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Selectivity of Experimental Gill Nets for Bloater Chubs (*Coregonus hoyi*) in Lake Michigan

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Fisheries Research Report No. 1951
January 27, 1988

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION

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ABSTRACT

Selectivity of various combinations of mesh sizes in experimental gill-net gangs, which could be use to index the bloater chub population in Lake Michigan, was evaluated by several approaches: frequencies of the logarithm of fish length:mesh perimeter ratios, weight-length regressions, von Bertalanffy's growth coefficient K, and survival rates.

Five combinations of mesh sizes, which spanned a range of 50.9 to 76.2 mm, were evaluated on intervals of 1.6, 3.2, 6.4, and 12.7 mm in April and August 1984–85. Additionally, two groups of variable combinations containing mesh sizes of 50.9, 54.0, 58.7, 63.5 mm (April) and 50.9, 54.0, 57.2, 60.3, and 65.1 mm (August) were also examined.

No one combination of mesh sizes performed consistently well over all categories tested, as the results varied by the month in which the data were obtained. A system of ranking devised to summarize results indicated that the variable mesh combination produced the best overall raking in April, while a mesh interval of 3.2 mm provided a superior overall rating in August. It was recommended that an experimental gill-net gang to index the exploitable segment of the bloater chub population consist of mesh sizes 50.9 mm to 73.0 mm, and on an interval of 3.2 mm. Mesh intervals of 6.4 mm or larger for indexing bloaters should not be used.

INTRODUCTION

The bloater chub population in Lake Michigan was near collapse when the fishery was suspended in August 1976. For the purpose of evaluating the bloater population's progress subsequent to closure, four chub fishermen were chosen by lottery to represent four widely dispersed geographical areas (Muskegon, Manistee, Leland, and Manistique) of Lake Michigan. The assessment fishermen operated under research permits with a lakewide quota of 56,700 kg. Additionally, depth restrictions of not less than 30 fathoms at Muskegon and 40 fathoms elsewhere were imposed on the chub assessment fishery to protect small lake trout. The chub population has since responded positively, and the lakewide catch quota in 1986 was set at 934,000 kg.

Because the assessment fishery used gill nets, the stretched measure of which varied from 63.5 mm to 73.0 mm, sampling that fishery provided only age-size data of the catch and not the population. Thus, it was decided to assess the chub population with graded-mesh gill nets. Initially, the experimental index gill nets consisted of meshes 50.9 mm through 88.9 mm on a 12.7-mm interval. It has long been suspected that a 12.7-mm mesh interval was much too large to measure accurately a stock in which individuals seldom reach a total length greater than 30 cm and, according to commercial chub fishermen, is highly sensitive to changes in mesh size of as little as 1.6 mm. If that were true, then one would expect more distortion in the frequency distribution of length groups captured in meshes on the 12.7-mm interval than in some optimally spaces series of mesh sizes. Such distortion conceivably could cause biases in growth and mortality parameters, which ultimately would result in flawed management decisions.

Thus, the objective of the investigation was to evaluate combinations of gill net mesh sizes that best determined size distribution, growth parameters, and survival of the chub population.

METHODS

Gill nets were the sampling gear used in this project. A gill-net gang consisted of 25 panels, each of which was 1.8 m deep and 30.5 m long. Thread size was 210/2 (0.23 mm diameter) and meshes were hung on the half. The arrangement of mesh sizes in the gang was 50.9 mm (stretched measure) in the first panel and progressively increased on 1.6-mm intervals to 88.9 mm in the last panel.

One gang was set at each depth from 18.3 m through 91.4 m on an 18.3-m interval. The purpose of selecting these depths was to insure that all sizes of chubs vulnerable to the gear would be sampled in the event that size was depth dependent.

The Pentwater area of Lake Michigan was chosen as the study site because a substantial chub population existed in that locality. Northern Lake Michigan was the first choice but not enough large chubs were available in that area to provide a satisfactory length range.

In the event that selectivity changed seasonally, experimental fishing was done in April and August 1984–85. All nets were lifted after having fished one night so that the effort was distributed equally over depths, mesh sizes, months, and years.

Catch was recorded by mesh size. Length, weight, sex, maturity, and age were entered for up to 50 randomly selected chubs per mesh size. If the catch per mesh size exceeded 50 chubs, length frequencies only were recorded for the remainder. About 10% of the April catch was subsampled.

The monthly length classes by mesh-size frequencies were combined for 1984–85 (Appendices A1 and A2). The April data matrix was defined as length classes greater than 21 cm (classes equal to or greater than 31 cm were combined with the 30-cm group) and mesh sizes 50.9–69.9 mm; the August data matrix was defined as length classes greater than 20 cm (classes equal to or greater than 30 cm were combined with the 29-cm group) and mesh sizes 50.9–73.0 mm. Frequencies outside of these bounds were of minor importance.

Two methods were used to choose combinations of mesh sizes: (1) selection of meshes, which began at 50.9 mm, on uniform intervals of 1.6 mm, 3.2 mm, 6.4 mm, and 12.7 mm; and (2) comparison of the distribution of length classes in adjacent mesh sizes until a significant difference occurred, in which case the mesh size would then be included in the series (mesh interval is labeled as "variable" in Table 1).

Although the classical approach to gear selectivity is based on fish girth:mesh perimeter ratios, length:mesh perimeter ratios were used in these analyses by necessity. Aptly named, bloaters expand greatly in girth (a function of decreasing depth pressure) as the nets are lifted, which makes it virtually impossible to obtain an accurate girth measurement. The substitution of fish length:mesh perimeter ratios for girth:perimeter ratios was proposed by Gulland (1983).

The usual objective of a mesh selectivity project is to evaluate various combinations of mesh sizes that sample the fish population in proportion to its abundance. Because the length distribution of the chub population was unknown, and therefore length distribution in the experimental nets could not be compared directly with that of the population, the indirect method was used (Hamley 1975). This technique requires no knowledge of the size distribution of the population but instead relies on suitable assumptions about the nature of selectivity curves. Indirect estimates of selectivity are based on comparing catches of one size class of fish by nets of several mesh sizes. The application of the indirect method in this analysis followed that of McCombie and Fry (1960). Briefly, they (1) plotted frequencies for each size class of lake whitefish on the lognormal girth:perimeter ratio of each mesh size; (2) brought each plot to the same vertical scale by adjusting each to have one unit area under the frequency-girth:perimeter curve (to compensate for decreasing frequencies caused by mortality); and (3) combined all adjusted frequency-girth:perimeter points into a single master curve that contained all size classes.

