State of California
The Resources Agency
DEPARTMENT OF FISH AND GAME

FISH OCCURRENCE, SIZE, AND DISTRIBUTION IN THE SACRAMENTO RIVER NEAR HOOD, CALIFORNIA DURING 1973 AND 1974

by

Raymond G. Schaffter
Bay-Delta Fishery Project

Anadromous Fisheries Branch
Administrative Report No. 80-3
March, 1980

FISH OCCURRENCE, SIZE, AND DISTRIBUTION IN THE SACRAMENTO RIVER NEAR HOOD, CALIFORNIA DURING 1973 AND 1974[1/]

by

Raymond G. Schaffter[2/]
Bay-Delta Fishery Project

ABSTRACT

A midwater trawl survey was conducted in the lower Sacramento River between February 1973 and September 1974 to determine the seasonal occurrence and sizes of fishes to be screened at the headworks of the proposed Peripheral Canal. Sampling was centered at Hood, but extended upstream to Clarksburg and downstream to Walnut Grove.

Juvenile chinook salmon, Oncorhynchus tshawytscha, were abundant from January through early July, with fry dominant during the first half of the period and smolts during the latter. Young American shad, Alosa sapidissima, were abundant in the study area from August through mid-November. Juvenile striped bass were present during all but winter months, but never reached the concentration of shad or salmon. Other species were infrequently collected or of sufficient size not to present any special requirements for screening at the entrance of the proposed Peripheral Canal.

1/ Anadromous Fisheries Branch Administrative Report No. 80-3. Submitted March, 1980.
This study was conducted as part of the Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary whose members include: California Department of Fish and Game, California Department of Water Resources, U. S. Bureau of Reclamation, and U. S. Water and Power Resources Service.

2/ Current Address: Department of Fish and Game, Contract Services Section, P.O. Box 607, Red Bluff, CA 96080

INTRODUCTION

The proposed Peripheral Canal is an integral feature of the California State Water Project (SWP). This facility will have the capacity to divert up to 650 m^3/s (23,000 cfs) from the Sacramento River near Hood, California.

Nearly all of California's Central Valley chinook salmon, American shad, striped bass, Morone saxatilis, steelhead, Salmo gairdneri, and sturgeon, Acipenser spp., spawn in the Sacramento River system upstream from the planned diversion point. Their young must be protected from diversion during their downstream migration by adequate fish screens and diversion operating procedures. The objectives of this study were to assess fish sizes, occurrence, and distributions near Hood to aid in development of biological design criteria for fish screens.

STUDY AREA

The Sacramento River between Clarksburg Bend and Walnut Grove is a leveed channel 120-245 m (400-800 ft) wide with an average depth of 8.5 m (28 ft). Most levee banks support annual grasses and shrubs with only small areas at Clarksburg Bend and Steamboat Slough supporting quality riparian vegetation. Long sections of levees in the study area have been cleared of vegetation and riprapped.

Most of the water drainage from the Sacramento Valley watershed is contained within the central channel between Hood and Clarksburg. Between Hood and Walnut Grove, Sutter Slough, Steamboat Slough, Georgiana Slough, and the Delta Cross Channel remove water from the main channel narrowing the Sacramento River below Walnut Grove (Figure 1). Flow reversals are not present in the study area except on occasions of low outflow, extreme high tide, and high diversion rates which result in a minor tidal reversal below the Delta Cross Channel (Walnut Grove).

Average monthly flows during the survey ranged from near 425 m^3/s (15,000 cfs) during the summer of 1973 to over 2,150 m^3/s (76,000 cfs) in January, 1974 (Table 1). Water temperatures during the study ranged from 6.5°C (45.5°F) to 23.0°C (73.4°F) (Table 2).

MATERIALS AND METHODS

Sample Locations

Eleven transects used as the midpoints of sampling corridors were established at three bends in the Sacramento River (Figure 2). These were at Clarksburg Bend (three transects) at river kilometer (RK) 69.5 (river mile--RM--43.2), Hood (four transects) at RK 61.2 (RM 38.0), and Walnut Grove (four transects) at RK 43.6 (RM 27.0).

