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FECUNDITY OF HUMPBACK WHITEFISH AND LEAST CISCO, CHATANIKA RIVER, ALASKA[1]

By

John H. Clark

and

David R. Bernard

Alaska Department of Fish and Game
Division of Sport Fish
Juneau, Alaska 99802

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ABSTRACT

Fecundity of 73 humpback whitefish *Coregonus pidschian* and 38 least cisco *Coregonus sardinella* collected from the Chatanika River in 1988 was estimated. These data were pooled with fecundity information from 20 humpback whitefish and 42 least cisco collected in the early 1970's to develop fork length versus fecundity relationships for each of the two species. Predicted humpback whitefish fecundities ranged from 6,905 eggs per female for 305 millimeter fork length fish to 80,203 eggs per female for 545 millimeter fork length fish. Predicted least cisco fecundities ranged from 32,138 eggs per female for 285 millimeter fork length fish to 80,494 eggs per female for 445 millimeter fork length fish.

KEY WORDS: humpback whitefish, least cisco, *Coregonus pidschian*, *Coregonus sardinella*, Chatanika River, fecundity.

INTRODUCTION

Large runs of humpback whitefish *Coregonus pidschian* and least cisco *Coregonus sardinella* spawn in the Chatanika River near Fairbanks, Alaska, each fall (Figure 1). Because of the close proximity of the river to Fairbanks and because of the large magnitude of the spawning runs of whitefish, the Chatanika River supports the largest recreational whitefish fishery in Alaska. During the ten year period from 1978 through 1987, about 51% (98,824 of 193,793 fish) of all whitefish harvested in Alaska by recreational fishermen were taken from the Chatanika River (Mills 1980-1988). Most of this harvest occurred during the popular fall (mid-September through mid-October) spear fishery where fishermen harvest spawning whitefish (least cisco, humpback whitefish, and a few round whitefish *Prosopium cylindraceum*) with spears during hours of darkness. Recreational fishing effort and whitefish harvests have increased dramatically during recent years due to regional population growth, increasing angler awareness of the unique spear fishery, and growing interest in sport fishing throughout Alaska. Estimated harvest of whitefish from the Chatanika River increased from 1,635 fish in 1977 to 25,074 fish in 1987 (Table 1).

The Alaska Department of Fish and Game (ADF&G) began stock assessment studies of Chatanika River whitefish populations in 1986 due to the expanding sport fishery. Based upon mark-recapture methodology, humpback whitefish abundance was estimated at 14,906 fish in 1986 and exploitation rate by the fall recreational spear fishery was subsequently estimated to have been 17% (Hallberg and Holmes 1987). Using the same methodology, Hallberg and Holmes (1987) estimated least cisco abundance in 1986 at 73,006 fish and they estimated that the fall recreational spear fishery harvested 22.7% of the spawning least cisco. In 1987, Hallberg (1988) estimated humpback whitefish abundance at 28,165 fish and least cisco abundance at 55,620 fish with exploitation rates by the fall spear fishery being estimated at 16.3% and 42.7% respectively. Although a season lasting from 1 September through 30 April had been established, no other regulations were in effect for this fishery through the 1987 fishing season. Prior to the 1988 fishery, the Alaska Board of Fisheries established limits of 15 whitefish daily and in possession due to high rates of exploitation by the recreational fishery.

Due to continued concerns for stock conservation, ADF&G continued to monitor spawning populations of humpback whitefish and least cisco in the Chatanika River during 1988. As part of these studies, it was decided to augment available information concerning fecundity of humpback whitefish and least cisco. Available data consisted of information reported during the early 1970's by Kepler (1973) and by Townsend and Kepler (1974). The objective of this portion of the research program was to estimate fecundity of female humpback whitefish and least cisco. This report is written to summarize findings relative to whitefish fecundity and a second report is being prepared that will summarize abundance and exploitation rate estimates for whitefish during 1988 (Hallberg 1989).

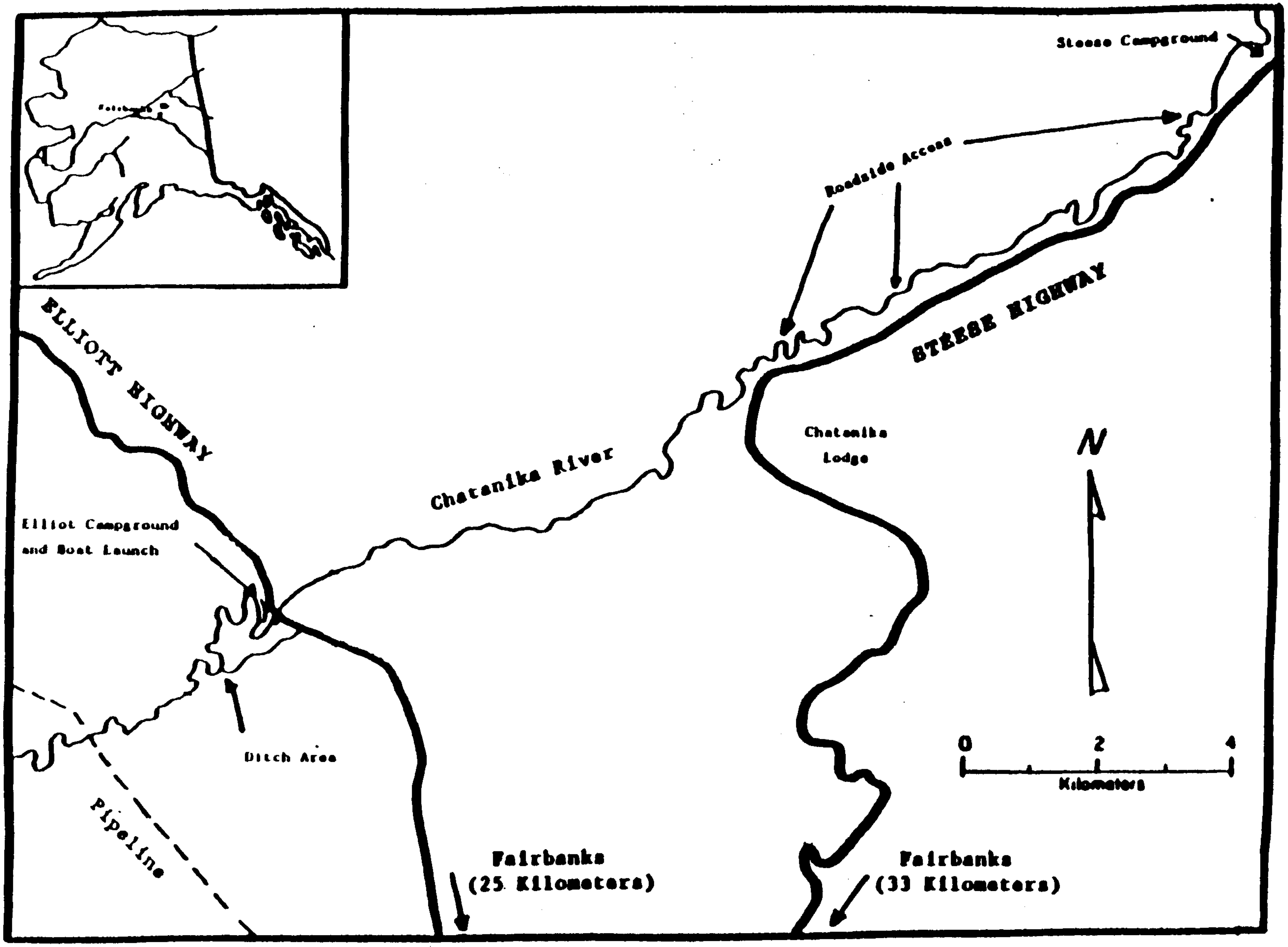

Figure 1. The Chatanika River showing its proximity to the Steese and Elliott Highways.

Table 1. Estimated annual harvest of whitefish in sport fisheries of the Chatanika River and in Alaska.

