RESULTS

Catch Composition

A total of 8043 fish were caught over the five trips. Catch was dominated by three families; Serranidae, Lutjanidae and Lethrinidae, which accounted for more than 97% of the total catch. Six species, *P. leopardus* (57%), *C. cyanostigma* (12%), *L. bohar* (3%), *L. carponotatus* (6%), *L. atkinsoni* (4%) and *L. miniatus* (3%) dominated the catch (85% of total catch) (table 3). Other common but less abundant species included *Epinephelus merra, Epinephelus quoyanus, Epinephelus fuscoguttatus, Plectropomus laevis, Lutjanus sebae, Lutjanus russelli, Lutjanus vitta, Symphorus nemataphorus, Lethrinus semicinctus* and *Lethrinus* sp. 2.

The general pattern of catch composition among reefs and trips was similar, with *P. leopardus* dominant on all reefs, followed by *C. cyanostigma, L. carponotatus* and *L. atkinsoni* (tables 3 and 4). The rank of *L. bohar* and *L. miniatus* alternated between five and six among reefs (tables 3 and 4). However, despite this general pattern, there was significant effect of reef on the frequency of occurrence of each species in the total catch also ($\text{Chi-sq}_{0.05, 24} = 216.328$, $p = 0.0000$, figure 3). Correspondence analysis suggested this was the result of *C. cyanostigma*, and to a lesser extent *L. bohar,* comprising a greater percentage of the catch at Potter and Taylor Reefs while *L. carponotatus* and *L. atkinsoni* were proportionally more abundant at Beaver Reef (figure 4).

There was a significant effect of trip on species composition ($\text{Chi-sq}_{0.05, 24} = 248.45$, $p = 0.0000$, figure 5). Correspondence analysis suggested that this was caused by an increased frequency of occurrence of *P. leopardus* in the catch in September 1992 and October 1993, while there were proportionally more *C. cyanostigma, L. carponotatus* and *L. atkinsoni* during April 1992, 1993 and February 1994 (figure 6).

Table 3. Response profiles of dominant taxa by trip from contingency table analysis: April 1992 (a), September 1992 (b), April 1993 (c), October 1993 (d) and February 1994 (e)

Species	Trip					
	a	b	c	d	e	All
Cephelopholis cyanostigma	0.1332	0.0735	0.1548	0.0942	0.1498	0.1181
Plectropomus leopardus	0.5407	0.6300	0.5423	0.6140	0.5009	0.5671
Lutjanus bohar	0.0273	0.0359	0.0278	0.0235	0.0303	0.0291
L. carponotatus	0.0560	0.0405	0.0624	0.0638	0.0749	0.0587
Lethrinus atkinsoni	0.0426	0.0393	0.0290	0.0211	0.0681	0.0412
L. miniatus	0.0389	0.0479	0.0323	0.0347	0.0062	0.0327
Others	0.1614	0.1328	0.1514	0.1487	0.1697	0.1532
Total sample size	2162	1754	898	1614	1615	8043

Table 4. Response profiles of catch composition by reef from contingency table analysis: Beaver (b), Farquharson (f), Little Potter (lp), Potter (p) and Taylor (t)

Species	Reef					
	b	f	lp	p	t	All
Cephelopholis cyanostigma	0.0823	0.1133	0.1203	0.1419	0.1489	0.1181
Plectropomus leopardus	0.5642	0.5762	0.6086	0.5529	0.5506	0.5671
Lutjanus bohar	0.0239	0.0392	0.0204	0.0309	0.0298	0.0291
L. carponotatus	0.0827	0.0597	0.0612	0.0392	0.0417	0.0587
Lethrinus atkinsoni	0.0584	0.0342	0.0387	0.0392	0.0265	0.0412
L. miniatus	0.0496	0.0355	0.0418	0.0196	0.0132	0.0327
Others	0.1389	0.1419	0.1091	0.1764	0.1893	0.1532
Total sample size	2260	1607	981	1684	1511	8043

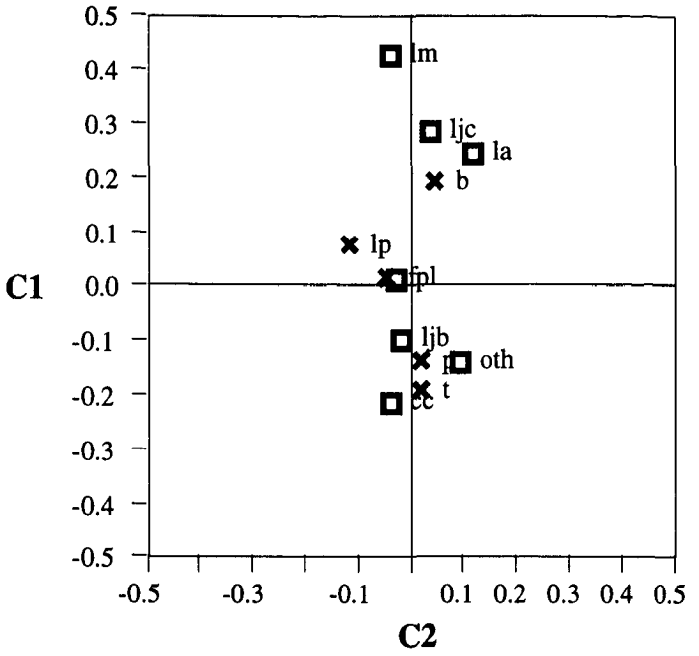

Figure 4. Correspondence analysis of species composition of catch by reef. The first two axes accounted for 90.2% of the total inertia, C1 (75.8%) and C2 (14.4%). The species are *Cephalopholis cyanostigma* (cc), *Plectropomus leopardus* (pl), *Lutjanus bohar* (ljb), *L. carponotatus* (ljc), *Lethrinus atkinsoni* (la), *L. miniatus* (lm), and others (oth). Reefs are Beaver (b), Taylor (t), Farquharson (f), Little Potter (lp), and Potter (p) Reefs.

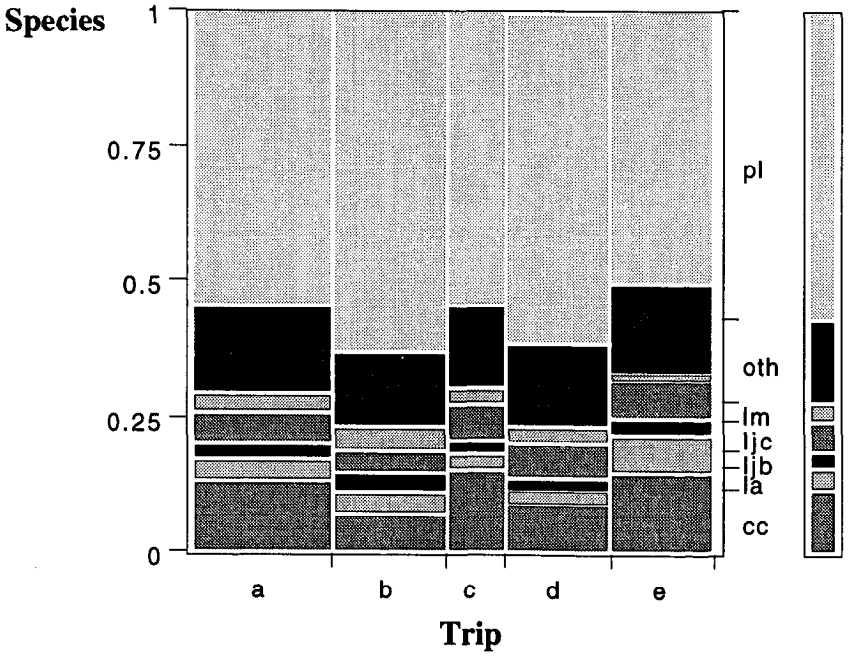

Figure 5. Mosaic plot of species composition of catch by trip. The species are *Cephalopholis cyanostigma* (cc), *Plectropomus leopardus* (pl), *Lutjanus bohar* (ljb), *L. carponotatus* (ljc), *Lethrinus atkinsoni* (la), *L. miniatus* (lm), and others (oth). Trips are April 1992 (a), September 1992 (b), April 1993 (c), October 1993 (d) and February 1994 (e).

