An Investigation into the Abundance of European Carp (*Cyprinus carpio*) in Lakes Crescent and Sorell.

By The Inland Fisheries Service Carp Management Program.

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Prepared by Paul Donkers.
Senior Technical Officer – Carp Management Program

Inland Fisheries Service 2003
Tasmania
Australia

© For further information contact:

Inland Fisheries Service
PO Box 288
Moonah Tas 7009
Telephone: (03) 6233 4140
Facsimile: (03) 6233 4141
Email: infish@ifs.tas.gov.au

Find further information about IFS on the internet site http://www.ifs.tas.gov.au

This report is part of a series of documents, which provide information and details of carp eradication efforts in lakes Sorell and Crescent as part of the Lakes Sorell and Crescent Carp Management Project.

The aim of the project is to control the spread of carp within the state of Tasmania, with a view to their eradication.

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1.0 INTRODUCTION

Abundance estimation is the cornerstone of fisheries management; however, accuracy in estimating absolute population numbers has remained an elusive goal. According to extensive experiments carried out in European lakes (Dahm *et al* 1992), mark-recapture and hydroacoustic population estimation methods were the most accurate of the currently used techniques in inland lakes (which included Virtual Population Analysis, Catch Per Unit Effort and Filtered Volume). Despite recent refinements, hydroacoustic methods were shown to be unsuitable for estimating fish abundance in large, shallow lakes (Mous & Kemper 1996). Mark-recapture methods based on a model developed by Petersen (1896) remain the most often used technique of population estimation in inland waters.

According to Davis (1963) stated that the failure of wildlife investigators to check population estimates against known number is a deplorable situation (Seber 1982). Buck and Thoits (1965) undertook a series of Petersen experiments using seine nets in 1 acre ponds. After confirming numbers through draining, the Petersen estimates were found to be largely biased, with error greater than could be expected by chance. The causes of bias were not satisfactorily found but it was hypothesised that certain groups of fishes were living in areas of high vulnerability to which they returned when marked and released. Employing a combination of fishing techniques has been used to obtain more useful population samples. Waters (1960) found that trap and recapture by trap and angling and recapture by angling produced inferior estimates of trout populations in small lakes when compared to employing both methods simultaneously for both marking and recapture.

Seber (1982) concluded that the Petersen method was the most useful of the abundance techniques that he had analysed provided that the assumptions underlying the method are satisfied and there are sufficient recaptures in the second sample. The Petersen assumptions (closed population, equal catchability, zero tag loss, no difference in vulnerability to capture for tagged fish) are seldom-if ever-met. In practice if the assumptions are approximately met useful deductions can be made about the status of fish populations (Ricker 1975). According to Seber (1982) if the Petersen estimate

is to be used extensively for a given species then it should be compared with other estimates.

The Petersen method was employed in a mark-recapture study of the European carp, *Cyprinus carpio*, population present in Lake Crescent, a large (23 km^2), shallow lake. This work was undertaken as a component of the IFS carp management program. The mark-recapture exercise used varied-sized gillnets, seine nets, fyke nets and both backpack and boat-based electrofishing methods. It provided an opportunity to compare the Petersen method with other closed-population change-in-ratio abundance estimators. The fact that carp were recaptured over a number of days allowed for the employment of the Schnabel method. Schnabel (1938) extended Petersen's method by using a series of samples and obtaining a weighted average. This estimator can be employed during the recapture procedure to produce a population estimate independent of the Petersen estimator.

2.0 Petersen Mark-Recapture 1998-99

A Petersen mark-recapture exercise was undertaken in the summer of 1998-99 to estimate the size of the carp population in Lake Crescent. The initial study was based on the single mark-release closed population model as described by Seber (1982) and Krebs (1999). The accuracy of the Petersen method depends on the validity of the five underlying assumptions. These will be examined in the context of the Lake Crescent study as follows:

2.0.1 Closed Population. Violation of the assumption of population closure can occur because of recruitment, deaths, immigration and emigration. The presence of new recruits in Lake Crescent is monitored using fine-mesh and all juvenile cohorts are known. Above 300mm length size the natural mortality of carp in Lake Crescent is very low as evidenced by the multiple recapture of tagged fish over the years. Natural mortality over the period of the initial study would be negligible. The high survival rate of implant fish which go through the trauma of capture, detention and surgery implies that the capture and tagging associated with the Petersen study would have little effect on survival. Immigration and emigration do not occur because the lake is closed.