Year	Chatanika River Whitefish Harvest: On-Site Creel Census	Chatanika River Whitefish Harvest: Postal Survey[1]	Alaskan Whitefish Harvest Estimated By Postal Survey[1]
1977	986[2]	1,635	6,748
1978	5,517[2]	6,013	11,731
1979	2,183[2]	3,021	9,666
1980	1,587[2]	3,340	11,464
1981		3,185	9,251
1982		6,640	15,433
1983		5,895	16,872
1984	5,758[2]	9,268	16,719
1985	4,561[2]	14,350	30,337
1986	19,105[2]	22,038	39,718
1987	28,312[3]	25,074	32,602

[1] Data taken from Mills (1979 - 1988).
[2] Harvest estimate applies to only the Elliott Highway area during the fall.
[3] Harvest estimate is for the fall only but includes the Elliott Highway area (19,003 fish) as well as the "Ditch" area (9,309 fish).

METHODS

Humpback whitefish and least cisco were captured within 15 km of the Elliott Highway Bridge using beach seine gear and a pulsed-DC electrofishing boat during mid-August. Fish used in this study were transferred to the ADF&G laboratory in Fairbanks where they were measured to the nearest mm for fork length (FL) and weighed to the nearest 5 grams. Scales were removed from each fish midway between their dorsal fin and lateral line directly below the posterior margin of the dorsal fin. Scales were stored in coin envelopes and were later removed, cleaned, and mounted on gum cards. Gum cards were used to make scale impressions on 20 mil acetate using a Carver press at 60,000 kg/cm^2 (20,000 psi) heated to 93° C for 30 seconds. Annuli were counted along the dorsal radius with the aid of a 3M Consultant Microfiche reader.

Ovaries were removed from 73 humpback whitefish and 42 least cisco. Ovaries from each fish were weighed and percent gonad weight was calculated by dividing gonad weight by the total weight of the fish and subsequently multiplying by 100. Ovaries were stored in plastic bags and preserved in Gilson's fluid (Bagenal and Braum 1971). Approximately three months later, these ovary samples were removed from the preservative and placed in a graduated cylinder to obtain a volumetric measurement to the nearest ml. Next, from one to four sub-samples of eggs were taken from the ovaries from each fish and the volume of each sub-sample was measured in a graduated cylinder to the nearest 0.1 ml. The eggs in each sub-sample were subsequently counted. The number of eggs per ml for each sub-sample was calculated by dividing the number of eggs in each sub-sample by the volume of that sub-sample. Fecundity was estimated as follows:

(1) $$\hat{F}_j = \frac{\sum^{i} \hat{f}_{ij}}{n_j}; \text{ and,}$$

(2) $$\hat{f}_{ij} = \frac{(ML_{ij})(Egg_{ij})}{ml_{ij}};$$

where: $\hat{F}_j$ = estimated fecundity of fish j based upon all sub-samples;

n = number of sub-samples taken from ovaries of fish j;

$\hat{f}_{ij}$ = estimated fecundity based upon sub-sample i from fish j;

ML_{ij} = volume of ovaries from fish j;

Egg_{ij} = number of eggs in a specific sub-sample from fish j; and,

ml_{ij} = volume of a specific sub-sample from fish j.

Sampling variance and standard error of the number of eggs for each fish for which more than one sub-sample was taken was calculated using standard normal procedures. Scatter plots of fecundity versus fork length and age, and scatter plots of fork length versus percent gonad weight and number of eggs per ml were developed as an aid in data analysis. Although data were collected during this study on length, weight, age, and fecundity of individual fish (Appendix tables 1 and 2), only data on fecundity and length were collected during earlier studies (Kepler 1973 & Townsend and Kepler 1974). Therefore, analyses on the combined data concentrated on the relationship between fecundity and length.

Four data sets (humpback whitefish sampled in 1973, humpback whitefish sampled in 1988, least cisco sampled in 1972, and least cisco sampled in 1988) consisting of paired information (natural log of fork length and natural log of fecundity) were analyzed with regression techniques utilizing a microcomputer with program MINITAB. Because preliminary inspection of data showed increasing variance in fecundity with increasing length in fish, the traditional power function of the fecundity-length relationship (Bagenel and Braum 1971) was transformed with logarithms:

(3) $ln\hat{y} = ln\hat{a} + \hat{b}(lnx)$;

where: $ln\hat{y}$ = natural log of estimated fecundity;

$ln\hat{a}$ = natural log of a constant;

$\hat{b}$ = an exponent; and,

lnx = natural log of a specific fork length.

According to Ricker (1975), when both x and y are variates, the functional regression is appropriate and when variation in both x and y is natural and when measurement error is relatively the same for both variates, the GM (geometric mean) regression can be used as the functional regression. Consequently, geometric mean regressions were calculated to compare the fork length-fecundity relationship of: (1) humpback whitefish sampled by Townsend and Kepler (1974) versus humpback whitefish sampled in this study; and, (2) least cisco sampled by Kepler (1973) versus least cisco sampled in this study. Geometric mean regressions were calculated as follows:

(4) $\hat{b}_{gm} = \frac{\hat{b}}{r}$;

where: $\hat{b}_{gm}$ = the slope in the geometric mean regression; and

$\hat{b}$ = regression coefficient (slope); and,

r = adjusted correlation coefficient.

After historical and recent data were statistically compared, these data were pooled providing fecundity data for 93 humpback whitefish and 80 least cisco. These two data sets (all humpback whitefish and all least cisco) were then subjected to regression analysis and fit to EQ 3.

The bootstrap technique of Efron (1982) was used to estimate the mean fecundity at length for both humpback whitefish and least cisco. One hundred bootstrap samples were drawn from the data on each species; each bootstrap sample consisted of 93 humpback whitefish (or 80 least cisco) drawn from the original data <u>with</u> replacement. The logarithm of fecundity was regressed against the logarithm of fork length for each bootstrap sample (EQ 3), and the fecundity for lengths in 10 mm increments was predicted with the fitted regression. The geometric mean regression was not calculated for the bootstrap sample. The Programs EGGBOOT.BAS (Appendix 3) and EGGBERT.BAS (Appendix 4) were used to bootstrap data on humpback whitefish and least cisco, respectively. The measured standard errors of predictions of fecundity at length were calculated as follows for each species:

$$(5) \quad \bar{F}_l = \frac{\sum F_{lk}}{100}; \text{ and, } V[\bar{F}_l] = \frac{\sum (F_{lk} - \bar{F}_l)^2}{99};$$

where: $\bar{F}_l$ = mean fecundity of fish with length l estimated with bootstrap procedures; and,

F_{lk} = fecundity of fish with length l estimated with bootstrap procedures.

Bootstrap means and variances were calculated for humpback whitefish from 305 to 645 mm FL and for least cisco from 285 to 445 mm FL.

RESULTS

Sub-sampling ovaries added insignificant amounts of variation to estimates of fecundity at length. Standard errors ranged from 87 to 1,519 eggs per fish for the 18 humpback whitefish and from 73 to 2,405 eggs for the 14 least cisco sub-sampled (Figure 2). Standard errors were small relative to fecundities (coefficient of variation for the 32 test fish ranged from 0.3 to 12.1% with 28 of the 32 test cases having a coefficient of variation of less than 5%); there appeared to be little effect of fish length on sampling error. Even though historic data were collected with the same procedures used in 1988 (Kepler 1973 & Townsend and Kepler 1974), the sampling variation in historic data could not be evaluated because sub-samples from ovaries were not replicated in 1972 and 1973.