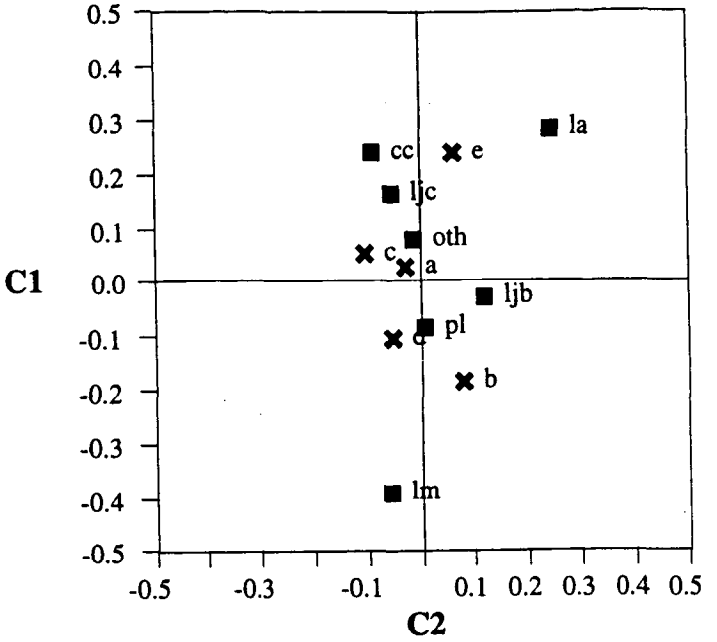

Figure 6. Correspondence analysis of species composition of catch by trip. The first two axes accounted for 90.2% of the total inertia, C1 (75.8%) and C2 (14.4%). The species are *Cephalopholis cyanostigma* (cc), *Plectropomus leopardus* (pl), *Lutjanus bohar* (ljb), *L. carponotatus* (ljc), *Lethrinus atkinsoni* (la), *L. miniatus* (lm), and others (oth). Trips are April 1992 (a), September 1992 (b), April 1993 (c), October 1993 (d) and February 1994 (e)

Catch Per Unit Effort

Effect of TRIP

Trip had a significant effect on the CPUE of *P. leopardus* ($F_{0.05,3,8} = 27.94$; $p = 0.0001$, table 5). Mean CPUE for *P. leopardus* was significantly higher in September 1992, October 1993 and February 1994 than in April 1992 (Tukey's HSD test $p < 0.05$). The highest mean CPUE for *P. leopardus* occurred in September 1992 and October 1993, which correspond to the peak in the *P. leopardus* spawning season, and the lowest during April 1992, February 1994 and, to a lesser extent, April 1993 (which was not included in the ANOVA) (figure 7).

Table 5. ANOVA table for 3-way mixed model ANOVA for effect of trip, reef and block on mean CPUE of *Plectropomus leopardus*. Includes data from back reef blocks of Beaver, Taylor, Farquharson and Potter Reefs and trips a, b, d, e only (see text, page 11). $\alpha = 0.05$, data were $\log_{10}(x+1)$ transformed.

Source	DF	Type III SS	MS	F ratio	Pr>F	Sign.	% var
Corrected total	1470	1614.86					
TRIP	3	136.00	45.33	27.94	0.0001	***	8.42
REEF	3	0.95	0.31	0.13	0.9412		0.05
BLOCK(REEF)	8	19.78	2.47	2.53	0.0097	***	1.22
TRIP*REEF	9	10.95	1.22	0.75	0.6615		0.68
TRIP*BLOCK(REEF)	23	37.31	1.62	1.66	0.0253	*	2.30
Residual	1424	1388.94	0.98				85.98

Effect of REEF

Mean CPUE for *P. leopardus* did not vary significantly among reefs ($F_{0.05,3,8} = 0.13$; $p = 0.9412$, table 5). Although CPUE for *P. leopardus* was generally higher on Beaver Reef, it was not significantly different from the other reefs. Catch per unit effort for *P. leopardus* was

consistently higher on Beaver, Farquharson and Little Potter (which was not included in the ANOVA) Reefs and lowest on Taylor and Potter Reefs (figure 7).

Effect of BLOCK

There was a significant effect of block on mean CPUE for *P. leopardus* ($F_{0.05,8,1424} = 2.53$; $p = 0.0097$, table 5) and a significant interaction between trip and block ($F_{0.05,23,1424} = 1.66$; $p = 0.0253$, table 5). It is apparent from figure 8, that the effect of block is likely to be the result of CPUE at block 1 of Beaver Reef being consistently higher than CPUE at block 4 and that the trip*block interaction is likely to be due to the very high CPUE recorded for Taylor Reef during trip d (figure 8).

Both CPUE and total catch of *P. leopardus* was generally higher in the back reef blocks of all reefs with the exception of Beaver Reef (figure 9, appendix 1a). This is most likely due to differences in the efficiency of the fishers (or gear) between the two reef locations rather than a real difference in the relative abundance of *P. leopardus*. The fishers tend to have greater difficulty finding and correctly anchoring on suitable hangs on the steep reef front slopes of Potter, Farquharson and Taylor Reefs and, as a result spend more time searching, do fewer hangs and have a higher percentage of zero catch hangs. The fact that CPUE and total catch of *P. leopardus* increased during trip d suggests that fishers may have learned to fish the reef fronts more effectively than on trip b (figure 9, table 11, appendix 1a).

Size Structure

Effect of TRIP

The mean length of *P. leopardus* decreased significantly over the 22 months of the study ($F_{0.05,3,8} = 5.17$; $p = 0.0070$, table 6). Although mean length of *P. leopardus* was not significantly different between April and September 1992, it decreased significantly from September 1992 to October 1993 and again from October 1993 to February 1994 (Tukey's HSD test, $p < 0.05$) (figure 10). This last decrease was most evident at Farquharson and Taylor Reefs (figure 10).

Effect of REEF

Mean length of *P. leopardus* varied significantly among reefs ($F_{0.05,3,8} = 5.44$; $p = 0.0247$, table 6). It was significantly greater on Taylor Reef than all other reefs (Tukey's HSD test $p < 0.05$) (figure 10). Farquharson and Potter Reefs had significantly larger mean length than Beaver Reef (Tukey's HSD test $p < 0.05$), but were not different from each other (Tukey's HSD test $p > 0.05$, figure 10). Mean length of *P. leopardus* at Beaver Reef was significantly lower than all other reefs (Tukey's HSD test $p < 0.05$, figure 10). Although not included in the ANOVA, the pattern in mean length at Little Potter Reef was similar to Beaver Reef, with mean length decreasing monotonically over trips (figure 10).

Effect of BLOCK

Mean length of *P. leopardus* varied significantly among blocks within reefs ($F_{0.05,8,2230} = 0.0041$; $p = 0.0041$, table 6) and there was a significant interaction between trip and block also ($F_{0.05,25,2230} = 1.62$; $p = 0.0311$). There was no clear pattern of mean length among blocks (figures 11 and 12).