2.0.2 All animals have the same chance of being caught in the first sample. The majority of carp tagged during the tagging period (225 out of 366) were caught with passive gear (gillnets). Fish caught in seine nets (121) were aggregations at a particular time in certain locations. In both cases they were mobile fish. Any fish which was not mobile during the tagging period had less chance of being caught.

2.0.3 Marked and unmarked animals are equally catchable. The period of 18 days between tagging and recapture would hopefully have ensured that the fish would have fully recovered from the capture and tagging and returned to normal behaviour. There is little doubt that the assumption of equal catchability holds for seine-netting and electrofishing where the plastic anchor tags would not affect the capture process. Most gillnetted carp were caught by gilling, wedging or entanglement via the dorsal spine. The location of the tag midway below the dorsal fin which is behind the main entrapment projections therefore ensures that gillnetting effectiveness is not changed.

2.0.4 Animals do not lose tags between sampling periods. Anal fin clips ensured that the two cases of lost tags identified during the tagging process did not affect the population estimates.

2.0.5 All marks are reported upon discover in the second sample. All fish were retained in the recapture and observed by at least two people so there was little likelihood of non-reported tags or fin clips.

2.1 Data Analysis

Petersen estimates were obtained using the unbiased estimator suggested by Seber (1982) for sampling without replacement:

N = (M+1)(C+1)/(R+1)-1

Where M = number of individuals marked during the tagging period

C = total number of individuals captured during the recapture period

R = number of marked individuals caught during the recapture period

Confidence intervals for the Petersen estimates were calculated according to Krebs (1999). For R/C<0.1 and R<50 Poisson confidence intervals were used. For R/C>0.1 Binomial confidence intervals were calculated from formulae given by Zar (1996).

Schnabel estimates of the juvenile population were obtained using the original formula (Schnabel 1938):

N = Σ(C*M)/ΣR

As applied to the recapture period data. The confidence intervals were obtained from the Poisson distribution as suggested by Krebs (1999) for ΣRt<50.

2.2 Materials and Methods

The mark-recapture exercise used varied sized gillnets, seine-nets, fyke-nets and both backpack and boat-based electrofishing (Figures 1 & 2 Table 1). Marking of fish was carried out over 13 fishing days beginning 30th November 1998.

Forty-four fyke nets were deployed about the perimeter of the lake for the duration of the mark-recapture exercise and checked on a daily basis.

The tracker (transmitter-implanted) fish were searched for every morning. On occasions when several trackers were found in close proximity to each other one or more gillnets were set around them. The assumption here was that

transmitter implanted fish behave similarly to untagged carp. Targeting an aggregation of trackers would therefore be an efficient way of reducing carp numbers. The remaining gillnets were deployed randomly about the lake. Soak time averaged 8 hours during which backpack electrofishing was carried out in likely carp habitat such as around fallen timber. Whenever aggregations of fish were noticed the area would either be sealed off with available gillnets and electrofished or surrounded and hauled with the seine net. Random beach-seining was carried out when circumstances permitted.

Adult fish were identified as those running ripe. Adult females were retained and killed. Healthy adult males and juveniles were weighed, measured, anal fin clipped, tagged with numbered plastic anchor tag and released (Plate 1).

The tagged carp were left to disperse and settle for 18 days before the recapture process began. Capture methods for the recapture were the same as described above except that all fish were retained and tag numbers recorded.