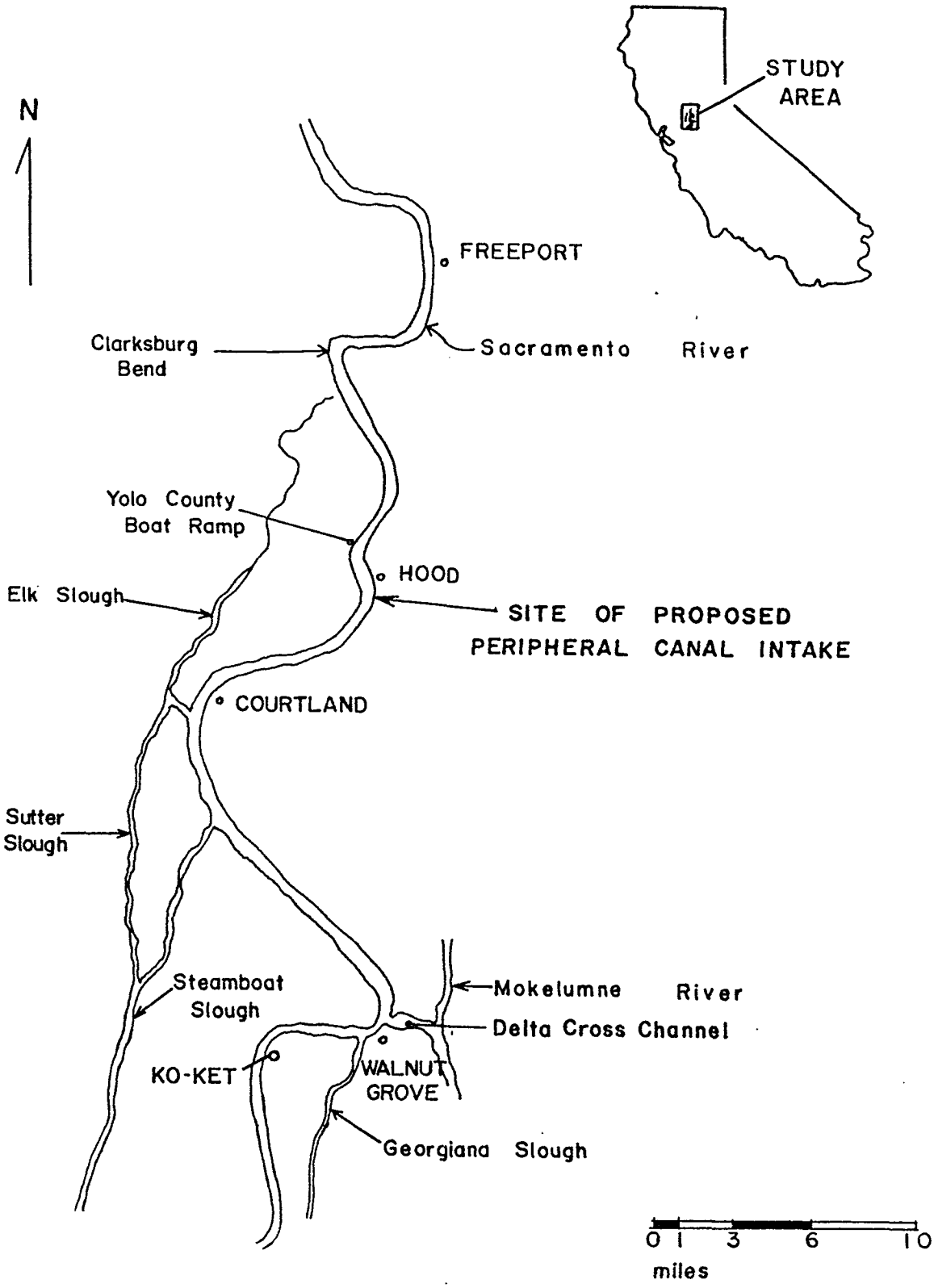


FIGURE 1. THE SACRAMENTO RIVER FROM FREEPORT TO WALNUT GROVE, 1973-74. PRIMARY TRAWL SITES WERE AT THE SITE OF THE PROPOSED Peripheral Canal INTAKE NEAR HOOD. SECONDARY TRAWL SITES WERE NEAR CLARKSBURG BEND AND WALNUT GROVE. THE PRIMARY BEACH SEINE SAMPLE AREA WAS AT THE YOLO COUNTY BOAT RAMP NORTH OF HOOD.