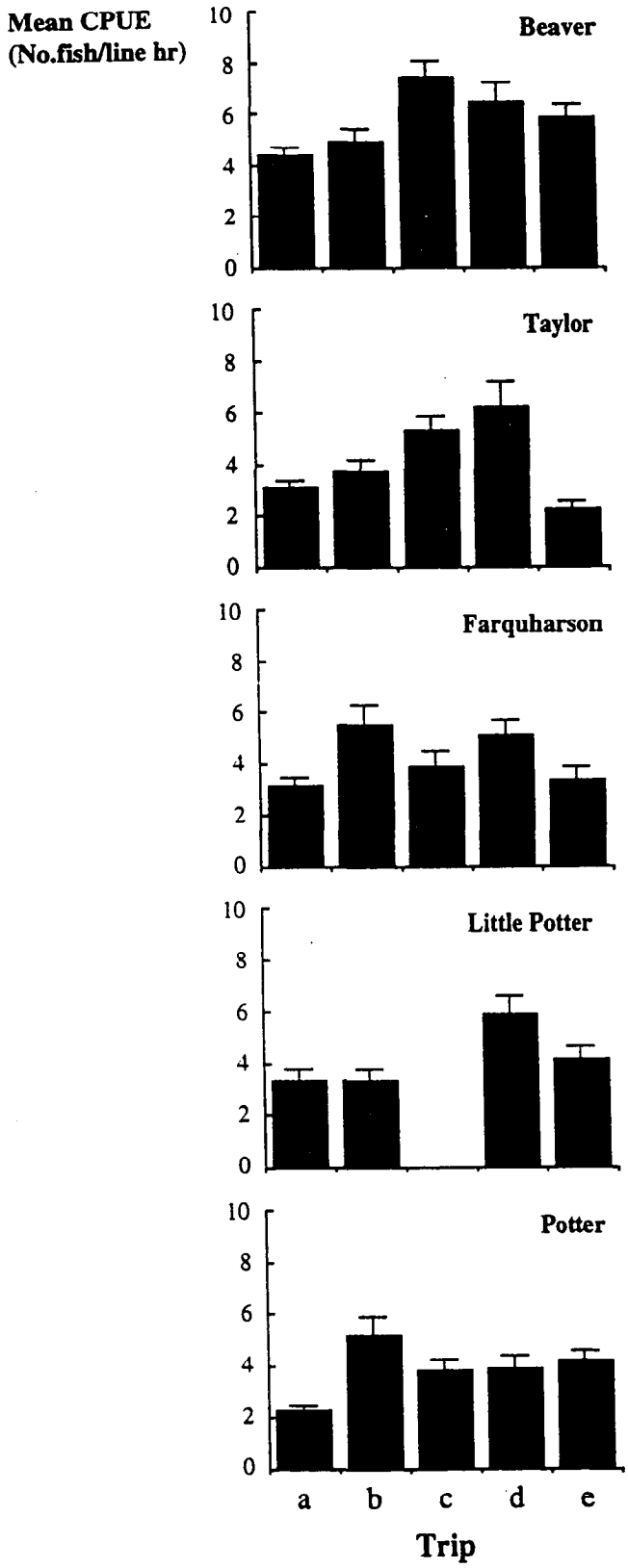

Figure 7. Mean CPUE (No. fish/line. hr) for *Plectropomus leopardus* by reef and trip. Trips are April 1992 (a), September 1992 (b), April 1993 (c), October 1993 (d) and February 1994 (e). Data from April 1993 (c) were not included in ANOVA for CPUE (see text, page 11). Data are untransformed. Error bars are standard errors.

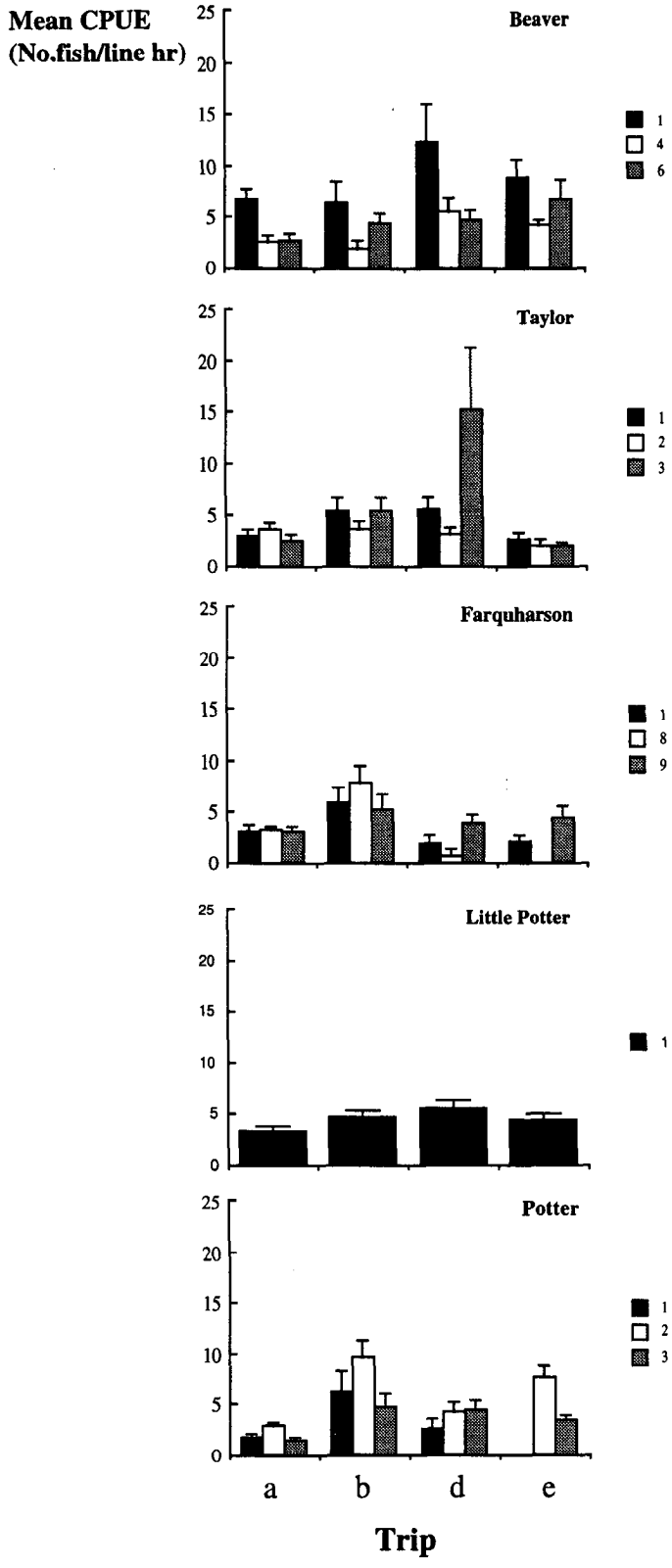

Figure 8. Mean CPUE (No. fish/line hr) for *Plectropomus leopardus* by block by reef by trip for back reef blocks only. Legend refers to block number in figure 2. Trips are April 1992 (a), September 1992 (b), October 1993 (d) and February 1994 (e). Data from April 1993 (c) were not included in ANOVA for CPUE (see text, page 11). Data are untransformed. Error bars are standard errors.