The change in the population between sampling events influenced how historic and contemporary data could be compared (Figure 3). Monotonic relationships between fecundity and length were evident for both species in the older data and for least cisco in the current data; no relationship is evident for humpback whitefish sampled in 1988. Comparisons between fecundity and age showed slight relationships for both species (Figure 4). For both species,

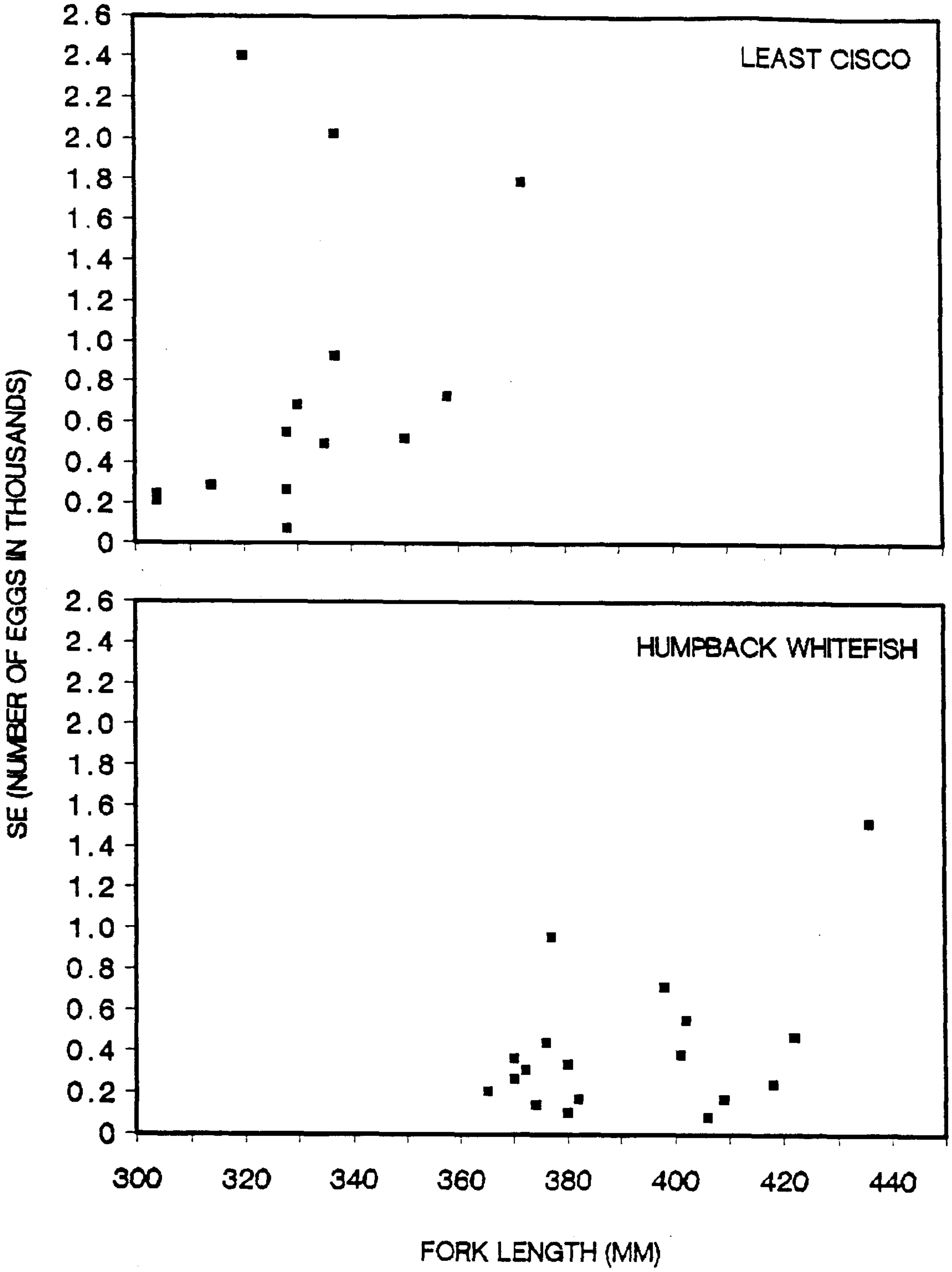

Figure 2. Fork length versus standard error of fecundity for humpback whitefish and least cisco sampled in 1988.

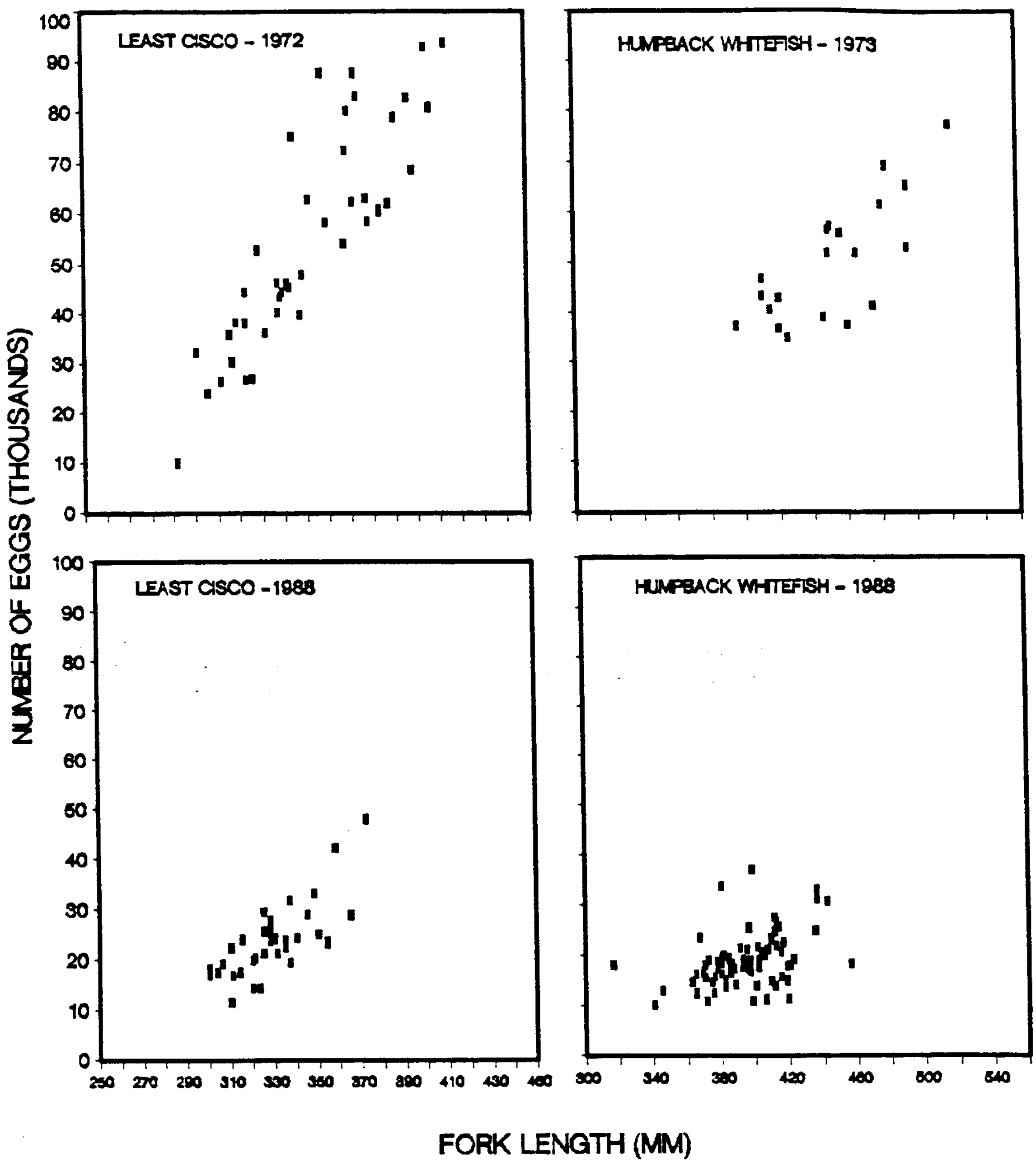

Figure 3. Fork length versus fecundity for humpback whitefish sampled in 1973 and 1988 and least cisco sampled in 1972 and 1988.