Table1: Equipment used for capturing carp in capture and recapture experiment in Lake Crescent during Summer 1998-99

Type	Qty	Mesh(mm)	Gauge(mm)	Length(m)	Drop(m)
Gillnets	1	70	0.47	500	1.8
	1	100	0.38	500	2
	1	130	0.6	500	2.4
	1	150	0.38	500	3.6
	1	190	0.38	500	2.4
	1	100	0.38	100	2
	1	130	0.6	100	2.4
	1	150	0.38	100	3.6
Seine net	1	30	9ply	100	2
Fyke nets	22	25	9ply	70*50cm D	Single
	9	27-21	12ply	60cm ring	Double
	8	25-19	12ply	70*50cm D	Single
	5	25	9ply	70*50cm D	Single
Backpack	Smith-Root 400 volts 4amps				
Electroboat	Smith-Root 750 volts 4amps				

2.3 RESULTS

2.3.1 Tagging Period

A total of 366 fish were tagged and released (Table 2). According to Krebs (1999) this sample size is sufficient to formulate an estimate for management purposes with an accuracy of ±25%. Nineteen juveniles were recaptured and re-released as was 1 adult male. Two recaptured males and one juvenile were not included because they had swum back into the gillnet immediately after the release.

Table 2: Captures and releases of carp during the tagging period of the Petersen study in Lake Crescent.

	Males	**Females**	**Juveniles**	**Total**
Captured	81	52	298	431
Released	75	0	291	366