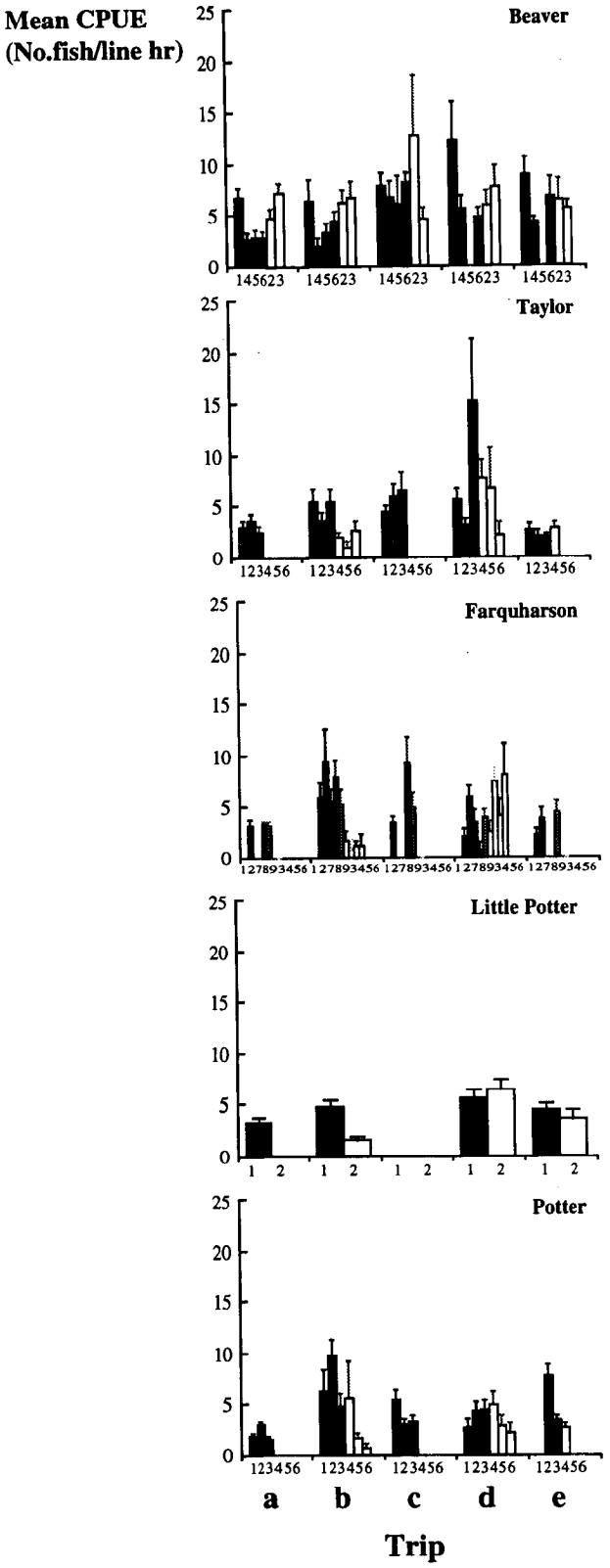

Figure 9. Mean CPUE (No. fish/line hr) for *Plectropomus leopardus* by block by reef by trip for all blocks. Filled columns are back reef blocks. Open columns are front reef blocks. Numbers under columns correspond to the number of each block. Trips are April 1992 (a), September 1992 (b), April 1993 (c), October 1993 (d) and February 1994 (e). Data from the front reef blocks and April 1993 (c) were not included in ANOVA for CPUE (see text, page 11). Data are untransformed. Error bars are standard errors.

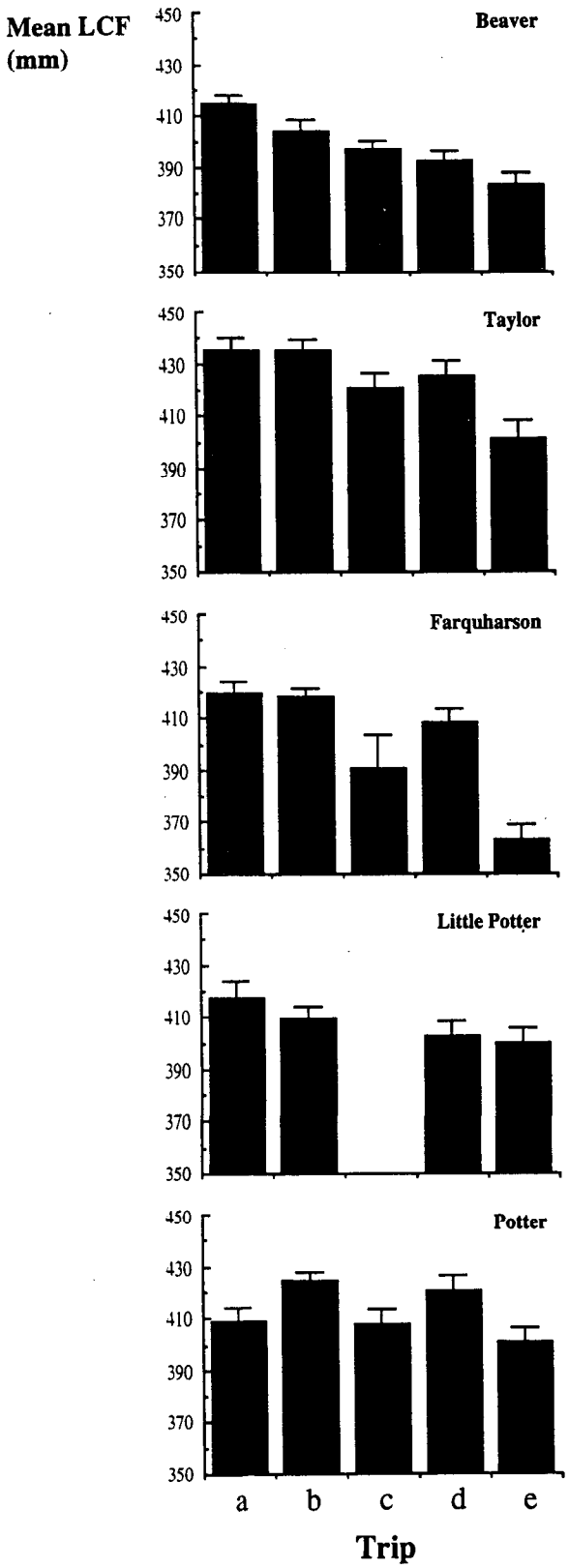

Figure 10. Mean length to caudal fork (mm) for *Plectropomus leopardus* by reef and trip. Trips are April 1992 (a), September 1992 (b), April 1993 (c), October 1993 (d) and February 1994 (e). Data from April 1993 (c) were not included in ANOVA for mean size (see text, page 11). Data are untransformed. Error bars are standard errors.