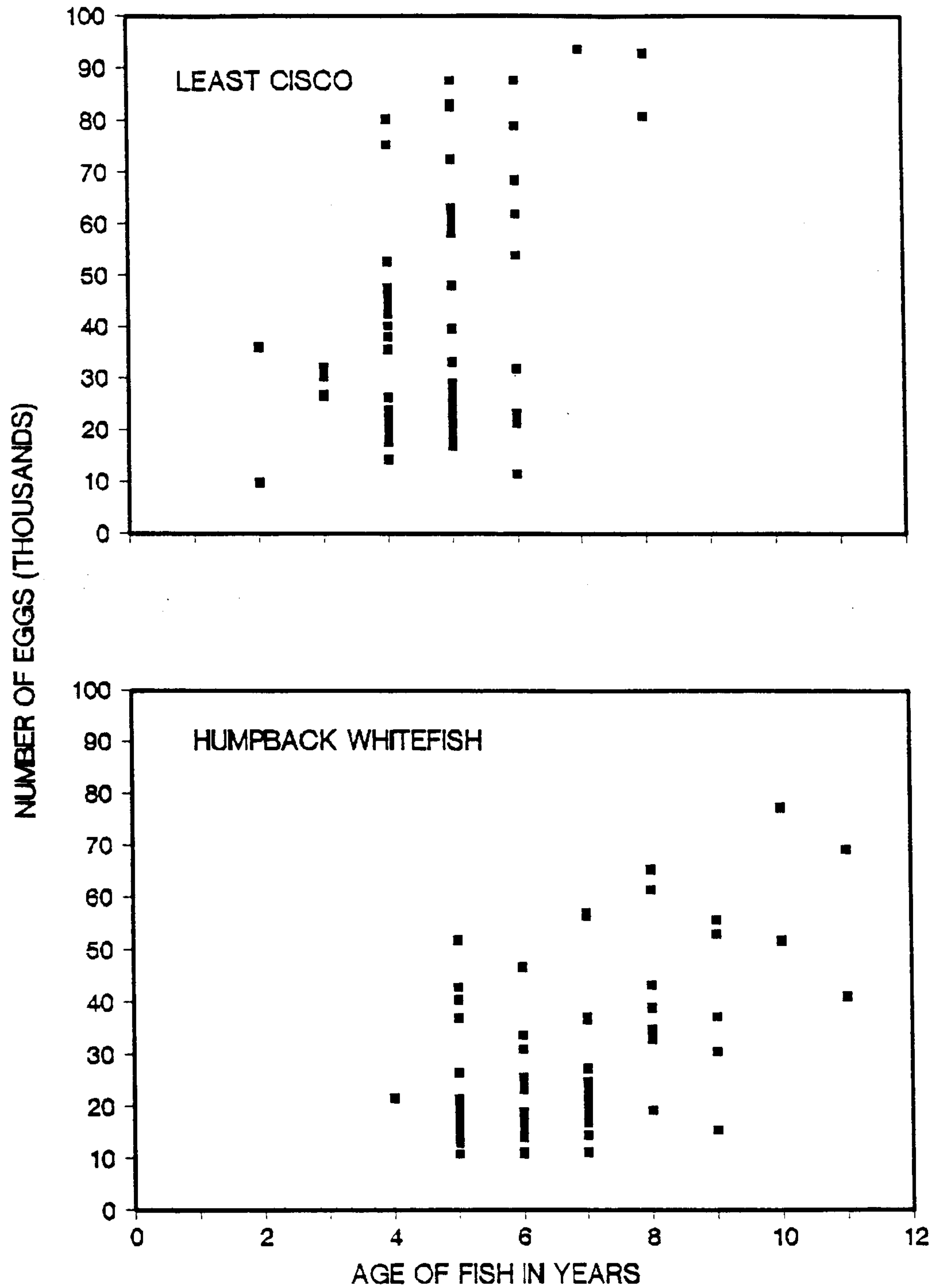

Figure 4. Age versus fecundity for humpback whitefish (sampled in 1973 and 1988) and least cisco (sampled in 1972 and 1988).

the fish sampled in 1988 were significantly smaller than in 1972 and 1973. Ranges of fish lengths in historic and contemporary samples overlap somewhat for least cisco; they do not for humpback whitefish. Contemporary data collected on both species covers a much shorter range than do historic data. Inspection of number of eggs per ml and percent gonad weight against fork length based on the truncated data collected in 1988 indicated little influence of length on these statistics (Figures 5 and 6).

Regressions of fecundity against fork length on historic and on contemporary data had similar statistics for both species (Table 2). However, the coefficients of determination for regressions on data collected in 1988 (17 and 51% for humpback whitefish and least cisco, respectively) were considerably lower than coefficients on older data (52 and 74%). When historic and contemporary data were pooled, slopes of the relationships steepened because the range of fecundity and length became larger as would be expected for bivariate data (Ricker 1973). The pooled data sets were continuous across their ranges for both species (Figure 7). The slopes of the geometric mean regressions of the pooled data sets were 4.23 and 5.60 for humpback whitefish and least cisco, respectively; the intercepts were -15.36 and -22.22, respectively. Correlation coefficients of the logarithms of fecundity and length were 0.75 and 0.81 for humpback whitefish and least cisco, respectively.

Predicted fecundities from bootstrap techniques were most precise for medium-sized humpback whitefish and the smallest least cisco (Figure 8). Predicted fecundity for humpback whitefish vary between 6,903 eggs for 305 mm FL fish and 80,203 eggs for 545 mm FL fish (Table 3). Predicted fecundity for least cisco vary between 32,138 eggs for 285 mm FL fish and 80,494 eggs for 445 mm FL fish. The smallest standard errors occurred at 385 mm FL for humpback whitefish and at 285 mm FL for least cisco; standard errors were largest for both species at the largest lengths.

DISCUSSION

Little published information is available concerning fecundity of humpback whitefish and least cisco, whereas, an abundance of information is available concerning fecundity of a close relative of humpback whitefish, the lake whitefish *Coregonus clupeaformis*. Healey and Dietz (1981) found that lake whitefish females (400 mm FL) in Lesser Slave Lake had from 12,900 to 21,260 eggs per female and that similar sized females sampled from Utikuma Lake had an average fecundity of 44,716 eggs. Female humpback whitefish of that size in this study were found to have a fecundity of about 21,000 eggs. Bidgood (1974) found that lake whitefish sampled from Pigeon Lake (350 mm FL) had an average of 11,112 eggs per female and that lake whitefish sampled from Buck Lake (475 mm FL) had an average fecundity of 49,114. In contrast, humpback whitefish of 350 mm FL from the Chatanika River had about 12,000 eggs per female and humpback whitefish of 475 mm had an average of 44,634 eggs per female (Table 3). Slopes of geometric mean regressions of fecundity against length calculated from Healey (1978) for several lakes in the Northwest Territories, Canada, were 4.41 for Baptiste Lake, 4.60 for Chitty Lake, 4.94

