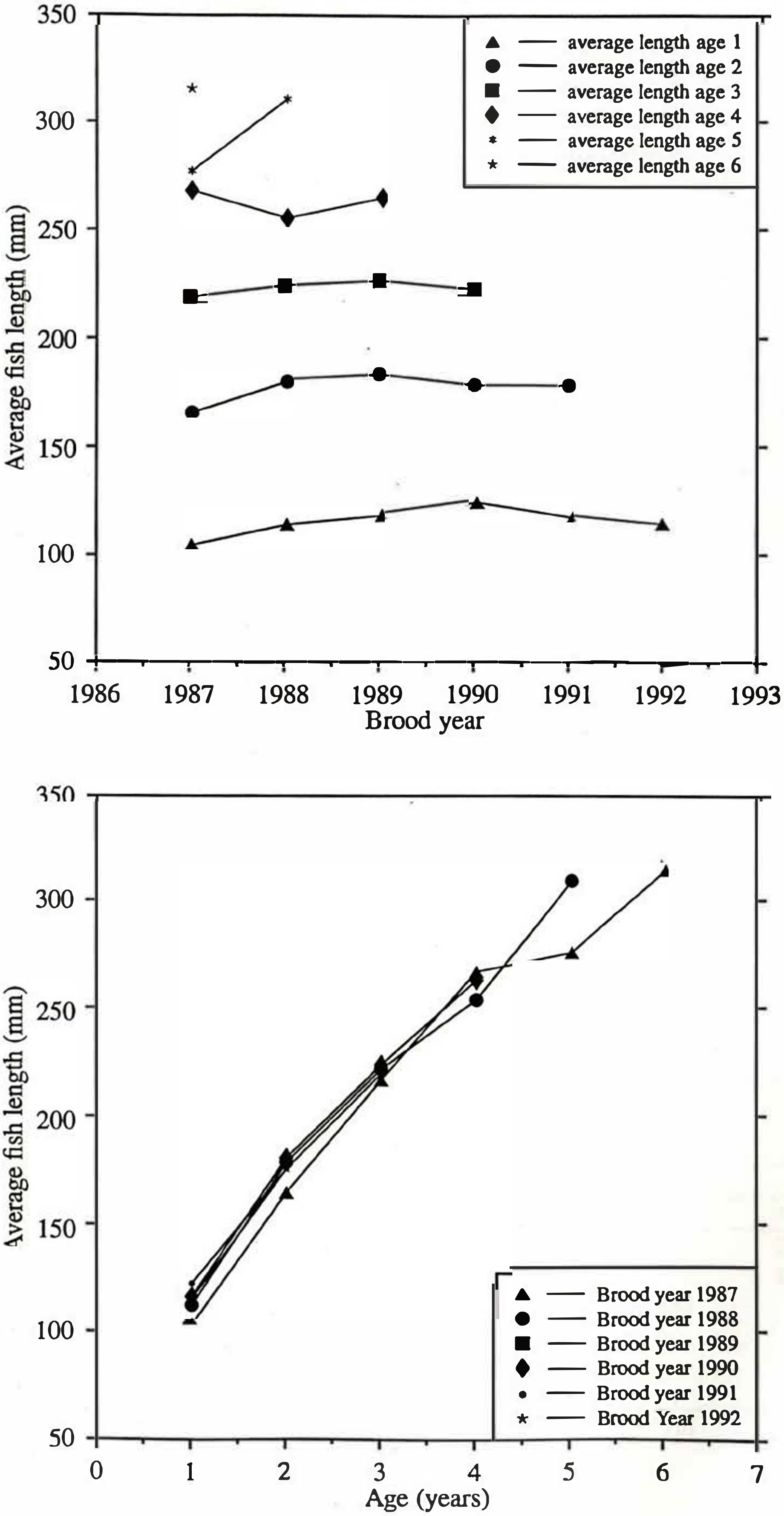


Figure 2.22: Changes in growth rates of perch with brood year caught in Hamilton Lake using the body proportional hypothesis (BPH).

Despite the low numbers of older male perch it appears that females have faster growth rates than males (Table 2.14 and 2.15, Figure 2.23).

Table 2.14: Back-calculation of male perch lengths using A) the scale proportional hypothesis (SPH), and B) the body proportional hypothesis (BPH).

A)

Brood year	Age at capture	Number of fish	Mean length at age					
			Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
1990	3+	1	111	154	205			
1991	2+	6	99	167				
Mean			101	165	205			

B)

Brood year	Age at capture	Number of fish	Mean length at age					
			Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
1990	3+	1	129	163	210			
1991	2+	6	116	168				
Mean			118	167	210			

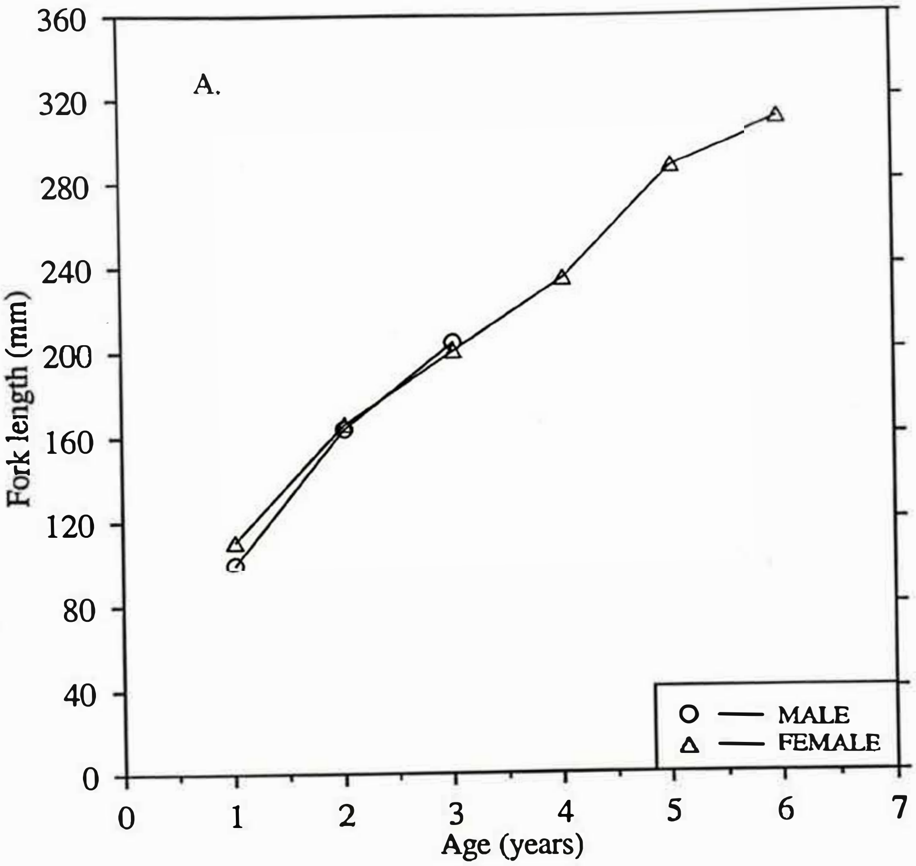
Table 2.15: Back-calculation of female perch lengths using A) the scale proportional hypothesis (SPH), and B) the body proportional hypothesis (BPH).

A)

Brood year	Age at capture	Number of fish	Mean length at age					
			Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
1987	6+	1	74	135	193	250	262	310
1988	5+	3	78	141	189	230	296	
1989	4+	2	84	151	191	236		
1990	3+	4	112	169	215			
1991	2+	16	102	176				
1992	1+	7	108					
Mean			112	167	201	235	288	310

B)

Brood year	Age at capture	Number of fish	Mean length at age					
			Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
1987	6+	1	106	167	219	269	278	316
1988	5+	3	115	181	224	256	311	
1989	4+	2	119	183	226	265		
1990	3+	4	134	179	220			
1991	2+	16	119	178				
1992	1+	7	114					
Mean			119	178	222	261	303	316



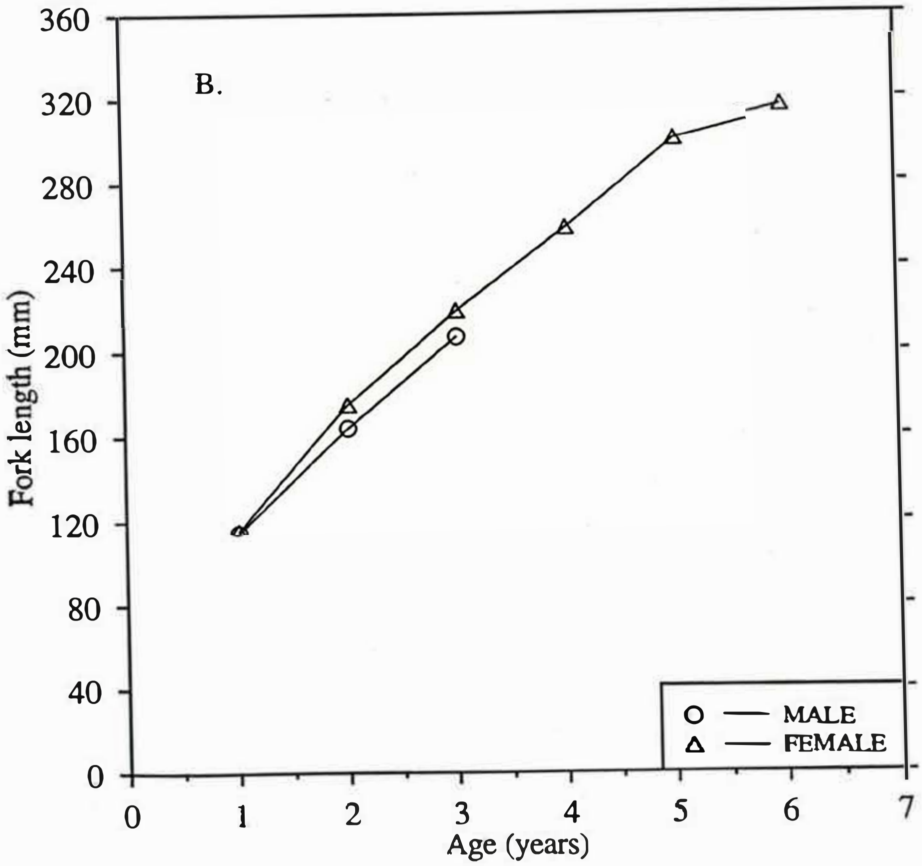


Figure 2.23: Mean fork length of perch from Hamilton Lake, back calculated using A) the scale proportional hypothesis (SPH), and B) the body proportional hypothesis (BPH).

2.4 DISCUSSION

2.4.1 FISH ABUNDANCE

All passive fishing techniques are to some extent selective for certain fish species and sizes (Hayes 1989). A combination of gill nets, fyke nets, and minnow traps were used to capture fish species in Hamilton Lake. The size selectivity of various mesh sizes is a problem in gill net sampling, as generally few fish with lengths which differ from the mean by more than 20% are caught (Hamley 1975). The effects of size selectivity were reduced by using five gill net mesh sizes.

Provided the same effort is invested in the capture of each fish species, the catch per unit effort (CPUE) of passive sampling techniques should be directly proportional to fish abundance (Hubert 1983). The CPUE for gill net sampling indicated that perch were the most abundant fish species sampled in Hamilton Lake, followed by rudd. Until recently (Wise 1990, Totome 1993) rudd appeared to be the more abundant of the two.

A comparison of CPUE data between Wise (1990) and the present study demonstrate that since 1990, perch have surpassed rudd as the more abundant species (Table 2.16). For the purpose of this comparison CPUE was calculated using the same mesh sizes as Wise (1990), (25 mm, 56 mm, and 84 mm mesh sizes) to avoid effects of net selectivity. To avoid seasonal variation in abundance, results of this study were compared to Wise's (1990) catches for December and January.

This comparison also suggests a dramatic decline in the abundance of rudd, with catch rates dropping by 67%. Perch have conversely increased in abundance, with catch rates increasing by 300%.

The decline in rudd abundance is likely to be associated with the collapse of submerged macrophyte beds in Hamilton Lake. Previously, rudd were reported to feed primarily on submerged aquatic macrophytes (Wise 1990). The decline of the beds has reduced the amount of food available to rudd (refer section 3.3.1.1), which has consequently reduced their abundance in Hamilton Lake.

The increase in perch abundance is probably related to a reduction in competition for food with rudd, particularly for invertebrates, which comprise important components in the diets of both juvenile perch and rudd (refer section 3.3.1.2).

Table 2.16: Catch rate per unit effort of perch and rudd in Hamilton Lake for 25 mm, 56 mm, and 84 mm mesh sizes combined.

Fish species	CPUE (fish hour^{-1} 100 m^{-1} of net)		Percentage change
	Wise (1990)	present study	
perch	0.445	1.778	300
rudd	1.497	0.495	-67

The low CPUE of catfish, tench, and goldfish in gill nets indicate their relatively low abundances in Hamilton Lake. The lack of previous studies involving gill net capture of goldfish and catfish make it difficult to determine the effect the decline in submerged macrophytes has had on their abundance. Tench were first introduced into the lake in February 1990 (Hicks 1994), and have not been studied previously in Hamilton Lake.

Catch rates, particularly of perch, rudd and catfish, were highest in the 38 mm and 56 mm gill net mesh sizes. This is indicative of the most common size classes of these three fish species, as gill nets of different mesh sizes were highly selective for specific sizes of fish. Catch rates were higher in the larger mesh sizes (84 mm and 106 mm) for tench and goldfish, implying that these two species are commonly larger. Only one fish, a perch, was captured in the 25 mm mesh size during the duration of this study. It has previously been noted that the smaller gill net mesh sizes are less efficient (Hamley 1975, Hubert 1983).

Shortfinned eels had the highest CPUE of any fish species caught in fyke nets in Hamilton Lake, followed by perch and rudd. Abundance of shortfinned eels could not be compared to those of perch or rudd, due to different capture methods. However, shortfinned eels appear to be relatively abundant in Hamilton Lake.

The high catches of shortfinned eels relative to catches of longfinned eels may be partially attributed to the greater tolerance of high water temperatures and low dissolved oxygen levels shown by the former species. In addition, longfinned eels show a marked preference for habitats with fast water velocities (Jellyman and Todd 1982). Such habitats do not exist in Hamilton Lake.

Catches of tench and catfish were relatively high in fyke nets compared to gill nets considering the overall sampling effort involved. These two species are probably susceptible to capture in fyke nets, due to their benthic feeding patterns (refer sections 3.3.1.4 and 3.3.1.5).

Mosquitofish catches were low, and probably not an accurate reflection of the numbers in the lake, as shoals of mosquitofish were observed in shallow waters around the lake edge.

Bullies have previously been an important component of the diet of perch in Hamilton Lake (Graynoth 1978). However, the number of bullies in the lake appears to have declined, as there was no record of bullies being consumed by any fish species in the present study (refer section 3.4.1.2)

Common smelt were not captured during the course of this study. Although smelt have previously been recorded in the lake, it has been suggested that due to heavy predation, particularly by perch, smelt may no longer exist in the Hamilton Lake (Stephens, pers. comm., Department of Conservation, Hamilton 1995).

There was considerable variation in fish catch rates between different sampling sites. This may reflect the variation in habitat and food resources within the lake. The low catch rates in the three basins (particularly the northern and southern basins) was probably a result of oxygen limitations at the time of sampling. Water deeper than 4 m had become almost completely deoxygenated. A shortfinned eel captured in a minnow trap in the northern basin (sampling site 9) was dead upon recovery, probably due to lack of oxygen. This may reflect diel fluctuations of oxygen concentrations in the lake.

Very few juvenile fish (less than 100 mm FL) were caught in this study. A number of recent attempts to capture juvenile fish including beach seining, purse seining, and electrofishing methods have resulted in low catches. Consistently low capture rates of juvenile fish in Hamilton Lake may be consistent with Johnson's (1994) theory that in unexploited populations, length-frequency distributions of dominant fish populations indicate an almost total absence of young fish. This results from the stability brought about by the dominance of larger fish, maintained by the gradual and ordered replacement of individuals. Although Hamilton Lake fish populations are not strictly unexploited, the majority of fish captured by anglers are returned alive to the lake. Further research is, however, needed to determine the applicability of Johnson's (1994) theory to the fish populations of Hamilton Lake.

2.4.2 FISH POPULATION CHARACTERISTICS

2.4.2.1 Perch

Female perch were considerably more abundant than males, with a female to male ratio of 2.43:1. This is consistent with previous studies in Hamilton Lake by Wise (1990) and Graynoth (1978) who obtained female to male ratios of 2.35:1 and 2.58:1 respectively, and with results obtained from Northern Hemisphere populations (Craig 1974, Le Cren et al. 1977). Results from the length frequency distributions also indicate that the larger fish were predominantly female. A number of studies have reported similar observations with approximately equal sex ratios for immature fish, and an increasing proportion of females with age and size beyond maturity (Shafi and Maitland 1971, Craig 1974, Jellyman 1980, Le Cren 1992). This is a consequence of males being more active than females, and thus having higher mortality rates (Jellyman 1980).

The low GSI values for perch are consistent with levels reported by Wise (1990) for the same time of the year. Wise (1990) found that perch spawned between August and October in Hamilton Lake, so the present study yielded predictably low GSI results.

Although growth rates for mature female perch are reportedly faster than for males (Le Cren 1958, Craig 1980, Diana and Salz 1990), no significant difference was established in the length-weight relationship between the two sexes. However, the length-weight regression line for perch had a low r^2 value. The r^2 fit improved greatly when catches from each sample site were plotted separately. The length-frequency distribution for perch also demonstrated variation of fish length among sampling sites. Similar observations have been recorded elsewhere (Hayward and Margraf 1987, Diana and Salz 1990) where some sampling sites revealed greater frequencies of older and larger perch and significantly different length-weight relationships. The weight variations were attributed to differences in food availability. Age-related behavioural differences were assumed to cause the differential distribution of perch sizes, as older fish occasionally encounter better food resources as they move further from spawning sites during summer foraging (Diana and Salz 1990). These differences in food availability and behaviour are likely explanations for length and weight variations of perch in Hamilton Lake.

Regression equation indicate that the length-weight relationship of perch in Hamilton Lake has not changed since Wise's (1990) study (Table 2.17), and is similar to results of other studies (Jellyman 1980).

Table 2.17: Comparison of length-weight coefficients of the linear equation [Ln(weight in g)=a+b(Ln(length in mm))] for perch caught in the Hamilton Lake between December 9 1993 and February 2 1994.

Site	Author	Sex	a	b
Hamilton Lake	Present study	male	-11.11	2.95
		female	-11.39	3.01
Hamilton Lake	Wise (1990)	male	-9.25	2.95
		female	-10.53	3.10
Lake Pounui	Jellyman (1980)	male	-9.62	2.96
		female	-10.30	3.07

2.4.2.2 Rudd

The length-frequency distribution indicates that larger female rudd are proportionally more abundant than larger males. This is probably due to faster growth rates and longer life spans of females (Kennedy and Fitzmaurice 1974, Cadwallader 1977).

Variation in rudd length between sampling sites in Hamilton Lake is apparent from examination of the length-frequency distributions. Rudd often form small groups which seldom stray far from their previous spawning ground. However, rudd occasionally migrate to seek new food resources during summer (Holcik 1967). The differential distribution of rudd lengths between sites in Hamilton Lake is probably due to the ability of larger fish to move further from spawning sites.

The relatively high GSI results obtained for rudd were again consistent with results obtained by Wise (1990). Wise (1990) found that rudd spawn in October, though a second GSI peak occurred in December, suggesting that rudd in Hamilton Lake spawn more than once per year, a phenomenon which is not uncommon (Holcik 1967). This suggestion is consistent with the present study, as a number of well developed eggs were observed in rudd during the sampling period.

Holcik (1967) described rudd in the Klicava Reservoir, USSR, as a low density population with abundant food. The similarity of the regression equations for the length-weight distribution between the present study and those of previous studies (Table 2.18) including Holcik (1967) , indicate that rudd in Hamilton Lake are in relatively good condition.

Female rudd have been reported as being somewhat heavier for their lengths than males (Kennedy and Fitzmaurice 1974). Although this phenomenon was not apparent in the present study, a significant difference ($p<0.05$) was noted between the separate regression equations for each sex. Females appeared to be heavier for their lengths at smaller sizes, while males became heavier for their lengths at the larger sizes.

Table 2.18: Comparison of length-weight coefficients of the linear equation [Ln(weight in g)=a+b(Ln(length in mm))] for rudd caught in the Hamilton Lake between December 9 1993 and February 2 1994.

Site	Author	a	b
Hamilton Lake	Present study	-12.47	3.29
Hamilton Lake	Wise (1990)	-11.84	3.19
USSR	Holcik (1967)	-11.47	3.16

2.4.2.3 Tench

Tench under 300 mm were not captured in the present study. This indicates that reproduction has probably not occurred since their first introduction to Hamilton Lake in 1990. Alternatively, juvenile fish present in the lake may not have been captured by the sampling methods used, but this seems unlikely. Tench captured were mature and possessed well-developed gonads. In order to spawn, tench require water temperatures of 18^{o}C and over during spring and summer (Kennedy and Fitzmaurice 1970, O'Maoileidigh and Bracken 1989, Penaz et al. 1989). While these temperature requirements are satisfied in Hamilton Lake in summer (Burns pers. comm. NIWA Hamilton 1995), spawning will not necessarily occur unless open water temperatures have been high for a sufficient period of time to induce complete ripening of the eggs and milt (Kennedy and Fitzmaurice 1970). The exact period of warmer temperatures required to induce ripening of eggs and milt is unknown, so it is uncertain whether sufficiently high water temperatures are maintained for long enough to induce spawning in Hamilton Lake.

Tench reproduction is also influenced by the availability of suitable spawning sites (Wright and Giles 1991). Tench require sheltered bays with submerged vegetation to spawn, although if submerged vegetation is unavailable they may spawn on bullrushes and similar emergent vegetation (Kennedy and Fitzmaurice 1970). These habitat requirements have reduced their breeding success in a number of lakes (O'Maoileidigh and Bracken 1989, Wright and Giles 1991). Wind exposure, and a paucity of submerged vegetation could possibly prevent tench from breeding in Hamilton Lake.

The tench is one of a number of fish species in which females grow faster than males after the first few years of life (Kennedy and Fitzmaurice 1970). Variation in growth was illustrated in the length-weight analysis where male and female tench demonstrated significantly different ($p<0.05$) regressions. Tench length-weight relationships also had low r^2 values. This may reflect variations in depth and body thickness, which cause substantial weight differences (Kennedy and Fitzmaurice 1970).

2.4.2.4 Catfish

There was no significant difference ($p>0.05$) between slopes and intercepts of the separate length-weight regressions for each sex. Growth for catfish was found to be isometric (i.e. $b=3.26$), a relationship found in many fish species (Patchell 1977). The symmetry of growth for catfish was consistent with results from previous studies (Table 2.19).

Table 2.19: Comparison of length-weight coefficients of the linear equation [Ln(weight in g)=a+b(Ln(length in mm))] for catfish caught in Hamilton Lake between December 9 1993 and February 2 1994.

Site	Author	a	b
Hamilton Lake	Present study	-12.68	3.26
Hamilton Lake	Wise (1990)	-12.70	3.30
Waikato	Patchell (1977)	-10.35	3.06
USA	Priegel (1967)	-11.65	3.07

Low GSI values for catfish are consistent with results obtained by Wise (1990) recorded at the same time of the year. Catfish in Hamilton Lake spawn in approximately October each year (Wise 1990), and consequently had predictably low GSI values during the sampling period.

2.4.2.5 Shortfinned eels

Gonad development was very poor in shortfinned eels captured in Hamilton Lake. Consequently, sex could not be accurately determined, even by internal examination. Shortfinned eels are slow-maturing, and gonads do not develop significantly until a few months before they migrate to spawn. The average migration age is 14 years for males, and 22 years for females (McDowall 1990).

The regression equation for the length-weight relationship was similar to that obtained by Chisnall (1987), (Table 2.20). Chisnall (1987) also found no significant seasonal variation in the length-weight relationship, suggesting that shortfinned eels maintain a similar condition throughout the year.

Table 2.20: Comparison of length-weight coefficients of the linear equation [Ln(weight in g)=a+b(Ln(length in mm))] for shortfinned eels caught in Hamilton Lake between December 9 1993 and February 2 1994.

Site	Author	a	b
Hamilton Lake	Present study	-15.02	3.30
Waikato River	Chisnall (1987)	-14.92	3.30

2.4.2.6 Goldfish

Female goldfish outnumbered males by a ratio of two to one, and were also larger than males. However, due to the low sample size results must be treated with caution. As with tench, no small goldfish (<170 mm in length) were caught in this study, although they have previously been reported to breed in the lake (Graynoth 1978). Goldfish gonads were particularly well developed, having the largest GSI of any fish species caught in the present study. No information previously existed on the spawning activities of goldfish in Hamilton Lake, but the presence of well developed gonads indicates that they were close to spawning during the sampling period, ending February 2nd. Elsewhere goldfish are known to spawn several times per season (Patchell 1977), and it is assumed that this occurs in Hamilton Lake.

2.4.2.7 Fish aging

Back calculation of fish body length has traditionally been performed using either the Dahl-Lea, or Fraser-Lee methods, despite the existence of more realistic proportional methods (Francis 1990). Francis (1990) recommended the use of both the body proportional hypothesis (BPH) and the scale proportional hypothesis (SPH) for back calculating fish length, concluding that one method was not more defensible than the other, and that the correct length-at-age lay somewhere between the two estimates. The difference in results between the two methods indicates the inaccuracy of back calculation methods.

2.4.2.8 Aging and growth rates of rudd

Steinmark (1974, cited in Cadwallader 1977) found that scale reading was a reliable method of aging rudd, and reported similar back-calculated lengths and actual measured lengths for rudd using this technique.

Results of the SPH and BPH methods for back calculation of fish body length for rudd in Hamilton Lake demonstrate the reverse of Lee's phenomenon (in which the older fish appear to have been slow early growers when back-calculated). Growth rates of rudd have declined, particularly in cohorts greater than one year of age. This decline in growth rates is likely to be associated with the collapse of submerged aquatic macrophytes in Hamilton Lake. Although complete macrophyte disappearance was not recorded until 1990, a dramatic decline was first noted in 1988. While present, submerged macrophytes were the preferred food item of rudd, comprising 84 % of the total dietary volume (Wise 1990). Adult rudd appear to be obligatory feeders of aquatic vegetation, still appearing to feed on aquatic vegetation to the same proportion as before the collapse, although submerged vegetation has been replaced with marginal vegetation (refer section 3.3.1.1). With the reduction in aquatic vegetation associated with the macrophyte decline, growth rates of rudd have also declined. The greater decline in rudd growth rates with increased age can probably be attributed to younger rudd including a greater proportion of invertebrates in their diets.

Although growth rates of rudd in Hamilton Lake have clearly declined, the average growth rates of rudd over the past six years are high compared to the majority of previous studies (Table 2.21). This is particularly apparent for young rudd which appear to have relatively rapid growth rates.

The rapid early growth of rudd in Hamilton Lake contrasts with results obtained by Wise (1990) where one year old rudd were on average less than half the length recorded in the present study. These sizes obtained by Wise (1990) were well below the size of observed 0+ fish length. The difference may be attributed to either the different back calculation formulas used or a difference in scale measurement techniques.

Table 2.21: Comparison of mean lengths of rudd in Hamilton Lake caught between December 1993 and February 1994 with previous studies.

			Mean length at age (mm)									
Site	Author	Sex	1	2	3	4	5	6	7	8	9	10
Hamilton	(SPH)	male	71	128	160	185	213					
Lake	(BPH)	male	76	133	166	193	203					
(present	(SPH)	female	77	141	181	206	225	273				
study)	(BPH)	female	85	150	186	209	232	276				
Hamilton	Wise	male	33	147	191	214	236	238	278	290		
Lake	(1990)	female	32	147	191	214	231	245	270	271		
USSR	Holcik	male	41	77	120	163	172	175	204	216	230	238
	(1967)	female	38	76	127	171	187					
Italy	Zerunian	male	75	105	125	130						
	et al.	female	90	115	130	150						
	(1986)											
Czecho-slovakia	Cihar and Stanislav (1958)		33	53	83							
Ireland	Kennedy and Fitzmaurice (1970)		28	59	97	135	176	208	239	274	289	292

Back calculation results indicate that female rudd had faster growth rates than males, particularly in larger fish. This is consistent with previous studies (Kennedy and Fitzmaurice 1974, Cadwallader 1977) where mature female rudd grew appreciably faster than males.