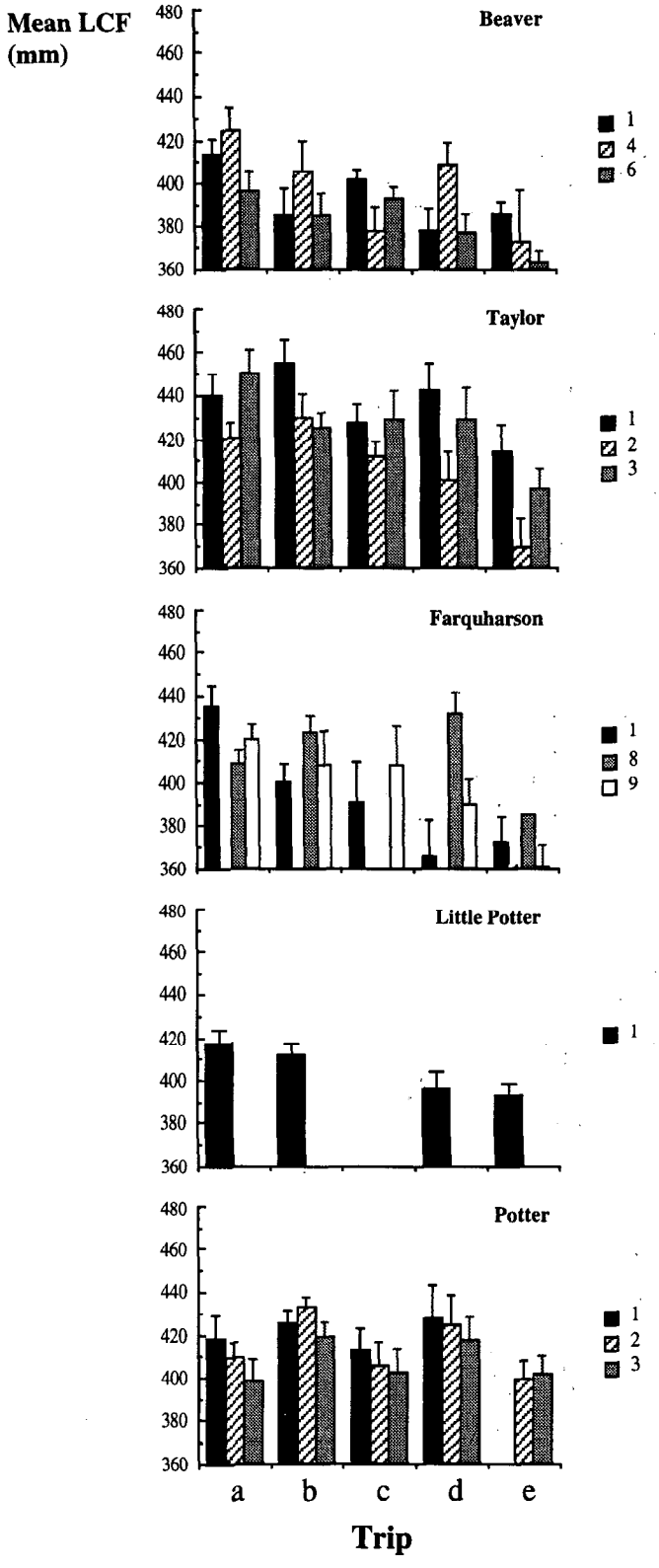

Figure 11. Mean length to caudal fork (mm) for *Plectropomus leopardus* by block by reef and trip. Legend refers to block numbers in figure 2. Only those blocks used in the ANOVA of mean length are presented (see text). Trips are April 1992 (a), September 1992 (b), April 1993 (c), October 1993 (d) and February 1994 (e). Data from April 1993 (c) were not included in the ANOVA for mean length (see text, page 11). Data are untransformed. Error bars are standard errors.

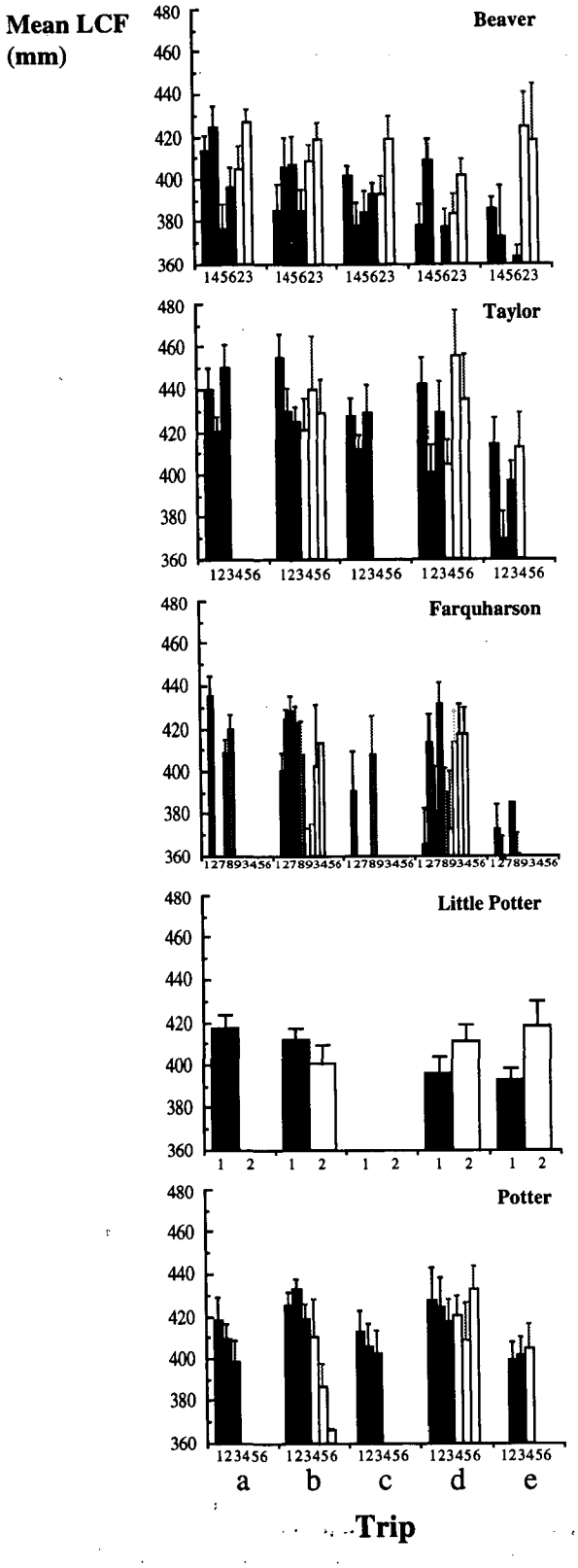

Figure 12. Mean length to caudal fork (mm) for *Plectropomus leopardus* by block by reef and trip. Filled columns are back reef blocks. Open columns are front reef blocks. Numbers under columns correspond to the number of each block. Trips are April 1992 (a), September 1992 (b), April 1993 (c), October 1993 (d) and February 1994 (e). Data from April 1993 (c) were not included in the ANOVA for mean length (see text, page 11). Data are untransformed. Error bars are standard errors.