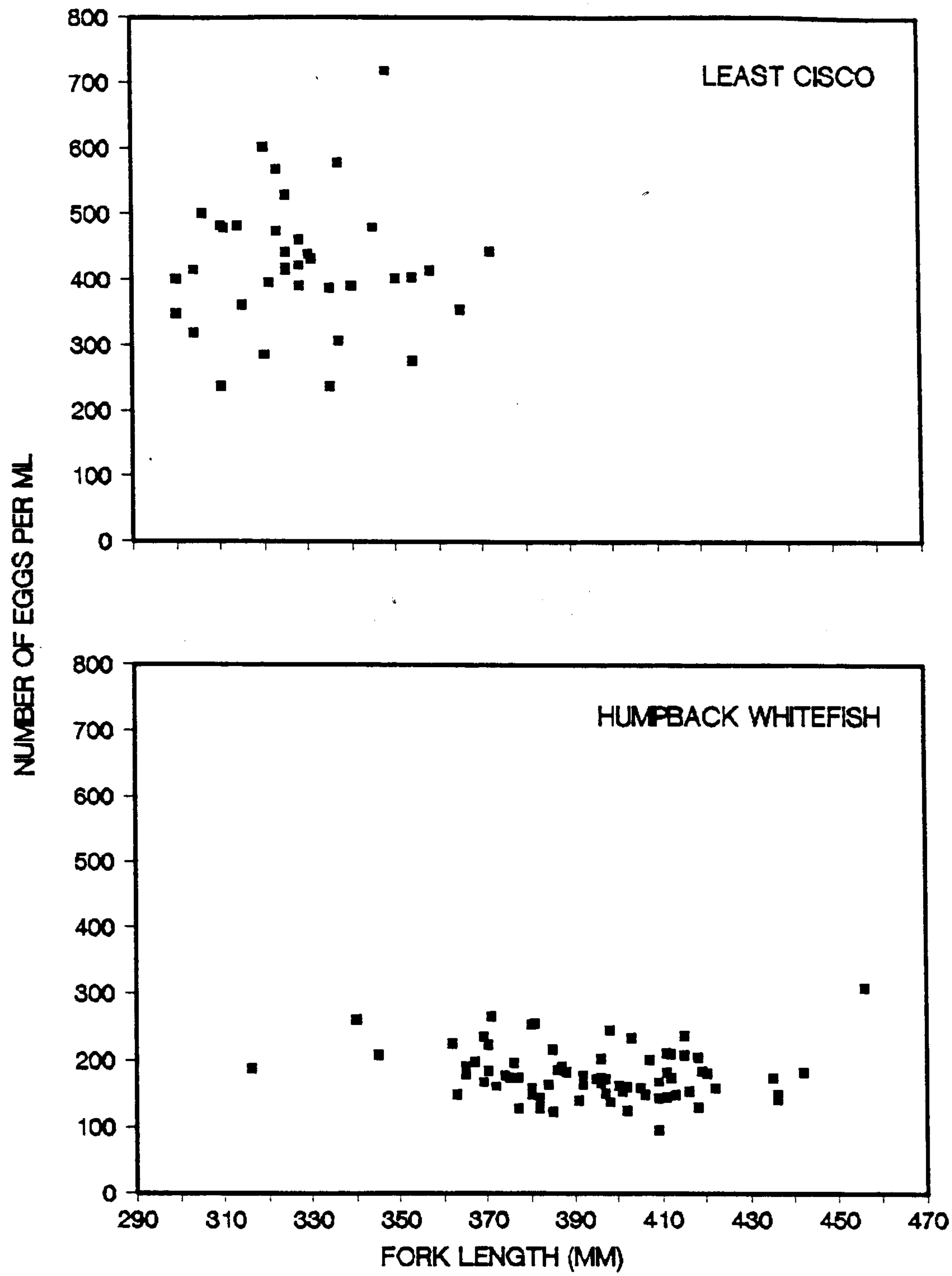

Figure 5. Fork length versus number of eggs per ml for humpback whitefish and least cisco sampled in 1988.

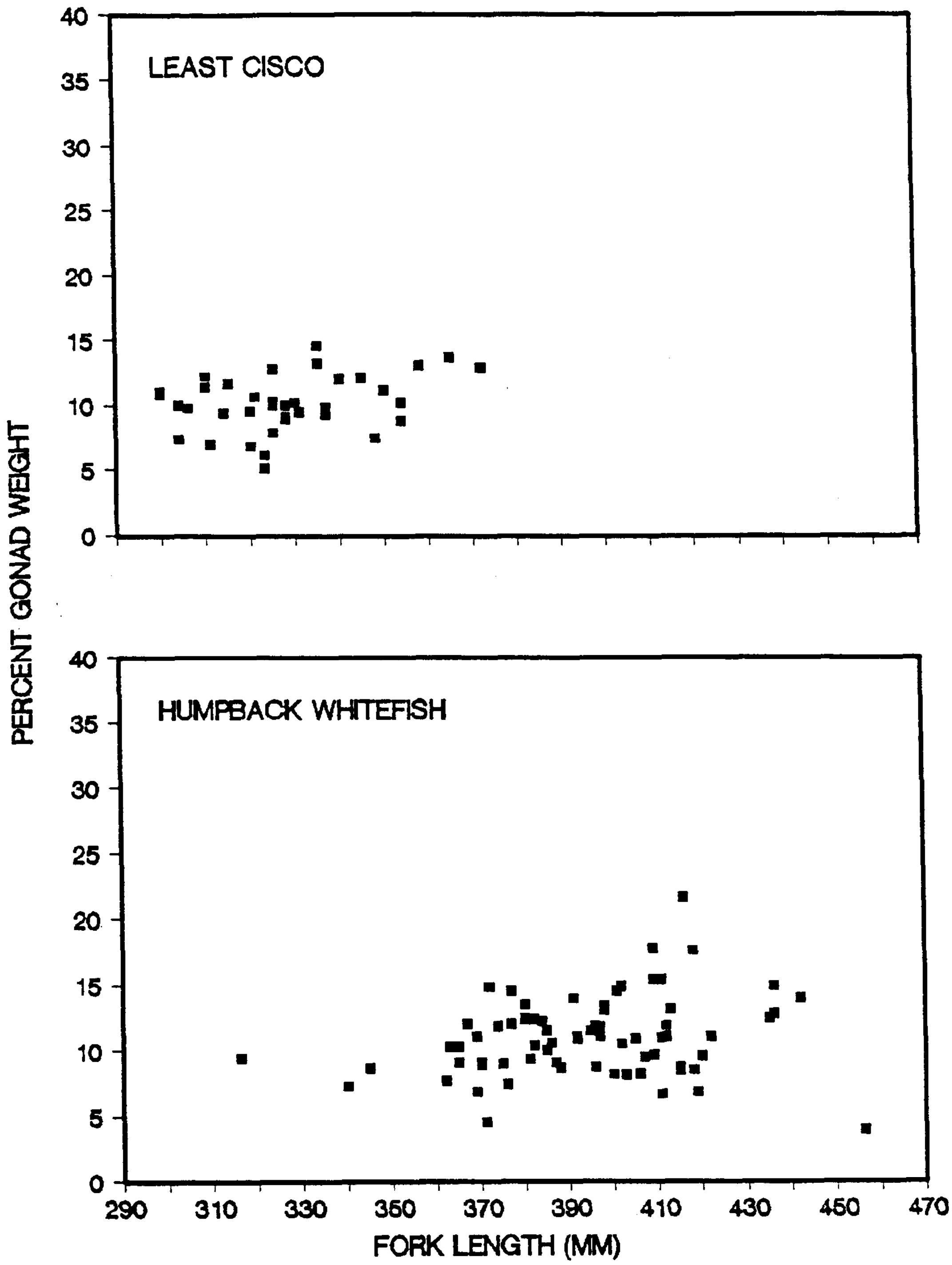

Figure 6. Fork length versus percent gonad weight for humpback whitefish and least cisco sampled in 1988.

Table 2. Regression and related statistics for the humpback whitefish (1973, 1988, and combined years) fork length versus fecundity relationships and for the least cisco (1972, 1988, and combined years) fork length versus fecundity relationships.

	Humpback whitefish			Least cisco		
Statistic	1973	1988	Combined	1972	1988	Combined
Regression Equations:						
a (intercept)	-3.276	-1.340	-15.360	-15.113	-12.529	-22.215
b (slope)	2.303	1.867	4.229	4.425	3.891	5.602
Standard Errors:						
a	3.032	2.816	2.348	2.393	3.602	2.614
b	0.496	0.471	0.911	0.408	0.622	0.449
regression	0.162	0.248	0.321	0.236	0.205	0.326
Coefficients of Determination:						
	0.519	0.169	0.558	0.740	0.508	0.662
Geometric Mean Regressions:						
	3.197	4.540		5.150	5.480	
Analysis of Variance:						
df: Regr.	1	1	1	1	1	1
Error	18	71	91	40	36	78
Total	19	72	92	41	37	79
SS: Regr.	0.566	0.966	12.019	6.517	1.637	16.589
Error	0.473	4.373	9.353	2.220	1.505	8.296
Total	1.039	5.339	21.372	8.738	3.142	24.885
MS: Regr.	0.566	0.966	12.019	6.518	1.637	16.589
Error	0.026	0.062	0.103	0.055	0.042	0.106
F	21.530	15.690	116.940	117.410	39.150	155.970
P	0.000	0.000	0.000	0.000	0.000	0.000

