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TESTS ON THE EFFECT OF MESH SIZE ON THE CAPTURE OF STRIPED BASS LARVAE IN THE SACRAMENTO-SAN JOAQUIN ESTUARY

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A Cooperative Study by:

California Department of Water Resources
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INTRODUCTION

Striped bass, *Morone saxatilis,* are the dominant sport fish of the Sacramento-San Joaquin Estuary, and their abundance has declined since the middle 1960s (Stevens et al, 1985). Several hypotheses have been proposed to explain this decline: reduced egg production, inadequate food supply, egg and larva entrainment, and toxics. All these suggest that year class success depends largely on the success of the earlier life stages.

Because of renewed interest in defining the factors that control early life stages, striped bass egg and larva surveys have become an important research tool in studying the bass decline. Since 1966, the California Department of Fish and Game has conducted field surveys to index the abundance of striped bass eggs and larvae. In 1988, DFG described field sampling methods, sampling stations, and analytical methods from 1984 through 1986 and reviewed surveys from 1968 to 1977 *(CDFG, 1988)*.

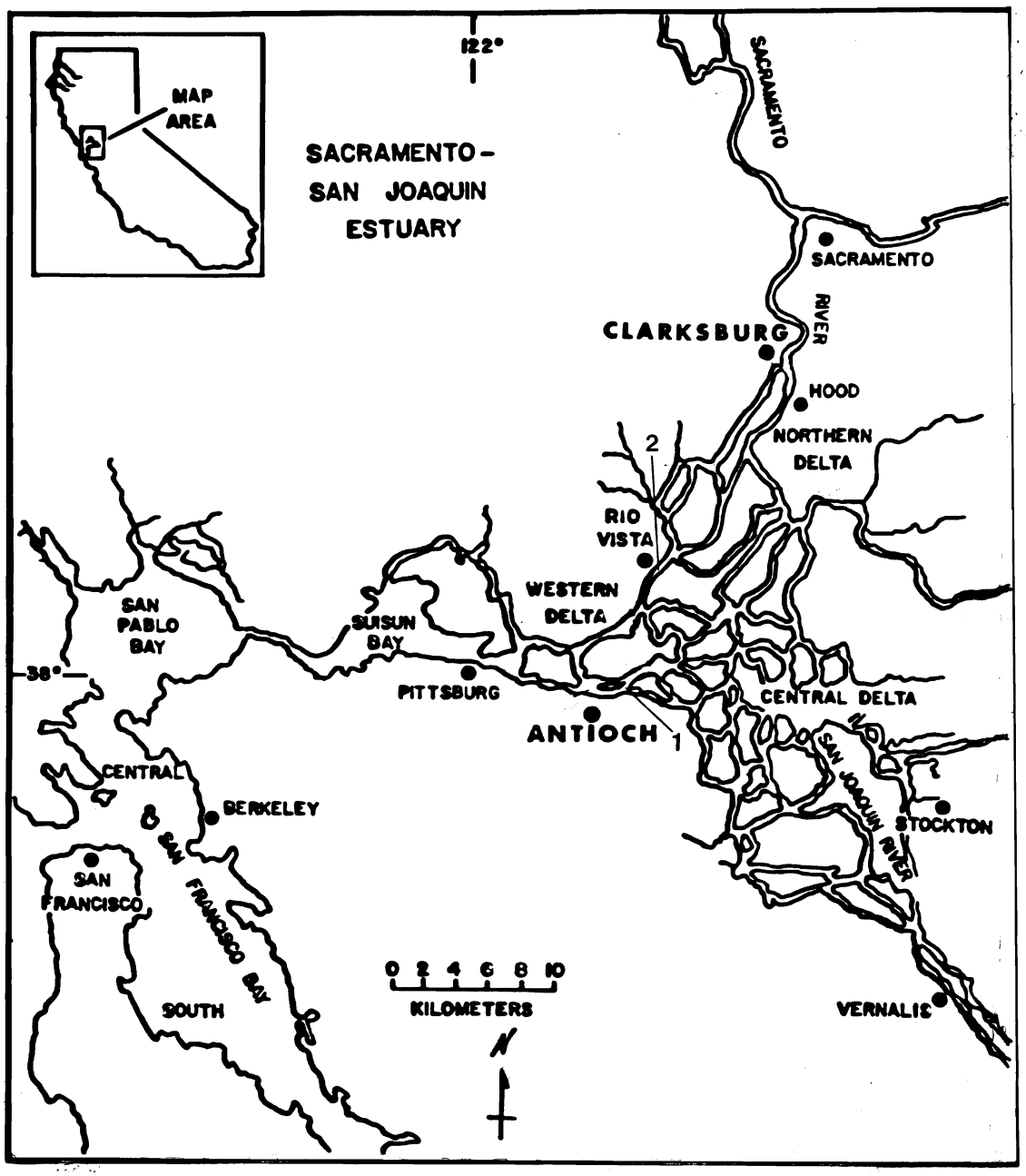
Since 1975, the primary sampling gear for the egg and larva surveys has been ichthyoplankton nets constructed from 505 micron nylon mesh netting. *Miller (1977)* found that nets used earlier were inefficient due to net design and mesh size (903 μm). Catches for larvae smaller than 6 mm consistently have been lower than catches of 6 mm larvae. Since higher catches of smaller larvae would be expected, I hypothesized that many smaller larvae were being extruded through the 505 μm mesh. Therefore, in 1987, a series of field experiments was conducted to determine effects of mesh size on larval bass catches. Accurate estimates of abundance are extremely important for determining survival and mortality.