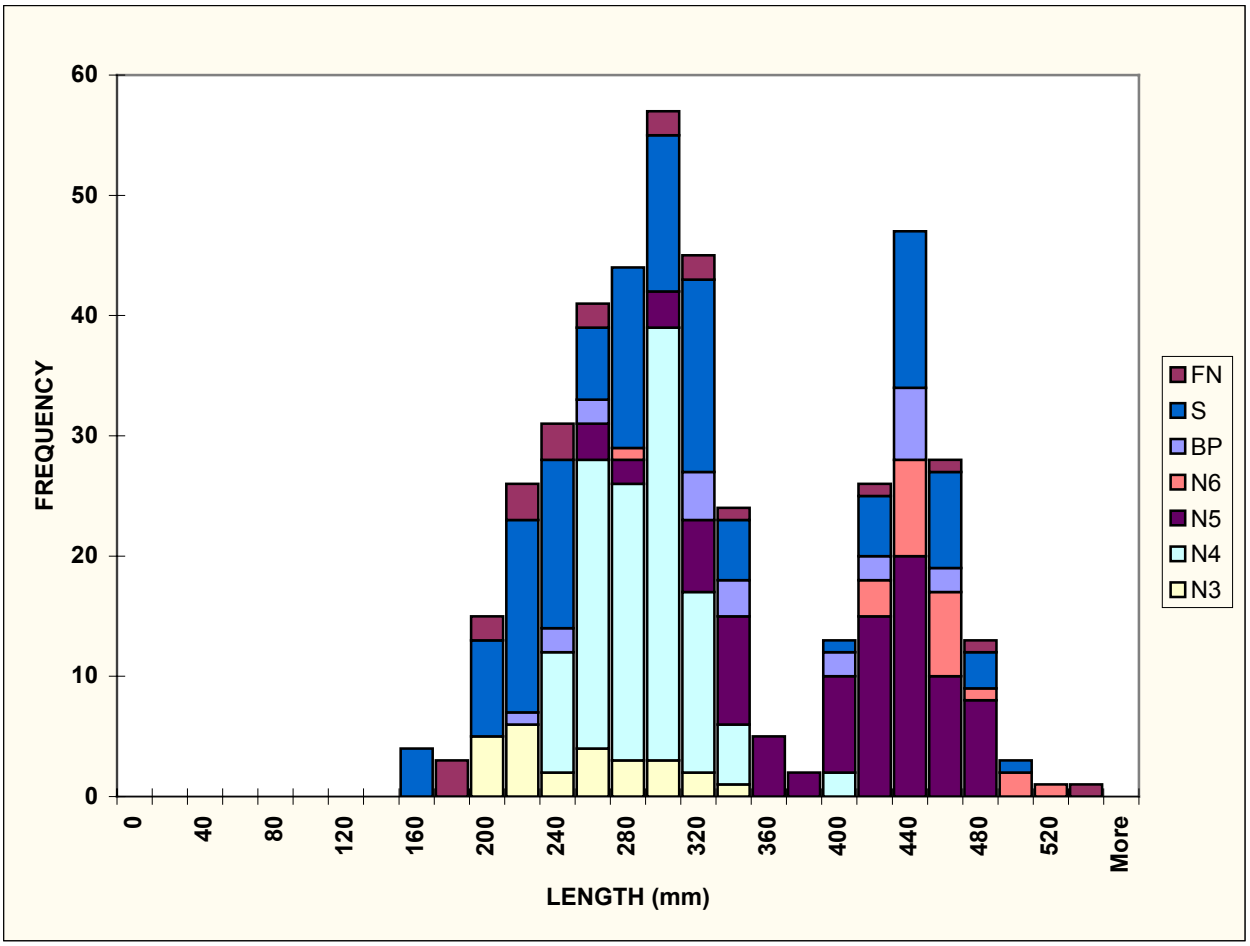

Figure 1: Selectivity of carp captured by various methods during the tagging period of the Lake Crescent Petersen study

2.3.2 Recapture Period

The recapture extended from 4th January to 15th January 1999 and resulted in 513 carp being caught (74 adult females, 124 adult males and 315 juveniles) of which 71 were tagged (23 males and 48 juveniles) (Table 3)

Table 3: Recapture results of the 1998-99 Petersen study at Lake Crescent

Date	Females	Juveniles	Males	Tagged Males	Tagged Juvs
04-Jan-99	9	7	9	2	0
05-Jan-99	22	136	74	12	23
06-Jan-99	3	50	5	1	10
07-Jan-99	11	25	16	4	3
08-Jan-99	10	20	1	0	2
09-Jan-99	0	1	0	0	0
11-Jan-99	2	30	5	1	4
12-Jan-99	11	30	5	0	3
13-Jan-99	3	4	6	2	1
14-Jan-99	3	12	2	1	2
15-Jan-99	0	0	1	0	0
Totals	**74**	**315**	**124**	**23**	**48**