Since it was assumed that length-class frequencies in the population were normally distributed, that combination of mesh sizes, which best approximated a normal distribution fitted to each data set, ideally would then also be the choice series for indexing stock. The lognormal length:mesh perimeter ratios were grouped into classes (each with a width of 0.05 units) and the adjusted frequencies were plotted as histograms. The calculated normal distribution for each data set was then superimposed on its histogram, and the chi-square statistic computed for the fit of observed to theoretical distributions. In addition to length:perimeter ratios, selectivity of various combinations of mesh sizes in experimental gill-net gangs was also evaluated by weight-length regressions, von Bertalanffy's K coefficients, and survival rates. The combination of mesh sizes, which most faithfully mirrored the actual parameters of the stock, could not be determined directly because the exact structure of the population itself was unknown. Moreover, no one combination of mesh sizes provided consistent results over all four categories. Thus, it was necessary to summarize results over all categories between mesh series. That was accomplished by first indexing each series element in a category, assigning each index a rank (1 was best, 5 was worst), and then summing the ranks for each series across categories. Conceptually, that mesh series with the smallest sum of ranks would be the best overall mesh combination to index the chub population. The master curve index simply was the probability level (expressed in percent) given for the comparison between observed and expected values. The indices for the weight-length regressions, von Bertalanffy K coefficients, and survival rates were expressed as the ratio of the 95% confidence limit to the parameter estimate. For example, the survival rate and its 95% confidence bound, estimated from mesh series 1 data in April, were 0.12 and ±0.037; the index was 100(0.037/0.12), or 30%. Since the weight-length regression index was based on slope, and there was no statistically significant difference between slopes or intercepts for the April data, indices for that month and variable were assigned a value of zero.

RESULTS

Selectivity

April and August data were analyzed separately because of an apparent change in selectivity between these months. Contingency table analysis showed that length-class distribution (21–30+ cm) over all mesh sizes (50.9–76.2 mm) was dependent upon month ($P < 0.001$). The catch in April had slightly larger proportions of 27- to 30+-cm chubs than did that in August, but the August catch contained somewhat larger proportions of 21- to 23-

cm fish than did the April sample (Table 2). Although the differences in distribution of length classes between months were of minor proportions, statistical significance resulted because of the large sample sizes.

Selectivity may have shifted because of changes in the weight-length relationship and condition factor from April to August. The slopes of the weight-length regressions did not differ significantly ($P > 0.05$) between months, but the intercepts were significantly different ($P < 0.05$); the adjusted mean weight of bloater chubs in the catch was 131 g in April and 142 g in August. Condition factors ($W \times 10^5/L^3$) of males and females were similar within each month. However, the mean condition factor for males increased from 0.75 in April to 0.81 in August; likewise, the mean condition factor for females advanced from 0.77 in April to 0.84 in August (Table 3). The effects of month, sex, and interaction on condition factor were all statistically significant ($P < 0.05$). Of particular interest was the lack of a statistically significant ($P = 0.286$) relationship between the covariate length and condition factor. Over the length range (210–420 mm) examined, length, as the independent variable, explained less than 1% of the variation about the regression line in 16 combinations of month, by sex, analyzed by four common linear, regression models (linear, exponential, logarithmic, and power). Since slope did not differ significantly from zero, any change in mean monthly condition factor would apply equally to all lengths. Thus, the length distribution in August may have contained smaller fish than the April catch because the more robust condition factor increased the vulnerability of that group to the experimental gill nets.

Selectivity curves obtained in April were based on length classes 27–30+ cm captured in mesh sizes 50.9–69.9 mm. Plots of the frequency of each length group on all mesh sizes showed that chubs less than 27 cm were incompletely recruited to the graded-mesh gill nets (examples of this are illustrated in Figure 1); even the 27-cm class was marginally vulnerable. The August selectivity curve began at 26 cm and likely reflects a slightly different selectivity due to the most robust condition of the chubs in that month. For those groups incompletely recruited, only the fastest growing members of the length class were captured, as indicated by the abbreviated ascending leg of the curve of the 25-cm length class (Figure 1).

The master curve that gave the best approximation to a normal distribution of the April catch (Figure 2) was the variable mesh size combination of 50.9, 54.0, 58.7, 63,5, and 66.7 mm. The poorest fits to a normalized distribution were for the mesh size combinations on the 6.4-mm and 12.7-mm intervals. In the mesh series on the 12.7-mm intervals, three length:mesh perimeter classes were absent. In the August sample, a much different ranking of mesh selectivity curves occurred (Figure 3). The 3.2-mm interval resulted in the best fit, followed by the variable mesh sizes 50.9, 54.0, 57.2, 60.3, and 65.1 mm, which is essentially a 3.2-mm interval. Even with four length:mesh perimeter classes missing, the 12.7-mm interval series had a much better fit than either the 6.4-mm or the 1.6-mm interval series. The 1.6-mm interval apparently over-sampled the 0.575 to 0.875 length:mesh perimeter classes as the histogram showed a slight leftward skew.

Effect on growth parameters

Generally, the combination of mesh sizes had little effect on the weight-length regression parameters within month. Analysis of covariance indicated that no significant difference ($P > 0.05$) occurred in either slope or intercept of weight-length regressions between the five series of mesh sizes (defined in Table 1) during April. The mean responses (adjusted mean weight) to the various combinations of mesh sizes were similar at 130 to 133 g (Table 4). Thus, a common regression with a mean slope and intercept of 3.1902 and –12.7953 satisfactorily fits all weight-length curves obtained from the April mesh series.

The August weight-length data produced results different from those in April. Interaction effects indicated that the slopes of weight-length regressions were significantly different ($P = 0.012$) between mesh series. Of the five contrasts of each calculated slope (b_i) and intercept (a_i) to the unweighted mean slope (B) and intercept (A) of all regressions, the regression parameters for the variable mesh size combination (series 5) were the most widely divergent (Table 5). As compared to the mean regression line, the predicted weights of chubs in series 5 were statistically larger at lengths less than 220 mm and significantly smaller at lengths greater than 260 mm. This unexpected result is inconsistent with the adjusted frequencies of length:perimeter ratios (Figure 3) where the variable mesh ranked second in agreement with theoretical frequencies ($P = 0.42$). Of course, it cannot be determined absolutely which of the weight-length regression series best reflects population conditions. However, series 5 is excessively misaligned with the other mesh combinations to be credible and therefore, is judged to be biased. The confidence limits on the slopes of the weight-length regressions in August were the narrowest for mesh series 1 and 2 and the widest for series 3–5 (Table 6).