C-045748

TABLE 1. Mean Monthly Flows Sacramento River at Sacramento in Cubic Feet Per Second (cfs).[1/]

Year	J	F	M	A	M	J	J	A	S	O	N	D
1973	--	64,290	51,460	20,790	16,440	15,190	15,140	15,970	17,420	16,500	49,260	64,540
1974	76,550	50,600	64,450	66,550	29,020	24,020	21,290	23,580	--	--	--	--

TABLE 2. Maximum and Minimum Monthly Water Temperatures at Freeport (Centigate).[1/]

Year		J	F	M	A	M	J	J	A	S	O	N	D
1973	max	--	11.0	13.0	18.5	21.5	23.0	23.0	23.0	20.5	18.0	14.5	10.5
	min	--	8.0	10.0	12.0	17.5	19.5	20.5	20.0	17.5	13.5	9.5	8.5
1974	max	9.5	9.5	12.0	15.0	19.5	21.5	23.0	--[2/]	--	--	--	--
	min	6.5	7.5	8.5	9.5	14.5	18.0	19.0	--	--	--	--	--

1/ Source: United States Department of Interior, Geological Survey.

2/ Data missing (no record).

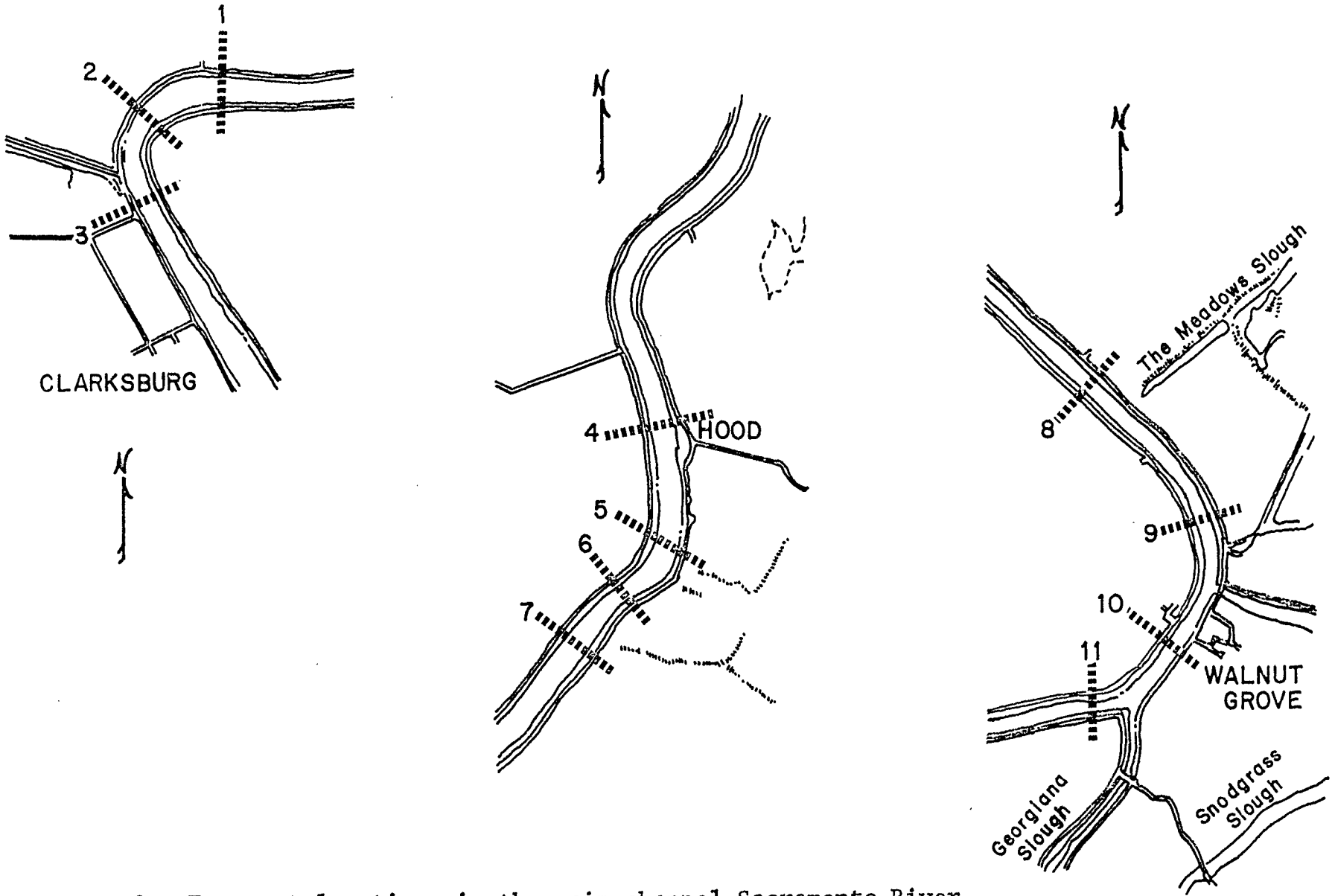


FIGURE 2. Transect locations in the main channel Sacramento River at Clarksburg Bend, Hood, and Walnut Grove.