METHODS

Nets with 335 and 400 μm Nitex nylon mesh were constructed to the same design and dimensions as the present 505 μm egg and larva net. The three nets were compared on the San Joaquin and Sacramento rivers in spring 1987 (Figure 1).

Fish eggs and larvae were preserved, processed, identified, and enumerated in the same manner as during routine surveys, except that standard length measurements were made to the nearest 0.5 mm instead of 1.0 mm.

Figure 1
LOCATION OF FIELD TRIALS OF EGG AND LARVA NETS WITH DIFFERENT MESH SIZES
San Joaquin River (1) and Sacramento River (2)



San Joaquin River Mesh Size Comparison

The three nets (335, 400, and 505 μm) were fished simultaneously from three boats at Egg and Larva Survey Station 39, near West Island, on May 5 and 7. Stepped oblique tows were made heading upstream for 10 minutes each, regardless of the tide. The boats were positioned about 30 meters apart in the center of the shipping channel and maintained in this array for the duration of each tow. Boats alternated position within the array after every tow.

Sacramento River Mesh Size Comparison

Catch data from 335 and 505 μm mesh were examined from stepped oblique 10-minute tows in the Sacramento River at Station 29, near Rio Vista, on May 21. Because only one boat was available, nets were mounted on similar sleds and alternated after two or three tows.

Statistical Procedures

I tested for differences in mean catch densities of larvae of the following lengths: 4 mm, 5 mm, 6 mm, 7 mm, 8 mm, and greater than 8 mm. Mean densities were transformed by $\log_e$ (density $\div$ 1000 m^3 + 1) to normalize and equalize sample variances, and a one-way ANOVA, or t-test, was applied to determine significant differences *(SAS, 1985)*.

Where mean catch densities from three mesh sizes were tested by ANOVA, the Student-Newman-Keuls multiple range test was used to determine which mesh sizes were significantly different from each other. If the number of tows for each treatment (mesh size) was not equal, significance testing was done using the General Linear Model option for the SNK test (*SAS, 1985)*. Mean (arithmetic) and standard deviation values given in this report were calculated from untransformed data.

Length frequency distributions of the total catch from each net during each trial were compared by inspecting length frequency histograms and by using the Kolmogorov-Smirnov test for significant differences between sample frequency distributions *(Smith and Richardson, 1977)*.

RESULTS

San Joaquin River Mesh Size Comparison

The apparent effect of mesh size on mean density varied between days for striped bass larvae smaller than 6 mm (Tables 1 and 2). On May 5, there was no statistically significant difference ($P > 0.37$) between mesh sizes for catches of these larvae, although nets with finer mesh had slightly lower catch densities. In contrast (and contrary to expectations), on May 7, the 335 μm net caught significantly fewer 4 mm ($P < 0.01$) and 5 mm ($P < 0.0001$) bass than were caught in the 400 or 505 μm mesh nets.

Differences in mean catch densities of striped bass larvae were not statistically significant for any size larger than 5 mm on either sampling day, although mean densities of 6 mm striped bass larvae were higher for the 505 μm mesh than for either of the smaller meshes.

Length frequency histograms also showed that the catches were more skewed toward smaller larvae in nets with larger mesh sizes (Figures 2 and 3). The proportions caught in the 5.5 to 6.0 mm length range were greater in larger meshes. Overall, mean body length of bass larvae caught in the 505 μm mesh was smaller than for larvae caught in the 335 and 400 μm nets. Kolmogorov-Smirnov testing showed that length frequency distributions differed significantly between mesh sizes ($P < 0.001$) in five out of six comparisons (Table 3).