Observed mean total length-at-age remained virtually unchanged between mesh series within month (Appendix B). In other than series 1, sample sizes were too small to assess accurately the mean size-at-age after age 5. However, length-at-age predicted from von Bertalanffy's growth coefficients showed considerably different growth patterns of chubs caught in the various mesh series (Figure 4). These growth patterns appear to follow the relative magnitudes of the K coefficients, which varied widely between mesh sizes (Table 7). The predicted growth curve of chubs caught in series 1, which contained seven age groups, showed age 3 to be the smallest for that group when compared to series 2–4, and age 9 to be the largest for all in that class. Series 2 and 3 each had six age groups and both have similar growth curves, which are somewhat larger at age 3 but smaller at age 9 than in the series-1 curve. Series-4 curve, which consists of four age classes, begins high but becomes asymptotic at about age 5 so that the predicted length at age 9 is much smaller than at the same age in the other three curves. The values predicted from the series 4 length-at-age curve are the closest to the observed values, and the K coefficient has the narrowest confidence limits of any series. The discrepancies in predicted lengths between mesh series were believed due to inadequate sample sizes in the 7–9 age groups, which depressed predicted values of younger fish and inflated those of the older ages. Omission of ages 7–9 from the calculations realigned the von Bertalanffy growth coefficients of chubs in all mesh series (Table 8) and especially improved the confidence limits of the August data. Some minor differences in the coefficients still remained because not all observed length-at-age data were identical between series. Thus, in this particular data set, the older age groups should be eliminated from the age-size analysis because of distortion that they cause in the age-length curve.

Effect on survival rate

Annual survival rates, as determined from catch-curve analysis (Robson and Chapman 1961), were little affected by either mesh series or months. Most survival estimates were within the range of 10–15% (Table 9). The least reliable survival rate was obtained in August from series 4 (mesh interval of 12.7 mm). Not only was that estimate lowest at 0.07 but the large variance also resulted in the widest confidence limits (±150%). Although most survival estimates were of comparable magnitude, variances were a function of sample size, which decreased as the mesh interval increased. In the pursuit of indexing, sample size can to some extent be controlled by the amount of gear fished. Nonetheless, mesh series 4 produced the most disjointed age distribution and fewest age groups (Table 10, Appendix C). The percentage frequency of 4- and 5-year-old chubs was quite consistent between most mesh series within month, mesh series 4 being the least. Thus, an interval of 12.7 mm cannot be trusted to produce consistently reliable results.

The predominance of age-4 chubs increased from 53.8% in April to 64.6% in August (series 1 in Table 10), which presumable was due to additional growth that increased catchability. Even so, 4-year-old chubs were not fully vulnerable to the experimental gill nets, and that is why survival rate was based on age-5 and older fish.

DISCUSSION

Selectivity of various combinations of mesh sizes in experimental gill-net gangs, which could be used to index the Lake Michigan bloater chub population, were evaluated by several categories: the goodness of fit between observed and theoretical frequencies of fish length:mesh perimeter ratios, weight-length regressions, von Bertalanffy's K coefficients, and survival rates. These categories were ranked for each mesh-size series, and the sum of ranks used to determine which series produced the best overall results (the lowest score).

The sum of ranks in April indicated that mesh series 1 and 5 produced the best overall results (Table 11). Economically, mesh series 5 (variable mesh sizes) would be preferred over series 1 (1.6-mm interval) because the former requires only 20% of the fishing and processing effort to obtain similar overall results. However, there are some differences within categories between the two series, as discussed in the results section; namely, series 5 is superior in the master curve and von Bertalanffy K coefficient categories, but was ranked third in the survival rate class (although the survival estimates given in Table 9 are similar at 0.12 and 0.11). There remains the possibility that selection of a group of mesh sizes, which is tailored to match differences in the distribution of length classes in adjacent meshes, may reflect that segment of the population momentarily available to the experimental gear. That such a condition may have occurred is suggested by the mesh size configuration of series 5 (variable mesh intervals) determined for the August catch, which differed modestly from the April series 5.

In August, the sum of ranks showed mesh series 2 (interval on 3.2 mm) to be the most desirable combination. Although the ordered sum of ranks in April closely followed the ranking of the series in the master-curve category, there was no such pattern in the August sum of ranks. This incongruity suggests that either the August data were inadequate, or that selectivity curves based on fish length:mesh perimeter ratios are not the only criteria upon which to design a series of mesh sizes for indexing chubs. Inadequacy in the selectivity curves may have occurred because length rather than girth was used in the fish size:mesh perimeter ratio. There was little difference in the distribution of length classes between months, but a notable discrepancy in condition factor occurred between the two time periods when the August means were the greater. If a change in condition factor implies a change in girth, then changes in selectivity over time may not be fully described by the fish length:mesh perimeter ratio method used in the analysis.

There may be no single combination of mesh sizes that does everything equally well. Thus, the chub stocks should be indexed with an experimental gang of gill nets that minimizes effort and reasonably approximates population parameters. Although of middle rank in April, an experimental gill-net gang, consisting of mesh sizes 50.9–73.0 mm on an interval of 3.2 mm, is recommended to index the fishable segment of the chub stocks in preference to meshes on a 1.6 mm or variable intervals. Mesh series 2 would reduce effort and processing time by 50% as compared to series 1, and lower the risk of tailoring a combination to fit the population that may exhibit a peculiar length distribution at some particular time. Mostly because all mesh series included the efficient 50.9-mm mesh, none of the observed length distributions could be declared to differ significantly at the 0.05 level from their normalized frequencies.

Nevertheless, it would be prudent to avoid using index gill nets with mesh intervals of 6.4 mm or larger.

A series of gill nets with the smallest mesh being 50.8 mm would adequately index the commercially exploitable segment of the chub stocks. In commercial gill nets, the modal total length of chubs varies from 26 to 27 cm, depending on the locality, season, and mesh size. If one wished to index pre-recruits as well as the fishable bloater stock, then the experimental gill-net gang must also contain smaller mesh sizes, perhaps beginning at 25.4 mm, to sample effectively length classes less than 26 cm. However, a series of very small-meshed gill nets is not an efficient mode of sampling the smaller members of the chub population. Trawls are a much more effective gear for indexing that segment of the stock, but that would require a statistical method of integrating the catches from the two types of gear.