2.4.2.9 Aging and growth rates of perch

Le Cren (1947) validated the use of opercular bones for studying perch growth rates by demonstrating that the bands found on the bones were consistent with their annual growth cycles. Wise (1990) confirmed this validation for perch in Hamilton Lake.

The back calculated growth rates for perch in Hamilton Lake demonstrated Lee's phenomenon, as the larger, older fish were slow early growers when back calculated. Growth rates were similar to those calculated by Graynoth (1978) and Wise (1990) in Hamilton Lake, and higher than the majority of those reported in the Northern Hemisphere (Le Cren 1958, Craig 1974, Linlokken 1991), (Table 2.22).

The similarity of results obtained in the present study with those obtained by Graynoth (1978) and Wise (1990) indicate that the introduction of rudd, catfish, and tench, and the collapse of the submerged aquatic macrophytes has not noticeably affected the growth of perch in Hamilton Lake.

Food availability, population density and water temperature are all known to influence the growth of perch (Le Cren 1958, Shafi and Maitland 1971, Craig 1980). The relatively warm summer water temperatures in Hamilton Lake are probably closer than Northern Hemisphere waters to the optimum temperature range of 22-25°C for perch growth (Craig 1987), and contribute to the faster growth rates compared to Northern Hemisphere perch populations.

Table 2.22: Comparison of mean lengths of perch in Hamilton Lake, caught between December 1993 and February 1994, with previous studies.

Site	Author	Sex	Length at age (mm)									
			1	2	3	4	5	6	7	8	9	10
Hamilton Lake (present study)	(SPH)	male	101	165	205							
	(BPH)	male	118	167	210							
	(SPH)	female	112	167	200	235	288	310				
	(BPH)	female	119	178	222	261	303	316				
Hamilton Lake	Wise (1990)	male	79	149	178	209	250					
		female	69	152	191	220	230	231	162	248	287	
Hamilton Lake	Graynoth (1978)	male	88	144	178	208	226	249				
		female	86	152	195	245	279	315	367	386	395	404
Lake Pounui	Jellyman (1980)	male	107	137	155	167	174					
		female	110	150	175	203	231	256				
Slapton Ley	Craig (1974)	male	76	125	153	197						
		female	78	125	167	191	216	231				
Windermere	Le Cren (1958)	male	70	114	131	140	146	152				
		female	73	114	136	146	152	158	163			
Netherlands	Houthuijzen et al.(1993)	male	221	290								
		female	237	301								
Norway	Linlokken et al.(1991)		118	141	146	173	183	178	182	176	182	191

Growth rates of female perch in Hamilton Lake appeared to be faster than those of males. This phenomena is consistent with results obtained in other studies (Graynoth 1978, Jellyman 1980).

The differences in results obtained using the SPH and BPH were relatively large, illustrating the inaccuracy involved in estimating fish growth rates. The compatibility of back calculated results and actual recorded fish lengths indicate that the SPH appears to be the more accurate method in estimating growth rates for perch in Hamilton Lake.

2.4.2.10 Aging and growth rates of tench

Tench aging was attempted using scale and operculum methods described by Weatherley (1959), Kennedy and Fitzmaurice (1970), O'Maoileidigh and Bracken (1989) and Wright and Giles (1991). However, growth rings of tench in Hamilton Lake were very poorly formed in both the operculum and scales, making aging these fish very difficult.

CHAPTER THREE:

Diet and Heavy Metal Concentrations of Fish in Hamilton Lake

3.1 INTRODUCTION

The diet of fish in Hamilton Lake was first addressed by Graynoth (1978), who studied the diet of perch. Following this, Wise (1990) and Totome (1993) examined the diets of perch, rudd and catfish, the latter two of which were first recorded in the lake in 1977. Totome (1993) also included a number of eel and goldfish in his dietary analysis, which was undertaken using stable carbon isotopes. Results of Totome's dietary analysis indicated that the collapse of the submerged aquatic macrophytes in 1990 has induced dietary changes in some fish species, particularly rudd which feed primarily on aquatic vegetation (Wise 1990).

Tench were introduced into the lake in a series of liberations between 1990 and 1992. Dietary studies of tench have not previously been undertaken in the lake, and tench are relatively unstudied in New Zealand.

The present study investigates the diet of perch, rudd, tench, catfish, goldfish and shortfinned eel in Hamilton Lake. Results are compared to those of previous studies undertaken both before (Graynoth 1978, Wise 1990) and after (Totome 1993) the submerged aquatic macrophyte collapse.

The majority of zinc, copper and lead has entered Hamilton Lake from stormwater inflows (Rajendram 1992). Arsenic is present in relatively high concentrations in the lake sediment, due to the addition of sodium arsenate for aquatic weed control in 1959 (Section 1.1.2). Henriques (1979) found that during summer arsenic concentrations were highest in bottom waters of the lake, due to the liberation of arsenic from sediments when waters become anoxic. Tanner and Clayton (1990) studied arsenic in the flesh of catfish, perch, rudd and eel in Hamilton Lake, and reported the highest arsenic concentrations in bottom feeding fish. Rajendram (1992) studied concentrations of arsenic, lead, copper and zinc in the same fish species in Hamilton Lake, and reported lower concentrations of arsenic in the flesh of fish

The present study investigates levels of arsenic, lead, copper and zinc in the flesh of perch, rudd, tench, catfish, goldfish and shortfinned eel in Hamilton Lake. Changes in concentrations with time are determined through comparison with results of previous studies.

3.2 METHODS

3.2.1 DIETARY ANALYSIS

Fish stomachs were removed and preserved in a 10% formalin solution. Prior to analysis, stomachs were washed in a solution of sodium sulphate and sodium sulphite before rinsing in cold water. Diet was assessed from gut contents, with food items being identified under a low-power binocular microscope. The relative contribution of different prey organisms to the fish diet was assessed using the following two approaches. To obtain a measure of presence or absence of potential prey taxa, occurrence was recorded as the number and percentage of all stomachs examined containing one or more individuals of each taxonomic group. To determine the contribution of the different prey taxonomic groups in terms of prey biomass, each taxonomic group was expressed as a percentage of the total volume of prey present.

3.2.2 HEAVY METAL ANALYSIS

A total of 74 of the largest fish were selected for the heavy metal analysis (Table 3.1). A strip of approximately 10-15 g wet weight of flesh (white muscle tissue) was removed from the left side of the fish. The skin was removed and the flesh was re-frozen for later analysis at R.J. Hill Laboratory. Six fish species were tested: perch, rudd, catfish, tench, shortfinned eels, and goldfish. Four samples of each fish species were obtained from sampling site 1, while the remaining sites were represented by a single sample from each fish species. Due to the low catch of some fish species at various sites they could not always be included in the analysis. The greatest number of samples come from sampling site 1, a combined site containing stormwater inflows 1,9, and 10 which is the area Rajendram (1992) identified as containing the highest concentrations of heavy metals. This sampling method enabled both variations between sites, and variation between fish at a given site, to be determined.

Table 3.1: Summary of heavy metal analyses in the flesh of fish caught between December 1993 and February 1994 in Hamilton Lake.

Sampling site	Fish species						Number of fish sampled per site
	catfish	goldfish	perch	rudd	short-finned eel	tench	
1	4	4	4	4	3	4	23
2	1	1	1	1	1	1	6
3	1	1	1	1	1	1	6
4	1	1	1	1	1	1	6
5	1	1	1	1	1	1	6
6	1	1	1	1	1	1	6
7	1	0	1	1	1	1	5
8	1	1	1	1	1	1	6
9	0	0	1	1	1	0	3
10	0	0	0	1	0	0	1
11	1	1	1	1	1	1	6
Total number of fish analysed							74

To better compare these results with those of previous heavy metal analyses, ten samples with a wide range of heavy metal concentrations were also analysed at Ruakura Agricultural Research Centre, where Rajendram's (1992) analyses were undertaken.

Determinations of heavy metals by R.J. Hill Laboratories used the following methods, with samples of NBS tuna R.M. 50 and NIES mussel No. 6 used as reference standards.

3.2.2.1 Arsenic

To determine arsenic concentrations, 0.5 g of homogenised sample was weighed and placed into 200 mm x 25 mm digestion tubes. A 12 ml volume of digestion acid (5:0.25:1, v/v, of HNO_3 : $HClO_4$: H_2SO_4) and three to four acid washed boiling chips were then added, and the sample was left to pre-digest at room temperature overnight. Samples were then digested on a digestion block at 100° C for 1 hour, 140°C for 1 hour, 165°C for 1 hour, 220°C for 30 minutes, and 320°C for fifteen minutes. After dilution to 10 ml with type 1 water, hydride generation AA determinations were performed on 4 ml aliquots of the digest.

3.2.2.2 Copper, lead and zinc

Copper, lead, and zinc concentrations were analysed by weighing 1 g of well-homogenised tissue into 150 mm x 25 mm digestion tubes. A 12 ml volume of 5:1 HNO_3 : $HClO_4$ (v/v) was then added before digesting on the digestion block at 125°C for 1 hour, 140°C for 1 hour, 165°C for 1 hour, and 205°C for 30 minutes. After dilution to 20 ml with Type 1 water, metals were analysed by flame AA or ICP-MS (Evans et al. 1979).

3.2.2.3 Sample re-analysis

Ten samples were re-analysed for arsenic and lead at Ruakura Agricultural Research Centre. Dissolution of samples involved a nitric acid/perchloric acid (5:2 HNO_3, $HClO_4$) digestion. Samples were ramped up for two hours, and fumed for 20 minutes at 220°C. Atomic absorption spectrometry was used at 193.7 nm using a nitrous oxide acetylene flame. Non-atomic absorption was measured using the same wavelength for each digest by means of a hydrogen hallow cathode lamp and subtracted. NIST pine needles and NIST ryegrass were used as reference samples for arsenic and lead respectively (Martinie and Schilt 1976).

3.3 RESULTS

3.3.1 DIETS OF FISH FROM HAMILTON LAKE

Of the six fish species examined catfish and tench appear to be the most generalised feeders, often feeding on a range of dietary items (Table 3.2). Rudd, goldfish, perch and shortfinned eel, however, often had only a single dietary item present in the stomachs analysed.

Table 3.2: Number of food categories per stomach of each fish species caught in Hamilton Lake between December 1993 and February 1994.

Number of food categories per stomach	Percentage (%) of stomachs					
	catfish	goldfish	perch	rudd	shortfinned eel	tench
1	15	57	58	52	60	11
2	30	14	29	14	15	44
3	25	21	8	14	10	28
4	15	7	4	10	10	11
5	10	-	-	7	5	6
6	5	-	-	3	-	-

3.3.1.1 Rudd

Over 50% of rudd had eaten items from a single food category (Table 3.2) although stomachs frequently contained many individual organisms from a single food category (for example 485 chironomid larvae were consumed by a 184 mm rudd). Chironomid pupae contributed the largest proportion of the diet in rudd less than 150 mm in length. The larger the size of rudd the more important plant material became in their diet (Figure 3.1). Plant material was the most important food item in rudd above 150 mm in length. Of the plant material that could be identified, emergent species dominated, with *Iris pseudacorus* and *Nymphaea* cultivars most common, while *Baumea articulata* was also frequently present. Other emergents, *Eleocharis sphacelata* and *Typha orientalis,* were rarely found. Phytoplankton appeared consistently, though in small quantities, and plankton consumption did not appear to be related to fish size (Table 3.3).

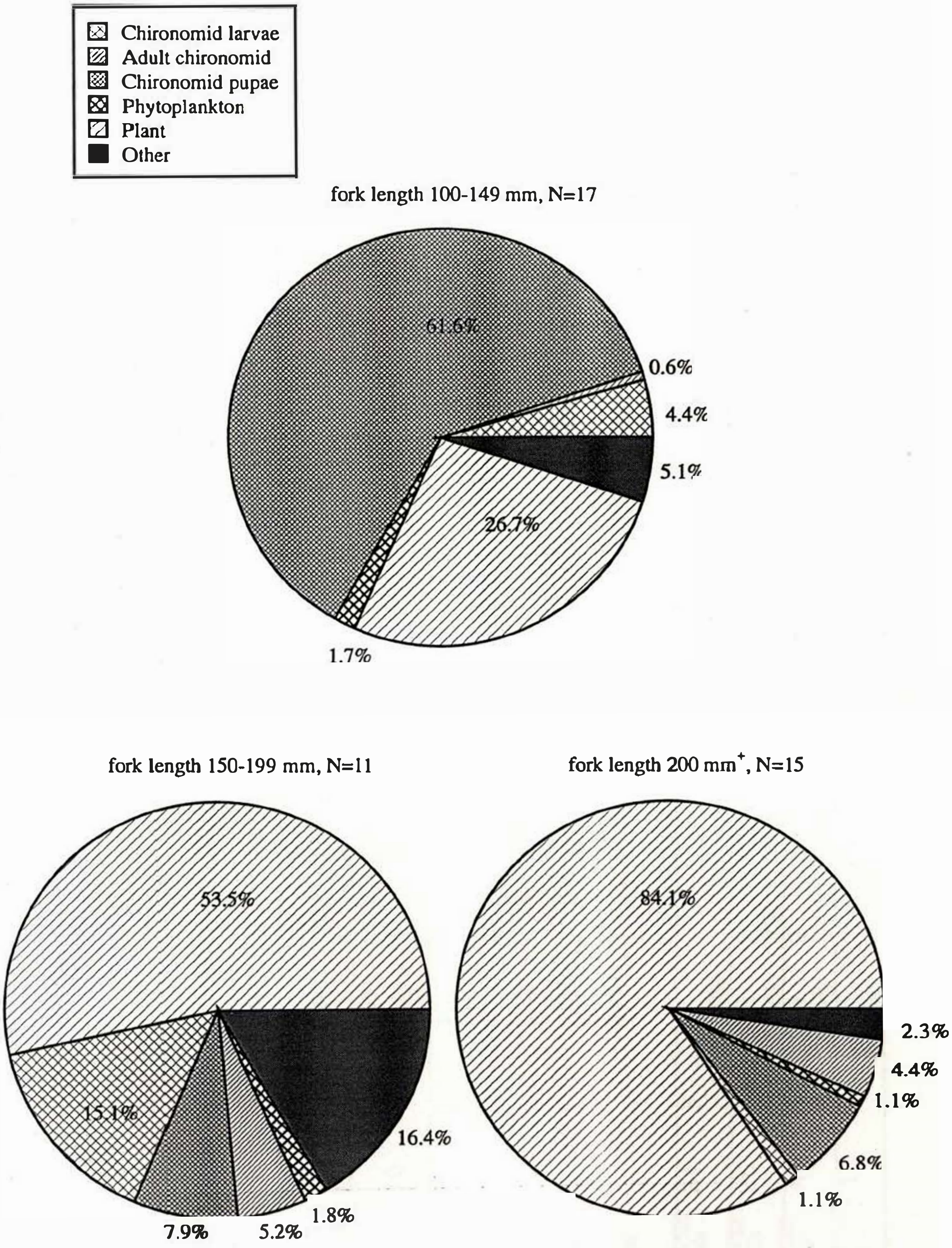


Figure 3.1: Percentage composition of food items by volume in the diet of rudd of different length classes, caught in Hamilton Lake between December 1993 and February 1994.

Table 3.3: Frequencies of stomachs analysed containing one or more individuals from each taxonomic group, from fish caught in Hamilton Lake between December 1993 and February 1994. In brackets is the occurrence of food items expressed as a percentage of all stomachs examined containing one or more individuals of each taxonomic group.

Species	Length class (mm) (Mean)	Number	Number empty	Chironomid			Oligochaetes	Fish	Plant	Phytoplankton	Detritus	*Physastra*	*Potamopyrgus*	terrestrial Invertebrates	Bird	Other
				larvae	pupae	adult										
Rudd	100-149	22	5	2 (12%)	10 (59%)	4 (24%)			8 (47%)	2 (12%)						1 (6%)
	150-199	15	4	5 (45%)	4 (36%)	3 (27%)			7 (64%)	2 (18%)	1 (9%)					1 (9%)
	>200	18	3	1 (6%)	4 (27%)	4 (27%)			12 (80%)	1 (6%)						1 (6%)
Perch	<100	1	0	1 (100%)												
	100-149	19	3	15 (94%)	2 (13%)	4 (25%)					2 (13%)					2 (13%)
	150-199	18	7	9 (82%)		5 (45%)					2 (18%)					2 (18%)
	200-249	20	8	3 (25%)		2 (17%)		7 (58%)	2 (17%)					1 (8%)		2 (17%)
	>250	4	1					3 (100%)								
Short-finned eel	365-920 (590)	31	5	5 (19%)				15 (58%)	3 (12%)	1 (4%)	3 (12%)	3 (12%)		5 (19%)	4 (15%)	
Catfish	134-320 (218)	26	1	23 (92%)	2 (8%)	4 (16%)	4 (16%)	3 (12%)	7 (28%)		18 (72%)	4 (16%)		2 (8%)		2 (8%)
Tench	310-485 (415)	40	16	19 (79%)	2 (8%)	3 (13%)			3 (13%)		11 (46%)	14 (58%)	5 (21%)	1 (4%)		2 (8%)
Goldfish	197-340 (241)	17	2	5 (33%)					4 (27%)	12 (80%)	2 (13%)	1 (7%)		1 (7%)		

3.3.1.2 Perch

Chironomid larvae were the most important food item of perch below 200 mm in length. Some adult chironomid were also taken, particularly by perch in the 150-199 mm length class, as were a smaller number of Odonata, Trichoptera, and detritus (Figure 3.2). There was a clear transition to a piscivorous diet in perch over 200 mm in length. In perch over 250 mm fish was the sole food item. The smallest perch containing fish in the gut samples was 205 mm in length. Of the identifiable fish (92%) in perch stomachs, rudd were most common (57%) followed by perch (43%). The largest fish consumed was a 151 mm (50 g) rudd found in the stomach of a 380 mm perch.

3.3.1.3 Shortfinned eels

Fish constitute the major component of the diets of shortfinned eels in Hamilton Lake. Fish were found in 58% of the stomachs examined, and were the sole food item in 49% of eels, comprising 76% of the total volume (Figure 3.3). The smallest shortfinned eel from which fish were recorded was 480 mm long. Virtually all (94%) of the 18 fish from eel stomachs were identifiable, comprising 56% rudd, 33% perch, and 11% catfish. The largest fish eaten was a 150 mm (62 g) rudd found in a 978 mm eel. Four individuals had stomach contents containing large amounts of bird remains. Plant material, detritus, chironomid larvae, *Botryococcus braunii, Physastra variabilis,* and Odonata were also recorded in small quantities.

3.3.1.4 Catfish

Chironomid larvae were the most frequently occurring prey item in the stomachs of catfish, occurring in at least 92% of the samples analysed and occupying 64% of the total volume (Figure 3.3). Detritus was the second largest category, with small amounts recorded in 72% of the gut samples analysed. Fish were the third largest category occupying 9% of the

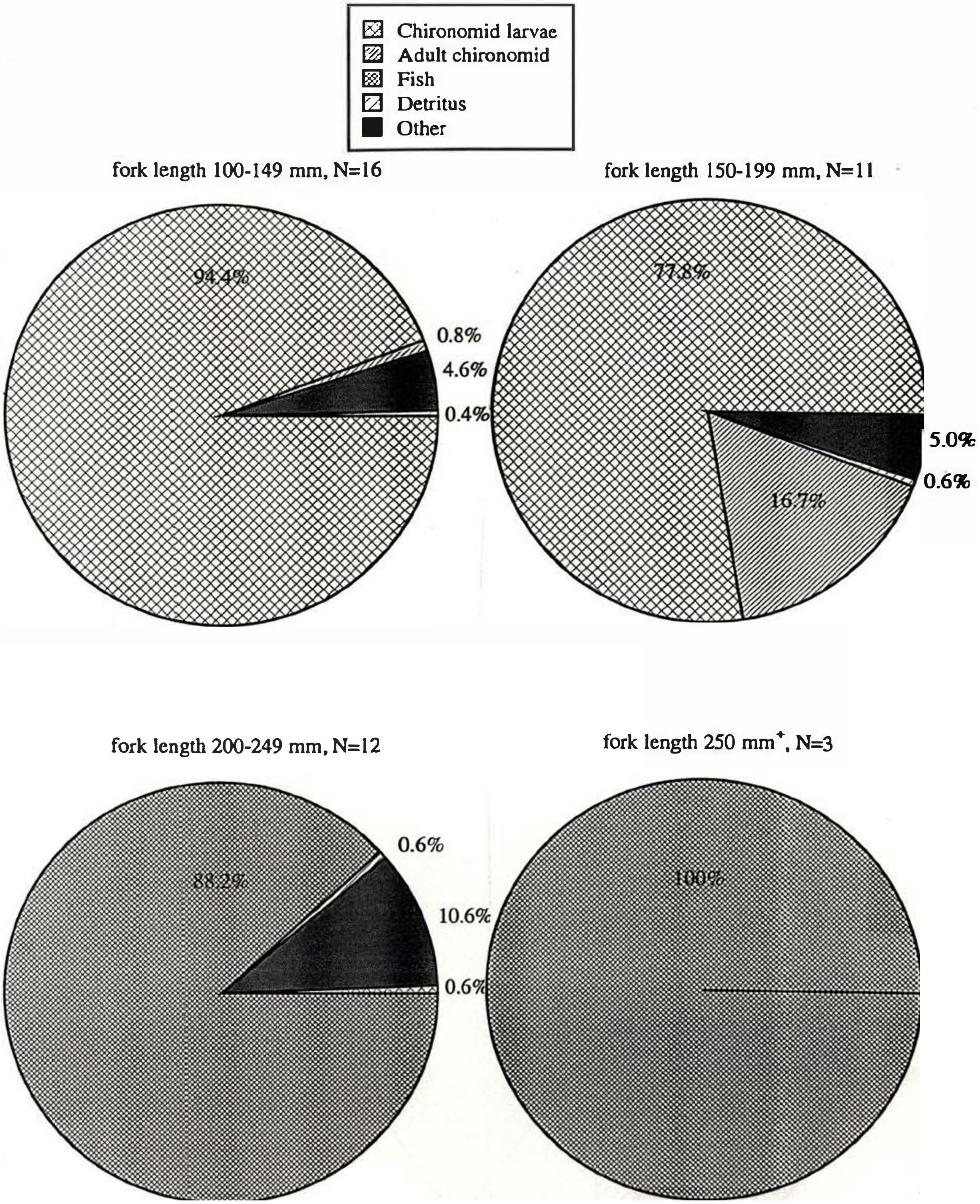


Figure 3.2: Percentage composition of food items by volume in the diet of perch of different length classes, caught in Hamilton Lake between December 1993 and February 1994.

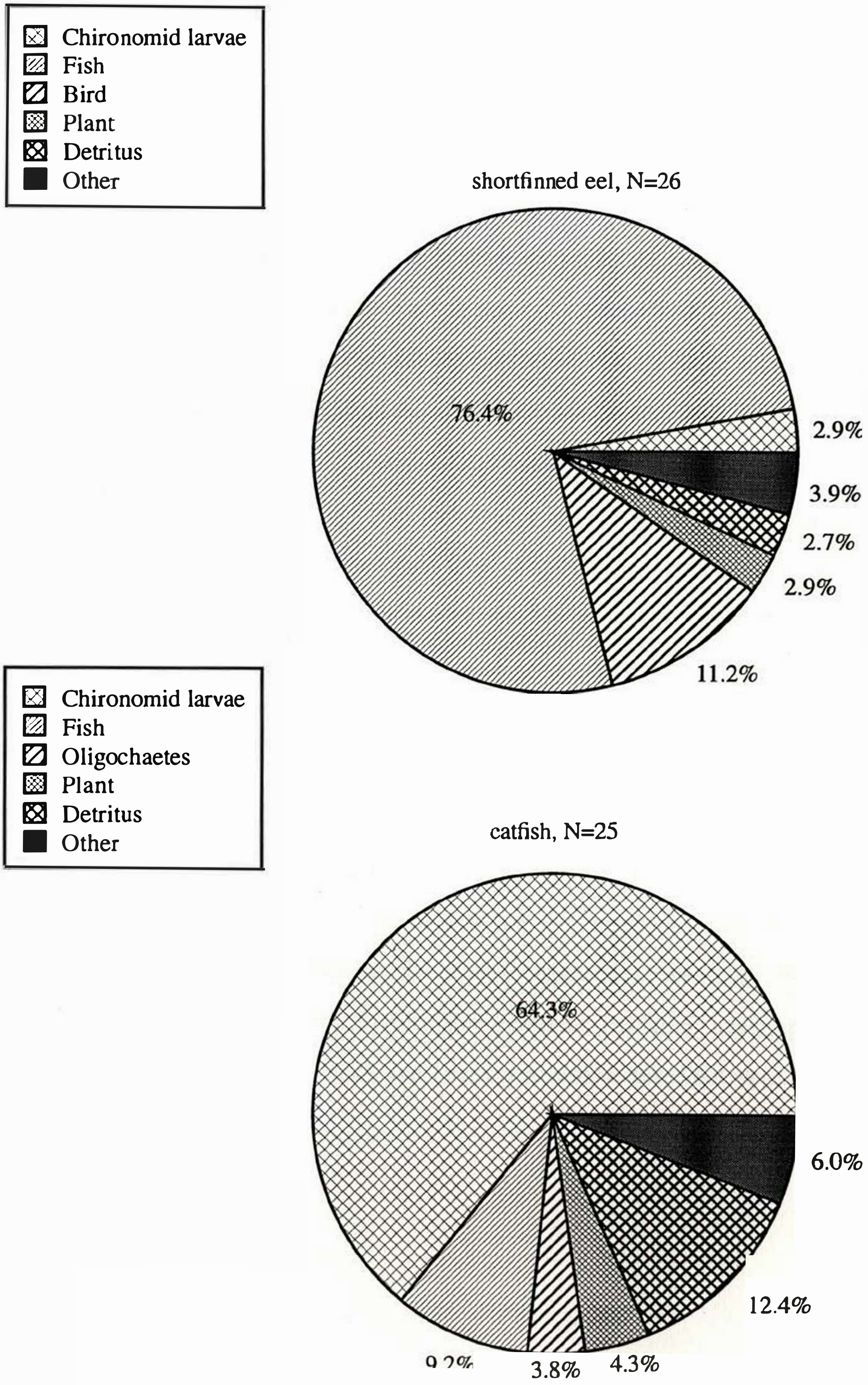


Figure 3.3: Percentage composition of food items by volume in the diet of shortfinned eel and catfish caught in Hamilton Lake between December 1993 and February 1994.

total volume. Oligochaetes, plant material, *Physastra variabilis,* and *Pisidium* spp. were minority components.

3.3.1.5 Tench

Table 3.3 shows the identifiable food items in tench stomachs. Chironomid larvae were the most important food item in the diet of tench, occurring in at least 79% of the gut contents examined, and comprising 51% of the total volume (Figure 3.4). Aquatic snails (*Physastra variabilis*, and *Potamopyrgus antipodarum*) also significantly contributed to the diet of tench, occurring in 79% of the gut samples examined and jointly comprising over 39% of the total volume. Small quantities of detritus were commonly present in gut samples, possibly reflecting the way in which tench ingest their food. Adult chironomid and pupae, plant material, and fragments of Odonata were also recorded in gut samples of tench.

3.3.1.6 Goldfish

The stomach contents of 17 goldfish were examined. Gut contents of goldfish were dominated by phytoplankton, particularly *Botryococcus braunii* although *Cyclotella* sp. was also present (Table 3.3). Chironomid larvae were the next largest category, found in 33% of the stomachs examined and comprising 25% of the total volume (Figure 3.4). Plant material was also present in small quantities. Terrestrial invertebrates (including adult lepidopterans, and hymenopterans), detritus, Odonata, and Trichoptera also occurred but were relatively rare in the goldfish diet.