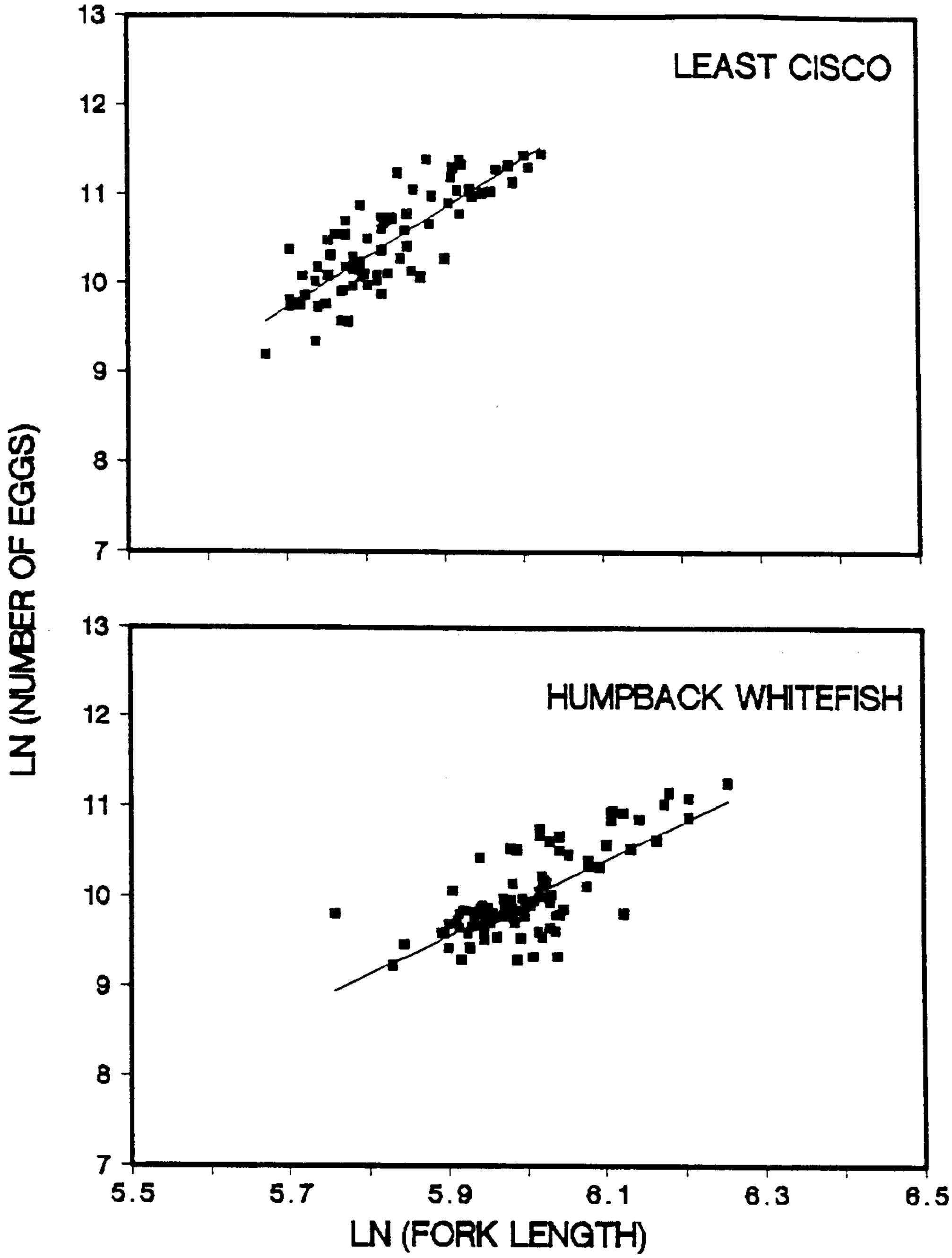

Figure 7. The log-log relationship between fork length (mm) and fecundity of humpback whitefish (sampled in 1973 and 1988) and least cisco (sampled in 1972 and 1988).

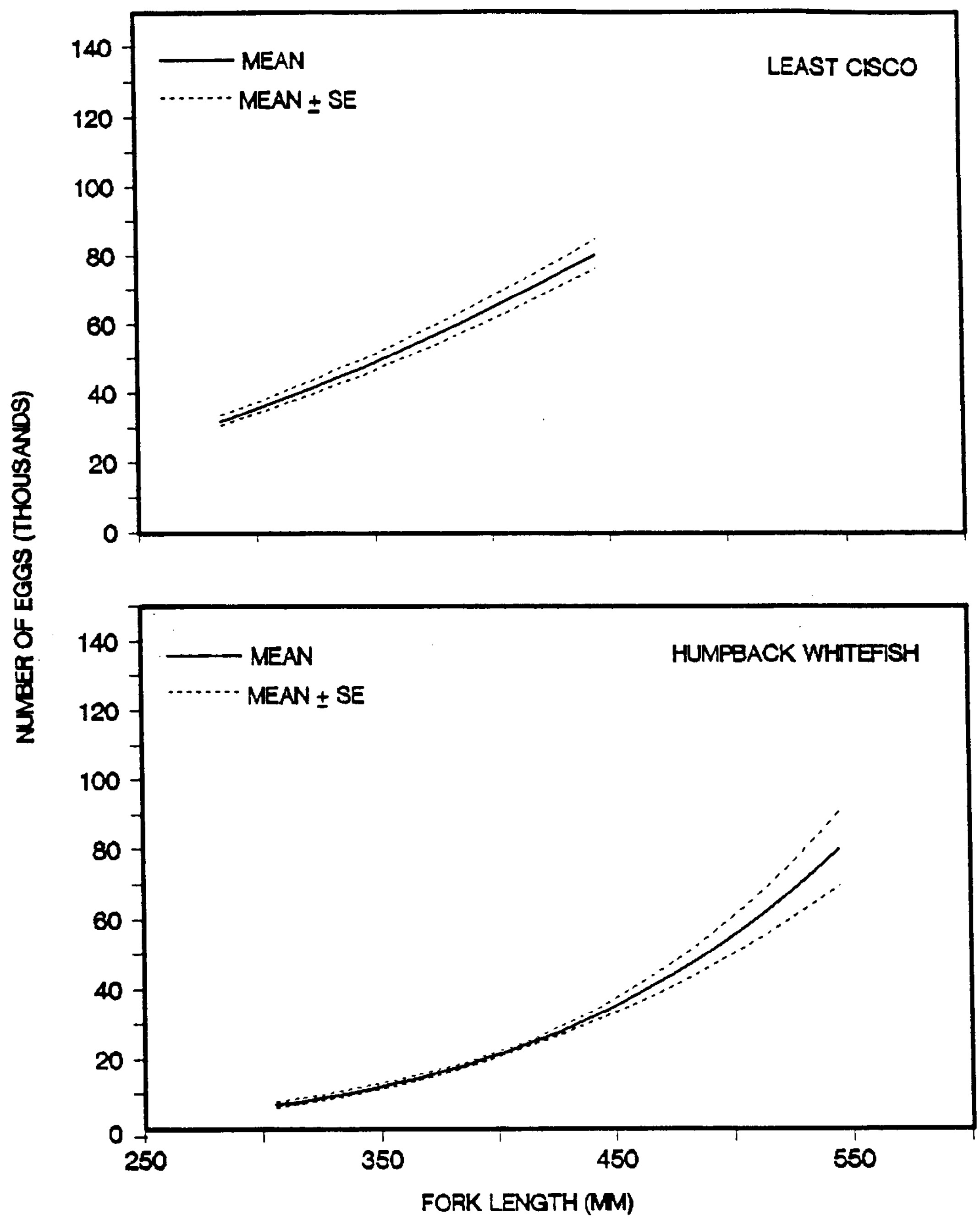

Figure 8. Means and means ± standard errors of the fork length versus fecundity relationship for humpback whitefish and least cisco developed from bootstrapping.

Table 3. Estimated fecundity of humpback whitefish and least cisco.

	Humpback Whitefish		Least Cisco	
Fork Length (mm)	Fecundity	SE	Fecundity	SE
285			32,138	1,514
295			34,504	1,640
305	6,903	830	36,958	1,772
315	7,899	845	39,498	1,909
325	9,002	850	42,125	2,051
335	10,221	843	44,840	2,200
345	11,563	823	47,641	2,354
355	13,036	792	50,531	2,514
365	14,651	751	53,507	2,680
375	16,416	709	56,572	2,852
385	18,341	678	59,725	3,030
395	20,436	681	62,965	3,214
405	22,711	748	66,294	3,404
415	25,178	896	69,711	3,599
425	27,846	1,128	73,217	3,801
435	30,728	1,438	76,811	4,010
445	33,835	1,824	80,494	4,224
455	37,180	2,283		
465	40,775	2,819		
475	44,634	3,434		
485	48,770	4,132		
495	53,196	4,920		
505	57,928	5,802		
515	62,979	6,786		
525	68,365	7,879		
535	74,101	9,087		
545	80,203	10,418		

for Drygeese Lake, and 5.85 for Alexie Lake. The corresponding coefficient was 4.23 for humpback whitefish in the Chatanika River.