ACKNOWLEDGMENTS

I wish to thank Kelley Smith for his indispensable analytical advice, Dr. W. Carl Latta for his editing efforts, Grace Zurek for typing the manuscript, and the crew members of the research vessel *S/V Steelhead* for the collection of data.

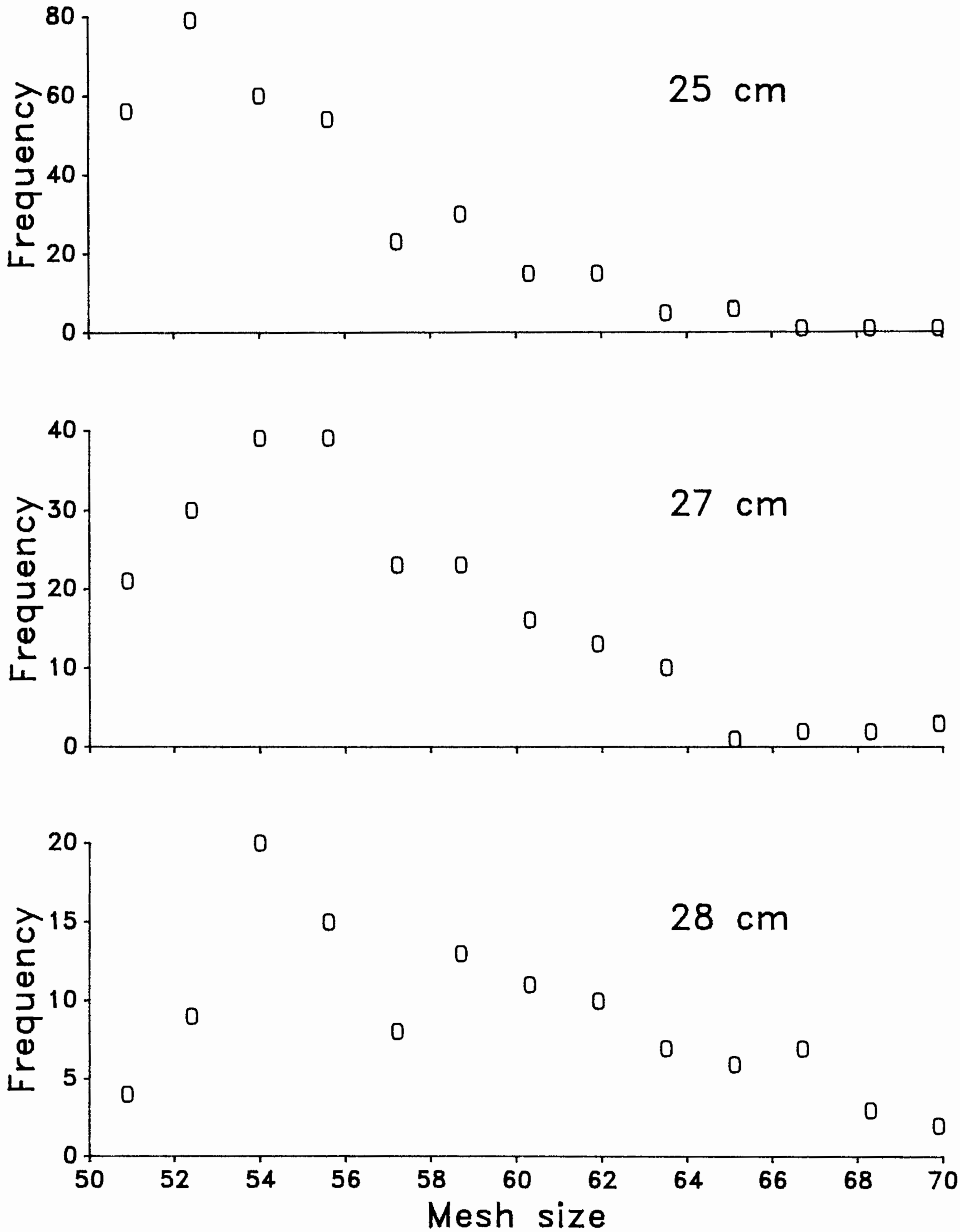

Figure 1. Frequency of bloater chubs in the 25-, 27-, and 28-cm length classes caught in each mesh size 50.9–69.9 mm on a 1.6-mm interval during April.