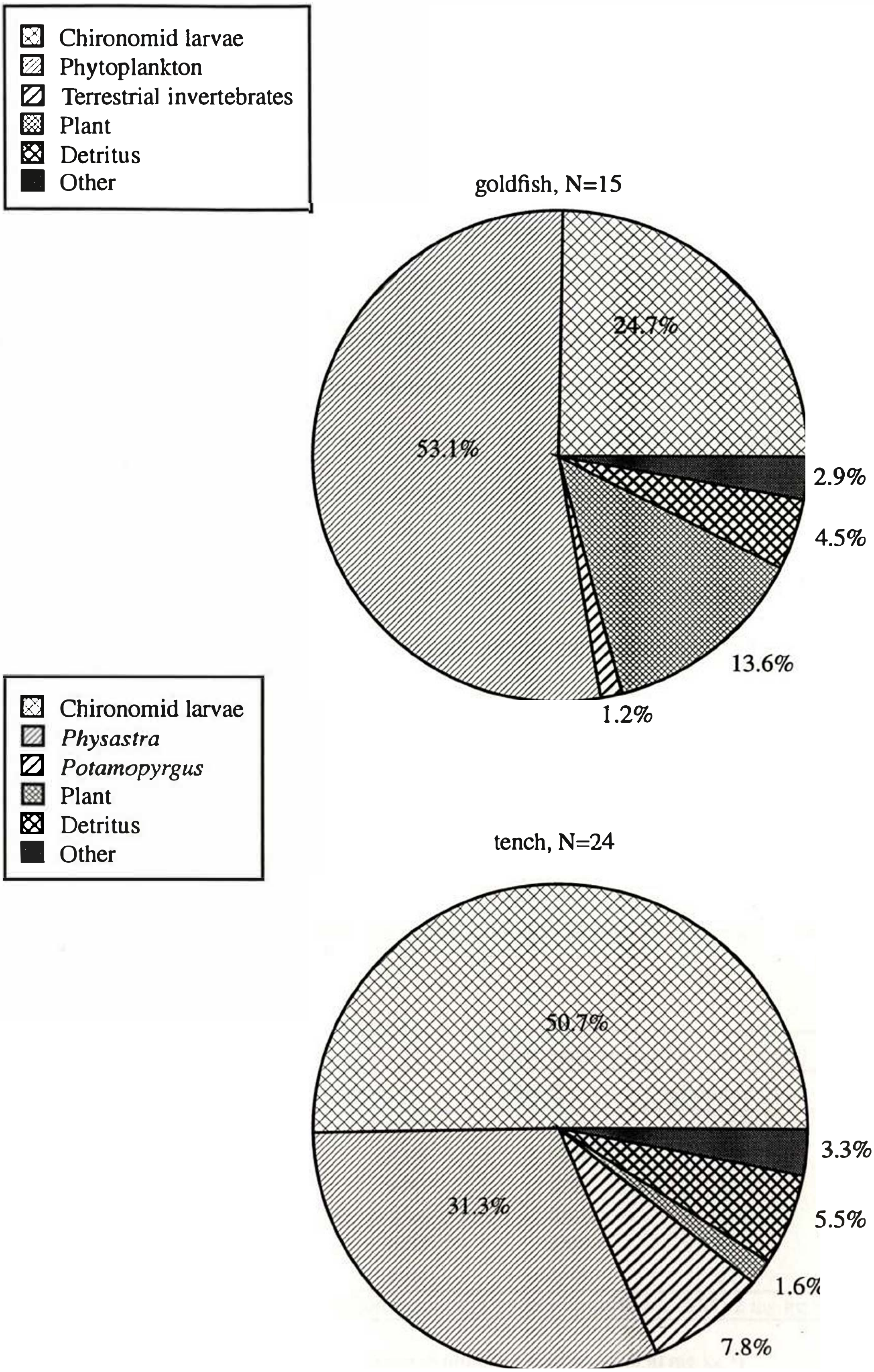


Figure 3.4: Percentage composition of food items by volume in the diet of tench and goldfish caught in Hamilton Lake between December 1993 and February 1994.

3.3.2 CONCENTRATION OF HEAVY METALS IN THE FLESH OF FISH FROM HAMILTON LAKE

Results from the heavy metal analysis are shown in Table 3.4 and Appendix 3. The fish tissue sampled contained low levels of lead and copper, with relatively higher levels of arsenic and zinc. The majority of fish tissue contained lead levels below the detection limit of 0.1 mg kg^{-1} wet weight. Levels of copper were also consistently low, with a maximum concentration of 1.2 mg kg^{-1} in the fish tissue, compared to the New Zealand maximum permitted level of 30 mg kg^{-1} (Statutory regulations 1984). Levels of copper exhibited relatively little variation between fish species and between sample sites.

Levels of arsenic and zinc in fish tissue showed a relatively large variation, between both sample sites and fish at a given site. The maximum concentration of 1.26 mg kg^{-1} arsenic found in a catfish was high relative to the maximum level of 2 mg kg^{-1} permitted in New Zealand. This was also apparent for zinc, with high levels recorded in goldfish, rudd, and shortfinned eel.

Table 3.4: Results from the heavy metal analysis for A) arsenic, B) zinc, C) copper, and D) lead, for each fish species examined (sites combined).

A) Arsenic[1]:

Species	Number	Concentration (mg kg^{-1} wet weight)			
		mean	95% C.I.	minimum	maximum
Catfish	12	0.778	0.201	0.170	1.260
Goldfish	11	0.173	0.038	0.100	0.300
Perch	12	0.095	0.036	0.030	0.24
Rudd	14	0.116	0.031	0.050	0.250
Shortfinned eel	11	0.155	0.070	0.050	0.340
Tench	12	0.373	0.076	0.170	0.560
Maximum permitted levels for human consumption (Statutory Regulations 1984) 2 mg kg^{-1} wet weight					

[1] An additional two samples were below detection limits for arsenic (<0.030 mg kg^{-1})

B) Zinc:

Species	Number	Concentration (mg kg^{-1} wet weight)			
		mean	95% C.I.	minimum	maximum
Catfish	12	4.892	0.169	3.700	8.000
Goldfish	11	11.945	0.038	7.200	19.300
Perch	13	4.269	0.048	2.700	6.100
Rudd	14	11.229	0.031	3.700	17.800
Shortfinned eel	12	11.450	0.067	6.900	15.600
Tench	12	4.058	0.076	2.800	5.800
Maximum permitted levels for human consumption (Statutory Regulations 1984) 40 mg kg^{-1} wet weight					

C) Copper[2]:

Species	Number	Concentration (mg kg^{-1} wet weight)			
		mean	95% C.I.	minimum	maximum
Catfish	9	0.800	0.176	0.500	1.100
Goldfish	10	0.810	0.192	0.0500	1.200
Perch	9	0.767	0.149	0.500	1.100
Rudd	11	0.845	0.176	0.500	1.200
Shortfinned eel	7	0.886	0.064	0.800	1.000
Tench	7	0.843	0.191	0.600	1.100
Maximum permitted levels for human consumption (Statutory Regulations 1984) 30 mg kg^{-1} wet weight					

[2] An additional 21 samples were below detection limits for copper (<0.400 mg kg^{-1})

D) Lead:

Species	Number	Concentration (mg kg^{-1} wet weight)	
		minimum	maximum
Catfish	12	<0.100	0.200
Goldfish	11	<0.100	1.100
Perch	13	<0.100	0.500
Rudd	14	<0.100	0.400
Shortfinned eel	12	<0.100	1.310
Tench	12	<0.100	0.400
Maximum permitted levels for human consumption (Statutory Regulations 1984) 2 mg kg^{-1} wet weight			

A comparison of results from R.J. Hill Laboratories and Ruakura Agricultural Research Centre revealed significant differences ($p<0.05$) in the concentrations of arsenic recorded in the flesh of fish from Hamilton Lake (Table 3.5). Concentrations recorded by Ruakura Agricultural Research Centre were lower than those of R.J. Hill Laboratories by a constant common factor (Figure 3.5).

Of the 10 samples analysed for lead, nine were below detection limits, and as a result no comparisons could be made between concentrations recorded by R.J. Hill Laboratory and Ruakura Agricultural Research Centre.

Table 3.5: Comparison of results from R.J. Hill Laboratories and Ruakura Agricultural Research Centre for concentrations of arsenic in the flesh of fish in Hamilton Lake.

Fish species	Arsenic concentration (mg kg^{-1} wet weight)		
	R.J. Hill	Ruakura	R.J.Hill/Ruakura
catfish	1.26	0.060	21.00
catfish	1.01	0.068	14.85
catfish	0.99	0.076	13.03
catfish	0.77	0.056	13.75
catfish	0.52	0.060	8.67
catfish	0.33	0.024	13.75
catfish	0.17	0.027	6.30
goldfish	0.16	0.024	6.67
goldfish	0.13	0.012	10.83
shortfinned eel	0.06	0.008	7.50
Mean	0.54	0.042	11.63

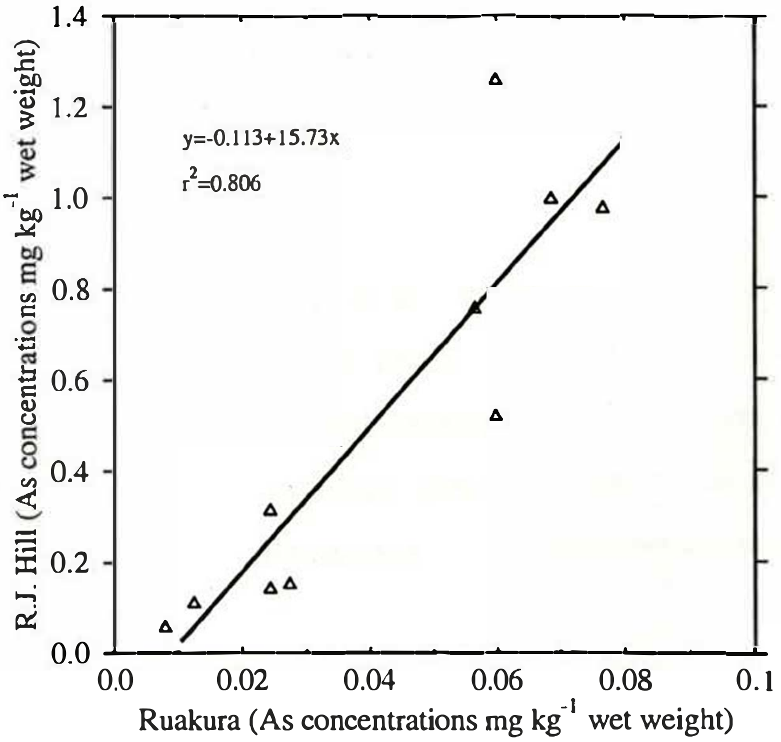


Figure 3.5: Results of arsenic concentrations in flesh of fish from Hamilton Lake, recorded by R.J. Hill Laboratory, and Ruakura Agricultural Research Centre.

3.4 DISCUSSION

3.4.1 DIETARY ANALYSIS

3.4.1.1 Rudd

Rudd are carnivores, and by virtue of the lower jaw, are morphologically adapted to foraging at the surface or mid water (Eklov and Hamrin 1989). They have been documented as feeding largely on plankton when small (< 75 mm FL), turning to a terrestrial and aquatic insect diet which includes some macrophytes up to a size of about 135 mm FL. Beyond this size their diet comprises primarily aquatic macrophytes, diverse insects, and worms (Cihar and Stanislav 1958, Kennedy and Fitzmaurice 1974, Cadwallader 1977).

Wise (1990) found that rudd above 100 mm in length in Hamilton Lake fed primarily on aquatic macrophytes (principally *Egeria densa* and to a lesser extent *Nitella* sp.). Some filamentous algae and insects (mainly terrestrial) also contributed to the diet. Between 1988 and 1990 a dramatic decline in submerged aquatic vegetation was recorded in Hamilton Lake. *Egeria densa* was the last recorded aquatic plant, finally disappearing in July 1990 (Tanner et al. 1990).

Following this collapse Totome (1993) reported that the majority of smaller rudd (110-127 mm FL) fed exclusively on chironomids, both larvae and winged adults, though small amounts of phytoplankton, plant material, and other insects were present in stomach contents. However the larger rudd (166-247 mm) still continued to feed primarily on plant material (mostly *Nymphaea* cultivars, and to a lesser extent *Baumea articulata*) but also took small quantities of chironomids.

Results of the present study show that chironomid pupae were the most commonly consumed food item of smaller rudd (100-149 mm FL), but as the size of the fish increased emergent plant material became increasingly important. This plant material consisted solely of marginal vegetation, particularly the emergent species, *Nymphaea* cultivars, *Iris pseudacorus*, and to a lesser extent *Baumea articulata*. The relatively low number of chironomid larvae consumed confirmed indications that rudd principally feed at surface and mid waters. Despite the total collapse of submerged aquatic macrophytes, which formed the bulk of the diet of rudd (Wise 1990), vegetation still remained the most important food item for adult rudd. This suggests that adult rudd >200 mm in length are obligate herbivores.

Rudd utilise only about 30% of plant material ingested, compared to 80% of animal material. The low utilisation of plant material is due to insufficient production of cellulose digesting enzymes (Vinberg 1956). As a result, herbivorous rudd consume large quantities of plant material, of which a large proportion is returned into the water in a degraded form. Ravera and Jamet (1991) found that 200 kg of plant material per hectare can be consumed in high feeding intensity of rudd. With such high amounts of plant consumption, rudd impose a high degree of grazing pressure on aquatic plant communities, and have consequently been suggested as a possible factor in the demise of the submerged aquatic macrophytes in Hamilton Lake (de Winton et al. 1994).

3.4.1.2 Perch

As perch grow, they show a progressive dietary shift, from small size prey such as zooplankton, particularly *Daphnia* sp. (Guma'a 1978, Wheeler 1969, Persson and Greenberg 1990a, Prout et al. 1990, Treasurer 1990), to invertebrates (most commonly amphipods, chironomid, and Trichoptera), and finally to fish (Duncan 1967, McCormack 1970, Sumari 1971, Craig 1974a, Griffiths 1976, Keast 1977, Janson and MacKay 1991, Guti 1993). Keast (1977) suggested that these diet shifts relate to changes in foraging efficiency and occur at an optimum fish size. Supporting this, Persson (1987) demonstrated that when fed *Daphnia*, 1^+ perch had a higher capture rate and a lower handling time than the larger 2^+ fish. However when fed chironomids, the 2+ fish had the higher capture rates. The fish size at which major dietary shifts occur varies in both timing and magnitude between populations (McCormack 1970, Craig 1974a, Craig 1978), and has been shown to be dependent on the relative abundances of food items (Popova and Sytina 1977). When food is scarce perch may eat plankton and benthos throughout their lives (Popova and Sytina 1977).

Piscivory in perch has most commonly been reported to occur between 130-150 mm FL, though some perch less than 100 mm FL have been known to feed on fish (McCormack 1970). Once perch reach sizes of above 250 mm their diet consists almost entirely of fish (Le Cren 1992). Engelmayer (1992) found hunting efficiency was higher when perch fed on only one type of food, as this did not necessitate inefficient changes in hunting strategy.

In the absence of vegetation, perch are apparently able to forage efficiently, although there may be a reduction in the availability of invertebrate prey to the extent that perch may be forced to consume less profitable zooplankton prey (Mattila 1992, Diehl 1993). Graynoth (1978) reported *Daphnia* consumption by perch prior to the collapse of submerged macrophytes, with Daphnia occupying approximately 10% of the total wet weight of food items consumed in the 50-99 mm and 100-149 mm length classes. If invertebrate abundance was limiting during the sampling period of the present study, an increase in consumption of zooplankton would be expected since Graynoth's study. However in the present study no zooplankton were recorded in the diet of perch of any length class, although the diet of only one perch less than 10 mm was examined.

Graynoth's (1978) dietary analysis of perch revealed a greater variety of food items consumed than did the present study. This is possibly a consequence of increased habitat homogeneity associated with the loss of aquatic macrophytes, and the possible reduction in invertebrate species present in the lake (Persson 1983). Graynoth (1978) also found that Odonata contributed to higher proportions of the perch diet at all length classes, comprising 49% of the total wet weight of food items consumed for perch 100-149 mm in length. He also noted that perch become piscivorous at smaller sizes, with fish being first recorded at lengths between 100-149 mm, and becoming the most important food item in perch 150-199 mm in length. Graynoth (1978) found that bullies formed a relatively significant component of the perch diet. The total absence of bullies in perch diets in the present study may indicate a decline in the bully population of Hamilton Lake over the past 16 years.

The transition from a diet of invertebrates to one of fish occurring at approximately 200 mm length was consistent with results obtained by Wise (1990). However Totome (1993) reported no consumption of fish by perch in Hamilton Lake. He attributed this to the decline in water quality associated with the collapse of the submerged macrophytes, as perch rely on visual hunting. The lack of fish in perch diets may have been a reflection of the relatively low maximum perch size studied (214 mm FL)

Only one perch less than 100 mm was caught in the present study, therefore no conclusions on the diet of this class of fish can be drawn. However, Graynoth's (1978) findings show that their diet comprises a combination of zooplankton and invertebrates.

3.4.1.3 Shortfinned eels

Shortfinned eels characteristically consume a wide range of food items. All dietary studies of shortfinned eels <40 cm in length demonstrate that they are opportunist feeders with a varied diet reflecting the availability of food. Benthic invertebrates, including crustaceans, molluscs, copepods, amphipods and chironomids are frequently consumed (Cairns 1942, Ryan 1984, Ryan 1986, Chisnall 1987, and Jellyman 1989). Above 40 cm in length shortfinned eels often become piscivorous, sometimes feeding almost exclusively on fish (Ryan 1986), as was apparent in this study.

The shortfinned eels in Hamilton Lake consumed a higher percentage of rudd than perch, although perch were numerically more abundant. This was expected as rudd fed in surface and mid waters making them more conspicuous and easier to locate by predators than perch. Experimental studies have also shown that predators prefer soft-rayed fish over spiny-rayed species (Mauck and Coble 1971). Perch are therefore likely to be less vulnerable to predation than rudd due to their fin and gill spines (Eklov and Hamrin, 1989).

Although eels ate a variety of food items in Hamilton Lake, individual eels were normally very selective in their diet, typically consuming many members of a single food category.

3.4.1.4 Catfish

The catfish is a predator and scavenger, locating food primarily with sensory barbels rather than with its small eyes (McDowall 1990). The diet of small catfish (<75 mm FL) include chironomids, cladocerans, Ostracoda, and Amphipoda (Raney and Webster 1939, Keast and Webb 1966). Above this size the diet primarily consists of chironomid larvae and benthic crustacea, and as fish become larger, molluscs, larger crustacea and fish become more important (Cable 1928, Frank 1955, Scott and Crossman 1973, Weisberg and Janicki 1990).

Catfish in this study fed primarily on chironomid larvae, though detritus, fish, oligochaetes, plant material, and molluscs (*Physastra variabilis*, and *Pisidium* spp.) were also present in stomach contents. These results are consistent with those obtained previously in Hamilton Lake (Wise 1990, Totome 1993), and with those obtained in other lakes and rivers in the area (Patchell 1977).

Although the sediment of Hamilton Lake contained higher numbers of oligochaetes than chironomids (Appendix 4), chironomids were more prevalent in catfish diets. Klarberg and Benson (1975) found that catfish fed selectively on chironomids, even though oligochaetes were present. However, it seems more likely that differential digestion rates resulted in proportionally more oligochaetes than chironomids being digested prior to stomach analysis (Kennedy 1969, Hyslop 1980). Consistent with this theory Totome (1993) using carbon isotope analysis found that oligochaetes were important dietary items for catfish in Hamilton Lake.

Detritus was observed in small quantities in at least 72% of the stomachs analysed. This is consistent with previous studies (Wise 1990, Totome 1993) where the volume of detritus comprised up to 68% of the total diet (Patchell 1977). Some authors have suggested that catfish intentionally feed on detritus and that it may supplement the nutritional requirements of fish (Klarberg and Benson 1975).

3.4.1.5 Tench

There is relatively little information available on the diet of tench within New Zealand. However, overseas documentation indicates that while less than 150 mm in length, tench are generalist foragers feeding on a range of zooplankton (particularly *Daphnia* spp.), turning to a diet of aquatic benthic invertebrates including insect larvae, crustaceans, amphipods, and molluscs thereafter (Weatherly 1959, Kennedy and Fitzmaurice 1970, Giles et al. 1990, McDowall 1990, Wright and Giles 1991).

The present study found that benthic invertebrates formed the majority of the diet of tench in Hamilton Lake, with chironomid larvae and aquatic snails (*Physastra variabilis* and *Potamopyrgus antipodarum*) being the preferred taxa. Tench often feed heavily on chironomid larvae, particularly in stagnant waters where such prey predominate (Kennedy and Fitzmaurice 1970). Like other Cyprinidae, tench lack jaw teeth but possess pharyngeal teeth enabling them to crush the shells of snails and mussels (Weatherley 1959). Previous studies have shown that molluscs comprise only relatively minor proportions of the tench diet. However, in a series of experiments Bronmark (1994) concluded that rather than being generalist foragers, tench are actually specialist foragers on molluscs. The findings of this study support Bronmark's conclusions, as molluscs comprised over 39% of the total dietary volume for tench in Hamilton Lake. Mollusc consumption in tench was thus far higher than for any other fish species sampled, with the next highest feeder of molluscs being catfish (<3% of the total dietary volume).

Although plant material was present in stomach samples, tench appear unable to utilise plants directly as food (Weatherly 1959). Plant material is commonly swallowed incidentally with preferred food items rather than being deliberately ingested (Kennedy and Fitzmaurice

1970). Similarly, the small amounts of detritus present can probably be attributed to the way in which tench ingest their food (Weatherly 1959).

3.4.1.6 Goldfish

Although very few dietary studies have been completed for wild goldfish in New Zealand, they are reportedly omnivorous, feeding on plant material, organic detritus, small insects, and crustaceans (McDowall 1990). Goldfish in Hamilton Lake appear to be principally herbivorous, feeding largely on plankton and plant material, although they supplement their diet with chironomid larvae, terrestrial invertebrates, Odonata, and Trichoptera. Goldfish are the only adult fish taking significant amounts of plankton in their diet. Zaret (1980) reported that most freshwater fish are capable of feeding on plankton, but are also capable of switching to insects or other prey items as they become available in lakes.

3.4.2 HEAVY METAL ANALYSIS

Several previous studies have been concerned with monitoring heavy metals concentrations in the flesh of fish in Hamilton Lake. The present study involved the examination of four elements: arsenic (As), Lead (Pb), copper (Cu), and zinc (Zn). These elements were of most interest due to high concentrations relative to the maximum permitted levels for human consumption, as documented by Rajendram (1992).

3.4.2.1 Arsenic

In a monthly survey between September 1990 and September 1991, Rajendram (1992) monitored levels of arsenic in Hamilton Lake. During this period arsenic levels of surface waters were found to average 0.007 parts per million (ppm) with a range of 0.003-0.015 ppm. Tanner and Clayton (1990) recorded results consistent with these findings, with surface waters averaging less than 0.010 ppm. In summer an estimated 15% of Hamilton

Lake (depth < 4 m) becomes stratified (Tanner and Clayton 1990)(refer section 2.2.5). The hypolimnion consequently becomes deoxygenated, causing the liberation of arsenic from lake sediments. Henriques (1979) recorded higher arsenic concentrations in bottom waters than in water sampled at other depths, with bottom water concentrations ranging from 0.010 to 0.550 ppm.

Levels of arsenic entering Hamilton Lake via stormwater inflows were less than 0.010 ppm between September 1990 and September 1991 (Rajendram 1992). Previous studies have found high concentrations of arsenic in surficial sediments from Hamilton Lake. Rajendram (1992) reported a mean concentration of 184 ppm (range of 12-900 ppm), while Tanner and Clayton (1990) reported a range of 540-780 mg kg^{-1} dry weight. This suggests that the high concentrations of arsenic in surface sediments originated from the 11,000 litres of sodium arsenate applied for weed control in 1959, which supplied over 5,500 kg of arsenic to the lake (Tanner and Clayton 1990).

In the present study arsenic levels were all below the maximum permitted levels for human consumption of 2 mg kg^{-1} (Statutory Regulations 1984). Concentrations of arsenic recorded in the flesh of fish during this study, however, proved to be relatively high compared to the next most recent analysis of fish flesh from Hamilton Lake by Rajendram (1992). Consequently ten samples with a range of arsenic concentrations were re-analysed at a second laboratory. The results proved to be significantly different ($p<0.05$), with flesh samples from the same fish analysed at Ruakura Agricultural Research Centre having considerably lower arsenic concentrations than those from R.J. Hill Laboratories.

Results from previous studies are shown in Table 3.6. The results of Rajendram (1992) show considerably lower concentrations of arsenic than those of Tanner and Clayton (1990). Clayton and Tanner (1994) attributed this reduction in arsenic concentrations to a change in the diet of fish following the collapse of the submerged aquatic macrophytes in Hamilton Lake. Results of the present study (from R.J. Hill) demonstrate that concentrations have not actually declined, but are relatively consistent with those of Tanner and Clayton (1990) considering their low sample sizes. The second set of results from Ruakura and those of Rajendram (1992), which were also analysed at Ruakura, showed similar concentrations of arsenic.

The lower concentrations of arsenic recorded from Ruakura could be attributed to the use of the wet ashing technique, while results from R.J. Hill and those from Cawthron Institute (used by Tanner and Clayton 1990) used a dry ashing technique for the release of arsenic from samples.

Arsenic in fish often exists in a variety of inorganic valency states. It is difficult to release arsenic from organically bound states by normal wet oxidation, and Evans et al. (1979) suggested that dry ashing was the most suitable means of releasing the total arsenic from samples of fish. The inability of wet oxidation to release all the arsenic from fish tissue probably resulted in an underestimate of the arsenic concentrations in results obtained by Ruakura.

Since arsenic concentrations obtained by R.J. Hill and Ruakura Agricultural Research Centre differed by a constant common factor, results obtained by Rajendram (1992) were amended to values consistent with those that would have been obtained through analysis at R.J. Hill laboratory (Table 3.6). The resulting arsenic concentrations in the flesh of perch, rudd, and shortfinned eels appeared more consistent with results obtained by Tanner and Clayton (1990), and those of the present study.

Table 3.6: Results from various studies examining concentrations of arsenic in the flesh of fish in Hamilton Lake.

Fish species	Arsenic concentrations (mg kg^{-1} wet weight)				
	Tanner and Clayton (1990)	Rajendram (1992)	Amended Rajendram (1992)	Present study (R. J. Hill Lab)	Present study (Ruakura)
catfish	0.9 n=1	0.148 n=4	2.22	0.778 n=12	0.053 n=7
goldfish				0.173 n=11	0.018 n=2
perch	0.4 n=2	0.035 n=10	0.44	0.095 n=12	
rudd	<0.2 n=3	0.013 n=11	0.09	0.116 n=14	
s/f eel	0.4 n=1	0.019 n=5	0.19	0.155 n=11	0.008 n=1
tench				0.373 n=12	

Maximum permitted levels for human consumption (Statutory Regulations 1984) 2mg kg^{-1} wet weight

A number of authors believe that arsenic is not a severe pollutant for fish species, as it does not accumulate to any large extent in freshwater or marine fish (Penrose et al. 1975, Moore and Ramamoorthy 1984). Freshwater fish possess the ability to convert inorganic arsenic which is moderately toxic, to a stable and probably non-toxic organic form, which can be readily excreted by humans (Moore and Ramamoorthy 1984). Moore and Ramamoorthy (1984) demonstrated this attribute by exposing rainbow trout to arsenic, causing high levels of inorganic arsenic to accumulate in various tissues within six hours. After this period, a gradual increase in the amount of organic arsenic and a corresponding decrease in inorganic forms occurred.

Although arsenic is not usually biomagnified, bottom feeding fish generally contain the highest concentrations of arsenic, as it is absorbed primarily through food rather than from water. This was apparent in Hamilton Lake, as catfish and to a lesser extent tench (both of which are principally benthic feeders), had the highest concentrations of arsenic in their flesh.

3.4.2.2 Copper, lead, and zinc

In a monthly survey conducted between September 1990 and September 1991, Rajendram (1992) reported a concentration range of 0.001-0.275, <0.001-2.30, and <0.01-2.06 ppm for lead, zinc, and copper respectively in water entering Hamilton Lake from stormwater inflows. Based on these concentrations Rajendram (1992) concluded that all three heavy metals were entering the lake via stormwater inflows.

Possible sources of lead in the stormwater entering Hamilton Lake include fumes from combustion engines and from the use of lead based paints (Roncero 1990). Zinc is likely to originate from galvanised products and tyre abrasion, while copper may originate from automobile brake shoes.