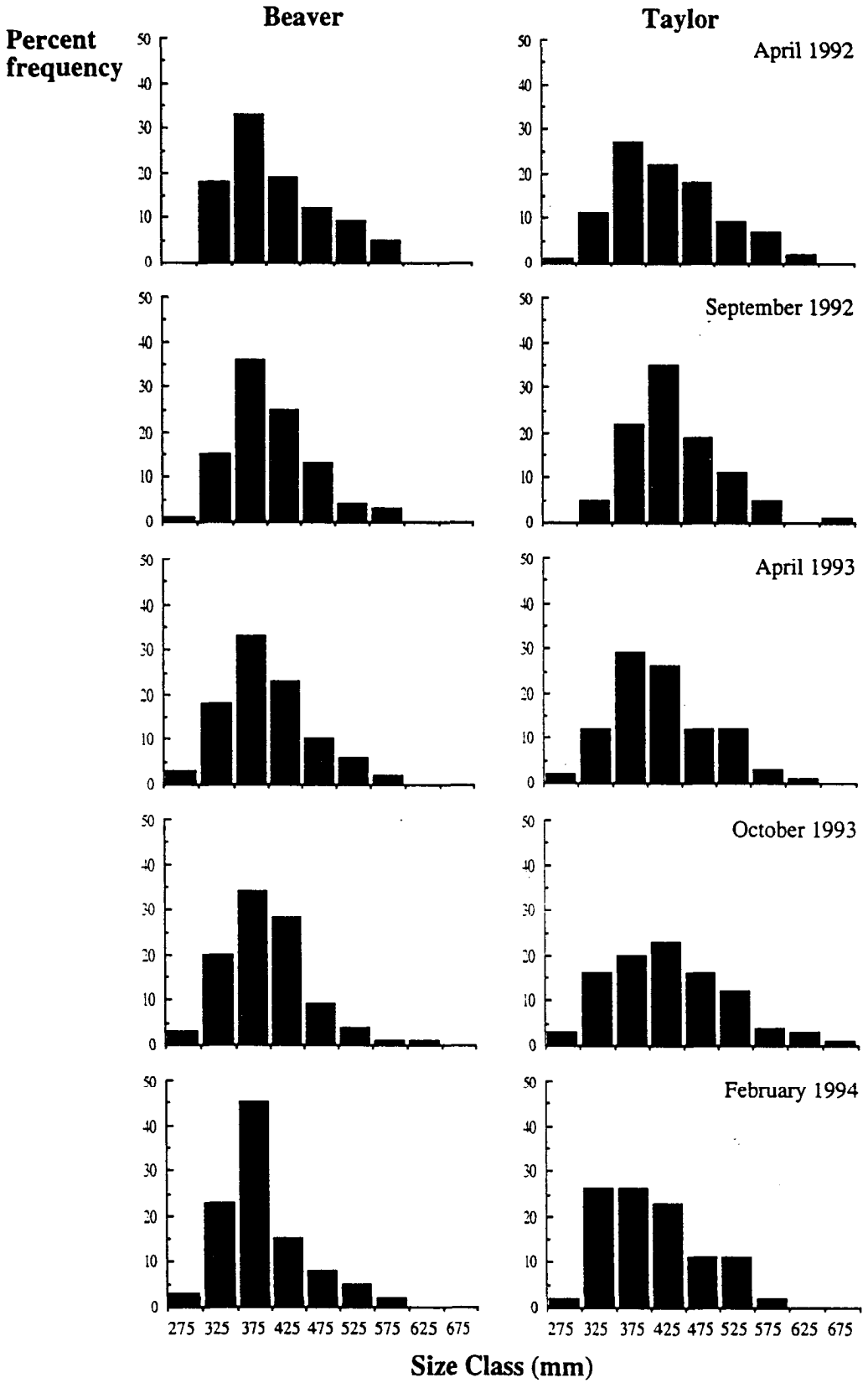

Figure 13. Length (LCF) frequency distributions for *Plectropomus leopardus* at Beaver and Taylor Reefs by trip (all blocks). Size classes are 50 mm. The mid-point of each size class is given. Trips are April 1992 (a), September 1992 (b), April 1993 (c), October 1993 (d) and February 1994 (e). Data from April 1993 (c) were not included in ANOVA for mean length (see text, page 11).

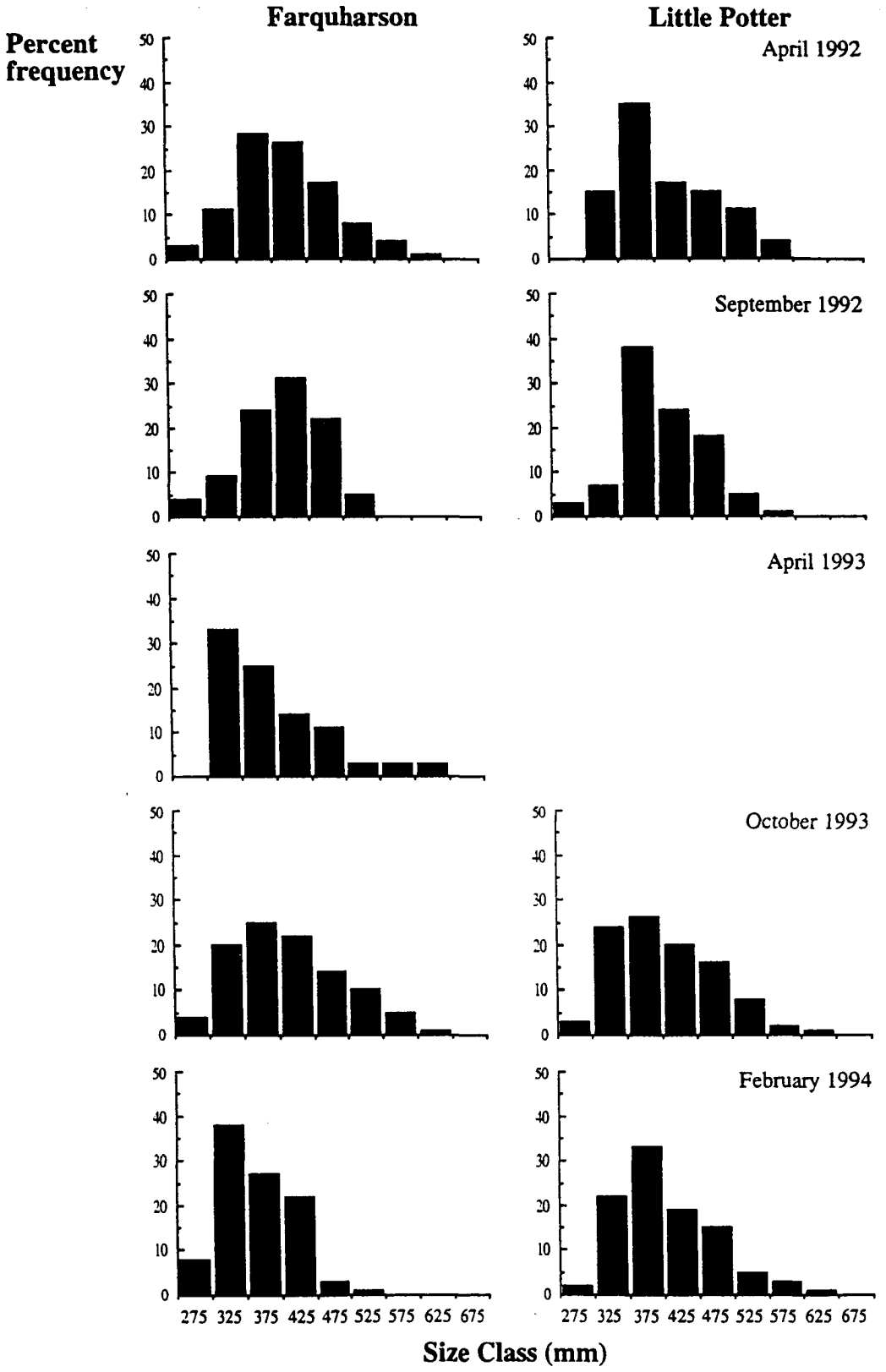

Figure 14. Length (LCF) frequency distributions for *Plectropomus leopardus* at Farquharson and Little Potter Reefs by trip (all blocks). Size classes are 50 mm. The mid-point of each size class is given. Trips are April 1992 (a), September 1992 (b), April 1993 (c), October 1993 (d), and February 1994 (e). Data from April 1993 (c) were not included in ANOVA for mean length (see text, page 11).