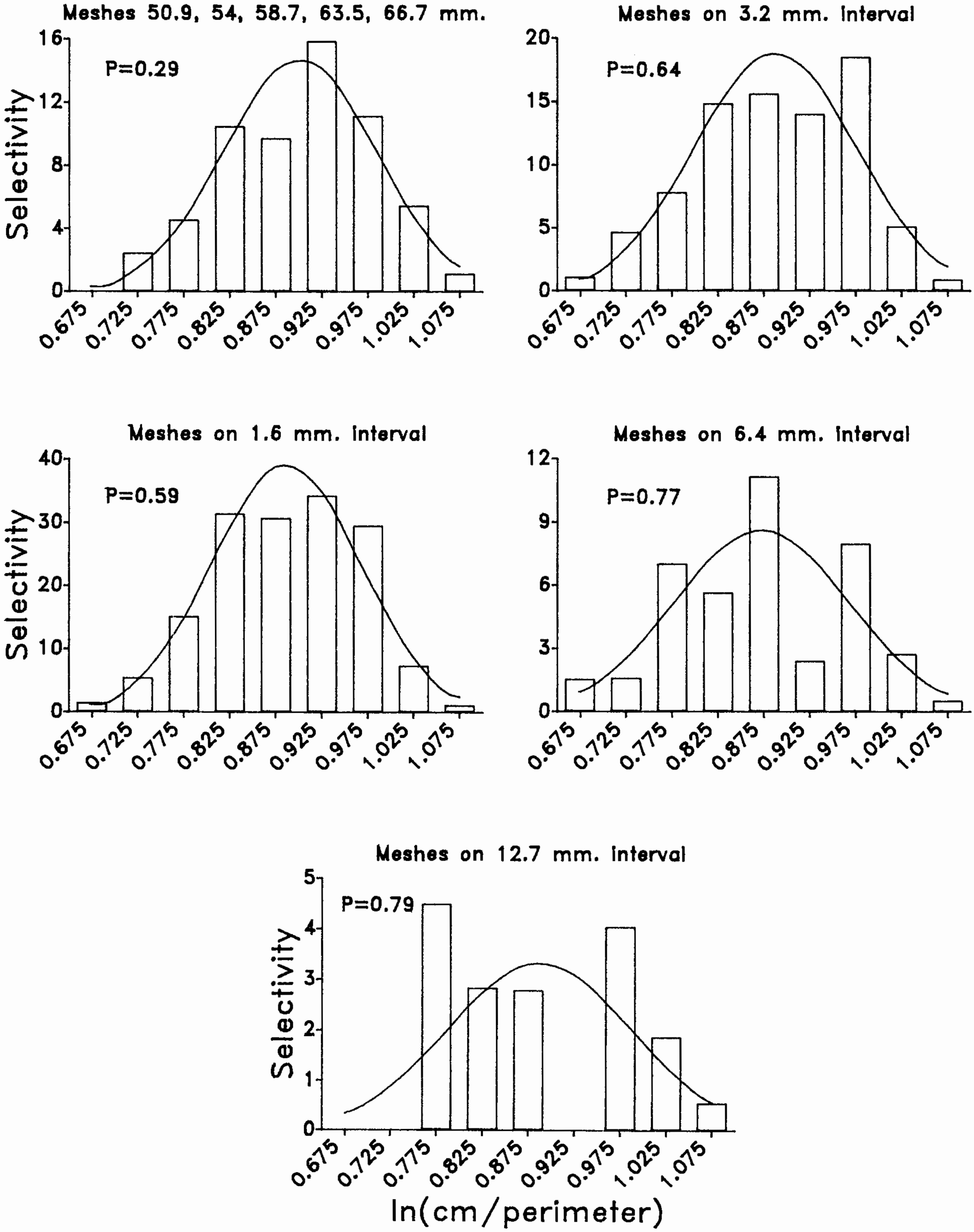

Figure 2. Master selectivity curves for bloater chubs in various combinations of mesh sizes in April.

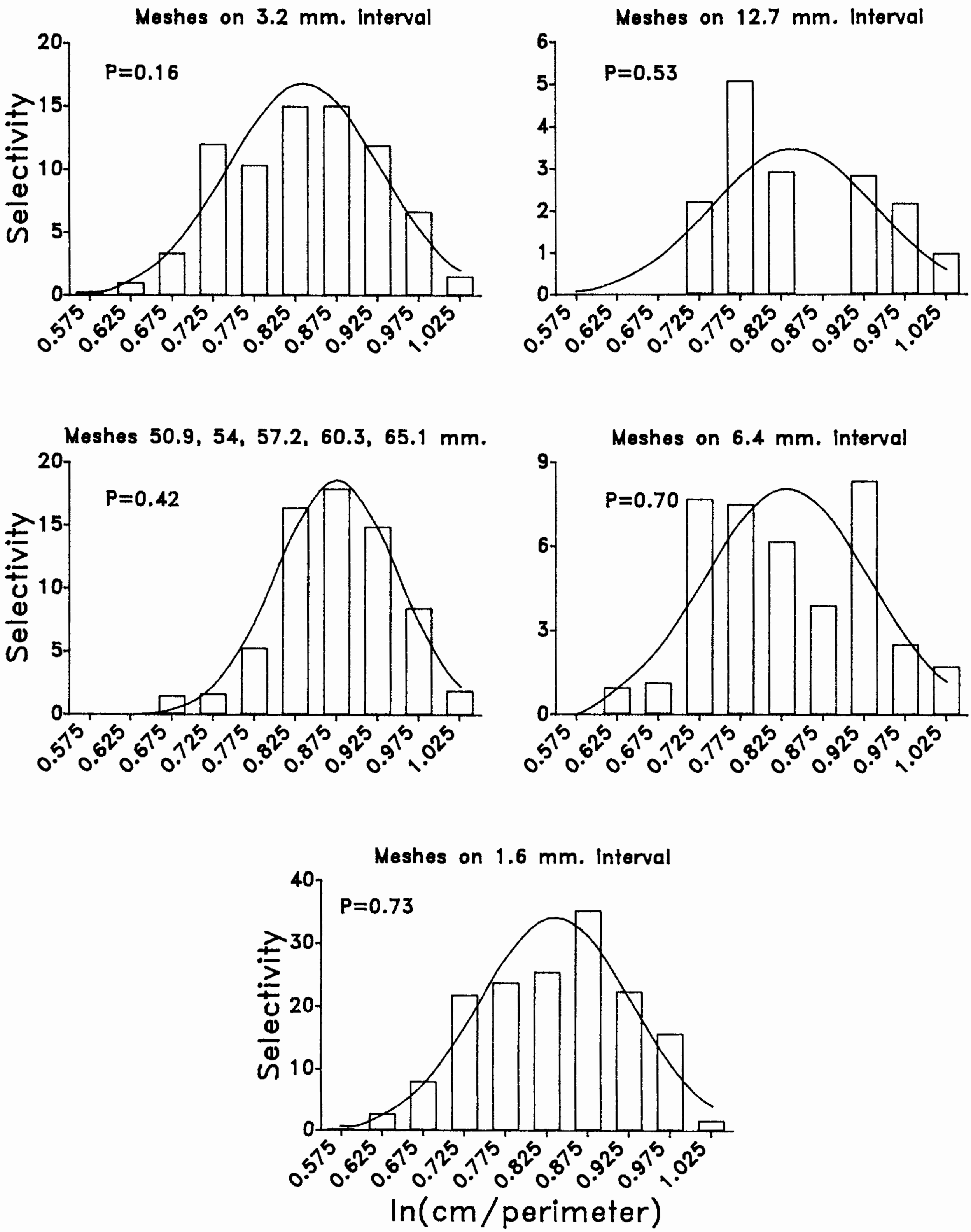

Figure 3. Master selectivity curves for bloater chubs in various combinations of mesh sizes in August.