Analysis of fish tissue revealed that levels of lead were generally low, often being less than the detection limit of 0.1 mg kg^{-1} wet weight (though a maximum concentration of 1.31 mg kg^{-1} wet weight was recorded). Comparisons with other studies are thus complicated as a mean lead value could not be accurately determined. However, lead concentrations for each fish species examined in the present study appear to be slightly higher than those obtained by Rajendram (1992), (Table 3.7), and consistent with previous studies undertaken in other lakes (e.g. Moore and Ramamoorthy 1984, Schmitt and Brumbaugh 1990, Sures 1994).

Table 3.7: Range of lead concentrations recorded in flesh of fish from Hamilton Lake.

Fish species	Concentration of lead (mg kg^{-1} wet weight)	
	Rajendram (1990)	Present study
catfish	<0.02 n=4	<0.1-0.2 n=12
perch	<0.02-0.06 n=10	<0.1-0.5 n=13
rudd	<0.02-0.06 n=11	<0.1-0.4 n=14
shortfinned eel	0.05-0.14 n=5	<0.1-1.31 n=12
Maximum permitted levels for human consumption (Statutory Regulations 1984) 2mg kg^{-1} wet weight		

Lead is a non-essential and non-beneficial element that has received a great deal of attention recently as an important aquatic pollutant (Ruparelia et al. 1989). Lead is known to cause biochemical changes, muscle tremors, caudal fin degeneration, black tail disease, and necrosis of the sensory and supporting cells of the lateral line in fish. However, it has been noted that fish species have different tolerances to lead, and some species are able to adapt to high lead levels (Moore and Ramamoorthy 1984).

Levels of copper in fish flesh were also very low, with no samples analysed exceeding 1.2 mg kg^{-1} wet weight. These results are well below the maximum permitted levels of 30 mg kg^{-1} for human consumption. There was very little variation in copper concentrations in the flesh of the various fish species caught in Hamilton Lake. A comparison of copper in fish flesh shows results obtained in this study are generally slightly higher than those obtained by Rajendram (1992) (Table 3.8).

Copper is normally more toxic to freshwater fish than any other heavy metal except mercury, though maximum copper concentrations in muscle tissue seldom exceed 1.5 mg kg^{-1} (Moore and Ramamoorthy 1984, Carpene et al. 1990, Unlu and Gumgum 1993). Brooks et al. (1976) analysed heavy metals in rainbow trout in 16 lakes around New Zealand and found the mean copper concentration in the flesh was 1.2 mg kg^{-1} wet weight. The maximum individual lake average was 2.7 mg kg^{-1} from Lake Rotoma. Because concentrations of copper are generally low, this heavy metal is unlikely to threaten fisheries, even in polluted waters (Moore and Ramamoorthy 1984).

Table 3.8: Mean concentration of copper and zinc in the flesh of fish from Hamilton Lake.

Fish species	Concentrations expressed as mg kg^{-1} wet weight			
	Rajendram (1992)		Present study	
	copper	zinc	copper	zinc
catfish	0.38 n=4	4.5 n=4	0.800 n=9	4.892 n=12
perch	0.21 n=10	4.2 n=10	0.767 n=9	4.269 n=13
rudd	0.66 n=11	11.3 n=11	0.845 n=11	11.229 n=14
shortfinned eel	0.73 n=5	13.3 n=5	0.886 n=7	11.450 n=12

Although levels of zinc were relatively high, results were very similar to those obtained by Rajendram (1992), and still well below the maximum permitted level of 40 mg kg^{-1} wet weight. Levels of zinc in fish flesh were highest in goldfish, and were also high in shortfinned eels and rudd. Smith and Health (1979, cited in Schmitt and Brumbaugh 1990) also found goldfish accumulated zinc to a greater extent than other fish species, although they were particularly tolerant to high concentrations of zinc. Brooks et al. (1976) examined zinc levels in flesh of rainbow trout in 16 New Zealand lakes. The average concentration for all lakes was 12.4 mg kg^{-1} wet weight, and the highest individual lake average was 18 mg kg^{-1} wet weight. These results demonstrate that concentrations of zinc are not particularly high in the flesh of fish from Hamilton Lake.

CHAPTER FOUR:
Conclusion

4.1 RELATIVE ABUNDANCE

A total of 1073 fish representing nine species were caught at 11 different sampling sites in Hamilton Lake between 9 December 1993 and 2 February 1994. Rudd and perch were the most commonly caught species in gill nets, while shortfinned eels had the highest catch rates of all species in fyke nets. During the course of this study very few juvenile fish (<100 mm fork length) were caught. This may support Johnson's (1994) theory that in unexploited fish populations there is an almost total absence of juvenile fish. Alternatively, sampling methods may not have been effective in juvenile fish capture.

A comparison of catch per unit effort (CPUE) data between Wise (1990) and the present study indicates that rudd have declined in abundance since 1990, with catch rates declining by 67%. Conversely, perch abundance has increased, with catch rates increasing by 300%. During this period perch have surpassed rudd as the most abundant fish species. The decline in rudd catch rates is probably associated with the collapse of submerged aquatic macrophytes in Hamilton Lake during 1990. As rudd feed primarily (84% of total dietary volume) on aquatic macrophytes (Wise 1990), it is expected that they would be severely affected by the collapse.

4.2 SEX RATIOS

With the exception of perch, relatively equal female to male sex ratios were established for all fish species in which sex was determined. Female perch outnumbered males by a ratio of 2.4:1, which is consistent with previous studies (Craig 1974, Graynoth 1978, Wise 1990) and is likely to be a consequence of higher male mortality rates (Jellyman 1980).

Most exotic fish species in Hamilton Lake reportedly spawn between August and October (Wise 1990). Gonadosomatic index (GSI) values were thus generally low during the sampling period. Rudd and goldfish, however, appear to spawn more than once per year in Hamilton Lake. Wise (1990) found that rudd spawn twice per year in Hamilton Lake, and results from the present study are consistent with his theory. Goldfish are also known to spawn several times per year (Patchell 1977) although this has not previously been documented in Hamilton Lake. However, high GSI values suggest that in addition to spawning between August and October, goldfish probably spawn again soon after the study period. Although the tench sampled had well developed gonads (particularly the females), they do not appear to be spawning in Hamilton Lake, as no fish under 300 mm in length were captured. This is probably due to their spawning habitat requirements which include warm water temperatures, wind shelter and the presence of submerged vegetation.

4.3 AGE, GROWTH RATES, AND SIZE OF FISH

The length-frequency distributions of perch and rudd, and the length-weight relationship for perch both showed variation between sampling sites. Larger sized perch were proportionally more abundant at sampling site 5, while higher proportions of smaller perch and rudd were recorded at sampling site 6. The variation in weight between sampling sites was attributed to differences in food availability, while the differential distribution of fish sizes was attributed to the ability of older, larger fish to move further from spawning grounds in search of food.

Rudd and tench were the only fish species in which males and females exhibited a significant difference ($p<0.05$) in length-weight regression equations. In general the regression equations indicated that length-weight relationships of fish in Hamilton Lake had not changed since Wise's (1990) study, and were similar to other studies (Holcik 1967, Patchell 1977, Jellyman 1980, Chisnall 1987).

Ages of rudd were determined using scales, while perch were aged using opercular bones. Back-calculation of fish length involved the use of both the scale proportional hypothesis (SPH), and body proportional hypothesis (BPH) (Francis 1990). Results from the SPH appeared more accurate due to better compatibility with actual observed fish lengths. Sizes of one and two year old rudd appear to have declined over the past six years in Hamilton Lake. In 1987, the mean fish lengths of one and two year old rudd were 87 mm and 207 mm respectively, while in 1991 the same aged fish were 69 mm and 127 mm in length. Growth rates of rudd appear to have been influenced by the collapse of the submerged aquatic macrophytes. However, average growth rates of rudd over the past six years are still higher than in the majority of studies undertaken elsewhere (Cihar and Stanislav 1958, Holcik 1967, Kennedy and Fitzmaurice 1970, Zerunian 1986).

Perch growth rates do not appear to have changed over the past six years. Back-calculated lengths are similar to those obtained in previous studies involving perch in Hamilton Lake (Graynoth 1978, Wise 1990), and are generally faster than those recorded in the Northern Hemisphere. The similarity of back-calculated results between this study and Graynoth (1978) indicate that the introductions of rudd and catfish have not obviously affected perch growth rates. Back calculation results were also similar to those of Wise (1990) indicating that the collapse of the submerged macrophytes has also had no discernible effect on perch growth.

Attempts were made to age tench, using both scale and operculum methods. However, due to the poor formation of growth rings on both scales and opercula, accurate aging of tench from Hamilton Lake was not possible.

4.4 DIETARY ANALYSIS

Chironomids and oligochaetes dominated the invertebrate fauna in the bottom sediments of Hamilton Lake. Chironomids consequently featured heavily in the diets of most fish species. However, few oligochaetes were consumed, possibly because fish selectively feed on chironomids, but probably due to differential digestion rates which resulted in proportionally more oligochaetes than chironomids being digested prior to stomach analysis.

Despite the total collapse of submerged aquatic macrophytes, which formed the bulk (84% by volume) of the diet of rudd (Wise 1990), aquatic vegetation remained the most important food item of adult rudd in the present study, although this now comprised entirely of emergent marginal vegetation (Figure 3.1). This suggests that rudd >200 mm in length are obligate herbivores. Invertebrates were the major dietary item of perch up to a length of approximately 200 mm. Beyond 200 mm in length perch principally fed on fish. Fish were the major dietary item for most shortfinned eels caught in this study, although few eels under 400 mm in length were captured. Phytoplankton were the major dietary item for goldfish, which was the only species to consume significant amounts of plankton. Although chironomids were the major food item of tench, they consumed significantly greater amounts of molluscs than any other fish species in the lake. Results thus support the theory that tench are specialised feeders on molluscs (Bronmark 1994). Catfish were generalist feeders, feeding on a range of benthic invertebrates, particularly chironomids.

4.5 HEAVY METAL ANALYSIS

Concentrations of arsenic, lead, copper and zinc in the white muscle of fish caught in the present study were all below maximum permitted levels for human consumption. Arsenic concentrations were highest in bottom feeding fish, particularly catfish (mean 0.778 mg kg^{-1} wet weight, compared to the maximum permitted level of 2 mg kg^{-1} wet weight) due to high arsenic concentrations in lake sediments.

Concentrations of arsenic in the flesh of fish from Hamilton Lake do not appear to have been affected by the collapse of the submerged aquatic macrophytes. Declines in arsenic concentrations suggested by Clayton and Tanner (1994) appear to have been a consequence of the use of different analytical techniques between their study and that of Rajendram (1992). Techniques reported by Ruakura Agricultural Research Centre (used by Rajendram

1992) failed to recover all arsenic in the fish flesh. The use of the dry ashing technique (Evans et al. 1979), as used in this study, is necessary to release the total arsenic from samples of fish.

Concentrations of lead, zinc and copper in the fish tissue were similar to previous results obtained in Hamilton Lake (Rajendram 1992), and to results obtained elsewhere (Brooks et al. 1976, Moore 1984, Schmitt and Brumbaugh 1990, Sures 1994).

Appendices

APPENDIX I:

Results from the fish sampling in the Hamilton Lake (Lake Rotoroa), between 9 December 1993 and 2 February 1994.

Sample site	Date set YYMMDD	Time set (h)	Net type	Net number	Mesh size (mm)	Fish species	Length mm	Weight g	Sex	Gonad weight g	Sample code

b=bullies
c=catfish
g=goldfish
le=lf eel
m=mosquitofish
p=perch
r=rudd
se=sf eel
t=tench

site	yy	mm	dd	time	ntype	netno	msizemm	species	length	weight	sex	gonadwt	scode
1	93	12	9	18.2	g	1	38	p	134	32.9	f	0.39	0071
1	93	12	9	18.2	g	1	38	p	130	30.9	m	0.25	0072
1	93	12	9	18.2	g	1	38	p	123	29.4	f	0.25	0073
1	93	12	9	18.2	g	1	38	p	128	31.2	m	0.22	0074
1	93	12	9	18.2	g	1	38	p	147	44.4	f	0.50	0075
1	93	12	9	18.2	g	1	38	p	129	26.9	f	0.27	0076
1	93	12	9	18.2	g	1	38	r	140	47.4	f	1.38	0077
1	93	12	9	18.2	g	1	38	r	120	29.6	m	1.35	0078
1	93	12	9	18.2	g	1	38	r	133	41.3	m	1.48	0079
1	93	12	9	18.2	g	1	38	r	134	38.8	m	1.23	0080
1	93	12	9	18.2	g	1	38	p	130	29.1	f	0.23	0081
1	93	12	9	18.2	g	1	57	p	212	116.5	f	0.17	0066
1	93	12	9	18.2	g	1	57	p	202	100.3	f	0.17	0067
1	93	12	9	18.2	g	1	57	r	180	105.0	f	1.14	0068
1	93	12	9	18.2	g	1	57	p	188	107.3	m	0.74	0069
1	93	12	9	18.2	g	1	57	r	200	166.3	f	9.52	0070
1	93	12	9	17.9	g	2	38	p	128	30.2	f	0.63	0026
1	93	12	9	17.9	g	2	38	p	125	26.8	m	0.27	0027
1	93	12	9	17.9	g	2	38	p	135	34.0	f	0.28	0028
1	93	12	9	17.9	g	2	38	p	129	29.4	f	0.25	0029
1	93	12	9	17.9	g	2	38	p	124	27.8	f	0.50	0030
1	93	12	9	17.9	g	2	57	p	220	134.0			0004
1	93	12	9	17.9	g	2	57	p	208	115.2	f	0.55	0005
1	93	12	9	17.9	g	2	57	p	220	142.9	f	1.43	0006
1	93	12	9	17.9	g	2	57	p	218	153.9	f	5.30	0007
1	93	12	9	17.9	g	2	57	p	208	123.3			0008
1	93	12	9	17.9	g	2	57	p	215	121.2	f	0.99	0009
1	93	12	9	17.9	g	2	57	p	195	99.9	f	0.69	0010
1	93	12	9	17.9	g	2	57	p	203	118.7	m	0.72	0011
1	93	12	9	17.9	g	2	57	p	210	129.4	f	0.84	0012
1	93	12	9	17.9	g	2	57	r	216	183.2	f	14.61	0013
1	93	12	9	17.9	g	2	57	r	208	170.6	f	4.13	0014
1	93	12	9	17.9	g	2	57	r	170	82.3	f	4.44	0015
1	93	12	9	17.9	g	2	57	c	270	321.2			0016
1	93	12	9	17.9	g	2	57	c	237	227.8	f	0.84	0017
1	93	12	9	17.9	g	2	57	r	180	94.6	f	2.14	0018
1	93	12	9	17.9	g	2	57	r	206	162.6	f	7.59	0019
1	93	12	9	17.9	g	2	57	p	220	133.9	f	1.08	0020
1	93	12	9	17.9	g	2	57	p	213	122.8	f	0.79	0021
1	93	12	9	17.9	g	2	57	r	215	178.7	f	11.80	0022
1	93	12	9	17.9	g	2	57	r	204	155.7	f	14.06	0023
1	93	12	9	17.9	g	2	57	p	202	108.9	f	2.16	0024
1	93	12	9	17.9	g	2	86	g	210	231.6	m	7.75	0025
1	93	12	9	17.9	g	2	108	t	445	1272.4	f	92.60	0001
1	93	12	9	17.9	g	2	108	t	382	904.9	f	54.00	0002
1	93	12	9	17.9	g	2	108	g	240	394.6	f	24.00	0003
1	93	12	9	18.8	g	3	38	r	129	34.3	m	1.56	0031
1	93	12	9	18.8	g	3	38	r	127	31.9	m	0.92	0032
1	93	12	9	18.8	g	3	38	r	131	40.9	m	1.83	0033
1	93	12	9	18.8	g	3	38	r	129	37.5	f	0.74	0034
1	93	12	9	18.8	g	3	38	r	135	39.3	f	3.56	0035
1	93	12	9	18.8	g	3	38	r	135	40.8	m	1.35	0036
1	93	12	9	18.8	g	3	38	r	133	36.2	f	2.73	0037
1	93	12	9	18.8	g	3	38	r	132	39.0	m	1.10	0038
1	93	12	9	18.8	g	3	38	r	138	45.1	f	2.72	0039
1	93	12	9	18.8	g	3	38	r	129	38.0	f	1.91	0040
1	93	12	9	18.8	g	3	38	r	138	40.7	m	1.35	0041

Appendix 1 (continued)

site	yy	mm	dd	time	ntype	netno	msizemm	species	length	weight	sex	gonadwt	scode
1	93	12	9	18.8	g	3	38	p	129	28.7	f	0.19	0042
1	93	12	9	18.8	g	3	38	p	128	27.3	m	0.31	0043
1	93	12	9	18.8	g	3	38	p	142	38.6	f	0.27	0044
1	93	12	9	18.8	g	3	38	p	149	46.7	f	2.12	0045
1	93	12	9	18.8	g	3	38	p	129	32.4	f	0.29	0046
1	93	12	9	18.8	g	3	38	p	138	34.6			0048
1	93	12	9	18.8	g	3	57	r	209	162.1	m	3.18	0049
1	93	12	9	18.8	g	3	57	r	224	201.6	f	2.82	0050
1	93	12	9	18.8	g	3	57	r	163	97.1	m	2.99	0051
1	93	12	9	18.8	g	3	57	p	195	106.8	f	0.24	0052
1	93	12	9	18.8	g	3	57	p	204	118.8	f	0.76	0053
1	93	12	9	18.8	g	3	57	p	192	105.8	m	0.69	0054
1	93	12	9	18.8	g	3	57	p	194	97.9	f	0.18	0055
1	93	12	9	18.8	g	3	57	p	196	100.6	f	0.23	0056
1	93	12	9	18.8	g	3	57	g	170	124.1	m	1.08	0057
1	93	12	9	18.8	g	3	57	p	204	107.6	f	2.59	0058
1	93	12	9	18.8	g	3	86	r	188	127.2	f	2.43	0059
1	93	12	9	18.8	g	3	86	r	235	251.0	f	19.45	0060
1	93	12	9	18.8	g	3	86	c	287	393.5	m	1.85	0061
1	93	12	9	18.8	g	3	108	g	250	474.9	f	63.80	0062
1	93	12	9	18.8	g	3	108	t	425	1282.4	f	79.69	0063
1	93	12	9	18.8	g	3	108	t	414	1220.2	m	9.94	0064
1	93	12	9	18.8	g	3	108	t	352	679.2	m	2.76	0065
1	93	12	9	19.0	f	1	25	se	756	952.6		1.81	0085
1	93	12	9	19.0	f	1	25	se	582	403.9		0.62	0086
1	93	12	9	19.0	f	1	25	se	632	507.3			0087
1	93	12	9	19.0	f	1	25	p	125	29.4	f	0.18	0088
1	93	12	9	19.0	f	1	25	r	122	32.6	f	3.33	0089
1	93	12	9	19.0	f	1	25	p	114	13.4	m	0.96	0090
1	93	12	9	19.0	f	2	25	c	307	522.6	m	0.44	0082
1	93	12	9	19.0	f	2	25	c	310	415.9	m	0.62	0083
1	93	12	9	19.0	f	2	25	t	466	1634.8	f	155.60	0084
6	93	12	14	18.0	g	1	38	p	132	29.8	f	0.24	0104
6	93	12	14	18.0	g	1	38	p	131	29.1	m	0.18	0105
6	93	12	14	18.0	g	1	38	p	130	31.4	f	0.37	0106
6	93	12	14	18.0	g	1	38	r	132	36.4	m	1.78	0107
6	93	12	14	18.0	g	1	38	p	137	34.0	m	0.23	0108
6	93	12	14	18.0	g	1	38	p	126	27.8	f	0.24	0109
6	93	12	14	18.0	g	1	38	p	130	27.5	f	0.37	0110
6	93	12	14	18.0	g	1	38	p	125	27.5	m	0.86	0111
6	93	12	14	18.0	g	1	38	p	132	28.2	m	0.24	0112
6	93	12	14	18.0	g	1	38	p	131	30.7	f	0.88	0113
6	93	12	14	18.0	g	1	38	p	130	29.2	m	0.21	0114
6	93	12	14	18.0	g	1	38	p	130	26.5			0115
6	93	12	14	18.0	g	1	38	p	128	28.0	f	0.05	0116
6	93	12	14	18.0	g	1	38	p	137	35.7	f	0.71	0117
6	93	12	14	18.0	g	1	38	p	132	31.4	m	0.24	0118
6	93	12	14	18.0	g	1	38	p	128	29.3	m	0.21	0119
6	93	12	14	18.0	g	1	38	p	147	41.2	f	0.24	0120
6	93	12	14	18.0	g	1	38	p	127	29.7	f	0.23	0121
6	93	12	14	18.0	g	1	38	p	137	37.7	f	0.46	0122
6	93	12	14	18.0	g	1	38	p	127	29.3	m	0.03	0123
6	93	12	14	18.0	g	1	38	r	130	36.9	m	1.64	0124
6	93	12	14	18.0	g	1	38	r	137	45.3	f	4.35	0125
6	93	12	14	18.0	g	1	38	r	134	37.7	f	2.95	0126
6	93	12	14	18.0	g	1	38	r	131	33.9	f	1.52	0127
6	93	12	14	18.0	g	1	38	r	127	32.7	m	0.91	0128
6	93	12	14	18.0	g	1	38	r	133	39.9	m	1.00	0129
6	93	12	14	18.0	g	1	38	r	121	28.7	m	1.16	0130
6	93	12	14	18.0	g	1	38	r	133	38.0	f	1.02	0131
6	93	12	14	18.0	g	1	38	r	130	36.9	f	1.48	0132
6	93	12	14	18.0	g	1	38	r	127	32.8	f	1.62	0133
6	93	12	14	18.0	g	1	38	r	129	34.0	m	0.95	0134
6	93	12	14	18.0	g	1	38	c	140	33.5	m	0.07	0135
6	93	12	14	18.0	g	1	38	c	139	33.0	f	0.03	0136
6	93	12	14	18.0	g	1	38	p	134	32.5	f	0.38	0137
6	93	12	14	18.0	g	1	38	p	131	29.8	m	0.57	0138
6	93	12	14	18.0	g	1	57	p	197	100.0	f	0.15	0091
6	93	12	14	18.0	g	1	57	p	193	96.1	f	0.73	0092
6	93	12	14	18.0	g	1	57	p	204	99.2	m	0.20	0093
6	93	12	14	18.0	g	1	57	r	230	235.4	f	14.66	0094
6	93	12	14	18.0	g	1	57	p	186	95.2	f	0.16	0095
6	93	12	14	18.0	g	1	57	p	230	152.3	f	1.13	0096
6	93	12	14	18.0	g	1	57	r	182	122.3	m	3.95	0097
6	93	12	14	18.0	g	1	57	r	207	149.3	m	1.17	0098
6	93	12	14	18.0	g	1	57	r	216	160.1	f	4.90	0099
6	93	12	14	18.0	g	1	57	p	187	90.4	f	0.34	0100
6	93	12	14	18.0	g	1	57	p	213	89.2	f	0.69	0101
6	93	12	14	18.0	g	1	57	p	197	99.2	m	0.90	0102
6	93	12	14	18.0	g	1	57	p	188	90.1	f	0.70	0103
6	93	12	14	17.8	g	2	38	r	132	38.9	m	1.13	0166
6	93	12	14	17.8	g	2	38	r	129	31.8	f	1.33	0167
6	93	12	14	17.8	g	2	38	r	126	31.9	f	3.57	0168
6	93	12	14	17.8	g	2	38	p	124	26.0	m	0.19	0169
6	93	12	14	17.8	g	2	38	r	119	27.8	m	0.93	0170
6	93	12	14	17.8	g	2	38	r	128	36.5	m	1.60	0171
6	93	12	14	17.8	g	2	38	r	122	29.8	m	1.32	0172
6	93	12	14	17.8	g	2	38	r	132	39.5	f	2.03	0173
6	93	12	14	17.8	g	2	38	r	134	35.1	f	1.66	0174
6	93	12	14	17.8	g	2	38	r	121	30.5	m	1.45	0175
6	93	12	14	17.8	g	2	38	r	136	39.7	f	1.57	0176
6	93	12	14	17.8	g	2	38	r	131	40.2	m	1.38	0177
6	93	12	14	17.8	g	2	38	r	130	35.4	m	1.13	0178
6	93	12	14	17.8	g	2	38	r	134	37.7	f	1.46	0179
6	93	12	14	17.8	g	2	38	r	144	51.1	m	0.32	0180
6	93	12	14	17.8	g	2	38	r	119	27.7	m	0.90	0181