Additional single transects were established 200 m (656 ft) downstream in each of three divergent Delta channels: Steamboat Slough, Georgiana Slough, and the Delta Cross Channel. Steamboat and Georgiana sloughs were only sampled during high water because of submerged snags; the Delta Cross Channel was only sampled when the water was low enough to provide 3 m (9.9 ft) clearance beneath the raised radial gate structure for boat passage.

Each Sacramento River transect was divided into three stations, one as near to each bank as could be sampled (normally about 20 m--66 ft--offshore) and the third in the river center. Under normal flow conditions, a 10 min tow would cover 300 m (1,000 ft), 150 m (500 ft) on either side of a transect line. During high flows when less distance was covered, the tow was started and terminated closer to the transect line. During low flows, tow duration was reduced to avoid trawling beyond the established zone. In the divergent channels, only the center of the transect was sampled.

During 1974, a beach seine sample site at the Yolo County boat ramp 1.5 km (1 mile) upstream from Hood was established. Other seining sites between Garcia Bend (RK 86.9--RM 54) and Rio Vista (RK 16.9--RM 10.5) were occasionally sampled.

Sample Gear and Methods

The vessel used in trawl investigations was a 7.3 m (24 ft) commercial-type fishing launch powered by a 140 hp diesel. Two single drum hydraulic winches, each equipped with 76 m (250 ft) of 4.8 mm (0.19 in.) cable, were mounted on stands amidships. The towing cables passed through blocks attached to transom-mounted L-frames. The nets, hydrofoils, depressors, and bridle were similar to those used by VonGeldern (1972) except that wings were added to the net mouth and the depressors were reduced in size and weight to allow the net to be towed on the surface at 5.1 km/h (2.8 knots) with a bridle and cable length of 38.1 m (125 ft). Effective net mouth area was 6.7 m^2 (1.8 X 3.7 m) (72 ft^2 -- 6 X 12 ft). Most tows were made with the hydrofoils breaking the surface, but subsurface trawls could be made by increasing the cable length. Volume sampled by the midwater trawl was determined by multiplying the area of the net mouth by the distance traversed through the water.

Before June of 1973, the distance towed was calculated by multiplying the time of tow by the water velocity as determined by a Kenyon KMX sailboat speedometer. The speedometer was calibrated during actual net tows over a measured mile course.

After June 1973, the distance towed through the water was measured with a General Oceanic flowmeter towed from a side boom in undisturbed water approximately 1 m (3.3 ft) from the boat hull. The meter was activated when the hydrofoils "bit" on the cast of the net and was removed from the water when the depressors showed on the surface during retrieval.

To test the efficiency of the trawl net for chinook salmon fry, a sled-mounted fixed-frame tow net of 1.3 cm (0.5 in.) mesh with a mouth area of 1.5 m^2 (16.2 ft^2) was used during the winter and spring of 1974.

During vertical distribution sampling, a 0.6 X 3.0 m (2 X 10 ft) otter trawl was used for benthic sampling. A modified plankton net constructed of 505 nitex was used to collect eggs and larvae of American shad.

Catches of chinook salmon and American shad were converted to fish per 1,000 m^3 (35,310 ft^3), while less frequently caught species were grouped as fish per standard (10 min) tow.

The 0.32 cm (0.125 in.) Delta mesh beach seine used for inshore sampling measured 12.8 X 1.2 m (42 X 4 ft). It was impossible to reproduce the exact areas sampled from week to week because of fluctuating water levels, but an effort was made to sample the same volume of water during each sample day. This volume was estimated at about 200 m^3 (7,000 ft^3).

All fish collected were identified and measured to the nearest mm fork length (FL). Most were returned to the water, however subsamples were preserved in 10% formalin for verification of identification.