Sacramento River Mesh Size Comparison

In the Sacramento River, none of the comparisons of mean catch densities within length intervals showed significant differences ($P > 0.17$) due to mesh size (Table 4). However, mean catch densities of smaller larvae (4 and 5 mm) again were greater in the 505 μm mesh net.

Length frequencies showed that the 505 μm mesh net caught relatively more 5.5 mm bass larvae than did the 335 μm mesh net, but the converse was true for 6.0 mm larvae (Figure 4). Mean larval size was smaller for bass caught in the 505 μm mesh net than for bass from the 335 μm mesh. The difference between the length frequency distributions of summed catches was highly significant (D-max = 0.1389; $P < 0.001$).

Table 1
CATCHES OF SEVERAL LENGTH GROUPS OF STRIPED BASS CAUGHT IN THREE MESH SIZES, SAN JOAQUIN RIVER, MAY 5, 1987
(Larvae per 1000 Cubic Meters)

		Striped Bass Larva Length					
		4 mm	5 mm	6 mm	7 mm	8 mm	>8 mm
335 μm	$\bar{x}$	18.0	578.8	592.5	257.3	202.3	125.6
(N=13)	SD	16.1	369.3	311.0	157.5	142.1	105.0
400 μm	$\bar{x}$	19.5	601.0	617.7	256.5	195.1	116.8
(N=14)	SD	22.4	245.2	200.0	122.7	82.4	68.3
505 μm	$\bar{x}$	19.4	733.9	728.8	250.8	190.3	101.9
(N=14)	SD	18.4	373.4	358.3	139.3	111.6	50.1
Ratios of Mean Density:							
335 : 505		0.93	0.79	0.81	1.03	1.06	1.23
400 : 505		1.01	0.82	0.85	1.02	1.03	1.15
ANOVA Results on Mean Densities:							
	F	0.02	1.00	0.75	0.01	0.01	0.28
	P	0.98	0.38	0.48	0.99	0.99	0.76

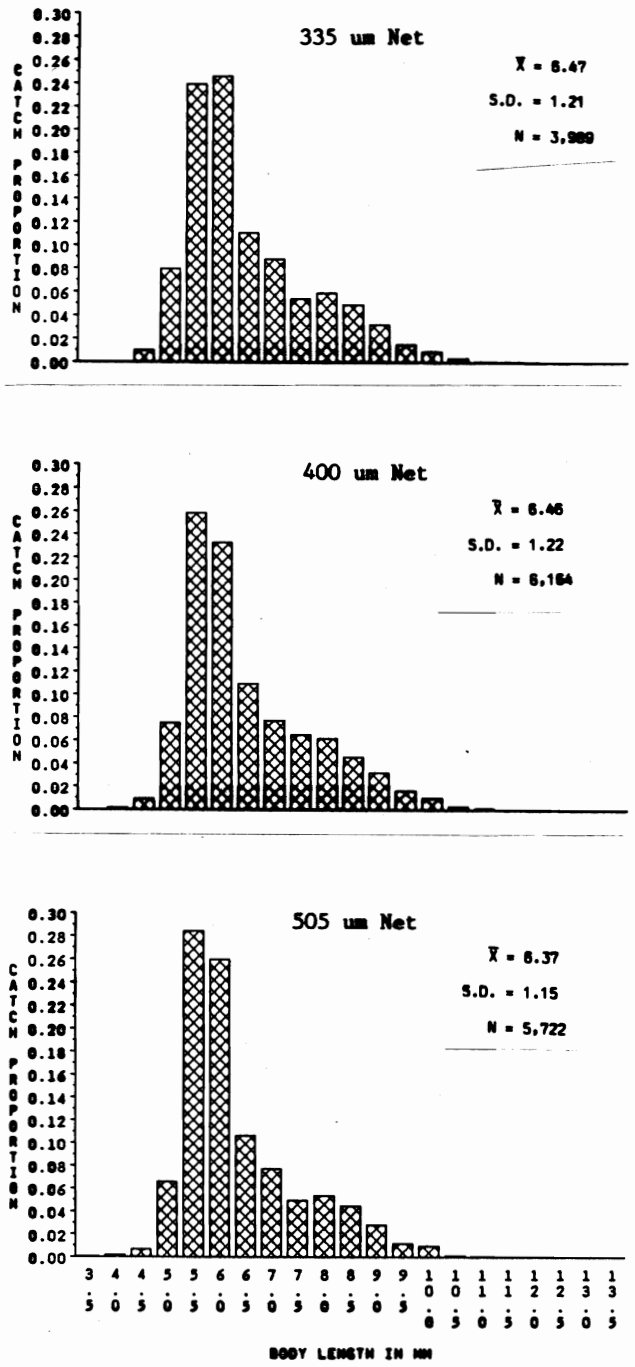
$\bar{x}$ = Mean Density per Length Interval
SD = Standard Deviation
N = Number of Tows