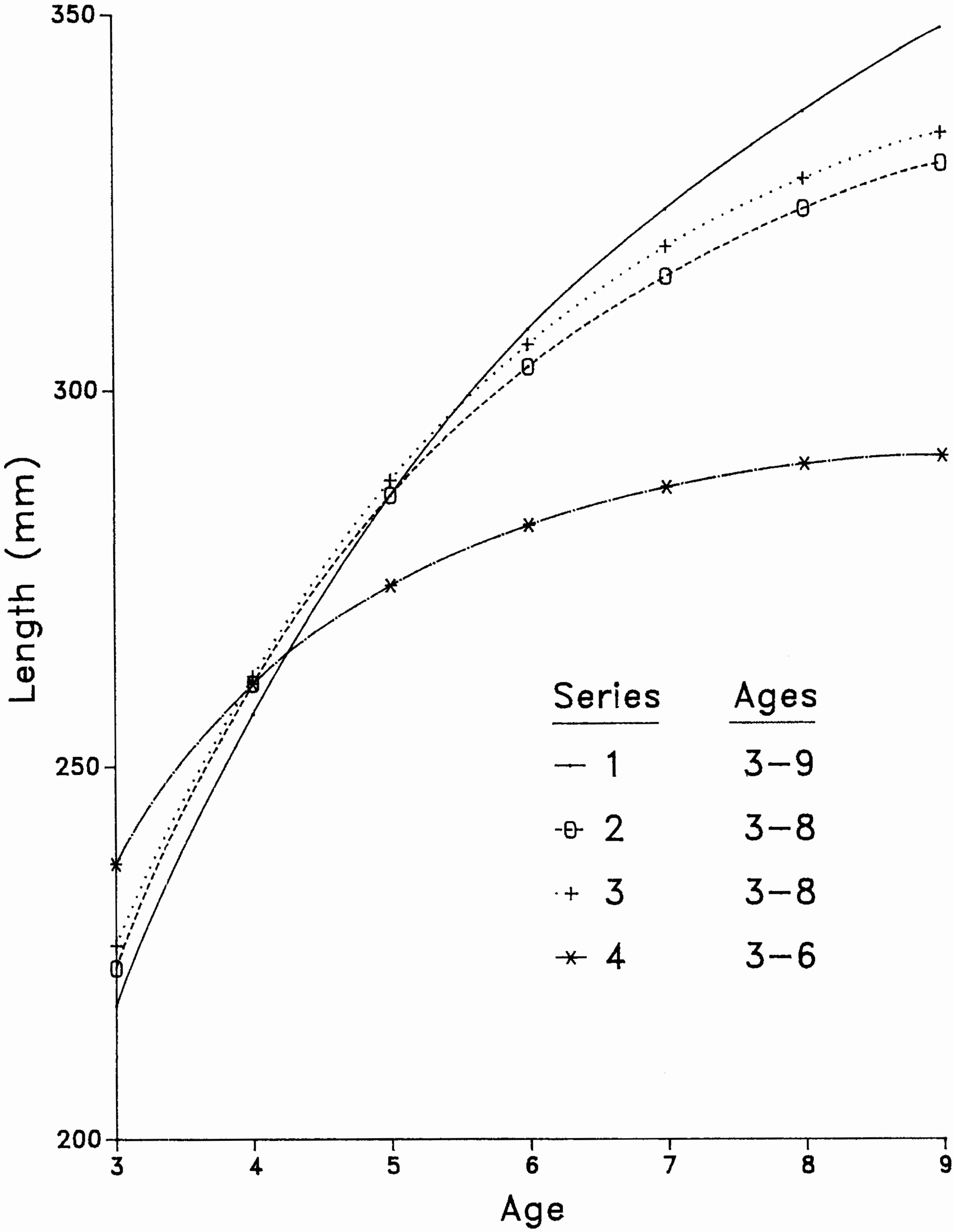

Figure 4. Predicted length-at-age for bloater chubs caught in experimental gill nets in April by mesh series.

Table 1. Combinations of mesh sizes in each selectivity series tested by month.

Month	Series number	Interval (mm)	Mesh size (mm)
April	1	1.6	50.9–69.9
	2	3.2	50.9–69.9
	3	6.4	50.9–69.9
	4	12.7	50.9–76.2
	5	variable	50.9, 54.0, 58.7, 63.5, 66.7
August	1	1.6	50.9–73.0
	2	3.2	50.9–76.2
	3	6.4	50.9–69.9
	4	12.7	50.9–76.2
	5	variable	50.9, 54.0, 57.2, 60.3, 65.1

Table 2. Percentage distribution of length of chubs (21–30+ cm) in graded-mesh gill nets (50.9–73.0 mm) by month, 1984–85. Sample size in April was 1,490 fish and in August 2,377 fish.

Length class	April	August
21	0.5	1.6
22	2.0	3.6
23	6.7	8.8
24	16.9	16.8
25	23.6	23.9
26	21.7	21.8
27	15.2	13.5
28	7.8	6.6
29	3.0	1.9
30+	2.7	1.6

Table 3. Mean condition factor of chubs in experimental gill nets (meshes on 1.6-mm intervals) by month and sex, 1984–85. Number of fish in parentheses.

Month	Male	Female
April	0.75 (507)	0.77 (848)
August	0.81 (769)	0.84 (1,651)

Table 4. Mean and adjusted mean weight (g) of chubs in April by mesh series.

Mesh number	Observed	Adjusted
1	133	131
2	135	133
3	132	132
4	125	130
5	131	131

Table 5. Comparison of calculated slopes (b) and intercepts (a) to the mean of each parameter for length-weight regressions of chubs caught in various combinations of mesh sizes in August.

Parameter	Coefficient	Standard error	P level
Mean B	3.02317	0.03471	0.00
Mean A	-11.83776	0.19245	0.00
Contrast[1] **(b_i-B)**			
b_1	0.0094	0.0508	0.854
b_2	0.0482	0.0625	0.440
b_3	0.1536	0.0763	0.044
b_4	0.0235	0.0834	0.778
b_5	-0.2348	0.0692	0.001
(a_i-A)			
a_1	-0.0480	0.2822	0.865
a_2	-0.2602	0.3472	0.454
a_3	-0.8502	0.4233	0.045
a_4	-0.1410	0.4623	0.760
a_5	1.2995	0.3841	0.001

[1]Subscript i corresponds to the following mesh series:

1 = mesh series 50.9–73.0 mm on 1.6-mm intervals.
2 = mesh series 50.9–73.0 mm on 3.2-mm intervals.
3 = mesh series 50.9–69.9 mm on 6.4-mm intervals.
4 = mesh series 50.9–76.2 mm on 12.7-mm intervals.
5 = mesh series 50.9, 54.0, 57.2, 60.3, and 65.1 mm.