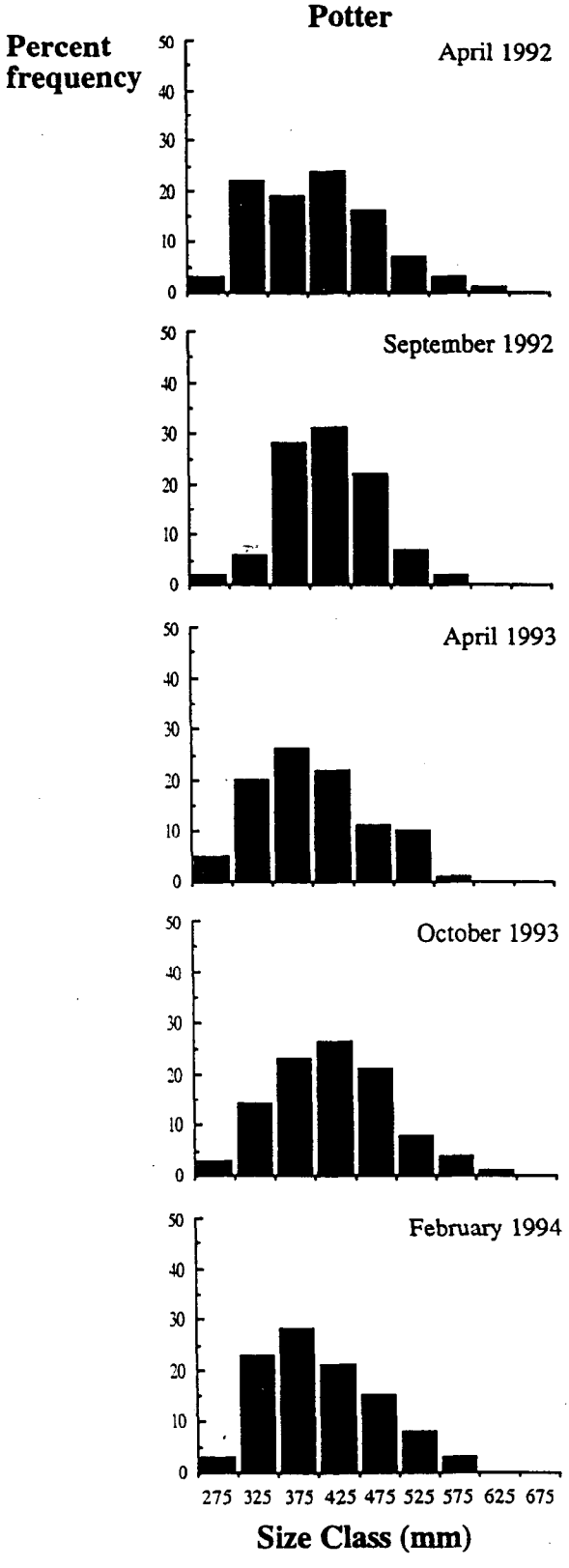

Figure 15. Length (LCF) frequency distributions for *Plectropomus leopardus* at Potter Reef by trip (all blocks). Size classes are 50 mm. The mid-point of each size class is given. Trips are April 1992 (a), September 1992 (b), April 1993 (c), October 1993 (d), and February 1994 (e). Data from April 1993 (c) were not included in ANOVA for mean length (see text, page 11).

Table 7. Summary of tag loss data for t-bar anchor tags from public and research tag returns of *Plectropomus leopardus* tagged with two t-bar anchor tags and returned up to 480 days following release. t_i is the mid-point of the i th time period (60 days) since release, r_{di} is the number of fish returned with two tags in the i th period, r_{si} is the number of fish returned with one tag in the i th period and K_i is the estimated probability of tag retention at t_i. * denotes data omitted from analysis.

t_i (days)	Public			Research		
	r_{di}	r_{si}	K_i	r_{di}	r_{si}	K_i
30	20	11	0.7843	9	0	1.0000
90	24	11	0.8135	14	11	0.7180
150	23	11	0.8070	10	9	0.6897
210	9	3	0.8571	4	4	0.6667
270*	10	10	0.6667	1	4	0.3333
330	7	2	0.8750	2	3	0.5714
390	1	0	1	5	9	0.5263
450	4	11	0.4211	0	0	-

Table 8. Estimates of tag shedding parameters p (type I) and L (type II) from the Bayliff and Morbran (1972) tag shedding model for t-bar anchor tag returns from the public and research exercises, and for the common regression. Sample size (n), proportion of total variance accounted for by the model (r^2) and significance level of parameter estimate ($Pr>t$) are given also. Standard errors of parameter estimates are in parentheses.

Source	n	r^2	ln p	$Pr>t$	p	L	$Pr>t$
Public	136	0.886	-0.0959 (0.0323)	0.04 *	0.9086	0.000885 (0.00016)	0.01 **
Research	80	0.821	-0.1446 (0.0663)	0.10 ns	0.8654	0.001328 (0.00031)	0.01 **
Commonreg	217	0.862	-0.1135 (0.0377)	0.03 *	0.8927	0.00101 (0.00018)	0.002 **

Comparison of Rates of Tag Loss of t-bar Anchor Tags and Dart Tags

A summary of the tag loss data for dart tags and TBA tags from the pooled public and research returns is presented in table 9. The regression for TBA tags and dart tags from the public returns was not significant ($F_{0.05,1,2} = 2.4183$; $p = 0.2602$). It was not possible to fit a regression to the research returns as there were too few returns in each time interval. Consequently, data from both sources were pooled (table 9). The regression for TBA tags for the pooled data was significant ($F_{0.05,1,5} = 16.2216$; $p = 0.0100$, figure 17a), with significant intercept and slope, and parameter estimates of $p = 0.7160$ ($p = 0.0133$) and $L = 0.00159$ ($p = 0.0100$) (table 10). However, the fit for dart tags was poor ($r^2 = 0.542$) and not significant ($F_{0.05,1,3} = 3.5471$; $p = 0.1562$) (figure 17b). Consequently it was not possible to make valid estimates of tag loss parameters for dart tags (table 10).

Comparison of Frequency of Return of t-bar Anchor Tags and Dart Tags

There was a significantly higher frequency of returns of fish retaining the TBA tag than those retaining the dart tag for *P. leopardus* tagged with both tag types and recaptured in the research recovery exercises (Chi-$sq_{0.05,1,}$ = 10.678; $p < 0.005$). However, there was no significant difference in the frequency of return of the two tag types for the returns from the public (Chi-$sq_{0.05,1,}$ = 0.6127; $p > 0.25$). The significant difference among tag types from the research

returns suggests that the dart tags are shed more frequently than the TBA tags. The lack of a significant effect from the public returns suggests that the larger dart tags are more likely to be observed and reported by the public than the smaller t-bar tags and that this compensates somewhat for their higher rate of shedding.