Table 2
CATCHES OF SEVERAL LENGTH GROUPS OF STRIPED BASS CAUGHT IN THREE MESH SIZES, SAN JOAQUIN RIVER, MAY 7, 1987
(Larvae per 1000 Cubic Meters)

		Striped Bass Larva Length					
		4 mm	5 mm	6 mm	7 mm	8 mm	>8 mm
335 μm	$\bar{x}$	18.2*	261.3*	502.4	282.6	190.0	190.2
(N=8)	SD	18.8	154.6	123.2	139.4	94.5	135.8
400 μm	$\bar{x}$	72.4	503.3*	569.2	286.1	150.9	94.7
(N=8)	SD	24.0	123.4	243.0	206.5	56.2	38.3
505 μm	$\bar{x}$	88.5	772.5*	610.2	314.0	164.9	138.4
(N=8)	SD	67.6	181.6	161.5	155.5	97.7	121.7
Ratios of Mean Density:							
335 : 505		0.21	0.34	0.82	0.90	1.15	1.37
400 : 505		0.82	0.65	0.93	0.91	0.92	0.68
ANOVA Results on Mean Densities:							
	F	6.52	26.70	2.08	0.52	0.10	1.58
	P	0.006	0.0001	0.15	0.60	0.91	0.24

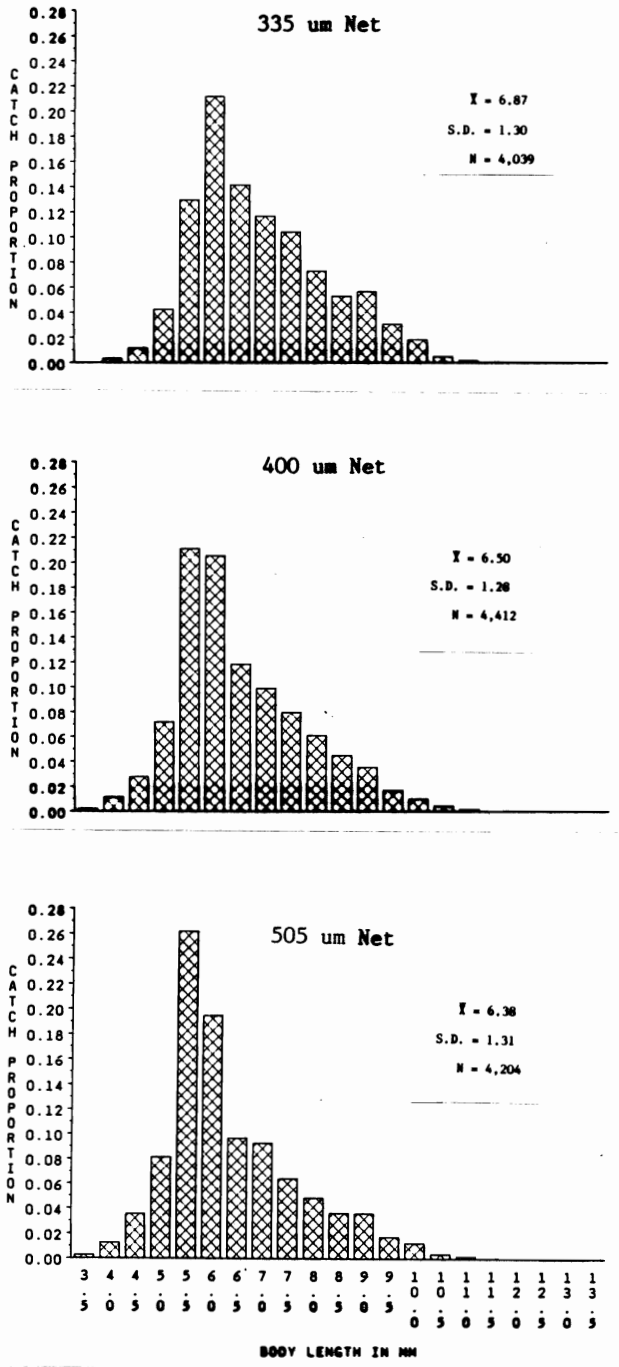
$\bar{x}$ = Mean Density per Length Interval
SD = Standard Deviation
N = Number of Tows
* Means differed significantly (P = 0.05, SNK Multiple Range Test)