Appendix 1 (continued)

site	yy	mm	dd	time	ntype	netno	msizemm	species	length	weight	sex	gonadwt	scode
6	93	12	14	17.8	g	2	38	r	130	37.7	m	1.36	0182
6	93	12	14	17.8	g	2	38	r	129	34.1	m	0.94	0183
6	93	12	14	17.8	g	2	38	r	133	39.6	f	4.45	0184
6	93	12	14	17.8	g	2	38	r	136	43.0	m	1.31	0185
6	93	12	14	17.8	g	2	38	r	138	44.6	m	1.33	0186
6	93	12	14	17.8	g	2	38	r	129	36.1	m	1.27	0187
6	93	12	14	17.8	g	2	38	r	121	29.6	m	1.05	0188
6	93	12	14	17.8	g	2	38	p	133	33.7	m	0.23	0189
6	93	12	14	17.8	g	2	38	p	174	73.8	f	0.63	0190
6	93	12	14	17.8	g	2	38	p	136	32.5	m	0.23	0191
6	93	12	14	17.8	g	2	38	p	131	27.9	m	0.06	0192
6	93	12	14	17.8	g	2	38	p	128	27.2	m	0.16	0193
6	93	12	14	17.8	g	2	38	p	147	41.6	m	0.51	0194
6	93	12	14	17.8	g	2	38	p	129	29.8	f	0.04	0195
6	93	12	14	17.8	g	2	38	p	138	35.7	f	0.45	0196
6	93	12	14	17.8	g	2	38	p	134	34.7	f	0.34	0197
6	93	12	14	17.8	g	2	38	p	123	24.5	f	0.03	0198
6	93	12	14	17.8	g	2	38	p	136	34.9	m	0.26	0199
6	93	12	14	17.8	g	2	38	p	143	38.5	f	0.44	0200
6	93	12	14	17.8	g	2	38	p	129	29.8	f	0.18	0201
6	93	12	14	17.8	g	2	38	p	130	28.9	f	0.04	0202
6	93	12	14	17.8	g	2	57	p	212	106.2	f	0.66	0203
6	93	12	14	17.8	g	2	57	p	202	108.4	f	3.44	0204
6	93	12	14	17.8	g	2	57	p	222	153.8	f	0.32	0205
6	93	12	14	17.8	g	2	57	p	206	120.6	m	0.88	0206
6	93	12	14	17.8	g	2	57	p	206	105.7	f	1.51	0207
6	93	12	14	17.8	g	2	57	p	196	102.3	f	0.81	0208
6	93	12	14	17.8	g	2	57	p	192	102.9	f	0.18	0209
6	93	12	14	17.8	g	2	57	r	174	87.1	f	3.66	0210
6	93	12	14	17.8	g	2	57	r	180	115.8	m	1.46	0211
6	93	12	14	17.8	g	2	86	t	312	405.0	m	0.16	0212
6	93	12	14	17.8	g	2	108	g	242	466.4	f	43.19	0213
6	93	12	14	16.8	g	3	38	p	137	36.2	m	0.43	0223
6	93	12	14	16.8	g	3	38	p	137	34.8	f	0.34	0224
6	93	12	14	16.8	g	3	38	p	132	31.3	m	0.35	0225
6	93	12	14	16.8	g	3	38	p	129	29.3	f	0.18	0226
6	93	12	14	16.8	g	3	38	p	131	29.9	f	0.19	0227
6	93	12	14	16.8	g	3	38	p	122	28.3	f	0.08	0228
6	93	12	14	16.8	g	3	38	p	125	26.5	f	0.24	0229
6	93	12	14	16.8	g	3	38	p	134	35.2	f	1.06	0230
6	93	12	14	16.8	g	3	38	p	126	27.4	f	0.23	0231
6	93	12	14	16.8	g	3	38	p	127	28.6	f	0.18	0232
6	93	12	14	16.8	g	3	38	p	139	36.3	f	0.34	0233
6	93	12	14	16.8	g	3	38	p	132	31.9	f	0.23	0234
6	93	12	14	16.8	g	3	38	p	134	33.1	m	0.69	0235
6	93	12	14	16.8	g	3	38	p	141	40.0	f	0.45	0236
6	93	12	14	16.8	g	3	38	p	130	30.2	f	0.61	0237
6	93	12	14	16.8	g	3	38	p	133	31.0	f	0.10	0238
6	93	12	14	16.8	g	3	38	p	135	39.0	f	0.24	0239
6	93	12	14	16.8	g	3	38	p	135	32.6	m	0.27	0240
6	93	12	14	16.8	g	3	38	p	130	30.5	f	0.35	0241
6	93	12	14	16.8	g	3	38	p	126	29.1	f	0.20	0242
6	93	12	14	16.8	g	3	38	p	138	36.2	m	0.33	0243
6	93	12	14	16.8	g	3	38	p	135	33.1	f	0.25	0244
6	93	12	14	16.8	g	3	38	p	139	37.4	f	0.36	0245
6	93	12	14	16.8	g	3	38	p	140	36.7	m	0.26	0246
6	93	12	14	16.8	g	3	38	p	129	28.5	m	0.15	0247
6	93	12	14	16.8	g	3	38	r	134	40.1	f	1.72	0248
6	93	12	14	16.8	g	3	38	r	125	34.1	m	1.17	0249
6	93	12	14	16.8	g	3	38	r	136	43.4	f	1.11	0250
6	93	12	14	16.8	g	3	38	r	129	35.7	m	0.65	0251
6	93	12	14	16.8	g	3	38	r	142	42.2	f	1.43	0252
6	93	12	14	16.8	g	3	38	r	138	40.5	m	1.51	0253
6	93	12	14	16.8	g	3	38	r	139	42.7	f	1.80	0254
6	93	12	14	16.8	g	3	38	r	129	34.9	f	1.16	0255
6	93	12	14	16.8	g	3	38	r	128	35.3	f	1.70	0256
6	93	12	14	16.8	g	3	38	r	134	42.9	f	1.48	0257
6	93	12	14	16.8	g	3	38	r	131	37.7	m	1.15	0258
6	93	12	14	16.8	g	3	38	r	129	38.1	f	1.51	0259
6	93	12	14	16.8	g	3	38	r	141	42.9	m	1.05	0260
6	93	12	14	16.8	g	3	38	r	119	28.4	m	1.17	0261
6	93	12	14	16.8	g	3	38	r	120	27.7	m	1.18	0262
6	93	12	14	16.8	g	3	38	r	126	32.9	f	1.08	0263
6	93	12	14	16.8	g	3	38	r	133	37.7	f	1.51	0264
6	93	12	14	16.8	g	3	38	r	136	43.6	m	1.41	0265
6	93	12	14	16.8	g	3	38	r	138	38.9	m	1.10	0266
6	93	12	14	16.8	g	3	38	r	131	31.5	f	1.45	0267
6	93	12	14	16.8	g	3	38	c	139	33.7	m	0.08	0268
6	93	12	14	16.8	g	3	57	p	207	106.8	m	0.25	0214
6	93	12	14	16.8	g	3	57	p	201	93.5	f	0.17	0215
6	93	12	14	16.8	g	3	57	p	205	127.5	f	0.21	0216
6	93	12	14	16.8	g	3	57	p	199	97.6	f	0.18	0217
6	93	12	14	16.8	g	3	57	p	181	82.7	m	0.74	0218
6	93	12	14	16.8	g	3	57	p	209	105.6	f	0.74	0219
6	93	12	14	16.8	g	3	57	p	183	88.0	f	0.75	0220
6	93	12	14	16.8	g	3	57	p	196	91.7	f	0.91	0221
6	93	12	14	16.8	g	3	57	r	183	108.1	m	2.11	0222
6	93	12	14	18.5	f	1	25	p	198	97.8	m	0.63	0139
6	93	12	14	18.5	f	1	25	p	124	24.4	f	0.02	0140
6	93	12	14	18.5	f	1	25	p	126	26.5	f	0.22	0141
6	93	12	14	18.5	f	1	25	p	123	25.7	f	0.05	0142
6	93	12	14	18.5	f	1	25	p	162	56.8	f	0.11	0143
6	93	12	14	18.5	f	1	25	p	134	29.9	m	0.24	0144
6	93	12	14	18.5	f	1	25	p	136	35.1	f	0.29	0145
6	93	12	14	18.5	f	1	25	p	136	31.7	m	0.34	0146

Appendix 1 (continued)

site	yy	mm	dd	time	ntype	netno	msizemm	species	length	weight	sex	gonadwt	scode
6	93	12	14	18.5	f	1	25	p	131	27.1			0147
6	93	12	14	18.5	f	2	25	c	229	156.4	m	0.41	0148
6	93	12	14	18.5	f	2	25	se	486	254.9		0.79	0149
6	93	12	14	18.6	f	3	25	r	144	46.7	f	1.61	0150
6	93	12	14	18.6	f	3	25	r	156	62.3	f	2.14	0151
6	93	12	14	18.6	f	3	25	r	125	29.6	m	0.80	0152
6	93	12	14	18.6	f	3	25	p	217	123.1	f	0.21	0153
6	93	12	14	18.6	f	3	25	c	323	492.6	m	0.26	0154
6	93	12	14	18.6	f	3	25	p	198	148.3	m	1.03	0155
6	93	12	14	18.6	f	3	25	se	765	991.7		1.55	0156
6	93	12	14	18.6	f	3	25	se	585	447.7		0.99	0157
6	93	12	14	18.6	f	3	25	se	490	244.2		2.22	0158
6	93	12	14	18.6	f	3	25	se	570	379.2		1.11	0159
6	93	12	14	18.6	f	3	25	se	539	286.2		0.21	0160
6	93	12	14	18.6	f	3	25	se	465	212.0		0.39	0161
6	93	12	14	18.6	f	3	25	r	132	31.2	m	0.74	0162
6	93	12	14	18.6	f	3	25	r	124	29.1	m	1.33	0163
6	93	12	14	18.6	f	3	25	r	154	57.5	f	3.40	0164
6	93	12	14	18.6	f	3	25	r	78	7.4		0.05	0165
6	93	12	14	18.6	m	2	5	m	20	0.029			1056
6	93	12	14	18.6	m	2	5	m	15	0.019			1057
6	93	12	14	18.6	m	2	5	m	19	0.028			1058
6	93	12	14	18.6	m	2	5	m	21	0.072			1059
6	93	12	14	18.6	m	2	5	m	18	0.028			1060
6	93	12	14	18.6	m	2	5	m	18	0.041			1061
6	93	12	14	18.6	m	2	5	m	17	0.039			1062
6	93	12	14	18.6	m	2	5	m	18	0.029			1063
6	93	12	14	18.6	m	2	5	m	20	0.03			1064
6	93	12	14	18.6	m	2	5	m	16	0.018			1065
6	93	12	14	18.6	m	2	5	m	17	0.039			1066
6	93	12	14	18.6	m	2	5	m	20	0.023			1067
6	93	12	14	18.6	m	2	5	m	19	0.031			1068
6	93	12	14	18.6	m	2	5	m	22	0.078			1069
6	93	12	14	18.6	m	2	5	m	17	0.036			1070
6	93	12	14	18.6	m	2	5	m	20	0.069			1071
6	93	12	14	18.6	m	3	5	b	47	1.019			1032
6	93	12	14	18.6	m	3	5	m	23	0.066			1033
6	93	12	14	18.6	m	3	5	m	21	0.062			1034
6	93	12	14	18.6	m	3	5	m	18	0.024			1035
6	93	12	14	18.6	m	3	5	m	23	0.082			1036
6	93	12	14	18.6	m	3	5	m	20	0.056			1037
6	93	12	14	18.6	m	3	5	m	19	0.032			1038
6	93	12	14	18.6	m	3	5	m	21	0.055			1039
6	93	12	14	18.6	m	4	5	m	18	0.016			1040
6	93	12	14	18.6	m	4	5	m	19	0.033			1041
6	93	12	14	18.6	m	4	5	m	16	0.024			1042
6	93	12	14	18.6	m	4	5	m	19	0.024			1043
6	93	12	14	18.6	m	4	5	m	18	0.024			1044
6	93	12	14	18.6	m	4	5	m	20	0.034			1045
6	93	12	14	18.6	m	4	5	m	19	0.034			1046
6	93	12	14	18.6	m	4	5	m	20	0.035			1047
6	93	12	14	18.6	m	4	5	m	21	0.055			1048
6	93	12	14	18.6	m	4	5	b	31	0.326			1049
6	93	12	14	18.6	m	5	5	m	20	0.057			1050
6	93	12	14	18.6	m	5	5	m	20	0.044			1051
6	93	12	14	18.6	m	5	5	m	19	0.026			1052
6	93	12	14	18.6	m	5	5	m	19	0.037			1053
6	93	12	14	18.6	m	5	5	m	20	0.041			1054
6	93	12	14	18.6	m	5	5	m	23	0.053			1055
8	93	12	20	16.0	g	1	38	c	144	36.9			0357
8	93	12	20	16.0	g	1	38	c	152	45.7			0358
8	93	12	20	16.0	g	1	38	p	171	71.6	m	0.15	0359
8	93	12	20	16.0	g	1	57	c	274	311.4	m	0.45	0351
8	93	12	20	16.0	g	1	57	c	189	94.8	f	0.35	0352
8	93	12	20	16.0	g	1	57	p	201	110.9	f	0.75	0353
8	93	12	20	16.0	g	1	57	p	186	90.7	f	0.54	0354
8	93	12	20	16.0	g	1	57	p	199	108.1	f	0.89	0355
8	93	12	20	16.0	g	1	57	p	188	100.3	f	0.85	0356
8	93	12	20	16.0	g	1	86	g	235	311.3	f	19.07	0350
8	93	12	20	16.6	g	2	38	p	131	31.0	f	0.22	0319
8	93	12	20	16.6	g	2	38	p	134	29.5	f	0.22	0320
8	93	12	20	16.6	g	2	38	p	125	29.7	f	0.33	0321
8	93	12	20	16.6	g	2	38	p	133	32.5	f	0.24	0322
8	93	12	20	16.6	g	2	38	p	134	32.2	f	0.26	0323
8	93	12	20	16.6	g	2	38	p	129	32.5	m	0.37	0324
8	93	12	20	16.6	g	2	38	p	195	96.2	f	0.58	0325
8	93	12	20	16.6	g	2	38	p	125	26.6	f	0.22	0326
8	93	12	20	16.6	g	2	38	p	138	37.2	f	0.25	0327
8	93	12	20	16.6	g	2	38	p	135	34.9	f	0.33	0328
8	93	12	20	16.6	g	2	38	r	131	36.9	f	1.30	0329
8	93	12	20	16.6	g	2	38	c	134	32.2	m	0.01	0330
8	93	12	20	16.6	g	2	57	p	183	88.8	m	0.81	0300
8	93	12	20	16.6	g	2	57	p	202	104.4	m	0.12	0301
8	93	12	20	16.6	g	2	57	p	217	139.9	f	0.82	0302
8	93	12	20	16.6	g	2	57	p	206	115.5	f	0.78	0303
8	93	12	20	16.6	g	2	57	p	195	104.1	f	0.74	0304
8	93	12	20	16.6	g	2	57	p	205	98.2	f	0.62	0305
8	93	12	20	16.6	g	2	57	p	197	102.4	m	0.22	0306
8	93	12	20	16.6	g	2	57	p	202	104.9	f	0.18	0307
8	93	12	20	16.6	g	2	57	p	205	119.9	f	0.93	0308
8	93	12	20	16.6	g	2	57	p	213	120.1	m	0.72	0309
8	93	12	20	16.6	g	2	57	p	225	133.8	f	0.74	0310
8	93	12	20	16.6	g	2	57	p	243	181.0	f	1.16	0311
8	93	12	20	16.6	g	2	57	p	197	100.6	f	0.73	0312
8	93	12	20	16.6	g	2	57	p	196	103.4	f	0.78	0313

Appendix 1 (continued)

site	yy	mm	dd	time	ntype	netno	msizemm	species	length	weight	sex	gonadwt	scode
8	93	12	20	16.6	g	2	57	c	245	208.9	f	0.33	0314
8	93	12	20	16.6	g	2	57	c	253	242.1	f	1.14	0315
8	93	12	20	16.6	g	2	57	c	230	175.5	m	0.18	0316
8	93	12	20	16.6	g	2	57	r	234	232.9	f	10.99	0317
8	93	12	20	16.6	g	2	86	g	220	260.6	f	21.30	0318
8	93	12	20	16.6	g	3	38	p	126	27.3	m	0.14	0331
8	93	12	20	16.6	g	3	38	p	136	31.8	m	0.42	0332
8	93	12	20	16.6	g	3	38	p	137	36.6	f	0.76	0333
8	93	12	20	16.6	g	3	38	p	126	27.7	m	0.19	0335
8	93	12	20	16.6	g	3	38	p	132	33.5	f	0.46	0336
8	93	12	20	16.6	g	3	38	p	132	31.8	f	0.25	0337
8	93	12	20	16.6	g	3	38	r	130	37.4	f	0.80	0338
8	93	12	20	16.6	g	3	38	c	164	53.4	f	0.04	0339
8	93	12	20	16.6	g	3	57	p	193	97.9	m	0.70	0342
8	93	12	20	16.6	g	3	57	p	200	100.8	f	0.60	0343
8	93	12	20	16.6	g	3	57	p	204	107.2	f	1.08	0344
8	93	12	20	16.6	g	3	57	p	204	99.0	f	0.65	0345
8	93	12	20	16.6	g	3	57	p	227	135.5	f	0.05	0346
8	93	12	20	16.6	g	3	57	p	215	129.7	m	0.88	0347
8	93	12	20	16.6	g	3	86	c	320	526.3	m	0.54	0340
8	93	12	20	16.6	g	3	86	g	231	294.4	f	21.40	0341
8	93	12	20	16.6	g	3	108	g	340	371.8	f	14.17	0348
8	93	12	20	16.6	g	3	108	t	382	920.2	m	6.67	0349
8	93	12	20	16.9	f	1	25	p	245	220.8	f	1.18	0360
8	93	12	20	16.9	f	1	25	r	128	37.0	m	1.16	0361
8	93	12	20	16.9	f	1	25	r	122	30.8	m	1.20	0362
8	93	12	20	16.9	f	1	25	r	129	33.4	f	2.44	0363
8	93	12	20	16.9	f	1	25	r	121	29.4	m	1.22	0364
8	93	12	20	16.9	f	1	25	r	126	32.6	f	0.62	0365
8	93	12	20	16.9	f	1	25	le	635	842.9		0.86	0366
8	93	12	20	16.9	f	1	25	se	650	631.4		2.76	0367
8	93	12	20	16.9	f	1	25	se	367	93.3		0.26	0368
8	93	12	20	17.2	f	2	25	g	216	267.7	m	8.87	0370
8	93	12	20	17.2	f	2	25	se	480	255.5		0.17	0371
8	93	12	20	17.2	f	2	25	se	585	387.4		0.16	0372
8	93	12	20	17.2	f	2	25	se	493	291.3		1.61	0373
8	93	12	20	17.2	f	3	25	p	338	655.3	f	9.98	0369
4	94	1	10	17.8	g	1	38	p	122	28.6	m	0.08	0416
4	94	1	10	17.8	g	1	38	p	125	28.2	f	0.29	0417
4	94	1	10	17.8	g	1	38	p	129	30.4	f	0.72	0418
4	94	1	10	17.8	g	1	38	p	134	32.4	f	0.27	0419
4	94	1	10	17.8	g	1	38	p	120	23.7	f	0.18	0420
4	94	1	10	17.8	g	1	38	p	121	24.7	f	0.10	0421
4	94	1	10	17.8	g	1	38	p	120	22.4	f	0.14	0422
4	94	1	10	17.8	g	1	38	r	129	35.3	f	2.32	0423
4	94	1	10	17.8	g	1	38	r	123	30.2	m	1.25	0424
4	94	1	10	17.8	g	1	38	r	136	40.0	f	3.89	0425
4	94	1	10	17.8	g	1	38	r	129	33.9	f	2.43	0426
4	94	1	10	17.8	g	1	38	r	136	40.2	f	0.83	0427
4	94	1	10	17.8	g	1	38	r	135	43.4	m	0.27	0428
4	94	1	10	17.8	g	1	38	r	135	45.9	f	4.30	0429
4	94	1	10	17.8	g	1	38	r	125	28.9	m	1.31	0430
4	94	1	10	17.8	g	1	38	r	130	39.9	f	2.54	0431
4	94	1	10	17.8	g	1	38	r	130	35.1	m	1.12	0432
4	94	1	10	17.8	g	1	57	p	209	131.9	f	0.20	0433
4	94	1	10	17.8	g	1	57	p	185	91.0	m	0.83	0434
4	94	1	10	17.8	g	1	57	r	199	159.4	m	8.25	0435
4	94	1	10	17.8	g	1	57	r	200	145.4	m	6.19	0436
4	94	1	10	17.8	g	1	108	t	396	944.7	m	5.07	0438
4	94	1	10	17.8	g	1	108	t	388	839.2	f	45.66	0439
4	94	1	10	17.8	g	1	108	t	367	756.7	m	5.40	0440
4	94	1	10	17.8	g	1	108	t	345	708.1	f	39.07	0441
4	94	1	10	17.8	g	1	108	t	402	970.9	f	37.33	0442
4	94	1	10	16.8	g	2	38	p	128	26.3	m	0.11	0456
4	94	1	10	16.8	g	2	38	p	131	31.1	f	0.49	0457
4	94	1	10	16.8	g	2	38	p	131	33.0	f	0.28	0458
4	94	1	10	16.8	g	2	38	p	124	27.2	m	0.03	0459
4	94	1	10	16.8	g	2	38	p	132	30.8	f	0.26	0460
4	94	1	10	16.8	g	2	38	p	136	36.6	f	0.73	0461
4	94	1	10	16.8	g	2	38	p	122	26.5	m	0.22	0462
4	94	1	10	16.8	g	2	38	p	127	28.4	m	0.22	0463
4	94	1	10	16.8	g	2	38	p	132	30.3	f	0.37	0464
4	94	1	10	16.8	g	2	38	p	132	30.2	f	0.21	0465
4	94	1	10	16.8	g	2	38	p	133	32.1	f	0.19	0466
4	94	1	10	16.8	g	2	38	r	131	37.5	f	2.33	0467
4	94	1	10	16.8	g	2	38	r	129	35.1	m	0.26	0468
4	94	1	10	16.8	g	2	38	r	135	40.3	m	0.64	0469
4	94	1	10	16.8	g	2	38	r	130	35.6	f	1.51	0470
4	94	1	10	16.8	g	2	57	p	218	132.4	f	0.97	0443
4	94	1	10	16.8	g	2	57	p	231	162.6	f	1.23	0444
4	94	1	10	16.8	g	2	57	p	210	111.1	m	0.77	0445
4	94	1	10	16.8	g	2	57	p	207	117.1	f	1.15	0446
4	94	1	10	16.8	g	2	57	p	220	137.2	f	0.88	0447
4	94	1	10	16.8	g	2	57	p	216	131.6	f	1.28	0448
4	94	1	10	16.8	g	2	57	p	190	99.3	m	0.74	0449
4	94	1	10	16.8	g	2	57	p	193	102.8	f	0.59	0450
4	94	1	10	16.8	g	2	57	p	220	122.8	f	0.85	0451
4	94	1	10	16.8	g	2	57	p	220	133.4	f	1.09	0452
4	94	1	10	16.8	g	2	57	p	212	109.6	f	0.53	0453
4	94	1	10	16.8	g	2	57	p	190	105.9	f	0.64	0454
4	94	1	10	16.8	g	2	57	p	205	97.7	m	0.17	0455
4	94	1	10	16.8	g	2	108	t	352	682.8	f	14.82	0471
4	94	1	10	16.8	g	2	108	t	391	948.2	f	45.95	0472
4	94	1	10	16.8	g	2	108	t	416	1082.0	m	6.06	0473
4	94	1	10	17.8	g	3	25	p	120	24.3	m	0.11	0437

Appendix 1 (continued)

site	yy	mm	dd	time	ntype	netno	msizemm	species	length	weight	sex	gonadwt	scode
4	94	1	10	17.8	g	3	38	p	136	33.0	m	0.24	0379
4	94	1	10	17.8	g	3	38	p	137	33.2	m	0.23	0380
4	94	1	10	17.8	g	3	38	p	140	36.2	f	0.19	0381
4	94	1	10	17.8	g	3	38	p	132	30.7	f	0.62	0382
4	94	1	10	17.8	g	3	38	p	128	30.4	f	0.18	0383
4	94	1	10	17.8	g	3	38	p	132	31.9	f	0.24	0384
4	94	1	10	17.8	g	3	38	p	131	34.1	f	0.24	0385
4	94	1	10	17.8	g	3	38	p	122	27.0	m	0.05	0386
4	94	1	10	17.8	g	3	38	p	128	30.0	f	0.97	0387
4	94	1	10	17.8	g	3	38	p	129	29.0	f	0.22	0388
4	94	1	10	17.8	g	3	38	p	126	25.7	f	0.12	0389
4	94	1	10	17.8	g	3	38	p	127	28.3	m	0.19	0390
4	94	1	10	17.8	g	3	38	p	126	28.5	f	0.05	0391
4	94	1	10	17.8	g	3	38	p	137	36.5	f	0.21	0392
4	94	1	10	17.8	g	3	38	p	125	30.7	f	0.55	0393
4	94	1	10	17.8	g	3	38	p	130	33.6	m	0.35	0394
4	94	1	10	17.8	g	3	38	p	123	27.3	f	0.35	0395
4	94	1	10	17.8	g	3	38	p	130	31.0	f	0.23	0396
4	94	1	10	17.8	g	3	38	r	131	34.0	m	1.02	0397
4	94	1	10	17.8	g	3	38	r	121	31.9	m	1.44	0398
4	94	1	10	17.8	g	3	38	r	139	42.1	f	3.64	0399
4	94	1	10	17.8	g	3	38	r	130	35.8	m	0.18	0400
4	94	1	10	17.8	g	3	38	r	128	36.3	f	0.69	0401
4	94	1	10	17.8	g	3	38	r	129	35.9	m	1.47	0402
4	94	1	10	17.8	g	3	38	r	130	36.4	f	1.88	0403
4	94	1	10	17.8	g	3	38	r	133	40.2	f	2.63	0404
4	94	1	10	17.8	g	3	38	r	135	45.1	f	2.99	0405
4	94	1	10	17.8	g	3	38	r	136	45.1	m	0.65	0406
4	94	1	10	17.8	g	3	38	r	134	41.0	f	0.50	0407
4	94	1	10	17.8	g	3	38	r	125	35.2	f	0.79	0408
4	94	1	10	17.8	g	3	38	r	130	38.5	f	2.16	0409
4	94	1	10	17.8	g	3	38	r	133	39.5	m	0.20	0410
4	94	1	10	17.8	g	3	38	r	134	40.2	f	1.02	0411
4	94	1	10	17.8	g	3	38	r	125	30.1	m	0.37	0412
4	94	1	10	17.8	g	3	38	r	145	45.2	f	0.99	0413
4	94	1	10	17.8	g	3	38	r	132	38.2	m	1.36	0414
4	94	1	10	17.8	g	3	38	c	157	50.5	f	0.11	0415
4	94	1	10	17.8	g	3	57	r	213	180.6	f	16.84	0376
4	94	1	10	17.8	g	3	57	p	199	144.8	m	0.75	0377
4	94	1	10	17.8	g	3	57	p	186	89.5	f	0.63	0378
4	94	1	10	17.8	g	3	86	g	225	257.7	m	9.61	0375
4	94	1	10	17.8	g	3	108	t	349	629.6	m	7.78	0374
4	94	1	10	18.0	f	1	25	t	447	1450.4	m	8.42	0504
4	94	1	10	18.0	f	1	25	t	463	1533.1	f	67.30	0505
4	94	1	10	18.0	f	1	25	r	201	127.9	f	7.55	0506
4	94	1	10	18.0	f	1	25	c	276	294.8	f	1.36	0507
4	94	1	10	18.0	f	1	25	r	158	58.7	f	3.56	0508
4	94	1	10	18.0	f	1	25	p	178	64.7	f	0.14	0509
4	94	1	10	18.0	f	1	25	se	449	158.3		0.59	0510
4	94	1	10	18.0	f	1	25	se	504	258.1		1.08	0511
4	94	1	10	18.0	f	1	25	se	586	448.0		0.21	0512
4	94	1	10	18.0	f	2	25	t	435	1191.3	f	76.20	0493
4	94	1	10	18.0	f	2	25	t	476	1601.6	m	16.80	0494
4	94	1	10	18.0	f	2	25	t	467	1456.7	f	68.30	0495
4	94	1	10	18.0	f	2	25	r	130	35.6	f	0.14	0496
4	94	1	10	18.0	f	2	25	r	119	28.7	m	0.77	0497
4	94	1	10	18.0	f	2	25	se	552	355.4		0.07	0498
4	94	1	10	18.0	f	2	25	se	610	541.8		18.90	0499
4	94	1	10	18.0	f	2	25	c	143	34.6	f	0.23	0500
4	94	1	10	18.0	f	2	25	c	170	55.9	m	0.06	0501
4	94	1	10	18.0	f	2	25	c	166	62.4	m	0.08	0502
4	94	1	10	18.0	f	2	25	c	156	47.6	m	0.04	0503
4	94	1	10	18.0	f	3	25	t	483	1803.9	f	168.40	0474
4	94	1	10	18.0	f	3	25	t	425	1170.4	m	7.46	0475
4	94	1	10	18.0	f	3	25	t	418	1181.7	m	13.75	0476
4	94	1	10	18.0	f	3	25	t	327	524.9	f	13.28	0477
4	94	1	10	18.0	f	3	25	t	390	895.7	f	50.10	0478
4	94	1	10	18.0	f	3	25	p	263	274.4	f	1.99	0479
4	94	1	10	18.0	f	3	25	p	215	149.5	f	0.57	0480
4	94	1	10	18.0	f	3	25	p	163	62.6	f	0.11	0481
4	94	1	10	18.0	f	3	25	p	186	86.1	m	0.79	0482
4	94	1	10	18.0	f	3	25	p	192	94.1	f	0.71	0483
4	94	1	10	18.0	f	3	25	p	194	104.8	f	0.58	0484
4	94	1	10	18.0	f	3	25	p	167	65.2	m	0.06	0485
4	94	1	10	18.0	f	3	25	p	181	81.6	f	0.62	0486
4	94	1	10	18.0	f	3	25	p	135	32.7	f	0.18	0487
4	94	1	10	18.0	f	3	25	p	134	35.5	f	0.20	0488
4	94	1	10	18.0	f	3	25	p	135	30.7		0.24	0489
4	94	1	10	18.0	f	3	25	p	140	37.1	f	0.24	0490
4	94	1	10	18.0	f	3	25	r	150	54.1	f	0.64	0491
4	94	1	10	18.0	f	3	25	r	105	16.5			0492
4	94	1	10	18.0	m	2	5	se	468	194.2			0514
4	94	1	10	18.0	m	3	5	r	164	73.7	f	7.48	0513
4	94	1	10	18.0	m	4	5	m	18	0.034			1072
2	94	1	17	12.6	g	1	38	p	123	24.2	f	0.04	0573
2	94	1	17	12.6	g	1	38	p	130	28.9	f	0.21	0574
2	94	1	17	12.6	g	1	38	r	131	35.7	f	0.90	0575
2	94	1	17	12.6	g	1	38	r	136	43.4	m	0.31	0576
2	94	1	17	12.6	g	1	38	r	135	39.8	m	0.40	0577
2	94	1	17	12.6	g	1	57	c	258	272.6	m	0.22	0591
2	94	1	17	12.6	g	1	57	c	190	83.4	f	0.21	0592
2	94	1	17	12.6	g	1	57	p	294	428.4	f	2.44	0593
2	94	1	17	12.6	g	1	57	p	191	100.1	m	0.14	0594
2	94	1	17	12.6	g	1	57	p	202	121.7	f	1.01	0595
2	94	1	17	12.6	g	1	57	r	205	180.6	f	14.62	0596
2	94	1	17	12.6	g	1	57	r	213	215.2	f	17.87	0597