Although historic and contemporary data from the Chatanika River incorporate almost two different size groups of whitefish, the relationships between fecundity and length reported here should still be representative for each species. Historic samples of least cisco and humpback whitefish were taken directly from the fishery (Kepler 1973 & Townsend and Kepler 1974) while electrofishing gear was used to garner contemporary samples. Hallberg (1988) has shown that samples taken with electrofishing gear in 1987 were representative of the harvest for both species. Since the fishery is conducted on mature fish, the reduction in mean length over the past 15 years reflects a real drop in mean size of the spawning fish. The catches of both humpback whitefish and least cisco in the spear fishery have increased an order of magnitude since 1980 (Mills 1979 - 1988), thereby making the fishery on the Chatanika River the most probable cause behind the reduction in average size. Populations of lake whitefish compensate for exploitation by increasing growth rates for individuals with fish maturing younger and at smaller sizes (Healey 1975), but not by changing the relationship between fecundity and length (see Healey 1978). The separation of historic and contemporary data from the Chatanika River is consistent with least cisco and especially humpback whitefish maturing at smaller sizes in later years. Unfortunately, only limited data on age and maturity were collected in 1972 and 1973 (Kepler 1973 & Townsend and Kepler 1974). However, if humpback whitefish and least cisco do respond to exploitation in the same way as lake whitefish, the relationships between fecundity and length reported here should still be representative of each population regardless of past rates of exploitation.

Of the three methods traditionally used to estimate fecundity for whitefish (volumetric, wet weight, and dry weight), expansion based on dry weight of sub-samples has had the smallest sampling error. Healey and Nicol (1975) reviewed several studies in which expansions were by volume or by wet weight and found generally an error rate of greater than 10% in fecundity estimates based on a single sub-sample. The volumetric method used in this study was more precise than those cited by Healey and Nicol (1975) but less precise than their method based on dry weight. However, 3,000 to 5,000 eggs were counted from each sub-sample in the method based on dry weight; each sub-sample in this study consisted of a few hundred eggs. Since the number of eggs in sub-samples from Healey and Nicol (1975) were about an order of magnitude beyond numbers used here, sub-sample size, and not method, is most likely the reason behind better precision with the dry method.

The bootstrap predictions of fecundity at length and their standard errors were based on the bivariate nature of the data on fecundity and length instead of the more traditional approach for linear regression. Although inspection of fecundity against length indicated only a linear relationship, the model $f = al^b$ was chosen and transformed to represent fish morphometry and to stabilize variance, respectively (Bagenal and Braum 1971). Unfortunately, standard errors of predictions can not be estimated from the transformed, geometric mean regression. By resampling the original data pairs of fecundity and length, a series of predictive regressions were used to produce a series of conditional distributions for each length. Usually, the residuals in regressions are resampled in building bootstrap regressions, not the original data (Efron 1982). However, bootstrapping the original data retained the bivariate nature of the relationship such that geometric mean regressions need not be used in the bootstrap process. As a result, the bootstrap predictions followed the geometric mean regression on the original data as was desired.

Generally, prediction of egg production by the spawning population is the ultimate aim in searching for relationships concerning fecundity and other variables. Calculation of egg production from fish length is analogous to a multistage sampling procedure with variation in fecundity among fish and variation due to the prediction of fecundity. A sample of "m" fish is drawn, and measurement of length is rounded to the nearest 10 mm FL for each fish. The appropriate estimate of fecundity and its standard error are obtained from Table 3. The total egg production and its variance are estimated with equations for multistage sampling from Cochran (1977):

$$\hat{F} = \frac{N \sum^{m} \hat{F}_j}{m}; \text{ and,}$$

$$V[\hat{F}] = \frac{N^2 \sum^{m} (\hat{F}_j - \bar{F})^2}{m(m-1)} + \frac{N^2 \sum^{m} V[\hat{F}_j]}{m^2};$$

where: N = abundance of females;
F_j = estimated abundance of fish j predicted from its length;
m = the number of fish in the sample; and,
F = egg production by the spawning population.

Estimated egg production of the spawning populations could be more easily calculated on predictions of fecundity based on age. However, fecundity has been shown to be only loosely related to age in whitefish in general (Healey 1978) as is the case in this study. Therefore, more cumbersome estimates of egg production based on length are more precise than would be estimates based on age.

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APPENDIX

Appendix Table 1. Length, age, weight, and fecundity data for humpback whitefish, Chatanika River, 1988.

Fork Length	Age	Weight (gr)	Egg Weight (gr)	Percent Gonad Weight	Egg Volume (ml)	Average Eggs Per ml	Estimated Fecundity: Mean	n	Var.	SE
316		962	91	9.4	96	188	18,071	1		
340		499	36	7.3	39	261	10,181	1		
345	5	527	45	8.6	62	209	12,947	1		
362		590	45	7.7	65	225	14,655	1		
363	6	617	64	10.3	99	149	14,702	1		
365		599	54	9.1	69	179	12,372	3	129,701	208
365	5	617	64	10.3	85	191	16,261	1		
367	6	754	91	12.0	118	199	23,439	1		
369	5	663	45	6.8	70	236	16,494	1		
369	7	654	73	11.1	100	168	16,800	1		
370	9	699	64	9.1	84	185	15,547	3	213,198	267
370	6	717	64	8.9	81	223	18,077	3	405,707	368
371	5	599	27	4.5	41	266	10,925	1		
372	6	672	100	14.9	117	162	18,933	3	295,728	314
374	7	690	82	11.8	82	178	14,573	3	61,723	143
375		708	64	9.0	71	175	12,444	1		
376	6	735	54	7.4	80	197	15,789	3	595,364	445
377	6	681	82	12.0	100	174	17,444	1		
377		749	109	14.5	145	129	18,692	3	2,773,910	962
380	6	663	82	12.3	106	152	16,099	1		
380	6	799	100	12.5	115	159	18,248	3	32,280	104
380	5	672	91	13.5	131	148	19,414	3	345,538	339
380	6		100		132	255	33,695	1		
381	5	681	64	9.3	78	256	19,968	1		
382	5	699	73	10.4	95	144	13,668	3	89,955	173
382	5	808	100	12.4	117	129	15,087	1		
384	7	745	91	12.2	118	164	19,352	1		
385	5	454	45	10.0	76	217	16,492	1		
385	7	708	82	11.5	144	124	17,856	1		
386	7	772	82	10.6	98	187	18,311	1		
387	5	799	73	9.1	90	192	17,314	1		
388	6	735	64	8.6	77	183	14,053	1		
391	5	908	127	14.0	152	141	21,418	1		
392		735	82	11.1	107	165	17,655	1		
392		754	82	10.8	107	178	19,091	1		
395	5	790	91	11.5	122	173	21,147	1		
396	7	763	91	11.9	103	166	17,146	1		
396	7	790	91	11.5	109	174	19,007	1		
396	6	835	73	8.7	125	203	25,395	1		

-Continued-

Appendix Table 1. Length, age, weight, and fecundity data for humpback whitefish, Chatanika River, 1988 (Continued).