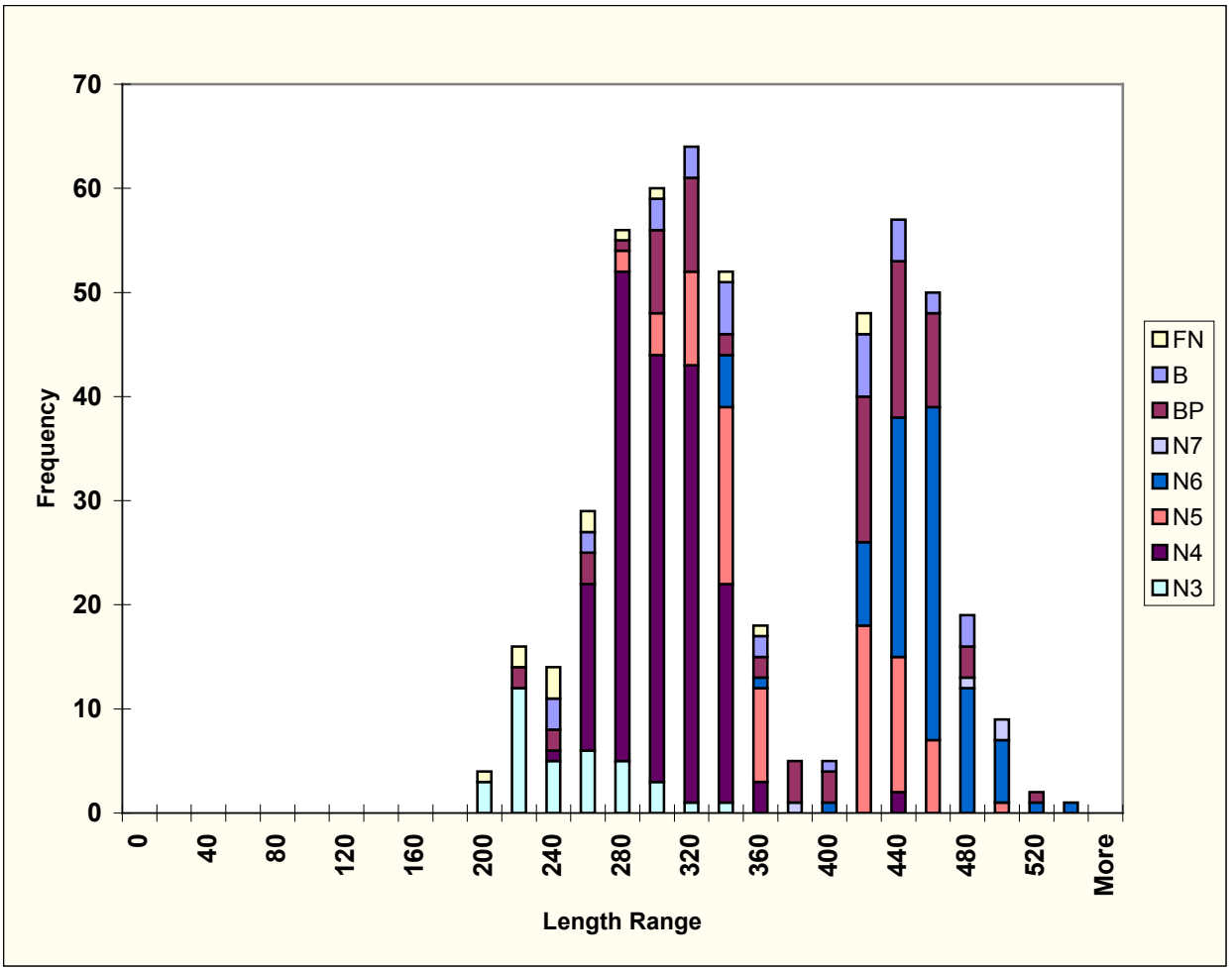

Figure 2: Recapture methods for Petersen study at Lake Crescent in 1998-99

2.3.3 Chi-squared test for catchability between subgroups (Juveniles and Adult Males)

The critical $\chi^2_{(0.05,1)}$ value is 3.84, hence in both cases (Table 3) H_0 is rejected and H_1 is accepted i.e. there is a significant difference in the probability of recapture between juveniles and adult males. This means that the data could not be pooled and that Petersen estimates needed to be obtained separately for adult males and juveniles.

Table 4 : Chi-squared value for selected recapture days

Tagging		**Recapture**							
		Day 7				**Day 11**			
		Recaptured		**Not Recaptd**		**Recaptured**		**Not Recaptd**	
		Obs	**Exp**	**Obs**	**Exp**	**Obs**	**Exp**	**Obs**	**Exp**
Male	75	20	13.3	55	61.7	27	15.8	48	59.2
Juvenile	291	45	51.7	246	239.3	50	61.2	241	229.8
$\underline{(O-E)^2}$ E	**M**	3.38		0.72		7.9		2.12	
	J	0.87		0.19		2.05		0.55	
χ^2		5.2				12.6			

3.0 Abundance Estimates

3.1 Petersen

Males and Juveniles were estimated separately (Table 4) as directed by the Chi-squared tests. Females were estimated by multiplying the proportion of females caught to untagged males caught by the Petersen estimate of males i.e.

$F/(M-M_u)*M\hat{}$

Where F = females captured

M = males captured

M_u = untagged males captured

M^ = Petersen estimate of males

Table 5: Petersen estimates derived from the total recapture results

	Estimate	**Minus captures**
Males	394.83	270.83
Juveniles	1882.10	1567.10
Females	289.28	215.28
Total	2566.21	**2053**

3.2 Schnabel

The Schnabel estimator was applied to the whole recapture period where the number of marked fish was adjusted on a daily basis. Table 5 is derived from the data in Table 3.

Table 6: Schnabel estimates for mark-recapture study in Lake Crescent

Date	**C_m* M_m (Males)**	**C_j * M_j (Juveniles)**	**Females**
4-Jan-99	675	2037	
5-Jan-99	5402	39576	
6-Jan-99	305	13400	
7-Jan-99	960	6450	
8-Jan-99	56	5100	
9-Jan-99	0	253	
11-Jan-99	280	7590	
12-Jan-99	275	7470	
13-Jan-99	330	984	
14-Jan-99	106	2940	
15-Jan-99	52	0	
Total	8441	85800	
Estimate	367	1787	268
Minus captures	243	1472	195
Total Schnabel Estimate		**1910**	