Appendix 1 (continued)

site	yy	mm	dd	time	ntype	netno	msizemm	species	length	weight	sex	gonadwt	scode
2	94	1	17	12.6	g	1	57	r	208	169.3	f	13.08	0598
2	94	1	17	12.6	g	1	57	r	172	106.7	f	8.03	0599
2	94	1	17	12.6	g	1	57	r	192	147.1	m	5.30	0600
2	94	1	17	12.6	g	1	57	r	215	198.5	f	10.78	0601
2	94	1	17	12.6	g	1	86	r	281	428.1	f	8.35	0590
2	94	1	17	12.6	g	1	108	g	215	440.8	f	38.44	0578
2	94	1	17	12.6	g	1	108	t	380	897.6	f	71.10	0579
2	94	1	17	13.3	g	2	38	p	146	44.0	f	0.30	0555
2	94	1	17	13.3	g	2	38	p	140	38.2	f	0.25	0556
2	94	1	17	13.3	g	2	38	p	130	28.5	f	0.17	0557
2	94	1	17	13.3	g	2	38	p	190	96.2	m	0.09	0558
2	94	1	17	13.3	g	2	38	p	130	30.2	f	0.22	0559
2	94	1	17	13.3	g	2	38	p	130	31.4	f	0.88	0560
2	94	1	17	13.3	g	2	38	p	120	23.9	m	0.06	0561
2	94	1	17	13.3	g	2	38	p	126	28.1	f	0.43	0562
2	94	1	17	13.3	g	2	38	p	131	30.8	f	0.23	0563
2	94	1	17	13.3	g	2	38	p	130	28.6	f	0.17	0564
2	94	1	17	13.3	g	2	38	r	135	38.7	f	1.08	0565
2	94	1	17	13.3	g	2	38	r	127	37.0	f	1.24	0566
2	94	1	17	13.3	g	2	38	c	158	47.6	m	0.02	0567
2	94	1	17	13.3	g	2	38	c	200	91.9	m	0.09	0568
2	94	1	17	13.3	g	2	38	c	168	54.9	f	0.02	0569
2	94	1	17	13.3	g	2	57	c	224	158.9	m	0.21	0543
2	94	1	17	13.3	g	2	57	c	194	93.2	f	0.36	0544
2	94	1	17	13.3	g	2	57	p	205	114.5	m	0.04	0545
2	94	1	17	13.3	g	2	57	p	216	113.8	m	0.84	0546
2	94	1	17	13.3	g	2	57	p	211	110.9	f	0.75	0547
2	94	1	17	13.3	g	2	57	p	212	115.4	f	0.24	0548
2	94	1	17	13.3	g	2	57	p	195	97.6	m	0.64	0549
2	94	1	17	13.3	g	2	57	p	214	123.0	f	0.78	0550
2	94	1	17	13.3	g	2	57	p	211	122.7	f	0.23	0551
2	94	1	17	13.3	g	2	57	p	201	103.2	f	0.87	0552
2	94	1	17	13.3	g	2	57	p	203	113.4	f	0.73	0553
2	94	1	17	13.3	g	2	57	r	200	150.6	f	6.36	0554
2	94	1	17	13.3	g	2	108	p	339	643.6	f	4.34	0529
2	94	1	17	13.3	g	2	108	g	272	582.2	f	71.00	0530
2	94	1	17	13.3	g	2	108	t	339	978.8	f	74.20	0531
2	94	1	17	13.3	g	3	38	r	130	40.2	f	2.02	0522
2	94	1	17	13.3	g	3	38	p	222	151.6	f	0.94	0523
2	94	1	17	13.3	g	3	38	p	124	25.6	f	0.32	0524
2	94	1	17	13.3	g	3	38	p	132	31.9	f	0.37	0525
2	94	1	17	13.3	g	3	38	p	123	26.0	m	0.05	0526
2	94	1	17	13.3	g	3	38	p	122	26.0	f	0.04	0527
2	94	1	17	13.3	g	3	38	p	142	38.4	f	0.26	0528
2	94	1	17	13.3	g	3	57	c	213	117.4	f	0.08	0532
2	94	1	17	13.3	g	3	57	p	187	87.2	f	0.57	0533
2	94	1	17	13.3	g	3	57	p	182	85.4	m	0.14	0534
2	94	1	17	13.3	g	3	57	p	224	159.4	f	1.14	0535
2	94	1	17	13.3	g	3	57	p	197	95.3	f	0.15	0536
2	94	1	17	13.3	g	3	57	r	195	145.0	m	4.67	0537
2	94	1	17	13.3	g	3	57	r	179	108.4	f	5.88	0538
2	94	1	17	13.3	g	3	57	r	186	131.1	m	3.20	0539
2	94	1	17	13.3	g	3	57	r	209	179.6	f	3.11	0540
2	94	1	17	13.3	g	3	57	r	188	142.2	m	7.59	0541
2	94	1	17	13.3	g	3	57	r	169	85.8	m	1.55	0542
2	94	1	17	13.3	g	3	86	t	310	404.5	m	0.85	0570
2	94	1	17	13.3	g	3	108	g	237	399.1	f	43.30	0602
2	94	1	17	13.9	f	1	25	se	526	254.3		1.18	0520
2	94	1	17	13.9	f	1	25	c	145	36.0	m	0.08	0521
2	94	1	17	13.9	f	2	25	p	380	1171.6	f	6.08	0580
2	94	1	17	13.9	f	2	25	p	185	101.9	f	0.75	0581
2	94	1	17	13.9	f	2	25	p	134	57.1	m	0.07	0582
2	94	1	17	13.9	f	2	25	p	170	68.3	f	0.45	0583
2	94	1	17	13.9	f	2	25	p	138	33.3	f	0.27	0584
2	94	1	17	13.9	f	2	25	p	165	61.4	m	0.12	0585
2	94	1	17	13.9	f	2	25	p	165	60.9	f	0.50	0586
2	94	1	17	13.9	f	2	25	p	165	66.5	f	0.45	0587
2	94	1	17	13.9	f	2	25	r	227	220.5	f	8.68	0588
2	94	1	17	13.9	f	2	25	r	142	47.9	f	0.18	0589
2	94	1	17	13.9	f	3	25	se	675	665.7		0.70	0571
2	94	1	17	13.9	f	3	25	r	134	35.3	m	0.30	0572
9	94	1	19	13.5	g	1	38	r	129	33.5	f	0.48	0604
9	94	1	19	13.5	g	1	38	r	136	38.6	f	0.47	0605
9	94	1	19	13.5	g	1	38	r	131	35.2	m	0.20	0606
9	94	1	19	13.5	g	1	38	r	128	32.9	f	0.14	0607
9	94	1	19	13.5	g	1	38	r	127	31.3	f	0.65	0608
9	94	1	19	13.5	g	1	38	r	131	33.2	f	0.15	0609
9	94	1	19	13.5	g	1	38	r	130	35.4	m	0.20	0610
9	94	1	19	13.5	g	1	38	r	128	32.5	f	2.12	0611
9	94	1	19	13.5	g	1	38	r	125	30.4	f	0.51	0612
9	94	1	19	13.5	g	1	38	r	131	36.8	f	2.57	0613
9	94	1	19	13.5	g	1	38	r	136	42.3	m	0.59	0614
9	94	1	19	13.3	g	2	38	p	129	27.2	f	0.20	0603
9	94	1	19	13.3	g	2	57	p	203	98.4	f	0.79	0616
9	94	1	19	13.3	g	2	57	p	194	95.5	m	0.22	0617
9	94	1	19	13.3	g	2	57	p	182	80.2	f	0.68	0618
9	94	1	19	13.3	g	2	57	p	195	89.4	f	0.66	0619
9	94	1	19	13.3	g	2	57	p	211	96.9	f	0.80	0620
9	94	1	19	13.7	m	3	5	se	589	449.0		0.38	0615
10	94	1	24	13.1	g	1	38	r	129	32.2	m	0.15	0620
11	94	1	25	14.1	g	1	38	p	117	22.2	f	0.03	0641
11	94	1	25	14.1	g	1	38	p	125	25.8	f	0.18	0642
11	94	1	25	14.1	g	1	38	p	119	23.3	f	0.02	0643
11	94	1	25	14.1	g	1	38	p	120	23.4	m	0.06	0644
11	94	1	25	14.1	g	1	38	p	127	27.3	m	0.19	0645

Appendix 1 (continued)

site	yy	mm	dd	time	ntype	netno	msizemm	species	length	weight	sex	gonadwt	scode
11	94	1	25	14.1	g	1	57	c	275	295.6	f	0.84	0639
11	94	1	25	14.1	g	1	86	g	235	349.4	f	40.07	0640
11	94	1	25	14.2	g	2	57	p	236	162.9	f	1.78	0635
11	94	1	25	14.2	g	2	57	p	204	114.4	m	0.85	0636
11	94	1	25	14.2	g	2	57	p	203	114.5	f	0.66	0637
11	94	1	25	14.2	g	2	57	p	200	89.0	f	0.04	0638
11	94	1	25	14.2	g	2	108	t	385	939.3	f	6.10	0646
11	94	1	25	14.3	g	3	38	p	134	31.6	f	0.33	0621
11	94	1	25	14.3	g	3	38	r	135	41.4	m	0.86	0622
11	94	1	25	14.3	g	3	38	r	141	43.8	f	1.98	0623
11	94	1	25	14.3	g	3	38	r	133	39.7	m	0.65	0624
11	94	1	25	14.3	g	3	57	c	213	124.1	f	0.33	0630
11	94	1	25	14.3	g	3	57	p	198	94.4	f	0.13	0631
11	94	1	25	14.3	g	3	57	r	215	179.0	f	15.33	0632
11	94	1	25	14.3	g	3	86	c	300	428.7	m	0.43	0626
11	94	1	25	14.3	g	3	108	c	344	619.3	f	2.78	0629
11	94	1	25	14.5	f	1	25	se	920	1974.3		14.90	0633
11	94	1	25	14.5	f	1	25	p	140	36.2	f	0.22	0634
11	94	1	25	14.5	f	2	25	se	610	518.8		3.03	0625
11	94	1	25	14.5	f	3	25	se	535	314.4			0627
11	94	1	25	14.5	f	3	25	se	552	352.6		0.24	0628
7	94	1	26	14.7	g	1	38	p	131	28.8	m	0.17	0674
7	94	1	26	14.7	g	1	38	c	131	30.3			0675
7	94	1	26	14.7	g	1	38	c	153	46.3			0676
7	94	1	26	14.7	g	1	38	r	142	48.8	f	3.11	0677
7	94	1	26	14.7	g	1	38	r	130	39.0	m	0.50	0678
7	94	1	26	14.7	g	1	38	r	127	31.8	m	0.70	0679
7	94	1	26	14.7	g	1	38	r	126	36.3	m	0.97	0680
7	94	1	26	14.7	g	1	38	r	125	34.0	m	0.73	0681
7	94	1	26	14.7	g	1	38	r	136	39.8	f	1.99	0682
7	94	1	26	14.7	g	1	38	r	140	42.2	m	1.26	0683
7	94	1	26	14.7	g	1	38	r	132	39.3	m	0.87	0684
7	94	1	26	14.7	g	1	38	r	130	36.4	f	1.01	0685
7	94	1	26	14.7	g	1	38	r	128	35.7	m	1.36	0686
7	94	1	26	14.7	g	1	38	r	131	36.9	m	0.60	0687
7	94	1	26	14.7	g	1	38	r	127	32.5	f	1.29	0688
7	94	1	26	14.7	g	1	38	r	135	38.3	f	2.71	0689
7	94	1	26	14.7	g	1	38	r	125	33.9	m	0.10	0690
7	94	1	26	14.7	g	1	57	p	188	86.2	f	0.59	0691
7	94	1	26	14.7	g	1	57	p	223	167.4	f	1.21	0692
7	94	1	26	14.7	g	1	57	p	200	108.6	m	0.75	0693
7	94	1	26	14.7	g	1	57	p	192	93.2	f	0.58	0694
7	94	1	26	14.7	g	1	57	p	195	95.0	f	0.84	0695
7	94	1	26	14.7	g	1	57	p	200	107.1	f	0.15	0696
7	94	1	26	14.7	g	1	57	p	191	96.3	f	0.67	0697
7	94	1	26	14.7	g	1	57	r	195	124.6	f	3.02	0698
7	94	1	26	14.7	g	1	57	r	188	117.9	f	4.69	0699
7	94	1	26	14.7	g	1	57	r	203	216.6	m	10.22	0700
7	94	1	26	14.7	g	1	57	r	163	84.6	m	1.38	0701
7	94	1	26	14.7	g	1	57	r	185	120.5	m	4.63	0702
7	94	1	26	14.7	g	1	108	p	388	1064.2	f	8.83	0672
7	94	1	26	14.7	g	1	108	t	440	1241.5	f	79.48	0673
7	94	1	26	15.1	g	2	38	p	133	31.3	f	0.23	0723
7	94	1	26	15.1	g	2	38	p	138	36.7	f	0.20	0724
7	94	1	26	15.1	g	2	38	p	128	27.8	m	0.23	0725
7	94	1	26	15.1	g	2	38	p	133	31.4	f	0.21	0726
7	94	1	26	15.1	g	2	38	p	124	26.3	m	0.05	0727
7	94	1	26	15.1	g	2	38	p	132	29.8	f	0.06	0728
7	94	1	26	15.1	g	2	38	p	230	167.3	f	1.08	0729
7	94	1	26	15.1	g	2	38	p	145	39.5	f	0.32	0730
7	94	1	26	15.1	g	2	38	c	138	31.3	f	0.07	0731
7	94	1	26	15.1	g	2	38	c	162	55.3	f	0.14	0732
7	94	1	26	15.1	g	2	38	c	149	42.4			0733
7	94	1	26	15.1	g	2	38	r	134	42.2	f	2.55	0734
7	94	1	26	15.1	g	2	38	r	132	41.1	m	0.17	0735
7	94	1	26	15.1	g	2	38	r	130	39.8	m	0.13	0736
7	94	1	26	15.1	g	2	38	r	138	36.5	f	1.86	0737
7	94	1	26	15.1	g	2	38	r	125	31.3	f	1.02	0738
7	94	1	26	15.1	g	2	38	r	135	43.1	f	1.46	0739
7	94	1	26	15.1	g	2	38	r	125	39.2	f	2.73	0740
7	94	1	26	15.1	g	2	38	r	135	36.5	f	0.72	0741
7	94	1	26	15.1	g	2	38	r	125	34.3	f	1.80	0742
7	94	1	26	15.1	g	2	38	r	140	43.9	m	1.07	0743
7	94	1	26	15.1	g	2	38	r	125	34.7	f	2.70	0744
7	94	1	26	15.1	g	2	38	r	127	34.2	m	0.62	0745
7	94	1	26	15.1	g	2	38	r	131	39.4	m	0.53	0746
7	94	1	26	15.1	g	2	38	r	132	38.0	m	0.67	0747
7	94	1	26	15.1	g	2	38	r	132	36.3	f	0.92	0748
7	94	1	26	15.1	g	2	38	r	140	40.6	f	1.82	0749
7	94	1	26	15.1	g	2	38	r	133	36.5	m	0.96	0750
7	94	1	26	15.1	g	2	38	r	135	41.7	f	3.12	0751
7	94	1	26	15.1	g	2	38	r	135	38.9	f	2.18	0752
7	94	1	26	15.1	g	2	38	r	132	37.0	f	1.13	0753
7	94	1	26	15.1	g	2	38	r	133	38.1	f	1.33	0754
7	94	1	26	15.1	g	2	38	r	128	37.7	m	0.11	0755
7	94	1	26	15.1	g	2	38	r	135	41.4	m	0.81	0756
7	94	1	26	15.1	g	2	38	r	136	40.0	f	3.37	0757
7	94	1	26	15.1	g	2	38	r	124	31.7	m	0.32	0758
7	94	1	26	15.1	g	2	38	r	128	35.5	m	0.19	0759
7	94	1	26	15.1	g	2	57	p	243	174.4	f	1.68	0714
7	94	1	26	15.1	g	2	57	p	213	108.9	f	0.72	0715
7	94	1	26	15.1	g	2	57	p	205	120.4	f	0.79	0716
7	94	1	26	15.1	g	2	57	p	205	108.0	f	0.76	0717
7	94	1	26	15.1	g	2	57	p	198	116.0	f	0.66	0718
7	94	1	26	15.1	g	2	57	c	215	115.9	m	0.09	0719

Appendix 1 (continued)

site	yy	mm	dd	time	ntype	netno	msizemm	species	length	weight	sex	gonadwt	scode
7	94	1	26	15.1	g	2	57	r	140	46.8	m	0.82	0720
7	94	1	26	15.1	g	2	57	r	190	122.6	m	3.37	0721
7	94	1	26	15.1	g	2	57	r	194	142.8	f	4.80	0722
7	94	1	26	15.1	g	2	86	p	305	488.6	f	2.79	0713
7	94	1	26	15.1	g	2	108	t	375	846.3	m	2.28	0710
7	94	1	26	15.1	g	2	108	t	387	904.4	m	1.87	0711
7	94	1	26	15.1	g	2	108	t	420	1142.5	m	5.53	0712
7	94	1	26	15.7	g	3	38	c	189	80.3	m	0.04	0661
7	94	1	26	15.7	g	3	38	c	160	60.6	f	0.08	0662
7	94	1	26	15.7	g	3	38	c	182	73.7	f	0.25	0663
7	94	1	26	15.7	g	3	38	c	181	67.2	f	0.23	0664
7	94	1	26	15.7	g	3	38	c	185	78.1	f	0.18	0665
7	94	1	26	15.7	g	3	38	c	170	59.3	f	0.27	0666
7	94	1	26	15.7	g	3	38	c	140	33.6	f	0.08	0667
7	94	1	26	15.7	g	3	38	p	165	61.9	m	0.09	0668
7	94	1	26	15.7	g	3	38	p	128	25.9	f	0.40	0669
7	94	1	26	15.7	g	3	38	r	129	36.0	f	2.73	0670
7	94	1	26	15.7	g	3	38	r	133	38.2	f	1.85	0671
7	94	1	26	15.7	g	3	57	p	213	114.4	f	0.85	0648
7	94	1	26	15.7	g	3	57	p	199	90.7	m	0.10	0649
7	94	1	26	15.7	g	3	57	p	219	144.0	f	0.99	0650
7	94	1	26	15.7	g	3	57	p	223	157.6	f	1.15	0651
7	94	1	26	15.7	g	3	57	p	201	103.2	m	0.82	0652
7	94	1	26	15.7	g	3	57	r	193	155.8	f	6.11	0653
7	94	1	26	15.7	g	3	57	c	210	101.3			0654
7	94	1	26	15.7	g	3	57	c	255	226.6	f	0.64	0655
7	94	1	26	15.7	g	3	57	c	211	119.5	m	0.07	0656
7	94	1	26	15.7	g	3	57	c	218	130.8	f	0.16	0657
7	94	1	26	15.7	g	3	57	c	211	110.1	m	0.40	0658
7	94	1	26	15.7	g	3	57	c	182	70.4	f	0.04	0659
7	94	1	26	15.7	g	3	57	c	196	92.0	f	0.27	0660
7	94	1	26	15.7	g	3	108	t	418	1194.8	m	5.77	0707
7	94	1	26	15.7	g	3	108	t	391	897.8	m	3.07	0708
7	94	1	26	15.7	g	3	108	t	380	773.8	m	1.52	0709
7	94	1	26	15.7	g	3	108	t	366	770.8	m	3.58	0706
7	94	1	26	16.1	f	1	25	se	544	353.2		1.19	0799
7	94	1	26	16.1	f	1	25	t	461	1320.6	m	8.38	0800
7	94	1	26	16.1	f	1	25	se	674	695.0		2.50	0801
7	94	1	26	16.1	f	1	25	se	427	162.2		0.92	0802
7	94	1	26	16.1	f	1	25	se	541	294.0		0.39	0803
7	94	1	26	16.1	f	1	25	se	671	456.6		0.37	0804
7	94	1	26	16.1	f	1	25	t	485	1664.7	m	7.17	0805
7	94	1	26	16.1	f	1	25	t	382	835.9	m	3.54	0806
7	94	1	26	16.1	f	1	25	r	217	143.4	m	4.94	0807
7	94	1	26	16.1	f	1	25	se	434	174.5		0.61	0808
7	94	1	26	16.1	f	1	25	se	513	238.1		0.62	0809
7	94	1	26	16.1	f	1	25	se	567	369.2		1.06	0810
7	94	1	26	16.1	f	1	25	se	598	433.8		0.28	0811
7	94	1	26	16.1	f	1	25	se	629	545.2		1.59	0812
7	94	1	26	16.1	f	1	25	se	693	674.8		1.01	0813
7	94	1	26	16.1	f	1	25	se	611	395.4		0.79	0814
7	94	1	26	16.1	f	1	25	se	553	344.0		0.39	0815
7	94	1	26	16.1	f	1	25	se	759	969.1		3.44	0816
7	94	1	26	16.1	f	1	25	se	662	593.2		0.81	0817
7	94	1	26	16.1	f	1	25	p	278	272.2	f	1.70	0818
7	94	1	26	16.1	f	1	25	r	155	48.7	m	1.35	0819
7	94	1	26	16.1	f	1	25	r	154	59.5	m	1.66	0820
7	94	1	26	16.1	f	1	25	r	123	31.6	f	0.63	0821
7	94	1	26	16.1	f	1	25	r	151	55.0	m	0.26	0822
7	94	1	26	16.1	f	1	25	r	148	44.2	f	0.75	0823
7	94	1	26	16.1	f	1	25	r	202	156.9	f	15.10	0824
7	94	1	26	16.1	f	1	25	r	206	135.2	f	3.47	0825
7	94	1	26	16.1	f	1	25	r	181	101.0	m	1.18	0826
7	94	1	26	16.1	f	1	25	r	154	65.5	m	1.63	0827
7	94	1	26	16.1	f	1	25	r	147	45.0	m	1.04	0828
7	94	1	26	16.1	f	1	25	r	174	74.7	f	1.45	0829
7	94	1	26	16.1	f	1	25	p	209	127.1	f	0.78	0830
7	94	1	26	16.1	f	1	25	se	664	622.0		2.56	0831
7	94	1	26	16.1	f	1	25	se	562	357.1		0.29	0832
7	94	1	26	16.1	f	1	25	se	669	649.3		5.89	0833
7	94	1	26	16.1	f	1	25	se	530	295.9		0.89	0834
7	94	1	26	16.1	f	1	25	se	654	849.5		5.97	0835
7	94	1	26	16.1	f	1	25	r	151	46.1	m	1.15	0836
7	94	1	26	16.1	f	1	25	r	132	34.5	f	1.02	0837
7	94	1	26	16.2	f	2	25	se	818	1131.8		8.71	0760
7	94	1	26	16.2	f	2	25	se	467	199.7		0.18	0761
7	94	1	26	16.2	f	2	25	se	634	322.6		0.55	0762
7	94	1	26	16.2	f	2	25	se	820	1460.9		5.22	0763
7	94	1	26	16.2	f	2	25	se	433	149.0		0.83	0764
7	94	1	26	16.2	f	2	25	t	446	1305.0	m	10.27	0765
7	94	1	26	16.2	f	2	25	se	540	366.4		0.73	0766
7	94	1	26	16.2	f	2	25	c	157	45.3			0767
7	94	1	26	16.2	f	2	25	r	137	38.9	m	0.69	0768
7	94	1	26	16.2	f	2	25	c	177	69.8	m	0.06	0769
7	94	1	26	16.2	f	2	25	se	488	253.1		0.78	0770
7	94	1	26	16.2	f	2	25	p	212	126.8	m	0.25	0771
7	94	1	26	16.2	f	2	25	p	230	141.1	m	0.25	0772
7	94	1	26	16.2	f	2	25	c	148	40.9	f	0.09	0773
7	94	1	26	16.2	f	2	25	se	436	152.2		0.11	0774
7	94	1	26	16.2	f	2	25	c	159	47.7			0775
7	94	1	26	16.2	f	2	25	c	149	40.3			0776
7	94	1	26	16.2	f	2	25	r	155	61.2	f	3.05	0777
7	94	1	26	16.2	f	2	25	se	365	90.6		0.08	0778
7	94	1	26	16.2	f	2	25	se	524	317.4		0.89	0779
7	94	1	26	16.2	f	2	25	se	706	687.1		1.17	0780