Trawl Net Efficiency Test

High beach seine catches of chinook salmon fry in January and February 1974 suggested that small salmon were much more abundant than indicated by midwater trawl catches. The fixed-frame tow net was used to estimate the efficiency of the midwater trawl for chinook salmon fry. In February and March 1974, 20 paired (with both nets) trawls were made at transect three at Clarksburg Bend. Two or three stations were towed with either the tow net or trawl net, the gear was switched and each tow duplicated with the other net. Time between paired tows was usually 60 to 80 min, but occasionally only 15 min elapsed. Both nets were towed at the same speed and as close to the surface as possible; the midwater trawl sampled the surface 1.8 m (5.9 ft) and the tow net sampled the surface 1.2 m (3.9 ft). The distance each net passed through the water was calculated from the General Oceanics flowmeter during all tows.

As only two salmon larger than 51 mm (2 in.) were taken by the fixed frame tow net, this length was used as a division point between fry and larger fish in this analysis. This length was also a low point between two peaks in the March 1973 size distribution suggesting a length at which few fish passed Hood (Appendix A).

The density of fish determined by the midwater trawl was divided by the density of fish in the tow net for each paired tow (Table 3). A mean trawl efficiency of 18.1% was calculated after using a logarithmic transformation to compensate for extreme values.

TABLE 3. Summary of All Paired Net Evaluation Tests for Chinook Salmon.

Date 1974	Test #	Trawl net density fish/1,000m^3	Tow net density fish/1,000m^3	Trawl density / Tow density	Mean F.L. (mm) in trawl	Mean F.L. (mm) in tow net
27 Feb	1	0.29	3.55	0.08	42.7	39.0
	2	0.29	2.16	0.13	36.0	37.0
6 Mar	1	1.01	11.36	0.09	37.3	36.5
	2	0.15	1.34	0.11	36.0	35.3
	3	0.86	4.15	0.21	36.5	37.3
	4	0.55	13.16	0.04	38.5	37.2
	5	0.22	2.72	0.08	35.3	36.5
	6	0.40	4.09	0.10	36.0	36.5
11 Mar	1	1.37	3.70	0.37	35.6	35.9
	2	1.26	11.07	0.11	35.9	36.4
	3	0.96	7.95	0.12	36.0	36.9
	4	1.16	3.22	0.36	36.3	36.7
	5	1.04	8.16	0.13	36.1	36.2
	6	0.47	7.79	0.06	36.5	35.8
18 Mar	1	0.31	2.29	0.14	37.8	39.6
	2	0.47	0.93	0.51	39.2	38.5
	3	0.40	0.47	0.85	40.4	39.0
	4	0.81	1.83	0.45	37.8	36.0
	5	0.79	1.28	0.62	36.7	36.4
	6	0.72	0.79	0.91	39.1	38.5

N=20

$\overline{X}$ log (trawl/tow) = -0.7418

Trawl net efficiency = 18.1%

95% confidence interval: 12.5-26.3%

FL = Fork Length

To test for size selectivity within the size range of fry, mean lengths of salmon under 52 mm (2 in.) for each pair of tows (trawl and tow net) were calculated. In 50% of the paired tows, the mean length of fish in the trawl exceeded the mean length of fish in the tow net; exactly the expected ratio if there was no size selectivity (within the size range examined) for either net.

Densities of larger chinook salmon during the net evaluation tests were low, with only 29 salmon larger than 55 mm (2.2 in.) taken during these tests. Of these, only one was taken in the tow net suggesting that tow net efficiency dropped sharply as fish size increased. Trawl catches for 1973 and 1974 chinook salmon less than 52 mm (2 in.) FL were multiplied by 5.52 ($\frac{100}{18.1}$) to reflect size distribution and seasonal abundance at Hood.

RESULTS AND DISCUSSION

Chinook Salmon

1973 Migration

A surface-towed midwater trawl was the only gear used to sample downstream migrants in 1973. All fish sampled were taken from that portion of the river cross section with a net downstream velocity of 0.5-1.5 m/s (1.5-5.0 ft/s). Fish taken in this survey were assumed to be displaced downstream at near current velocity, regardless of size.

During the first week of sampling in late February, average densities of chinook salmon were near one fish/1,000 m^3 (Figure 3). Weekly catches fluctuated about this level until mid-April, when catches rapidly increased to over 3.5 fish/1,000 m^3. No sampling was conducted the first three weeks of May. Catches in the last week of May suggested densities during the entire month could have averaged approximately three fish/1,000 m^3. During June, catches declined rapidly until the average trawl catch was one fish, representing a concentration of approximately 0.1 fish/1,000 m^3. Fish concentrations remained at or below this level for the remainder of the year.