Table 6. Slopes and confidence limits of the weight-length regressions of chubs caught in various combinations of mesh sizes in August.

Series number	Slope (b)	95% confidence limits	Limits as percent of slope
1	3.0326	±0.0942	3.1
2	3.0715	±0.1318	4.3
3	3.1768	±0.1721	5.4
4	3.0467	±0.1921	6.3
5	2.7883	±0.1518	5.5

Table 7. The von Bertalanffy growth coefficients obtained for chubs based on age-3 and older fish and forced through zero, by month and mesh series.

Mesh number	L	T	K	95% confidence limits	Limits as percent of K
April					
1	373	-0.0332	0.2909	±0.1249	43
2	344	0.0015	0.3545	±0.1625	46
3	350	-0.0149	0.3431	±0.1651	48
4	293	-0.0018	0.5539	±0.2406	43
5	287	-0.0011	0.5931	±0.1819	31
August					
1	523	-0.1184	0.1565	±0.1249	80
2	422	-0.0541	0.2285	±0.1755	77
3	459	-0.0656	0.1984	±0.1670	84
4	293	-0.0011	0.5374	±0.1415	26
5	337	-0.0116	0.3712	±0.2131	57

Table 8. The von Bertalanffy growth coefficients obtained for chubs based on age groups 3–6 and forced through zero, by month and mesh series.

Mesh number	L	T	K	95% confidence limits	Limits as percent of K
April					
1	291	–0.0013	0.5682	±0.1907	34
2	289	–0.0013	0.5804	±0.2117	36
3	296	–0.0018	0.5424	±0.2282	42
4	293	–0.0018	0.5539	±0.2406	43
5	294	–0.0011	0.5501	±0.1389	25
August					
1	298	–0.0016	0.5217	±0.1691	32
2	294	–0.0011	0.5501	±0.1389	25
3	294	–0.0011	0.5418	±0.1300	25
4	293	–0.0011	0.5374	±0.1415	26
5	291	–0.0011	0.5659	±0.1578	28

Table 9. Annual survival rate of chubs by month and mesh series.

Mesh number	Age group	Annual survival	95% confidence limits	95% confidence limits as percent of survival
April				
1	5–7+[1]	0.12	±0.037	30
2	5–7+	0.13	±0.057	43
3	5–7+	0.15	±0.081	53
4	5–7+	0.14	±0.106	74
5	5–7+	0.11	±0.053	48
August				
1	5–8+	0.13	±0.046	36
2	5–8	0.12	±0.053	46
3	5–7+	0.12	±0.087	74
4	5–6	0.07	±0.107	150
5	5–7	0.10	±0.059	60

[1] + indicates pooled ages.

Table 10. Percentage age frequency of chubs in the April and August catches by mesh series.

Age group	1	2	3	4	5
April					
2	0.1	0.1	—	—	0.2
3	6.4	6.4	9.2	11.3	6.7
4	53.8	52.1	54.6	59.5	52.5
5	34.9	35.7	31.3	25.9	36.2
6	4.5	5.1	4.1	2.8	4.2
7	0.2	0.3	0.3	—	—
8	0.2	0.3	0.5	0.4	0.2
9	0.1	—	—	—	—
Number	661	337	186	125	299
August					
2	0.1	—	—	—	—
3	16.3	15.7	20.3	26.2	17.2
4	64.6	64.5	60.9	58.5	65.5
5	17.1	17.9	17.2	14.4	15.9
6	1.4	1.4	1.2	1.0	1.0
7	0.4	0.3	0.2	—	0.4
8	0.1	0.2	0.2	—	—
9	0.1	—	—	—	—
Number	1,182	624	325	195	533

Table 11. Ranking of variable indices by mesh series and month.

Mesh series	Master curve		Weight-length regression		Survival		von Bertalanffy K		Sum of ranks
	Index	Rank	Index	Rank	Index	Rank	Index	Rank	
April									
1	59	2	0	0	30	1	34	2	5
2	64	3	0	0	43	2	36	3	8
3	77	4	0	0	53	4	42	4	12
4	79	5	0	0	74	5	43	5	15
5	28	1	0	0	48	3	25	1	5
August									
1	73	5	3.1	1	36	1	32	5	12
2	16	1	4.3	2	46	2	25	2	7
3	70	4	5.4	3	74	4	25	1	12
4	51	3	6.3	5	150	5	26	3	16
5	42	2	5.5	4	60	3	28	4	13

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Report approved by W. C. Latta

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Appendix A1. Number of chubs caught in experimental gill nets in April 1984–85, by length group and mesh size.

Length group (cm)	Mesh size (mm)												
	50.9	52.4	54.0	55.6	57.2	58.7	60.3	61.9	63.5	65.1	66.7	68.3	69.9
18	—	—	—	—	—	1	—	1	—	1	—	—	—
19	—	—	1	—	2	—	1	—	—	1	—	—	—
20	—	—	—	1	—	—	—	—	—	—	—	—	—
21	—	3	—	1	1	—	1	—	—	—	1	1	—
22	9	8	1	4	2	3	1	—	—	—	2	—	—
23	22	39	13	11	5	3	—	1	2	2	—	—	—
24	64	70	38	36	15	9	5	5	—	2	1	1	1
25	56	79	60	54	23	30	15	15	5	6	1	1	1
26	42	64	63	55	22	22	13	13	11	4	9	1	1
27	21	30	39	39	23	23	16	13	10	1	2	2	3
28	4	9	20	15	8	13	11	10	7	6	7	3	2
29	1	2	2	6	3	9	4	5	7	2	1	—	2
30	—	—	2	1	5	1	2	2	1	1	—	1	1
31	—	—	1	—	1	1	1	—	3	2	—	1	1
32	—	—	—	—	—	—	—	—	1	1	1	—	1
33	1	—	—	—	—	—	1	—	—	—	—	—	—
34	—	—	—	—	1	—	—	—	—	—	—	—	—
35–40	—	—	—	—	—	—	—	1	—	—	—	—	—
Total	220	304	240	223	111	115	71	66	47	29	25	11	13

Appendix A1. Continued:

Length group (cm)	Mesh size (mm)												Total
	71.4	73.0	74.6	76.2	77.8	79.4	81.0	82.6	84.1	85.7	87.3	88.9	
18	—	—	—	—	—	—	—	—	—	—	—	—	3
19	—	—	—	—	—	1	—	—	—	—	—	—	6
20	—	—	—	—	—	1	—	—	—	—	—	—	2
21	—	—	—	—	—	1	—	—	—	—	—	—	9
22	—	—	—	—	—	2	—	—	—	—	—	—	32
23	1	1	—	—	—	—	—	—	—	—	—	—	100
24	2	3	—	—	—	—	—	—	—	—	—	—	252
25	2	1	2	—	1	2	—	—	—	—	—	—	354
26	1	1	1	—	—	—	1	—	—	—	1	—	325
27	2	—	2	—	—	1	—	—	—	—	—	—	227
28	1	—	—	—	—	—	—	—	—	—	—	—	116
29	—	—	—	—	—	—	—	—	—	—	—	—	44
30	1	—	—	—	—	—	—	—	—	—	—	—	18
31	—	1	—	—	—	—	—	—	—	—	—	—	12
32	—	—	—	—	—	—	—	—	—	—	—	—	4
33	—	—	—	—	—	—	—	—	—	—	—	—	2
34	1	—	—	—	—	—	—	—	—	—	—	—	2
35–40	1	—	—	—	—	—	—	—	—	—	1	—	3
Total	12	7	5	0	1	8	1	0	0	0	2	0	1,511

Appendix A2. Number of chubs caught in experimental gill nets in August 1984–85, by length group and mesh size.

Length group (cm)	Mesh size (mm)												
	50.9	52.4	54.0	55.6	57.2	58.7	60.3	61.9	63.5	65.1	66.7	68.3	69.9
18	—	—	—	1	2	1	3	2	—	2	—	—	2
19	1	2	—	3	—	1	—	—	—	—	1	1	1
20	1	2	2	2	—	—	1	—	1	2	3	—	—
21	5	7	6	3	1	2	1	4	2	1	1	—	3
22	27	27	5	7	4	4	—	2	2	2	2	—	1
23	47	51	25	28	8	6	5	5	4	7	5	6	2
24	60	88	57	65	33	27	12	13	6	14	8	8	4
25	78	72	100	72	53	52	34	34	14	12	17	5	10
26	37	51	103	64	45	46	27	42	29	21	18	7	11
27	22	23	33	38	34	23	42	23	24	14	20	11	10
28	7	6	14	11	9	15	20	13	19	12	8	8	8
29	—	—	3	5	8	2	5	3	4	2	1	1	7
30	—	—	—	1	—	2	2	2	—	—	3	2	1
31	—	—	—	—	—	—	3	1	3	1	—	1	1
32	—	—	—	—	—	—	—	2	—	—	—	—	—
33	—	—	—	—	—	—	1	—	—	—	—	—	—
34	—	—	—	1	—	—	—	—	—	—	—	—	—
35–40	—	—	—	1	—	—	—	—	—	1	—	1	—
Total	285	329	348	302	197	181	156	146	108	91	87	51	61

Appendix A2. Continued:

Length group (cm)	Mesh size (mm)												Total
	71.4	73.0	74.6	76.2	77.8	79.4	81.0	82.6	84.1	85.7	87.3	88.9	
18	—	—	—	—	—	—	—	—	—	1	3	—	17
19	2	1	—	—	3	—	—	—	2	—	1	1	20
20	—	1	—	—	—	—	1	2	—	—	1	—	19
21	—	—	2	—	2	1	1	1	1	—	—	1	45
22	2	—	—	—	1	—	2	1	1	1	3	1	95
23	2	4	3	—	—	2	2	1	2	—	1	—	216
24	2	3	—	—	1	2	—	4	—	2	7	1	417
25	11	2	1	—	4	3	2	3	2	—	1	—	582
26	10	4	2	—	4	1	1	1	—	—	—	3	527
27	2	3	—	—	1	—	2	1	1	—	—	1	328
28	5	1	1	—	—	—	—	—	1	—	—	—	158
29	1	—	2	—	1	—	—	—	—	—	—	—	45
30	1	—	1	—	—	—	—	—	—	—	—	—	15
31	—	—	—	—	1	—	—	—	—	—	—	—	11
32	—	—	1	—	—	—	—	—	—	—	—	—	3
33	—	—	2	—	—	—	—	—	—	—	—	—	3
34	—	1	—	—	—	—	—	—	1	—	—	—	3
35–40	1	1	—	—	1	—	—	1	—	—	—	—	7
Total	39	21	15	0	19	9	11	15	11	4	17	8	2,511

Appendix B. Mean total length-at-age (mm) of chubs, by month and mesh series. Sample size is in parentheses, 1984–85.

Age group	Mesh series 1	2	3	4	5
April					
2	270 (1)	270 (1)	— —	— —	270 (1)
3	243 (84)	244 (43)	244 (34)	244 (28)	243 (40)
4	255 (709)	255 (349)	255 (201)	253 (147)	255 (312)
5	268 (459)	267 (239)	268 (115)	267 (64)	267 (215)
6	288 (59)	288 (34)	293 (15)	291 (7)	285 (25)
7	337 (2)	337 (2)	344 (1)	— —	— —
8	325 (2)	325 (2)	325 (2)	325 (1)	325 (1)
9	365 (1)	— —	— —	— —	— —
August					
2	228 (2)	— —	— —	— —	— —
3	241 (385)	241 (195)	240 (131)	238 (102)	242 (183)
4	256 (1,525)	257 (803)	257 (393)	256 (228)	256 (696)
5	270 (403)	270 (223)	270 (111)	267 (56)	269 (169)
6	292 (33)	288 (17)	288 (8)	287 (4)	287 (11)
7	331 (10)	329 (4)	346 (1)	— —	333 (4)
8	386 (2)	386 (2)	392 (1)	— —	— —
9	420 (1)	— —	— —	— —	— —

Appendix C. Mean age frequency of chubs in the April and August catches, by mesh series, 1984–85.

Age group	Mesh series				
	1	2	3	4	5
April					
2	1	1	—	—	1
3	42	22	17	14	20
4	355	175	101	74	156
5	230	120	58	32	108
6	30	17	8	4	13
7	1	1	1	0	0
8	1	1	1	1	1
9	1	—	—	—	—
Number	661	337	186	125	299
August					
2	1	—	—	—	—
3	193	98	66	51	92
4	763	402	197	114	348
5	202	112	56	28	85
6	17	9	4	2	6
7	5	2	1	—	2
8	1	1	1	—	—
9	1	—	—	—	—
Number	1,183	624	325	195	533