Appendix 1 (continued)

site	yy	mm	dd	time	ntype	netno	msizemm	species	length	weight	sex	gonadwt	scode
7	94	1	26	16.2	f	2	25	se	978	2374.1		18.29	0781
7	94	1	26	16.2	f	2	25	c	171	63.4	f	0.13	0782
7	94	1	26	16.2	f	2	25	c	164	52.6	f	0.20	0783
7	94	1	26	16.2	f	2	25	c	150	46.1	f	0.12	0784
7	94	1	26	16.2	f	2	25	c	185	87.0	m	0.08	0785
7	94	1	26	16.2	f	2	25	c	134	29.4			0786
7	94	1	26	16.2	f	2	25	se	409	131.6		0.06	0787
7	94	1	26	16.2	f	2	25	r	122	28.8	m	0.65	0788
7	94	1	26	16.2	f	2	25	r	137	39.8	m	0.24	0789
7	94	1	26	16.2	f	2	25	r	142	44.1	m	0.93	0790
7	94	1	26	16.2	f	2	25	se	742	784.4		1.83	0791
7	94	1	26	16.2	f	2	25	se	542	346.8		1.42	0792
7	94	1	26	16.2	f	2	25	se	477	225.7		0.43	0793
7	94	1	26	16.2	f	2	25	se	472	221.0		0.62	0794
7	94	1	26	16.2	f	2	25	c	175	62.1			0795
7	94	1	26	16.2	f	2	25	se	524	309.4		1.05	0796
7	94	1	26	16.2	f	2	25	p	147	41.8	f	0.25	0797
7	94	1	26	16.2	f	2	25	c	136	31.1	f	0.14	0798
7	94	1	26	16.3	f	3	25	p	75	5.5	m	0.01	0703
7	94	1	26	16.3	f	3	25	r	129	28.7	m	0.90	0704
7	94	1	26	16.3	f	3	25	r	130	31.2	m	0.29	0705
7	94	1	26	16.3	m	2	5	r	180	104.0	m	4.05	0647
5	94	1	31	15.9	g	1	38	p	124	13.5	m	0.06	0883
5	94	1	31	15.9	g	1	38	p	133	15.1	m	0.08	0884
5	94	1	31	15.9	g	1	38	p	127	19.2	m	0.22	0885
5	94	1	31	15.9	g	1	38	r	130	22.3	m	0.84	0886
5	94	1	31	15.9	g	1	38	r	138	27.2	m	1.50	0887
5	94	1	31	15.9	g	1	57	p	204	82.9	f	0.88	0924
5	94	1	31	15.9	g	1	57	p	192	88.8	f	1.31	0925
5	94	1	31	15.9	g	1	57	p	215	72.2	f	1.26	0926
5	94	1	31	15.9	g	1	57	p	195	53.7	f	0.89	0927
5	94	1	31	15.9	g	1	57	p	206	58.8	m	0.25	0928
5	94	1	31	15.9	g	1	57	p	200	66.7	f	0.66	0929
5	94	1	31	15.9	g	1	57	p	201	84.0	m	0.88	0930
5	94	1	31	15.9	g	1	57	p	221	105.7	f	0.87	0931
5	94	1	31	15.9	g	1	57	p	201	87.3	f	0.72	0932
5	94	1	31	15.9	g	1	57	p	193	73.4	f	0.78	0933
5	94	1	31	15.9	g	1	57	p	188	69.1	f	0.69	0934
5	94	1	31	15.9	g	1	57	p	206	75.7	f	0.64	0935
5	94	1	31	15.9	g	1	57	p	192	71.1	f	0.14	0936
5	94	1	31	15.9	g	1	57	p	200	86.1	f	0.98	0937
5	94	1	31	15.9	g	1	57	p	237	148.9	f	1.08	0938
5	94	1	31	15.9	g	1	57	p	196	76.6	m	0.87	0939
5	94	1	31	15.9	g	1	57	p	200	81.5	f	0.91	0940
5	94	1	31	15.9	g	1	57	p	191	69.6	f	0.31	0941
5	94	1	31	15.9	g	1	57	p	196	89.7	m	0.77	0942
5	94	1	31	15.9	g	1	57	p	205	89.1	f	0.78	0943
5	94	1	31	15.9	g	1	57	p	209	95.3	m	0.81	0944
5	94	1	31	15.9	g	1	57	p	213	75.7	f	0.83	0945
5	94	1	31	15.9	g	1	57	p	189	72.3	f	0.62	0946
5	94	1	31	15.9	g	1	57	p	215	65.3	f	0.74	0947
5	94	1	31	15.9	g	1	57	p	207	94.7	f	0.83	0948
5	94	1	31	15.9	g	1	57	p	199	72.2	m	0.70	0949
5	94	1	31	15.9	g	1	57	p	206	57.5	m	0.14	0950
5	94	1	31	15.9	g	1	57	p	208	70.5	f	0.64	0951
5	94	1	31	15.9	g	1	57	p	190	60.9	f	0.64	0952
5	94	1	31	15.9	g	1	57	p	211	106.3	m	1.03	0953
5	94	1	31	15.9	g	1	57	p	195	58.3	f	0.96	0954
5	94	1	31	15.9	g	1	57	p	212	77.2	f	3.45	0955
5	94	1	31	15.9	g	1	57	p	211	99.0	f	1.01	0956
5	94	1	31	15.9	g	1	57	p	185	63.9	f	0.65	0957
5	94	1	31	15.9	g	1	57	p	258	198.8	f	1.50	0958
5	94	1	31	15.9	g	1	57	r	211	127.9	m	7.23	0959
5	94	1	31	15.9	g	1	57	r	193	112.4	f	6.52	0960
5	94	1	31	15.9	g	1	86	g	207	125.1	m	8.27	0838
5	94	1	31	15.9	g	1	108	g	263	247.0	f	47.62	0839
5	94	1	31	15.9	g	1	108	g	248	173.7	f	38.62	0940
5	94	1	31	15.9	g	1	108	t	396	553.0	f	62.99	0841
5	94	1	31	16.3	g	2	38	p	138	18.8	f	0.26	0888
5	94	1	31	16.3	g	2	38	p	128	17.2			0889
5	94	1	31	16.3	g	2	38	p	142	27.0	f	0.32	0890
5	94	1	31	16.3	g	2	38	p	122	15.7	m	0.05	0891
5	94	1	31	16.3	g	2	38	p	139	23.1	f	0.27	0892
5	94	1	31	16.3	g	2	38	p	127	20.2	m	0.03	0893
5	94	1	31	16.3	g	2	38	p	129	17.5	f	0.26	0894
5	94	1	31	16.3	g	2	38	p	122	14.7	f	0.96	0895
5	94	1	31	16.3	g	2	38	p	129	20.3	f	0.04	0896
5	94	1	31	16.3	g	2	38	p	134	21.2	f	0.27	0897
5	94	1	31	16.3	g	2	38	p	139	21.8	f	0.38	0898
5	94	1	31	16.3	g	2	38	p	140	21.6	f	0.28	0899
5	94	1	31	16.3	g	2	38	p	129	18.6	f	0.22	0900
5	94	1	31	16.3	g	2	38	p	130	16.1	f	0.26	0901
5	94	1	31	16.3	g	2	38	p	133	20.0	f	0.24	0902
5	94	1	31	16.3	g	2	38	r	132	27.0	f	2.85	0903
5	94	1	31	16.3	g	2	38	r	133	26.8	m	0.69	0904
5	94	1	31	16.3	g	2	38	r	130	20.6	m	1.01	0905
5	94	1	31	16.3	g	2	38	r	125	21.1	m	0.17	0906
5	94	1	31	16.3	g	2	38	r	134	42.6	m	0.33	0907
5	94	1	31	16.3	g	2	38	r	128	28.8	m	0.05	0908
5	94	1	31	16.3	g	2	38	r	132	26.0	m	0.50	0909
5	94	1	31	16.3	g	2	57	p	197	50.9	f	0.15	0910
5	94	1	31	16.3	g	2	57	p	202	93.8	m	0.27	0911
5	94	1	31	16.3	g	2	57	p	195	57.1	m	0.14	0912
5	94	1	31	16.3	g	2	57	p	188	60.9	f	0.79	0913
5	94	1	31	16.3	g	2	57	p	196	69.4	m	0.71	0914

Appendix 1 (continued)

site	yy	mm	dd	time	ntype	netno	msizemm	species	length	weight	sex	gonadwt	scode
5	94	1	31	16.3	g	2	57	p	197	60.9	f	0.77	0915
5	94	1	31	16.3	g	2	57	p	200	65.6	m	0.65	0916
5	94	1	31	16.3	g	2	57	p	194	54.8	f	0.80	0917
5	94	1	31	16.3	g	2	57	p	220	84.3	f	0.89	0918
5	94	1	31	16.3	g	2	57	p	202	73.8	f	0.20	0919
5	94	1	31	16.3	g	2	57	p	201	79.3	f	0.90	0920
5	94	1	31	16.3	g	2	57	p	188	80.4	m	0.82	0921
5	94	1	31	16.3	g	2	57	r	175	58.9	f	1.39	0922
5	94	1	31	16.3	g	2	57	r	209	107.3	f	1.96	0923
5	94	1	31	16.3	g	2	108	t	432	723.2	f	62.88	0882
5	94	1	31	16.7	g	3	38	p	134	15.4	f	0.28	0842
5	94	1	31	16.7	g	3	38	p	125	13.9	m	0.05	0843
5	94	1	31	16.7	g	3	38	p	138	11.3	f	0.33	0844
5	94	1	31	16.7	g	3	38	p	136	13.3	f	0.40	0845
5	94	1	31	16.7	g	3	38	p	126	8.0	m	0.25	0846
5	94	1	31	16.7	g	3	38	p	140	14.1	m	0.29	0847
5	94	1	31	16.7	g	3	38	p	134	14.8	f	0.49	0848
5	94	1	31	16.7	g	3	38	p	126	11.6	f	0.05	0849
5	94	1	31	16.7	g	3	38	r	115	11.9	m	0.33	0850
5	94	1	31	16.7	g	3	38	r	135	19.3	m	0.72	0851
5	94	1	31	16.7	g	3	38	r	136	19.0	m	0.41	0852
5	94	1	31	16.7	g	3	38	r	125	12.0	f	0.50	0853
5	94	1	31	16.7	g	3	38	r	133	15.5	f	0.78	0854
5	94	1	31	16.7	g	3	38	r	136	14.8	f	1.05	0855
5	94	1	31	16.7	g	3	38	r	139	19.8	m	0.83	0856
5	94	1	31	16.7	g	3	38	r	115	11.1	m	0.33	0857
5	94	1	31	16.7	g	3	38	r	140	17.3	m	0.28	0858
5	94	1	31	16.7	g	3	38	r	121	17.7	m	0.17	0859
5	94	1	31	16.7	g	3	57	p	194	47.8	f	0.17	0860
5	94	1	31	16.7	g	3	57	p	173	39.7	f	0.65	0861
5	94	1	31	16.7	g	3	57	p	204	61.9	f	0.72	0862
5	94	1	31	16.7	g	3	57	p	199	64.5	f	0.81	0863
5	94	1	31	16.7	g	3	57	p	194	49.3	f	0.65	0864
5	94	1	31	16.7	g	3	57	p	225	78.8	f	0.82	0865
5	94	1	31	16.7	g	3	57	p	200	61.2	f	0.94	0866
5	94	1	31	16.7	g	3	57	p	187	58.6	f	0.58	0867
5	94	1	31	16.7	g	3	57	p	203	82.3	m	0.89	0868
5	94	1	31	16.7	g	3	57	p	202	69.5	m	0.08	0869
5	94	1	31	16.7	g	3	57	p	187	59.8	f	0.55	0870
5	94	1	31	16.7	g	3	57	p	201	68.6	f	0.62	0871
5	94	1	31	16.7	g	3	57	p	201	69.6	f	0.81	0872
5	94	1	31	16.7	g	3	57	p	201	67.3	f	0.84	0873
5	94	1	31	16.7	g	3	57	p	195	55.8	m	0.64	0874
5	94	1	31	16.7	g	3	57	p	191	55.6	f	0.65	0875
5	94	1	31	16.7	g	3	86	t	345	398.4	m	1.38	0878
5	94	1	31	16.7	g	3	108	t	364	501.0	f	43.19	0876
5	94	1	31	16.7	g	3	108	t	417	755.1	f	11.59	0877
5	94	1	31	17.1	f	1	25	se	444	106.1		0.40	0968
5	94	1	31	17.1	f	1	25	se	401	83.6			0969
5	94	1	31	17.1	f	1	25	se	414	108.3			0970
5	94	1	31	17.1	f	1	25	c	166	26.9	m	0.10	0971
5	94	1	31	17.1	f	1	25	se	471	123.1			0972
5	94	1	31	17.1	f	1	25	se	423	96.6		0.30	0973
5	94	1	31	17.1	f	1	25	c	212	76.7	f	0.48	0974
5	94	1	31	17.1	f	1	25	p	201	59.8	m	0.15	0975
5	94	1	31	17.1	f	2	25	p	178	38.7	m	0.19	0880
5	94	1	31	17.1	f	2	25	p	197	66.9	m	0.50	0881
5	94	1	31	17.0	f	3	25	r	216	96.5	f	5.11	0961
5	94	1	31	17.0	f	3	25	se	257	58.5			0962
5	94	1	31	17.0	f	3	25	p	224	89.9	m	0.20	0963
5	94	1	31	17.0	f	3	25	se	461	106.3		0.73	0964
5	94	1	31	17.0	f	3	25	se	384	52.8		0.15	0965
5	94	1	31	17.0	f	3	25	se	648	279.3		2.72	0966
5	94	1	31	17.0	f	3	25	t	381	491.4	m	4.29	0967
5	94	1	31	17.0	m	2	5	r	160	33.3	m	2.48	0879
3	94	2	2	16.8	g	1	38	p	120	23.7	m	0.17	1020
3	94	2	2	16.8	g	1	38	p	129	20.7	m	0.21	1021
3	94	2	2	16.8	g	1	38	p	130	20.9	m	0.24	1022
3	94	2	2	16.8	g	1	38	p	123	17.8	f	0.06	1023
3	94	2	2	16.8	g	1	38	p	132	18.1	m	0.13	1024
3	94	2	2	16.8	g	1	38	p	115	15.3			1025
3	94	2	2	16.8	g	1	38	p	130	19.3	f	0.33	1026
3	94	2	2	16.8	g	1	38	p	128	19.4	f	0.24	1027
3	94	2	2	16.8	g	1	38	p	128	22.9	f	0.25	1028
3	94	2	2	16.8	g	1	38	p	133	27.8	f	0.22	1029
3	94	2	2	16.8	g	1	38	p	124	16.6	m	0.06	1030
3	94	2	2	16.8	g	1	38	p	130	17.3	f	0.25	1031
3	94	2	2	16.8	g	1	38	p	128	14.9	f	0.35	1032
3	94	2	2	16.8	g	1	38	p	125	20.6	f	0.63	1033
3	94	2	2	16.8	g	1	38	p	128	12.6	m	0.09	1034
3	94	2	2	16.8	g	1	38	p	128	22.7	f	0.33	1035
3	94	2	2	16.8	g	1	38	r	143	34.7	m	0.46	1036
3	94	2	2	16.8	g	1	38	r	131	31.6	f	0.78	1037
3	94	2	2	16.8	g	1	38	r	130	28.2	m	0.63	1038
3	94	2	2	16.8	g	1	38	r	142	30.0	f	0.82	1039
3	94	2	2	16.8	g	1	38	r	114	16.5	m	0.09	1040
3	94	2	2	16.8	g	1	38	r	132	27.9	m	1.20	1041
3	94	2	2	16.8	g	1	38	r	130	35.0	f	0.56	1042
3	94	2	2	16.8	g	1	38	r	124	26.6	m	0.68	1043
3	94	2	2	16.8	g	1	38	r	139	39.7	m	1.35	1044
3	94	2	2	16.8	g	1	38	r	135	33.9	f	0.63	1045
3	94	2	2	16.8	g	1	38	r	141	37.7			1046
3	94	2	2	16.8	g	1	38	r	131	25.6	f	0.56	1047
3	94	2	2	16.8	g	1	38	r	134	30.5	m	0.59	1048
3	94	2	2	16.8	g	1	38	r	113	16.6	f	0.33	1049
3	94	2	2	16.8	g	1	57	r	180	83.0	f	13.09	1050

Appendix 1 (continued)

site	yy	mm	dd	time	ntype	netno	msizemm	species	length	weight	sex	gonadwt	scode
3	94	2	2	16.8	g	1	57	p	223	100.7	f	2.12	1051
3	94	2	2	16.8	g	1	57	p	205	70.3	f	1.88	1052
3	94	2	2	16.8	g	1	57	p	195	70.8	f	0.75	1053
3	94	2	2	16.8	g	1	57	p	198	83.7	m	0.62	1054
3	94	2	2	16.8	g	1	57	p	213	94.3	m	0.89	1055
3	94	2	2	16.8	g	1	57	c	264	133.2	f	0.96	1056
3	94	2	2	16.8	g	1	57	g	197	82.3	m	2.33	1057
3	94	2	2	16.8	g	1	86	g	213	187.5	f	31.25	0978
3	94	2	2	16.8	g	1	86	g	214	156.8	m	5.26	0979
3	94	2	2	16.8	g	1	86	c	218	260.2	m	1.26	0980
3	94	2	2	16.8	g	1	108	g	252	310.3	f	66.61	0977
3	94	2	2	15.9	g	2	38	p	125	12.6	m	0.27	1008
3	94	2	2	15.9	g	2	38	p	128	21.1	f	0.20	1009
3	94	2	2	15.9	g	2	38	p	139	21.3	f	0.26	1010
3	94	2	2	15.9	g	2	38	p	133	24.8	f	0.27	1011
3	94	2	2	15.9	g	2	38	p	132	15.5	f	0.23	1012
3	94	2	2	15.9	g	2	38	p	135	24.7	f	0.32	1013
3	94	2	2	15.9	g	2	38	p	120	16.0	m	0.07	1014
3	94	2	2	15.9	g	2	38	p	125	13.8	m	0.05	1015
3	94	2	2	15.9	g	2	57	c	205	90.7	f	0.11	1016
3	94	2	2	15.9	g	2	86	g	210	204.9	m	5.37	1019
3	94	2	2	15.9	g	2	108	t	412	907.0	f	48.32	1017
3	94	2	2	15.9	g	2	108	t	390	670.1	m	3.67	1018
3	94	2	2	17.2	g	3	38	p	138	20.9	f	0.28	0985
3	94	2	2	17.2	g	3	38	p	129	16.0	f	0.28	0986
3	94	2	2	17.2	g	3	38	p	118	16.7	m	0.05	0987
3	94	2	2	17.2	g	3	38	p	131	21.7	f	0.28	0988
3	94	2	2	17.2	g	3	38	p	135	16.9	f	0.65	0989
3	94	2	2	17.2	g	3	38	p	125	9.3	f	0.34	0990
3	94	2	2	17.2	g	3	38	p	140	28.4	m	0.24	0991
3	94	2	2	17.2	g	3	38	p	130	27.1	f	0.20	0992
3	94	2	2	17.2	g	3	38	p	125	16.1	f	0.20	0993
3	94	2	2	17.2	g	3	38	p	124	16.5	m	0.07	0994
3	94	2	2	17.2	g	3	38	p	130	22.8	f	0.31	0995
3	94	2	2	17.2	g	3	38	p	128	26.4	m	0.23	0996
3	94	2	2	17.2	g	3	38	p	135	22.8	f	0.27	0997
3	94	2	2	17.2	g	3	38	p	135	19.2	f	0.23	0998
3	94	2	2	17.2	g	3	38	p	128	18.1	m	0.67	0999
3	94	2	2	17.2	g	3	38	r	132	33.0	m	0.71	1000
3	94	2	2	17.2	g	3	38	r	130	31.7	m	0.21	1001
3	94	2	2	17.2	g	3	38	r	112	16.9	m	0.22	1002
3	94	2	2	17.2	g	3	38	r	131	21.4	m	0.95	1003
3	94	2	2	17.2	g	3	57	p	204	72.9	f	0.89	0981
3	94	2	2	17.2	g	3	57	p	197	82.0	m	0.13	0982
3	94	2	2	17.2	g	3	57	r	190	97.9	m	3.74	0983
3	94	2	2	17.2	g	3	57	r	197	101.4	f	3.33	0984
3	94	2	2	17.2	g	3	86	g	211	210.9	f	8.60	0976
3	94	2	2	17.2	g	3	108	t	423	1032.0	f	92.36	1005
3	94	2	2	17.7	f	1	25	se	495	187.3		0.27	1058
3	94	2	2	17.7	f	1	25	c	178	60.6			1059
3	94	2	2	17.8	f	2	25	se	508	230.2		0.24	1007
3	94	2	2	17.8	f	2	25	se	409	134.1		0.39	1006
3	94	2	2	17.7	f	3	25	t	435	1018.2	m	3.67	1060
3	94	2	2	17.7	f	3	25	t	375	684.4	m	2.62	1061
3	94	2	2	17.7	f	3	25	r	249	186.0	f	12.20	1062
3	94	2	2	17.7	f	3	25	t	460	1157.6	f	57.90	1063
3	94	2	2	17.7	f	3	25	c	201	67.5	f	0.27	1064
3	94	2	2	17.7	f	3	25	t	328	426.1	m	1.58	1065
3	94	2	2	17.7	f	3	25	t	435	721.0	m	7.01	1066
3	94	2	2	17.7	f	3	25	p	177	48.8	m	0.49	1067
3	94	2	2	17.7	f	3	25	p	173	36.2	f	0.60	1068
3	94	2	2	17.7	f	3	25	r	150	35.9	f	0.91	1069
3	94	2	2	17.8	m	2	5	b	32	0.541			1004
4	94	3	2	18.7	g	1	38	r	146	24.6			
4	94	3	2	18.7	g	1	38	r	139	31.3			
4	94	3	2	18.7	g	1	38	r	137	22.2			
4	94	3	2	18.7	g	1	38	p	132	19.7			
4	94	3	2	18.7	g	1	38	p	137	22.9			
4	94	3	2	18.7	g	1	38	p	126	14.4			
4	94	3	2	18.7	g	1	38	r	134	24.5			
4	94	3	2	18.7	g	1	38	p	133	17.4			
4	94	3	2	18.7	g	1	38	p	134	20.9			
4	94	3	2	18.7	g	1	38	p	124	15.8			
4	94	3	2	18.7	g	1	38	p	131	19.3			
4	94	3	2	18.7	g	1	38	p	129	15.3			
4	94	3	2	18.7	g	1	86	p	121	13.1			
4	94	3	2	18.7	g	1	38	g	209	127.5			
4	94	3	2	18.8	g	2	38	r	124	22.1			
4	94	3	2	18.8	g	2	38	p	116	15.4			
4	94	3	2	18.8	g	2	38	p	124	15.7			
4	94	3	2	18.8	g	2	38	p	126	19.5			
4	94	3	2	18.8	g	2	38	p	128	20.1			
4	94	3	2	18.8	g	2	38	r	136	28.8			
4	94	3	2	18.8	g	2	38	p	122	15.6			
4	94	3	2	18.8	g	2	38	p	130	21.9			
4	94	3	2	18.8	g	2	38	p	129	20.9			
4	94	3	2	18.8	g	2	38	p	136	19.9			
4	94	3	2	18.8	g	2	38	p	125	17.1			
4	94	3	2	18.8	g	2	38	p	127	17.2			
4	94	3	2	18.8	g	2	38	p	133	19.6			
4	94	3	2	18.8	g	2	38	p	127	18.6			
4	94	3	2	18.8	g	2	38	p	128	16.6			
4	94	3	2	18.8	g	2	38	r	127	25.3			
4	94	3	2	19.3	g	3	38	p	139	18.1			
4	94	3	2	19.3	g	3	38	p	131	19.1			

Appendix 1 (continued)

site	yy	mm	dd	time	ntype	netno	msizemm	species	length	weight	sex	gonadwt	scode
4	94	3	2	19.3	g	3	38	p	127	16.5			
4	94	3	2	19.3	g	3	38	p	126	15.5			
4	94	3	2	19.3	g	3	38	p	132	17.3			
4	94	3	2	19.3	g	3	38	p	136	20.4			
4	94	3	2	19.3	g	3	38	p	134	20.2			
4	94	3	2	19.3	g	3	38	r	144	29.1			
4	94	3	2	19.3	g	3	38	r	141	24.3			
4	94	3	2	19.3	g	3	57	r	172	54.4			
4	94	3	2	19.3	g	3	108	t	425	652			
4	94	3	2	19.3	g	3	108	t	418	585.9			
4	94	3	2	19.5	f	1	25	p	177	42.9			
4	94	3	2	19.5	f	1	25	p	166	32			
4	94	3	2	19.5	f	1	25	p	224	108.9			
4	94	3	2	19.5	f	1	25	p	231	97			
4	94	3	2	19.5	f	1	25	p	197	53.5			
4	94	3	2	19.5	f	1	25	p	184	37.5			
4	94	3	2	19.5	f	1	25	p	224	80.3			
4	94	3	2	19.5	f	1	25	p	149	21.9			
4	94	3	2	19.5	f	1	25	p	140	20.9			
4	94	3	2	19.5	f	1	25	p	172	44.4			
4	94	3	2	19.5	f	1	25	p	174	38.8			
4	94	3	2	19.5	f	1	25	p	137	22			
4	94	3	2	19.5	f	1	25	p	172	31.2			
4	94	3	2	19.5	f	1	25	r	117	14.5			
4	94	3	2	19.5	f	1	25	c	175	45.7			
4	94	3	2	19.5	f	1	25	c	218	73			
4	94	3	2	19.5	f	1	25	c	219	67.6			
4	94	3	2	19.5	f	1	25	r	138	26.2			
4	94	3	2	19.5	f	1	25	p	138	24.3			
4	94	3	2	19.5	f	1	25	p	144	28.2			
4	94	3	2	19.5	f	1	25	c	216	77.9			
4	94	3	2	19.5	f	1	25	c	149	23.5			
4	94	3	2	19.5	f	1	25	r	118	14.1			
4	94	3	2	19.5	f	1	25	p	145	23.5			
4	94	3	2	19.5	f	1	25	c	150	25.5			
4	94	3	2	19.5	f	1	25	se	498	148.4			
4	94	3	2	19.5	f	1	25	se	396	76.2			

APPENDIX II:

Catch rates of fish caught in gill nets at 11 sampling sites in Hamilton Lake between 9 December 1993 and 2 Feburary 1994.

Sample site	Mesh size (mm)	CPUE (fish h^{-1} 100 m^{-1} of net)					
		Catfish	Goldfish	Perch	Rudd	Tench	Total
1	25	0.000	0.000	0.000	0.000	0.000	0.000
1	38	0.000	0.000	4.097	3.414	0.000	7.511
1	57	0.455	0.228	4.780	2.731	0.000	8.194
1	86	0.228	0.228	0.000	0.455	0.000	0.911
1	108	0.000	0.364	0.000	0.000	0.910	1.274
2	25	0.000	0.000	0.000	0.000	0.000	0.000
2	38	0.955	0.000	5.733	1.911	0.000	8.599
2	57	1.592	0.000	5.096	4.140	0.000	10.83
2	86	0.000	0.000	0.000	0.319	0.319	0.638
2	108	0.000	0.764	0.255	0.000	0.510	1.529
3	25	0.000	0.000	0.000	0.000	0.000	0.000
3	38	0.000	0.000	9.766	4.507	0.000	14.17
3	57	0.501	0.250	1.753	0.751	0.000	3.255
3	86	0.250	1.002	0.000	0.000	0.000	1.252
3	108	0.000	0.200	0.000	0.000	0.601	0.801
4	25	0.000	0.000	0.318	0.000	0.000	0.318
4	38	0.238	0.000	8.571	7.619	0.000	16.43
4	57	0.000	0.000	4.048	0.714	0.000	4.762
4	86	0.000	0.238	0.000	0.000	0.000	0.238
4	108	0.000	0.000	0.000	0.000	1.714	1.714
5	25	0.000	0.000	0.000	0.000	0.000	0.000
5	38	0.000	0.000	6.644	4.855	0.000	11.50
5	57	0.000	0.000	16.10	1.022	0.000	17.12
5	86	0.000	0.256	0.000	0.000	0.256	0.512
5	108	0.000	0.409	0.000	0.000	0.818	1.227
6	25	0.000	0.000	0.000	0.000	0.000	0.000
6	38	0.712	0.000	14.48	12.82	0.000	28.01
6	57	0.000	0.000	5.696	1.661	0.000	7.357
6	86	0.000	0.000	0.000	0.000	0.237	0.237
6	108	0.000	0.190	0.000	0.000	0.000	0.190
7	25	0.000	0.000	0.000	0.000	0.000	0.000
7	38	3.297	0.000	3.022	11.54	0.000	17.86
7	57	2.198	0.000	4.670	2.473	0.000	9.341
7	86	0.000	0.000	0.275	0.000	0.000	0.275
7	108	0.000	0.000	0.220	0.000	1.758	1.978
8	25	0.000	0.000	0.000	0.000	0.000	0.000
8	38	1.017	0.000	4.322	0.508	0.000	5.847
8	57	1.271	0.000	6.101	0.254	0.000	7.626
8	86	0.254	0.763	0.000	0.000	0.000	1.017
8	108	0.000	0.203	0.000	0.000	0.203	0.406
9	25	0.000	0.000	0.000	0.000	0.000	0.000
9	38	0.000	0.000	0.315	3.461	0.000	3.776
9	57	0.000	0.000	1.573	0.000	0.000	1.573
9	86	0.000	0.000	0.000	0.000	0.000	0.000
9	108	0.000	0.000	0.000	0.000	0.000	0.000
10	25	0.000	0.000	0.000	0.000	0.000	0.000
10	38	0.000	0.000	0.000	0.319	0.000	0.319
10	57	0.000	0.000	0.000	0.000	0.000	0.000
10	86	0.000	0.000	0.000	0.000	0.000	0.000
10	108	0.000	0.000	0.000	0.000	0.000	0.000
11	25	0.000	0.000	0.000	0.000	0.000	0.000
11	38	0.000	0.000	1.764	0.882	0.000	2.646
11	57	0.588	0.000	1.470	0.294	0.000	2.352
11	86	0.294	0.294	0.000	0.000	0.000	0.588
11	108	0.235	0.000	0.000	0.000	0.235	0.470

APPENDIX III:

Concentrations of arsenic, lead, zinc, and copper from the white muscle tissue of fish caught in Hamilton Lake between 9 December 1993 and 2 February 1994.

Fish species: c=catfish, g=goldfish, p=perch, r=rudd, se=shortfinned eel, t=tench.