Fork Length	Age	Weight (gr)	Egg Weight (gr)	Percent Gonad Weight	Egg Volume (ml)	Average Eggs Per ml	Estimated Fecundity: Mean	n	Var.	SE
397	6	772	91	11.8	110	151	16,622	1		
397	6	817	91	11.1	109	173	18,871	1		
398	6	881	118	13.4	79	138	10,897	4	2,055,465	717
398	5	972	127	13.1	150	246	36,844	1		
400		835	68	8.2	86	162	13,941	1		
401	4	872	127	14.6	140	155	21,641	3	451,897	388
402	5	854	127	14.9	142	124	17,648	3	924,786	555
402	8	863	91	10.5	120	160	19,252	1		
403		781	64	8.1	88	234	20,625	1		
405	5	917	100	10.9	126	159	20,020	1		
406	7	772	64	8.2	76	148	11,261	3	22,658	87
407		953	91	9.5	104	202	20,984	1		
409	6	844	82	9.7	104	143	14,907	1		
409	7	663	118	17.8	136	169	22,916	1		
409	7	944	145	15.4	243	96	23,388	3	88,209	171
411	5	953	64	6.7	76	184	13,960	1		
411	6	826	127	15.4	169	146	24,674	1		
411	7	1,071	118	11.0	129	212	27,394	1		
412	7	917	109	11.9	125	175	21,875	1		
412	5	899	100	11.1	126	210	26,460	1		
413	6	826	109	13.2	171	149	25,555	1		
415	6	863	73	8.4	75	209	15,671	1		
415	7	835	73	8.7	87	237	20,590	1		
416		463	100	21.6	145	155	22,403	1		
418	5	854	73	8.5	73	205	14,954	1		
418	6	1,081	191	17.6	137	130	17,816	3	182,688	247
419	6	935	64	6.8	61	185	11,301	1		
420	5	854	82	9.6	99	182	17,976	1		
422	5	899	100	11.1	120	160	19,146	3	684,369	478
435	7	944	118	12.5	142	175	24,808	1		
436	6	1,135	145	12.8	218	142	30,999	3	6,923,219	1,519
436	8	1,090	163	15.0	220	150	32,895	1		
442	9	1,035	145	14.0	167	183	30,551	1		
456		1,135	45	4.0	59	309	18,248	1		

Appendix Table 2. Length, age, weight, and fecundity data for least cisco, Chatanika River, 1988.

Fork Length	Age	Weight (gr)	Egg Weight (gr)	Percent Gonad Weight	Egg Volume (ml)	Average Eggs Per ml	Estimated Fecundity: Mean	n	Var.	SE
300		336	36	10.8	42	401	16,842	1		
300		327	36	11.0	52	348	18,091	1		
304		363	36	10.0	54	319	17,248	3	171,503	239
304	5	372	27	7.3	42	415	17,446	3	130,335	208
306	4	372	36	9.8	38	501	19,054	1		
310	4	400	45	11.4	46	483	22,233	1		
310	6	372	45	12.2	48	238	11,417	1		
311	5	390	27	7.0	35	479	16,753	1		
314	4	291	27	9.4	36	482	17,345	3	245,652	286
315		390	45	11.6	66	362	23,873	1		
320	4	381	36	9.5	50	286	14,286	1		
320	4	400	27	6.8	33	601	19,835	3	17,344,892	2,405
321		427	45	10.6	51	396	20,204	1		
323	4	445	27	6.1	25	567	14,182	1		
323	4	354	18	5.1	30	475	14,238	1		
325	5	354	36	10.3	48	442	21,216	1		
325	6	463	36	7.8	40	529	21,164	1		
325	5	454	45	10.0	61	418	25,479	1		
325		427	54	12.8	71	413	29,347	1		
328	5	499	45	9.1	60	461	27,666	3	907,027	550
328	5	454	45	10.0	62	422	26,167	3	210,403	265
328	5	409	36	8.9	51	460	23,460	1		
328	5	499	45	9.1	64	391	25,031	3	16,099	73
330	5	445	45	10.2	55	438	24,090	3	1,393,983	682
331	4	481	45	9.4	49	432	21,152	1		
335	4	499	73	14.5	100	238	23,778	1		
335	5	481	64	13.2	58	387	22,421	3	728,486	493
337	6	490	45	9.3	55	577	31,750	3	12,282,368	2,023
337	5	463	45	9.8	63	308	19,391	3	2,592,316	930
340	5	454	54	12.0	62	391	24,249	1		
345	5	527	64	12.1	60	480	28,800	1		
348	5	490	36	7.4	46	718	33,028	1		
350	5	490	54	11.1	62	402	24,952	3	813,437	521
354	5	536	54	10.2	85	276	23,478	1		
354	6	518	45	8.8	57	404	23,038	1		
358	4	627	82	13.0	102	414	42,245	3	1,582,275	726
365	5	599	82	13.6	81	355	28,792	1		
372	5	708	91	12.8	108	443	47,845	3	9,581,533	1,787

Appendix Table 3. Program EGGBOOT.BAS, developed by David R. Bernard, Division of Sport Fish, Department of Fish and Game, 333 Raspberry Road, Anchorage, Alaska.

```
10 REM ------------------------------------ HUMPBACK WHITEFISH
20 RANDOMIZE
30 N = 93
40 NBOOT = 100
50 DIM HOLD(N,2)
60 OPEN "HW7388.PRN" FOR INPUT AS #1
70 OPEN "HWBOOT.PRN" FOR OUTPUT AS #2
80 REM ------------------------------------ INPUT RAW DATA
90 FOR I = 1 TO N100 INPUT #1,X,Y
110 HOLD(I,1)=LOG(X)
120 HOLD(I,2)=LOG(Y)
130 NEXT I
140 REM ----------------------------------- DRAW A BOOTSTRAP SAMPLE
150 FOR I = 1 TO NBOOT
160 SUMXY=0
170 SUMX=0
180 SUMY=0
190 SUMX2=0
200 FOR J = 1 TO N
210 K = FIX(RND*N)+1
220 SUMX = SUMX+HOLD(K,1)
230 SUMY = SUMY+HOLD(K,2)
240 SUMX2 = SUMX2 + HOLD(K,1)*HOLD(K,1)
250 SUMXY = SUMXY + HOLD(K,1)*HOLD(K,2)
260 NEXT J
270 REM ----------------------------------- REGRESS
280 B = (SUMXY-SUMX*SUMY/N)/(SUMX2-SUMX*SUMX/N)
290 A = SUMY/N-B*SUMX/N
300 A = EXP(A)
310 REM ----------------------------------- PREDICT AND PRINT
320 PRINT #2,I;
330 PRINT I
340 FOR J = 305 TO 535 STEP 10
350 Y = FIX(J^B*A)
360 PRINT #2,Y;
370 PRINT Y;
380 NEXT J
390 Y=FIX(545^B*A)
400 PRINT #2,Y
410 PRINT Y
420 NEXT I
```

Appendix Table 4. Program EGGBERT.BAS, developed by David R. Bernard, Division of Sport Fish, Department of Fish and Game, 333 Raspberry Road, Anchorage, Alaska.

```
10 REM -------------------------------------- LEAST CISCO
20 RANDOMIZE
30 N = 80
40 NBOOT = 100
50 DIM HOLD(N,2)
60 OPEN "A:LC7288.PRN" FOR INPUT AS #1
70 OPEN "A:LCBOOT.PRN" FOR OUTPUT AS #2
80 REM -------------------------------------- INPUT RAW DATA
90 FOR I = 1 TO N
100 INPUT #1,X,Y
110 HOLD(I,1)=LOG(X)
120 HOLD(I,2)=LOG(Y)
130 NEXT I
140 REM ------------------------------------- DRAW A BOOTSTRAP SAMPLE
150 FOR I = 1 TO NBOOT
160 SUMXY=0
170 SUMX=0
180 SUMY=0
190 SUMX2=0
200 FOR J = 1 TO N
210 K = FIX(RND*N)+1
220 SUMX = SUMX+HOLD(K,1)
230 SUMY = SUMY+HOLD(K,2)
240 SUMX2 = SUMX2 + HOLD(K,1)*HOLD(K,1)
250 SUMXY = SUMXY + HOLD(K,1)*HOLD(K,2)
260 NEXT J
270 REM ------------------------------------- REGRESS
280 B = (SUMXY-SUMX*SUMY/N)/(SUMX2-SUMX*SUMX/N)
290 A = SUMY/N-B*SUMX/N
300 A = EXP(A)
310 REM ------------------------------------- PREDICT AND PRINT
320 PRINT #2,I;
330 PRINT I
340 FOR J = 285 TO 435 STEP 10
350 Y = FIX(J^B*A)
360 PRINT #2,Y;
370 PRINT Y;
380 NEXT J
390 Y=FIX(445^B*A)
400 PRINT #2,Y
410 PRINT Y
420 NEXT I
```