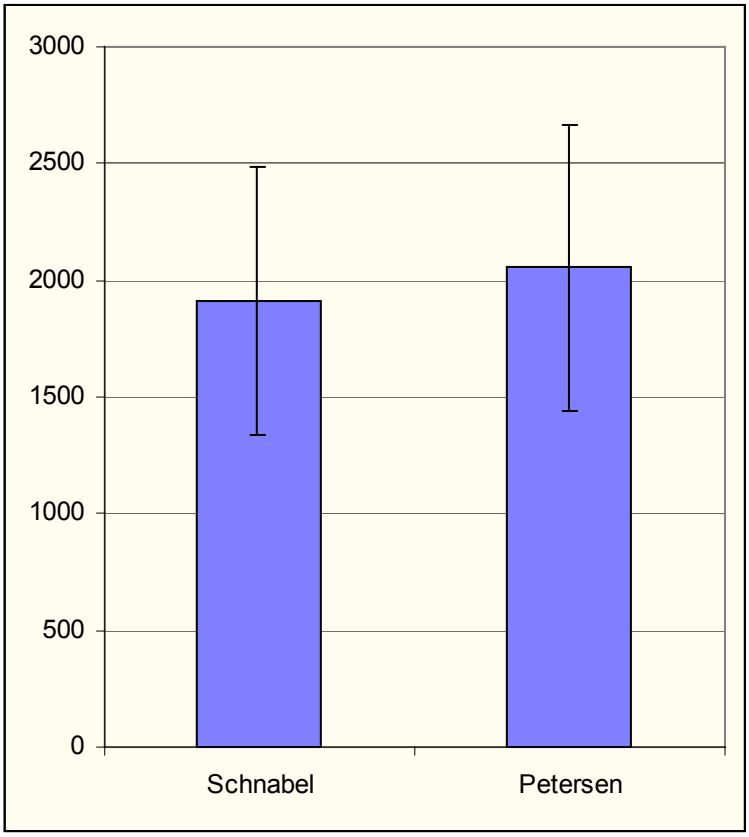

Figure 7: Comparison of Schnabel and Petersen estimates

Since the 1998-99 Petersen mark-recapture there have been 1701 carp removed from Lake Crescent. Thirty-two of these were from the Spring 2000 cohort. A further 225 male carp were caught, tagged and either released back into the lake; into holding pens or used as tracker fish. This means a total of 1894 fish are accounted for from the pre-2000 cohorts and if the Schnabel or Petersen estimates are accurate there are between 16 and 59 fish of the untagged pre-2000 cohorts remaining in Lake Crescent. An abundance estimate for the year 2000 cohort is found below.

3.3 Estimating the abundance of the 2000-2001 juvenile cohorts in Lakes Sorell and Crescent

3.3.1 Introduction

The most commonly used index of relative abundance in fisheries studies is catch per unit effort. If a fisher catches 20 fish per hour in one area and 40 fish per hour in a second area, the inference is that there are twice as many

fish in the second area. How reasonable this inference is depends on the fisher having used the same skills and the same kind of fishing gear in both areas; it also depends on the fish being randomly distributed and equally vulnerable to the fishing gear in both places (King 1995).

Since the 1998-99 Petersen study there has been successful recruitment of carp in both lakes resulting from spawning in the summer of 2000-01. The Inland Fisheries Service has been reluctant to tag and release juveniles for a mark-recapture study as it involves the release of females so an effort based parameter was used to give a ballpark estimate. Monthly juvenile fyke net surveys have been used in both lakes during the summer months for several years to check on recruitment. These surveys provide a relatively stable effort base for the capture rate of juvenile carp. The surveys involve setting between 45 and 60 fyke nets around the margins of the lake. Many are set in juvenile habitat such as marshes. In Lake Sorell the 2002-03 juvenile surveys were replicates of those of the previous season.