Figure 2
LENGTH FREQUENCY HISTOGRAMS OF STRIPED BASS LARVAE COLLECTED WITH 335, 400, AND 505 μm NETS, SAN JOAQUIN RIVER, MAY 5, 1987



$\bar{x}$ = Mean Body Length
SD = Standard Deviation
N = Number of Larvae

Figure 3
LENGTH FREQUENCY HISTOGRAMS OF STRIPED BASS LARVAE COLLECTED WITH 335, 400, AND 505 μm NETS, SAN JOAQUIN RIVER, MAY 7, 1987



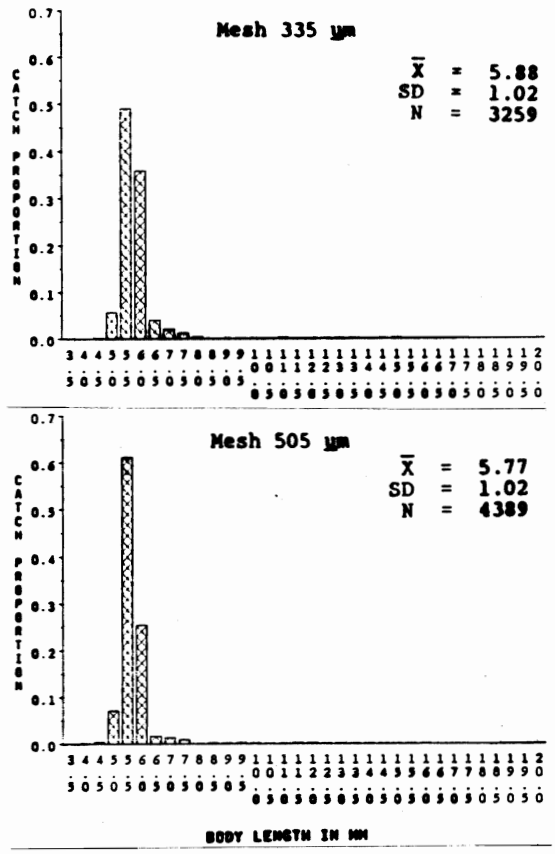
$\bar{x}$ = Mean Body Length
SD = Standard Deviation
N = Number of Larvae

Table 3
COMPARISON OF LENGTH FREQUENCY DISTRIBUTIONS OF STRIPED BASS LARVAE CAUGHT IN TWO MESH SIZES, SAN JOAQUIN RIVER

Date	Comparison	D-max
5/5/87	335 μm vs. 505 μm	0.0428*
	400 μm vs. 505 μm	0.0404*
	335 μm vs. 400 μm	0.0155
5/7/87	335 μm vs. 505 μm	0.2073*
	400 μm vs. 505 μm	0.0701*
	335 μm vs. 400 μm	0.1372*

* $P < 0.001$

Figure 4
LENGTH FREQUENCY HISTOGRAMS OF STRIPED BASS LARVAE COLLECTED WITH 335 AND 505 μm NETS, SACRAMENTO RIVER, MAY 21, 1987



x̄ = Mean Body Length
SD = Standard Deviation
N = Number of Larvae

Table 4
CATCHES OF SEVERAL LENGTH GROUPS OF STRIPED BASS CAUGHT IN TWO MESH SIZES, SACRAMENTO RIVER, MAY 21, 1987
(Larvae per 1000 Cubic Meters)

		Striped Bass Larva Length					
		4 mm	5 mm	6 mm	7 mm	8 mm	>8 mm
335 μm	x̄	5.1	1376.2	1192.6	114.5	21.9	30.6
(N=9)	SD	12.3	1003.2	1345.7	163.3	36.3	35.2
505 μm	x̄	13.2	2273.8	831.0	67.0	5.9	37.5
(N=9)	SD	18.1	1912.5	610.1	77.5	8.3	37.0
Ratios of Mean Density:							
335 : 505		0.39	0.61	1.44	1.71	3.71	0.82
ANOVA Results on Mean Densities:							
	F	1.25	1.98	0.24	0.53	1.67	0.17
	P	0.28	0.18	0.63	0.48	0.21	0.69

x̄ = Mean Density per Length Interval
SD = Standard Deviation
N = Number of Tows

DISCUSSION

Use of finer mesh did not increase the catch of small striped bass larvae. In fact, mean densities for 4 and 5 mm bass during the May 7 trial, as well as trends observed for mean length and length frequency histograms by mesh size, suggest that finer mesh may slightly reduce netting efficiency for small larvae. Therefore, based on my study, the hypothesis that many small larvae are being extruded through the 505 μm mesh should be rejected and smaller mesh sizes are not justified. However, reduced catches of small bass larvae by smaller meshes is counter-intuitive, since, in theory, a finer mesh should reduce extrusion of small larvae and increase the catch.