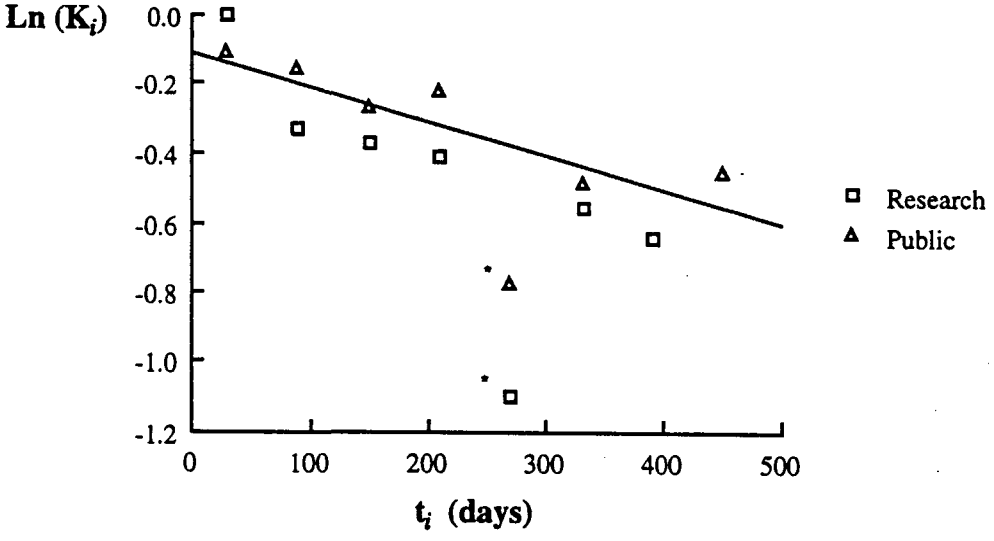

Figure 16a. Natural logarithm of estimated proportion of t-bar anchor tags retained ($\ln K_i$) over time (t_i), for tags returned from the public and those returned during research recovery exercises. The line has been fitted to the pooled data as there was no difference in rate of retention between the two sources of returns ($t_{0.05,(2),8} = -1.052$, $p > 0.5$).* denoted points which were omitted as outliers from the regression.

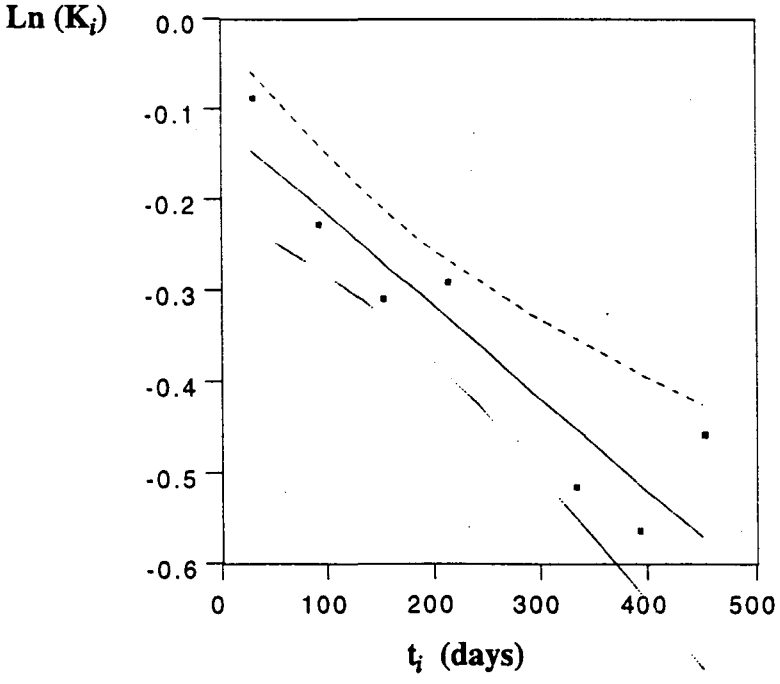

Figure 16b. Natural logarithm of estimated proportion of t-bar anchor tags retained ($\ln K_i$) over time (t_i), of pooled public and research returns for *Plectropomus leopardus* tagged with t-bar tags only, with confidence curves (95%). The regression is significant ($F_{0.05,1,5} = 31.1344$; $p < 0.0025$).

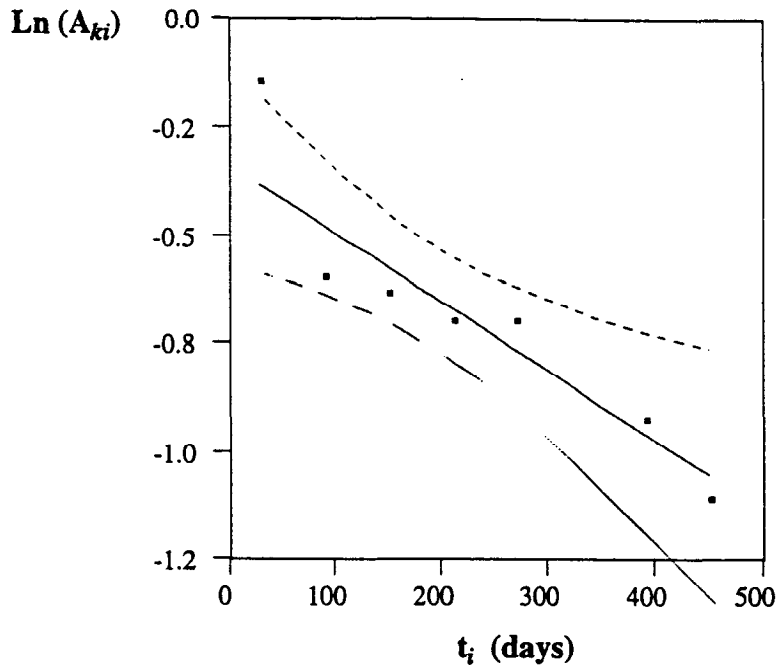

Figure 17a. Natural logarithm of estimated proportion of t-bar anchor tags retained ($\ln A_{ki}$) over time (t_i), for pooled public and research returns of *Plectropomus leopardus* tagged with one t-bar and one dart tag, with confidence curves (95%). The regression is significant ($F_{0.05,1,5} = 16.2216$; $p < 0.01$).

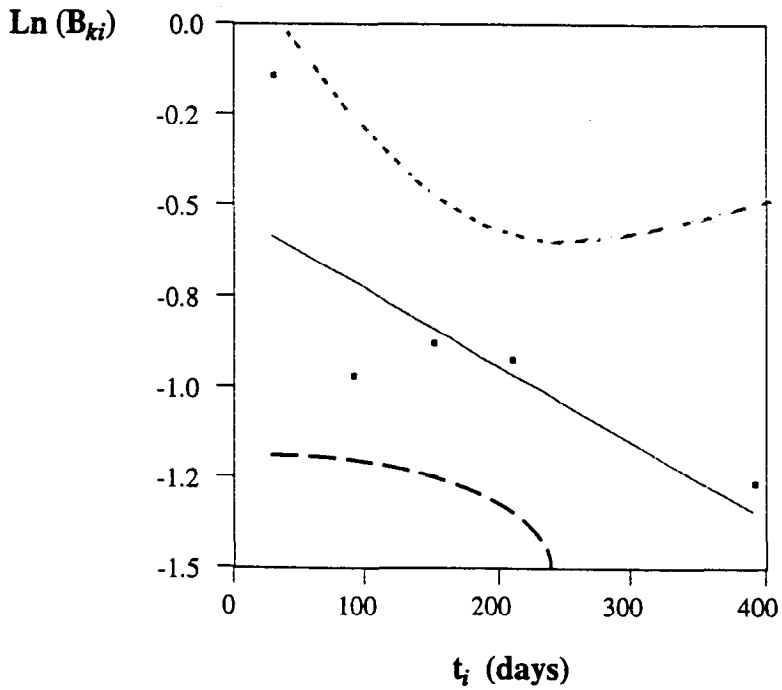

Figure 17b. Natural logarithm of estimated proportion of dart tags retained ($\ln B_{ki}$) over time (t_i), for pooled public and research returns of *Plectropomus leopardus* tagged with one t-bar tag and one dart tag, with confidence curves (95%). The regression is not significant ($F_{0.05,1,3} = 3.5471$; $p > 0.15$).