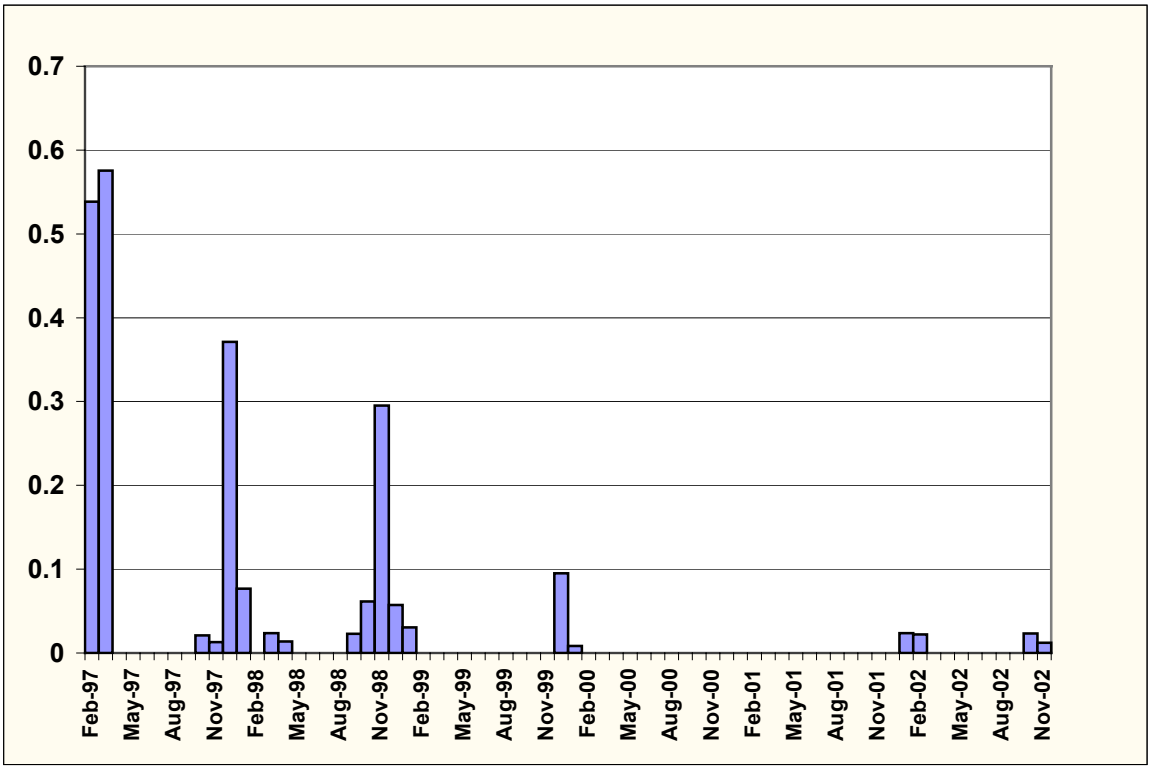

Figure 4: Juvenile carp caught per fykenet-hour in Lake Crescent during monthly fyke net surveys