My results also differ from those of other mesh size comparisons. *Houde et al. (1988)* found that, depending on size group, 333 μm mesh collected up to 2.3 times more of the smaller (3 to 5 mm) striped bass larvae than did 505 μm mesh gear during a survey on the Potomac River. They used a 60 cm bongo-type sampler with paired 333 and 505 μm mesh nets, and attributed the reduction in catch of small striped bass larvae in the 505 μm net to increased extrusion through the larger mesh.

Marine Research, Incorporated (1975) also caught more eggs and larvae in tows taken in a discharge channel of a nuclear power plant using 333 μm mesh during a similar bongo net comparison.

The cause of my results is unclear, and more work is needed. Possible explanations include:

- Lower catch densities from nets with finer mesh were the result of spatial and temporal variability in larval bass abundance, not the effect of mesh capture efficiency. Although I attempted to control the effects of large-scale spatial and temporal variation, I cannot discount the possibility that small-scale spatial variability confounded results. Future work using paired nets, like the bongo sampler, may further reduce effects of spatial variability and improve detection of true differences in net efficiency.
- Finer mesh is more susceptible to clogging. The smaller mesh openings reduce the theoretical filtering capacity of the 400 and 335 μm nets by 4 to 6 percent relative to the 505 μm mesh net. The associated greater clogging may increase avoidance of larvae by creating a pressure wave in front of the net, or perhaps it may actually increase extrusion of smaller larvae by reducing the number of mesh openings and increasing the hydraulic pressure through the remaining openings.

  Contrary to this hypothesis, metered water volumes filtered were not consistent with greater clogging in the smaller meshes (Table 5). Density estimates would be biased only if net clogging occurred, and flowmeter measurements failed to decline commensurate with the volumes filtered. Although *Bowles et al. (1978)* recommended that flowmeters be mounted both inside and outside of plankton nets, one inside flowmeter, as used in this study, usually is adequate to detect significant net clogging *(Smith and Richardson, 1977)*. Overall, net clogging alone does not appear to be a likely explanation for the lower densities in the smaller meshes.
- Net design may influence the catch size distribution. Although it is generally assumed that clogging occurs evenly over the entire net surface *(Smith and Richardson, 1977)*, the cod end design and its filtering characteristics may be important to avoid extrusion of larvae. *Faber (1968)* observed that a solid collection vessel produced a pressure head that caused fish larvae to remain in the netting ahead of the cod end and, thereby, increased extrusion. Collection jars used in my studies were identical, except that the filtering ports were covered

with wire mesh with the same mesh size of each net. If the smaller wire mesh clogged at a faster rate than in collection jars with larger mesh sizes, it is possible that selective clogging in the cod end increased extrusion without the flow-meters detecting a significant reduction in filtering rate. More work is needed to determine if the cod end design being used is causing significant extrusion of eggs and larvae.

In conclusion, these results indicate that more work is needed to better define the effects of mesh size on the capture of small striped bass larvae. The greater catches of small larvae in larger mesh are puzzling. Future tests should use closely paired net samplers like the bongo sampler to minimize differences due to spatial distribution. Modification of collection buckets to avoid clogging may also be needed to resolve this issue.

Table 5
AMOUNTS OF WATER FILTERED THROUGH NETS WITH DIFFERENT MESH SIZES

Date	Mesh Size (μm)	Number of Tows	Mean Volume (cubic meters)	Standard Deviation	Group*
5/5/87	400	14	243.2	26.6	A
	505	14	233.7	10.5	A B
	335	13	222.3	10.1	B
5/7/87	400	8	255.1	7.4	A
	505	8	229.3	6.2	B
	335	8	226.7	7.0	B
5/21/87	335	9	247.9	66.4	A
	505	9	223.5	6.4	A

* Mean volumes with same group letter are not significantly different (SNK Multiple Range or T-Test; P = 0.05).

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