		Heavy metal concentrations (mg kg^{-1} wet weight)				
		Arsenic	Zinc	Copper	Lead	
Detection limits		0.03	0.5	0.4	0.1	
Maximum permitted levels (Statutory regulations 1984)		2.0	40.0	30.0	2.0	
Fish species	Sample site					Sample code
c	1	1.03	4.0	0.6	<0.1	82
c	1	0.33	3.8	<0.4	<0.1	83
c	1	0.97	4.4	0.6	0.2	16
c	1	0.52	7.3	0.5	<0.1	61
c	2	1.26	4.4	0.7	<0.1	591
c	3	0.74	3.7	0.7	<0.1	1056
c	4	0.89	5.0	0.9	<0.1	507
c	5	1.01	4.5	1.1	<0.1	974
c	6	0.17	8.0	<0.4	<0.1	154
c	7	0.65	4.4	1.1	0.1	785
c	8	0.77	3.7	<0.4	<0.1	340
c	11	0.99	5.5	1.0	<0.1	629
g	1	0.20	7.2	0.5	0.2	57
g	1	0.13	10.6	0.9	0.2	3
g	1	0.19	10.5	1.0	<0.1	25
g	1	0.10	8.5	0.5	<0.1	62
g	2	0.11	9.1	1.0	<0.1	530
g	3	0.18	11.0	1.1	<0.1	978
g	4	0.18	18.4	0.6	1.1	375
g	5	0.22	8.4	0.8	0.2	839
g	6	0.30	16.9	0.5	0.4	213
g	8	0.16	19.3	<0.4	0.1	348
g	11	0.13	11.5	1.2	0.1	640
p	1	0.13	5.5	0.5	0.3	20
p	1	<0.03	3.2	<0.4	<0.1	6
p	1	0.06	4.5	0.5	0.1	4
p	1	0.08	3.5	<0.4	0.2	7
p	2	0.06	5.9	0.8	<0.1	580
p	3	0.09	4.1	0.9	<0.1	1051
p	4	0.15	3.5	0.7	<0.1	479
p	5	0.11	3.9	0.7	<0.1	938
p	6	0.08	4.4	<0.4	0.1	96
p	7	0.03	3.7	0.8	<0.1	672
p	8	0.05	2.7	<0.4	0.5	369
p	9	0.24	4.5	0.9	0.1	620
p	11	0.06	6.1	1.1	0.1	635
r	1	0.7	9.6	1.0	0.1	60
r	1	0.17	13.2	0.5	0.4	50
r	1	0.12	13.8	0.6	<0.1	22
r	1	0.06	3.7	0.5	<0.1	13
r	2	0.14	17.8	1.0	<0.1	590
r	3	0.13	8.3	<0.4	<0.1	1062
r	4	0.11	10.4	<0.4	<0.1	376
r	5	0.06	12.9	1.2	<0.1	959
r	6	0.08	12.1	0.5	0.1	94
r	7	0.05	8.8	1.0	<0.1	700
r	8	0.10	12.1	<0.4	0.2	317
r	9	0.25	11.2	1.0	<0.1	614
r	10	0.12	8.2	1.0	0.1	620
r	11	0.16	15.1	1.0	<0.1	632
se	1	0.19	8.1	<0.4	1.3	86
se	1	0.05	14.4	<0.4	0.2	85
se	1	0.06	11.9	<0.4	<0.1	87
se	2	0.13	13.8	0.9	<0.1	571
se	3	0.34	13.0	0.9	0.3	1007
se	4	0.21	15.6	0.9	<0.1	499
se	5	0.33	13.9	1.0	<0.1	966
se	6	0.06	12.1	<0.4	<0.1	156
se	7	<0.03	9.2	0.9	0.2	781
se	8	0.14	7.1	<0.4	0.1	367
se	9	0.15	6.9	0.8	0.4	615
se	11	0.05	11.4	0.8	<0.1	633
t	1	0.41	4.0	<0.4	0.4	84
t	1	0.56	3.8	0.6	<0.1	63
t	1	0.20	3.2	<0.4	<0.1	64
t	1	0.37	2.8	<0.4	<0.1	1
t	2	0.54	3.3	1.1	<0.1	579
t	3	0.26	5.5	0.6	<0.1	1060
t	4	0.47	3.6	0.8	<0.1	474
t	5	0.34	5.0	1.1	<0.1	882
t	6	0.40	3.6	<0.4	<0.1	212
t	7	0.17	4.4	0.9	<0.1	805
t	8	0.33	3.7	<0.4	0.2	349
t	11	0.43	5.8	0.8	0.3	646

APPENDIX IV

Relative abundance of invertebrates in surficial sediments in Hamilton Lake. Results from two seperate Peterson grab samples on 29 September 1993 (Data from McKinney 1995).

	L.Ham 1	L. Ham 2
Phylum Annelida		
Class Oligochaeta		
Oligochaeta indet	11	310
Phylum Nematoda		
Nematoda indet	35	9
Phylum Mollusca		
Class Gastropoda		
Physa sp		6
Potamopyrgus sp		3
Class Bivalvia		
Pisidium sp		
Phylum Arthropoda		
Subphylum Crustacea		
Class Branchiopoda		
Cladoceran indet		
Class Copepoda		
Copepod indet	2	
Class Ostracod		
Ostracod indet	16	1
Subphylum Uniromia		
Class Insecta		
Order Ephemeroptera		
Deleatidium lillii	2	
Order Trichoptera		
indet (Case only)	1	2
Order Diptera		
A. ungulatum		
Chironomid indet (L)	68	4
(P	5	

References

Bagenal, T. B. 1972: The variability in numbers of perch *Perca fluviatilis* L. caught in traps. *Freshwater Biology* 2: 27-36.

Boswell, J., Russ, M. and Simons, M. 1985: Waikato small lakes: resource statement. Waikato Valley Authority technical report 1985/7.

Bronmark, C. 1994: Effects of tench and perch on interactions in a freshwater, benthic food chain. *Ecology* 75(6) 1818-1828.

Brooks, R. R., Lewis, J. R. and Reeves, R. D. 1976: Mercury and other heavy metals in trout of central North Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 10(2) 233-244.

Burrough, R. J., Bregazzi, P. R. and Kennedy, C. R. 1979: Interspecific dominance amongst three species of coarse fish in Slapton Ley, Devon. *Journal of Fish Biology* 15 (5) 535-544.

Cable, L. E. 1928: Food of bullheads. *U.S. Bureau of Fisheries* Document 1037.

Cadwallader, P. L. 1977: Review of the ecology of rudd and the implications of its introduction into New Zealand. *Ministry of Agriculture and Fisheries, Fisheries Technical Report* 147: 1-18.

Cairns, D. 1942: Life history of the two species of fresh-water eel in New Zealand. II. Food and inter-relationships with trout. *New Zealand Journal of Science and Technology* 23(4) 132-148.

Carpene, E., Cattani, O., Serrazanetti, G. P., Fedrizzi, G. and Cortesi, P. 1990: Zinc and copper in fish from natural waters and rearing ponds in Northern Italy. *Journal of Fish Biology* 37 (2): 293-299.

Champion, P. D., de Winton, M. D. and de Lange, P. J. 1993: *The vegetation of the Lower Waikato lakes. Volume 2: Vegetation of 38 lakes in the Lower Waikato.* NIWA Ecosystems Publication no 8. 133pp.

Chapman, M.A. 1994: Plankton studies, in Clayton, J.S. and M. D. de Winton (Eds). *Lake Rotoroa: Change in an Urban Lake.* NIWA Ecosystems publication No 9, Hamilton. p68-70.

Chisnall, B.L. 1987: *Juvenile eel biology in the backwaters of the Waikato River.* Unpublished M.Sc. thesis, University of Waikato, New Zealand. 152pp.

Cihar, J. and Stanislav, F. 1958: The food and the determination of age and rate of growth from scales of rudds [*Scardinius erythrophthalmus* (Linnaeus)], *Vistnik Ceskoslovenske Spolecnosti Zoologicke* 1: 13-30.

Clayton, J. S. and Tanner, C. C. 1994: Environmental persistence and fate of arsenic applied for aquatic weed control, in Clayton, J.S. and M. D. de Winton (Eds). *Lake Rotoroa: Change in an Urban Lake.* NIWA Ecosystems publication No 9, Hamilton. p34-40.

Coffey, B. and Edgar, N. 1993: *Review of the current status of Lake Rotoroa, Hamilton.* Unpublished report submitted to the World Wildlife Fund, New Zealand, 19pp.

Coles, T. F. 1981: The distribution of perch, *Perca fluviatilis* L. throughout their first year of life in Llyn Tegid, North Wales. *Journal of Fish Biology* 18(1) 15-30.

Craig, J. F. 1974a: Population dynamics of perch, *Perca fluviatilis* L. in Slapton Ley, Devon. I. Trapping behaviour, reproduction, migration, population estimates, mortality and food. *Freshwater Biology* 4 (5) 417-431.

Craig, J. F. 1974: Population dynamics of perch, *Perca fluviatilis* L. in Slapton Ley, Devon. II. Age, growth, length-weight relationships and condition. *Freshwater Biology* 4 (5) 433-444.

Craig, J. F. 1975: Seasonal variation in the catching power of traps used for perch, *Perca fluviatilis* L., *Freshwater Biology* 5 (2) 183-187.

Craig, J. F. 1978: A study of the food and feeding of perch, *Perca fluviatilis* L., in Windermere. *Freshwater Biology* 8: 59-68.

Craig, J. F. 1980: Growth and production of the 1955 to 1972 cohorts of perch, *Perca fluviatilis* L., in Windermere. *Journal of Animal Ecology* 49(1) 291-315.

Craig, J. F. 1987: *The Biology of Perch and Related Fish.* Timber Press, Portland, Oregon. 333pp.

Craig, J.F., Kipling, C., Le Cren, E.D. and McCormack, J.C. 1979: Estimates of the numbers, biomass and year-class strengths of perch (*Perca fluviatilis* L.) in Windermere from 1967 to 1977 and some comparisons with earlier years. *Journal of Animal Ecology* 48 (1): 315-325.

de Winton, M. D. and Champion, P. D. 1993: *The vegetation of the Lower Waikato lakes. Volume 1: Factors affecting the vegetation of the lakes in the Lower Waikato.* NIWA Ecosystems Publication no7. 89pp.

de Winton, M. D. 1994: The history of aquatic vegetation management, in Clayton J. S. and M. D. de Winton, (Eds). *Lake Rotoroa: Change in an Urban Lake.* NIWA Ecosystems publication No. 9, Hamilton, p24-33.

de Winton, M. D., Clayton, J. S., Wells, R. D. and Tanner, C. C. 1991: *Review of Lake Rotoroa Monitoring and Management issues; 1987-1991.* Aquatic Plant Section, MAF, unpublished report.

Diana, J. S. and Salz, R. 1990: Energy storage, growth, and maturation of yellow perch from different locations in Saginaw Bay, Michigan. *Transactions of the American Fisheries Society* 119(6) 976-984.

Diehl, S. 1988: Foraging efficiency of three freshwater fishes: effects of structural complexity and light. *Oikos* 53(2) 207-214.

Diehl, S. 1993: Effects of habitat structure on resource availability, diet and growth of benthivorous perch, *Perca fluviatilis. Oikos* 67(3) 403-414.

Duncan, K. W. 1967: The food and population structure of perch (*Perca fluviatilis* L.) in Lake Mahinerangi. *Transactions of the Royal Society of New Zealand Zoology* 9(5) 45-52.

Edgar, N. B. 1993: *Trophic Manipulation of Freshwater Plankton Communities.* D.Phil. thesis, University of Waikato, New Zealand. 275pp.

Eklov, P. and Hamrin, S. F. 1989: Predatory efficiency and prey selection: interactions between pike *Esox lucius*, perch *Perca fluviatilis* and rudd *Scardinus erythrophthalmus. Oikos* 56(2) 149-156.

Engelmayer, A. 1992: The effect of prey type and density on the foraging efficiency of juvenile perch, (*Perca fluviatilis*). *Hydrobiologia* 231(2) 119-123.

Evans, W. H., Jackson, F. J. and Dellar, D. 1979: Evaluation of a method for determination of total antimony, arsenic and tin in foodstuffs using measurement by atomic-absorption spectrophotometry with atomisation in a silica tube using the hydride generation technique. *The Analyst* 104: 16-34.

Francis, R. I. 1990: Back-calculation of fish length: a critical review. *Journal of Fish Biology* 36: 883-902.

Frank, S. 1955: The food of the common bullhead in the Elbe Region. *Universitas Carolina Biologica* 1(1) 19-24.

Giles, N., Street, M. and Wright, R. M. 1990: Diet composition and prey preference of tench, *Tinca tinca* (L.), common bream, *Abramis brama* (L.), perch, *Perca fluviatilis* L. and roach, *Rutilus rutilus* (L.), in two contrasting gravel pit lakes: potential trophic overlap with wildfowl. *Journal of Fish Biology* 37(6) 945-957.

Graynoth, E. 1978: Unpublished data on surveys conducted in July and October of 1976, and January and April of 1977.

Green, J. D. and Lowe, D. J. 1994: Origin and development, in Clayton, J. S. and M. D. de Winton, (Eds). *Lake Rotoroa: Change in an Urban Lake.* NIWA Ecosystems publication No. 9, Hamilton, p13-24.

Griffiths, W. E. 1976: Food and feeding habitats of European perch in the Selwyn River, Canterbury, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 10(3) 417-428.

Grundy, K. 1993: *The Effect of a Collapse of Submerged Aquatic Macrophyte Populations on Rudd Growth in Lake Rotoroa (Hamilton Lake), North Island, New Zealand.* Unpublished 0770.307 'Special topics in biological sciences' report, University of Waikato.

Guma'a, S. A. 1978: The food and feeding habits of young perch, *Perca fluviatilis*, in Windermere. *Freshwater Biology* 8: 177-187.

Guti, G. 1992: The population density of perch, *Perca fluviatilis* L. in the Cikola backwater system of the river Danube, Hungary. *Hydrobiologia* 242(3) 195-198.

Guti, G. 1993: Mortality, growth and diet of perch *Perca fluviatilis* L. in the Cikola branch system of the Szigetkoz area, River Danube. *Archiv Fur Hydrobiologie* 128(3) 317-327.

Hamilton City Council (HCC). 1985: *The Hamilton Lake Management Plan.* Department of Recreation and Welfare, Hamilton City Council. 44pp.

Hamley, J. M. 1975: Review of gillnet selectivity. *Journal of Fisheries Research Board of Canada* 32(11) 1943-1969.

Hayes, J. W. 1989: Comparison between a fine mesh trap net and five other fishing gears for sampling shallow-lake fish communities in New Zealand. *New Zealand Journal of Marine and Freshwater Research,* 23: 321-324.

Hayward, R. S. and Margraf, F. J. 1987: Eutrophication effects on prey size and food available to yellow perch in Lake Erie. *Transactions of the American Fisheries Society* 116(2) 210-223.

Henriques, P.R. 1979: Hamilton Lake monitoring programme report, summer 1978/79. *Waikato Valley Authority technical publication No. 12*, Hamilton.

Hicks, B. J. 1994: The biology and feeding ecology of exotic fish, in Clayton, J. S. and M. D. de Winton, (Eds). *Lake Rotoroa: change in an urban lake.* NIWA Ecosystems publication No. 9, Hamilton. p71-79.

Holcik, J. 1967: Life history of the rudd - *Scardinius erythrophthalmus* (Linnaeus, 1758) in the Klicava reservoir. *Vestnik Ceskoslovenske Spolecnosti Zoologicke* 4: 335-348.

Houthuijzen, R. P., Backx, J. J. and Buijse, A. D. 1993: Exceptionally rapid growth and early maturation of perch in a freshwater lake recently converted from an estuary. *Journal of Fish Biology* 43(2) 320-324.

Hubert, W.A. 1983: Passive capture techniques, in Nielsen. L. A. and Johnson, D. L. (Eds) *Fisheries techniques.* American Fisheries Society, Bethesda, Maryland, p95-122.

Hyslop, E. J. 1980: Stomach contents analysis - a review of methods and their application. *Journal of Fish Biology,* 17: 411-429.

Jansen, W. and Mackay W. 1992: Foraging in yellow perch, *Perca flavescens:* biological and physical factors affecting diel periodicity in feeding, consumption, and movement. *Environmental Biology of Fishes* 34(3) 287-303.

Jellyman, D. J. 1980: Age, growth, and reproduction of perch, *Perca fluviatilis* L., in Lake Pounui. *New Zealand Journal of Marine and Freshwater Research* 14(4) 391-400.

Jellyman, D. J. 1989: Diet of two species of freshwater eel (*Anguilla* spp.) in Lake Pounui, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 23(1) 1-10.

Jellyman, D. J. and Todd, P. R. 1982: New Zealand freshwater eels: their biology and fishery. *NZ Ministry of Agriculture and Fisheries, Fisheries Research Division Information Leaflet* 11: 1-19.

Johnson, L. 1994: Pattern and process in ecological systems: a step in the development of a general ecological theory. *Canadian Journal of Fisheries and Aquatic Sciences* 51: 226-246.

Keast, A. and Webb, P. 1966: Mouth and body form in fish. *Journal Fisheries Research Board Canada* 23(12) 1859-1860.

Keast, A. 1977: Diet overlaps and feeding relationships between the year classes in the yellow perch (*Perca flavescens*). *Environmental Biology of Fish* 2: 53-70.

Kennedy, C. 1969: Tubificid oligochaetes as food of dace *Leuciscus leuciscus* (L.). *Journal of Fish Biology* 1(1) 11-15.

Kennedy, M. and Fitzmaurice, P. 1970: The biology of the tench *Tinca tinca* (L.) in Irish waters. *Proceedings of the Royal Irish Academy* 69 (3): 31-85.

Kennedy, M. and Fitzmaurice, P. 1974: Biology of the rudd *Scardinius erythrophthalmus* (L.) in Irish waters. *Proceedings of the Royal Irish Academy* 74: 245-303.

Klarberg, D. P. and Benson, A. 1975: Food habits of *Ictalurus nebulosus* in acid polluted waters of North Western Virginia. *Transactions of the American Fisheries Society* 104: 541-547.

Lake, M. 1994: *The Effect of the Collapse of the Submerged Aquatic Macrophytes on the Growth of European Perch (Perca fluviatilis L.).* Unpublished 0770.307 'Special topics in biological sciences' report, University of Waikato.

Le Cren, E. D. 1947: The determination of the age and growth of the perch (*Perca fluviatilis*) from the opercular bone. *Journal of Animal Ecology* 16: 188-204.

Le Cren, E. D. 1951: The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *Journal of Animal Ecology* 20: 201-219.

Le Cren, E. D. 1958: Observations on the growth of perch (*Perca fluviatilis* L.) over twenty-two years with special reference to the effects of temperature and changes in population density. *Journal of Animal Ecology* 27: 287-334.

Le Cren, E. D. 1987: Perch (*Perca fluviatilis*) and pike (*Esox lucius*) in Windermere from 1940 to 1985; studies in population dynamics. *Canadian Journal of Fisheries and Aquatic Sciences* 44: 216-228.

Le Cren, E. D. 1992: Exceptionally big individual perch (*Perca fluviatilis* L.) and their growth. *Journal of Fish Biology* 40(4) 599-625.

Le Cren, E. D., Kipling, C. and McCormack, J. C. 1977: A study of the numbers, biomass and year-class strengths of perch (*Perca fluviatilis* L.) in Windermere from 1941 to 1966. *Journal of Animal Ecology* 46(1) 281-307.

Linlokken, A., Kleiven, E. and Matzow, D. 1991: Population structure, growth and fecundity of perch (*Perca fluviatilis* L.) in an acidified river system in Southern Norway. *Hydrobiologia* 220(3) 179-188.

McCormack, J. C. 1970: Observations on the food of perch (*Perca fluviatilis* L.) in Windermere. *Journal of Animal Ecology* 39(1) 255-267.

McDowall, R. M. 1990: *New Zealand Freshwater Fishes, a Natural History and Guide.* Heinemann Reed, MAF Publishing Group, New Zealand. 553pp.

McKinney, L. C. 1995: *The Toxicity of Arsenic to Chironomus zealandicus (Diptera: Insecta) and Hyridella menziesi (Unionoida: Mollusca).* Unpublished M.Sc. thesis, University of Waikato.

Mann, R. H. and Steinmetz, B. 1985: On the accuracy of age-determination using scales from rudd, *Scardinius erythrophthalmus* (L.), of known age. *Journal of Fish Biology* 26(5) 621-628.

Martinie, G.D. and Schilt, A.A. 1976: Investigation of the wet oxidation efficiencies of perchloric acid mixtures for various organic substances and the identities of residual matter. *Analytical Chemistry* 48(1): 70-74.

Mattila, J. 1992: The effect of habitat complexity on predation efficiency of perch *Perca fluviatilis* L. and ruffe *Gymnocephalus cernuus* (L.). *Journal of Experimental Marine Biology and Ecology* 157(1) 55-67.

Mauck, W. L. and Coble, C. D. 1971: Vulnerability of some fishes to northern pike (*Esox lucius*) predation. *Journal of Fisheries Research Board of Canada* 28: 957-969.

Mills, C. A. and Hurley, M. A. 1990: Long-term studies on the Windermere populations of perch (*Perca fluviatilis*), pike (*Esox lucius*) and Arctic charr (*Salvelinus alpinus*). *Freshwater Biology* 23(1) 119-136.

Moore, J. W. 1972: Piscivorous activities of the brown bullheads in Lockhart Pond, Ontario, Canada. *Progressive Fish Culturalist* 3: 141-143.

Moore, J.W. and Ramamoorthy, S. 1984: *Heavy Metals in Natural Waters: Applied Monitoring and Impact Assessment.* Springer-Verlag, New York Inc. 268pp.

O'Maoileidigh, N. and Bracken, J. 1989: Biology of the tench, *Tinca tinca* (L.), in an Irish Lake. *Aquaculture and Fisheries Management* 20: 199-209.

Patchell, G. J. 1977: *Studies on the biology of the catfish Ictalurus nebulosus Le sueur in the Waikato Region.* Unpublished M.Sc. thesis, University of Waikato, New Zealand.

Penaz, M., Prokes, M., Kouril, J. and Hamackova, J. 1989: Influence of water temperature on the early development and growth of the tench, *Tinca tinca. Folia Zoologica* 38(3) 275-287.

Penrose, W. R., Black, R. and Hayward, M. J. 1975: Limited arsenic dispersion in seawater, sediments, and biota near a continuous source. *Journal of the Fisheries Research Board of Canada* 32: 1275-1281.

Persson, L. 1983: Food consumption and competition between age classes in a perch *Perca fluviatilis* population in a shallow eutrophic lake. *Oikos* 40(2) 197-207.

Persson, L. 1987: The effects of resource availability and distribution on size class interactions in perch, *Perca fluviatilis*. *Oikos* 48(2) 148-160.

Persson, L. and Greenberg, L. A. 1990a: Interspecific and intraspecific size class competition affecting resource use and growth of perch, *Perca fluviatilis*. *Oikos* 59(1) 97-106.

Persson, L. and Greenberg, L. A. 1990: Optimal foraging and habitat shift in perch (*Perca fluviatilis*) in a resource gradient. *Ecology* 71(5) 1699-1713.

Popova, O. A. and Sytina, L. A. 1977: Food and feeding relations of Eurasian perch (*Perca fluviatilis*) and pikeperch (*Stizostedion lucioperca*) in various waters of the USSR. *Journal of the Fisheries Research Board of Canada* 34(10) 1559-1570.

Priegel, S. 1966: Age-length and length-weight relationships of bullheads from Little Lake Buttes des Vortes, *Wisconsin Conservation Dept. Research Report Fisheries,* 17: 6.

Prout, M. W., Mills, E. L. and Forney, J. L. 1990: Diet, growth, and potential competitive interactions between age-0 white perch and yellow perch in Oneida Lake, New York. *Transactions of the American Fisheries Society* 119(6) 966-975.

Rajendram, G. 1992: *Study of Selected Chemical Constituents in Water, Sediments, Plants, and Fish in Lake Rotoroa, Hamilton, and Their Possible Effects on the Lake's Ecosystem.* Unpublished M.Sc. Thesis, University of Waikato, New Zealand.

Raney, E. C. and Webster, D. A. 1939: Food and growth of the young common bullhead in Cayuga Lake. *Transactions of the American Fisheries Society* 69: 205-209.

Ravera, O. and Jamet, J. L. 1991: The diet of the rudd (*Scardinius erythrophthalmus*, L.) in relation to the possible consequences for the removal of this species from an eutrophic lake. *Archiv Fur Hydrobiologie* 123(1) 99-109.

Roncero, V., Vincente, J., Redondo, E., Gazquez, A. and Duran, E. 1990: Experimental lead nitrate poisoning: microscopic and ultrastructural study of the gills of tench (*Tinca tinca,* L.). *Environmental Health Perspectives* 89: 137-144.

Ruparelia, S. G., Verma, Y., Mehta, N. S. and Salyed, S. R. 1989: Lead-induced biochemical changes in freshwater fish *Oreochromis mossambicus. Bull. Environ. Contam. Toxicol.* 43 (2): 310-314.

Ryan, P. A. 1984: Diet and seasonal activity of the shortfinned eel, *Anguilla australis*, in Lake Ellesmere, Canterbury, New Zealand. *Environmental Biology of Fishes* 11: 229-234.

Ryan, P. A. 1986: Seasonal and size related changes in the food of the shortfinned eel, *Anguilla australia*, in Lake Ellesmere, Canterbury, New Zealand. *Environmental Biology of Fishes* 15(1) 47-58.

Schmitt, C. J. and Brumbaugh, W. G. 1990: National contaminant biomonitoring program: concentrations of arsenic, cadmium, copper, lead, mercury, selenium, and zinc in U.S. freshwater fish, 1976-1984. *Archives of Environmental Contamination and Toxicology* 19: 731-747.

Scott, W. B. and Crossman, E. J. 1973: Freshwater fishes of Canada. *Fisheries Research Board of Canada Bulletin* 184: 1-966.

Shafi, M. and Maitland, P. S. 1971: The age and growth of perch (*Perca fluviatilis* L.) in two Scottish lochs. *Journal of Fish Biology* 3(1) 39-57.

Statutory regulations 1984: *Food Regulations.* p1361, section 257.

Sumari, O. 1971: Structure of the perch populations of some ponds in Finland. *Ann. Zool. Fennici* 8: 406-421.

Sures, B., Taraschewski, H. and Jackwerth, E. 1994: Comparative study of lead accumulation in different organs of perch (*Perca fluviatilis*) and its intestinal parasite *Acanthocephalus lucii. Bulletin of Environmental Contamination and Toxicology* 52(2) 269-273.

Tanner, C. C. and Clayton, J. S. 1990: Persistence of arsenic 24 years after sodium arsenite herbicide application to Lake Rotoroa, Hamilton, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 24 (2): 173 - 179.

Tanner, C. C., Clayton, J. S. and Coffey, B. T. 1990: Submerged-vegetation changes in Lake Rotoroa (Hamilton, New Zealand) related to herbicide treatment and invasion by *Elgeria densa. New Zealand Journal of Marine and Freshwater Research* 24(1) 45-57.

Tanner, C. C., Wells, R. D. and Clayton, J. S. 1987: *Lake Rotoroa, Hamilton: Aquatic Weed Control, Dissolved Oxygen, Water Clarity and Recommendations for Future Management.* Aquatic Plant Section, MAF unpublished report.

Totome, R. 1993: *Feeding Relationships Among Rudd, Perch and Catfish in Lake Rotoroa (Hamilton Lake): An Investigation Using Stable Carbon Isotopes.* Unpublished Diploma of Applied Science Dissertation, University of Waikato, New Zealand.

Treasurer. J. W. 1990: The food and daily food consumption of lacustrine 0+ perch, *Perca fluviatilis* L. *Freshwater Biology* 24(2), 361-374.

Unlu, E. and Gumgum, B. 1993: Concentrations of copper and zinc in fish and sediments from the Tigris River in Turkey. *Chemosphere* 26(11) 2055-2061.

Vinberg, G. G. 1956: The metabolic intensity and food requirements of fish. *Transactions of the Fisheries Research Board of Canada* 194.

Wang, N. and Eckmann, R. 1994: Distribution of perch (*Perca fluviatilis* L.) during their first year of life in Lake Constance. *Hydrobiologia* 277(3) 135-143.

Weatherley, A. H. 1959: Some features of the biology of the tench, *Tinca tinca* (Linnaeus) in Tasmania. *Journal of Animal Ecology* 28: 73-87.

Weatherley, A. H. and Gill, H. S. 1987: *The Biology of Fish Growth.* Academic Press, Harcourt Brace Jovanovich, Publishers. 443pp.

Weisberg, S. B. and Janicki, A. J. 1990: Summer feeding patterns of white perch, channel catfish, and yellow perch in the Susquehanna River, Maryland. *Journal of Freshwater Ecology* 5(4) 391-405.

Wheeler, A. 1969: *The Fishes of the British Isles and North West Europe*. MacMillan, London. 793pp.

Williamson, R. B. 1985: Urban stormwater quality 1. Hillcrest, Hamilton, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 19: 413-427.

Wise, R. G. 1990: *The Biology of Three Exotic Freshwater Fish Species in Hamilton Lake*. Unpublished M.Sc. thesis, University of Waikato, New Zealand. 104pp.

World Health Organisation 1981: *Health Hazards of the Human Environment,* N.H.O., Geneva. 387pp.

Wright, R. M. and Giles, N. 1991: The population biology of tench, *Tinca tinca* (L.), in two gravel pit lakes. *Journal of Fish Biology* 38(1) 17-28.

Zaret, T. M. 1980: *Predation and Freshwater Communities.* New Haven and London Yale University Press, 187pp.

Zerunian, S., Valentini, L. and Gibertini, G. 1986: Growth and reproduction of rudd and red-eye roach (Pisces, Cyprinidae) in Lake Bracciano, *Boll. Zool.* 53: 91-95.