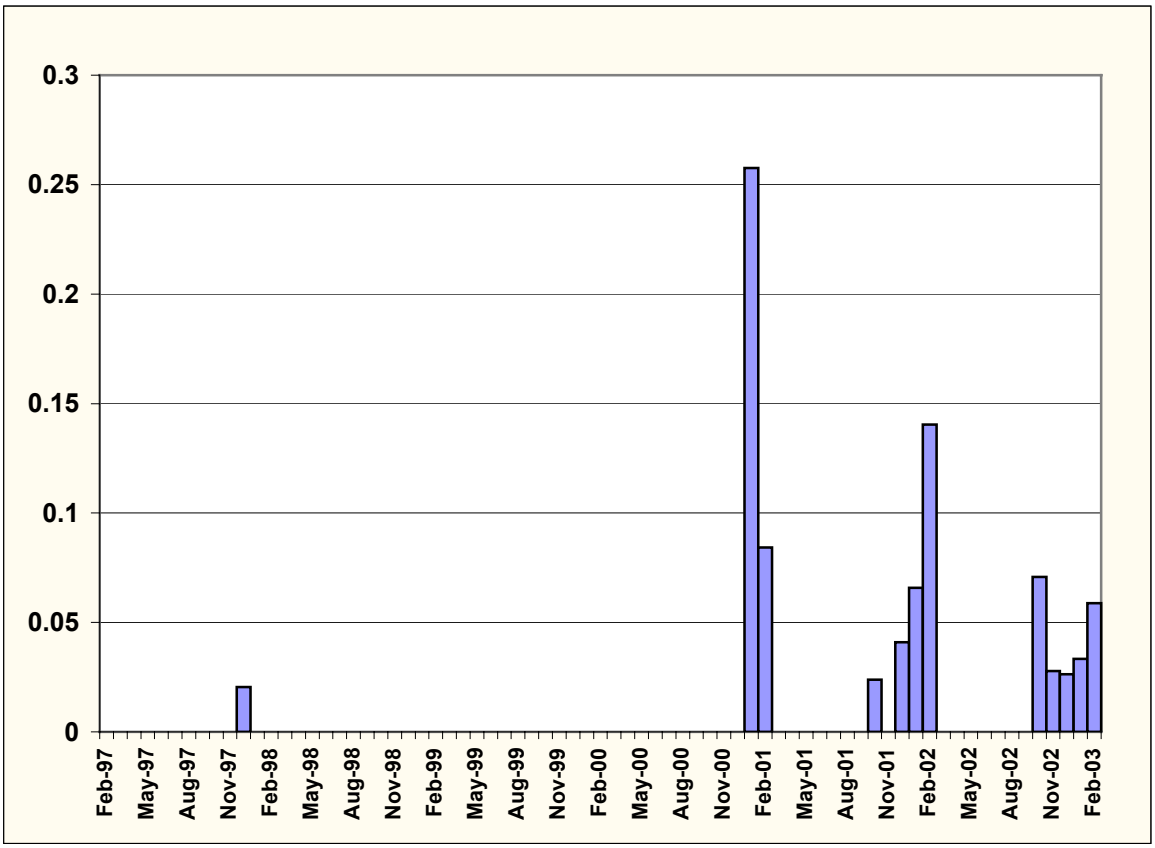

Figure 5: Juvenile carp caught per fykenet-hour in Lake Sorell during monthly fyke net surveys

Figures 4 and 5 show catch per unit effort (CPUE) for juvenile fyke net surveys. This was calculated as follows:

$$\mathbf{CPUE = C_j / (F_n * F_h)}$$

Where C_j = number of juvenile carp caught

F_n = number of fyke nets set in lake

F_h = number of hours the fyke nets were set

3.3.2 Data Analysis

As shown in Figures 4 and 5 the catch per unit effort of juvenile carp reduces markedly each successive season. This is due to a combination of reduced numbers through natural and fishing mortality and reduced catchability through the reluctance of larger carp to enter fyke nets.

The size of the 1996-97 cohort in Lake Crescent is estimated through our mark-recapture studies to be approximately 3053 carp (1882 Petersen juvenile estimate (Table 4) plus 1171 juveniles caught previous to the mark-recapture). Table 2 reveals that the initial fyke net catches of this cohort yielded a CPUE of approximately 0.57 and 0.54 giving an average of 0.56. Initial CPUE for the 2000 Sorell cohort was approximately 0.26 and 0.08 giving an average of 0.17. The volume of Lake Sorell averaged 3.25 times that of Lake Crescent during the period of juvenile surveys. If we assume that the juvenile carp are evenly distributed we can arrive at a conservative estimate of the Sorell juvenile cohort. This estimate is conservative (an overestimate) because it is more likely that juveniles were concentrated in the margins of the lake where the fyke nets were set.
The CPUE based population estimate can be calculated as follows:

$$(\text{CPUE}_{\text{Sorell}} / \text{CPUE}_{\text{Crescent}}) * (\text{VOLUME}_{\text{Sorell}} / \text{VOLUME}_{\text{Crescent}}) * N_C$$

where N_C = estimated number of 1996-7 cohort carp

This gives an estimate of 3012 juveniles for the 2000 Sorell cohort. 1810 of this cohort have been caught leaving an estimated 1202 remaining.

In Lake Crescent during January and February 2002 the CPUE for the year 2000 cohort was 0.024 and 0.022 respectively giving an average of 0.023. Comparing this directly to the 1996-97 cohort initial CPUE of 0.56 yields an estimate of 125 juveniles. Thirty-two of these have been caught leaving an estimated 93 left.

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