1974 Migration

Commencing January 6, 1974, a weekly beach seine survey was added to the study. Although nine areas between Sacramento and Crockett were sampled, only the beaches and boat ramp at the Yolo County Park, 1 km (0.62 mile) upstream from Hood, were sampled continuously. This was the closest site to the proposed Peripheral Canal entrance that could be sampled effectively.

On January 6, the first sample day at Hood, four salmon fry/seine haul were taken (Figure 4). Salmon abundance increased gradually through January, then peaked sharply in early February, reaching

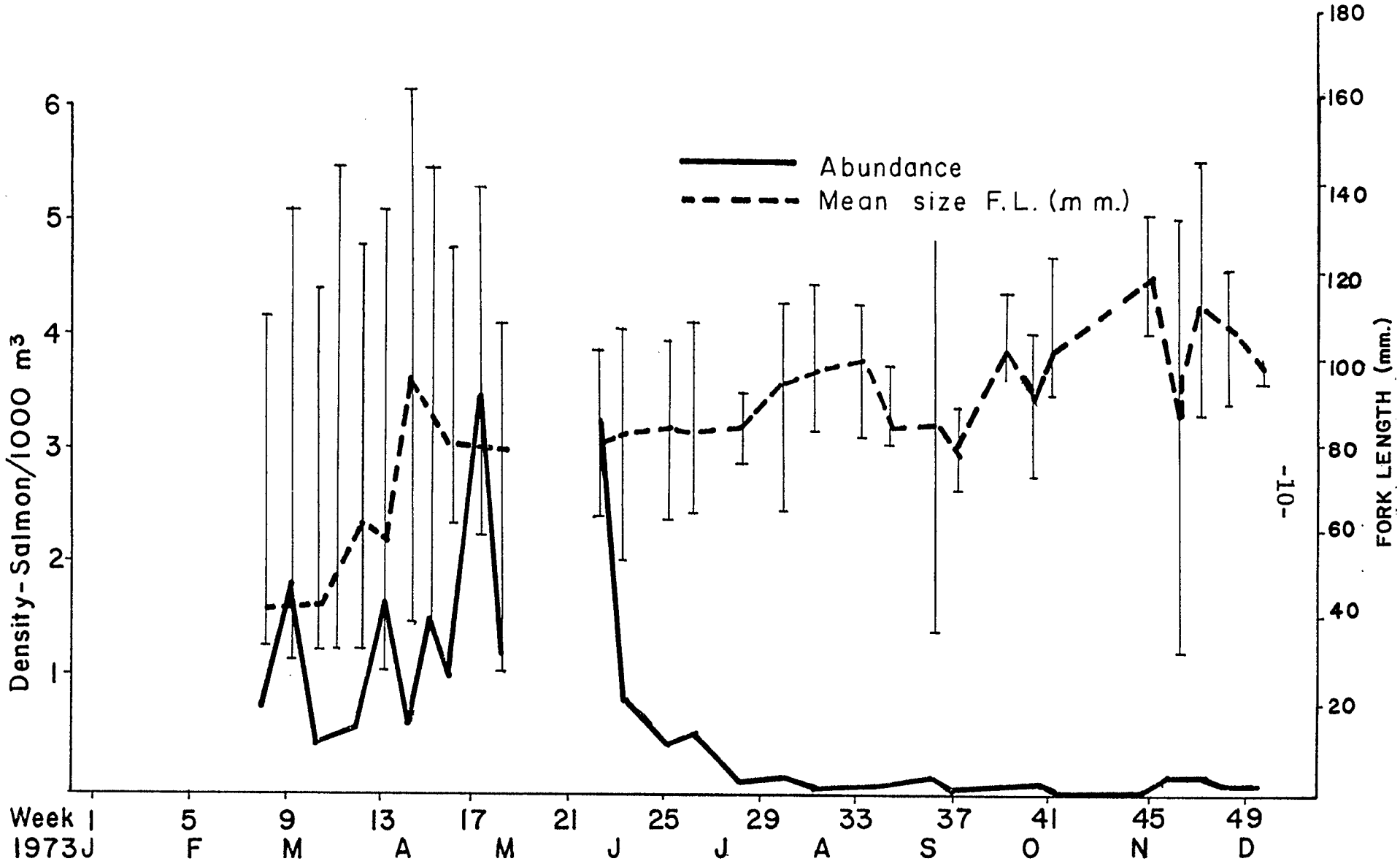


FIGURE 3. Chinook salmon - Weekly average abundance, mean fork length, and range in the Sacramento River between Clarksburg Bend and Walnut Grove, February to December, 1973.

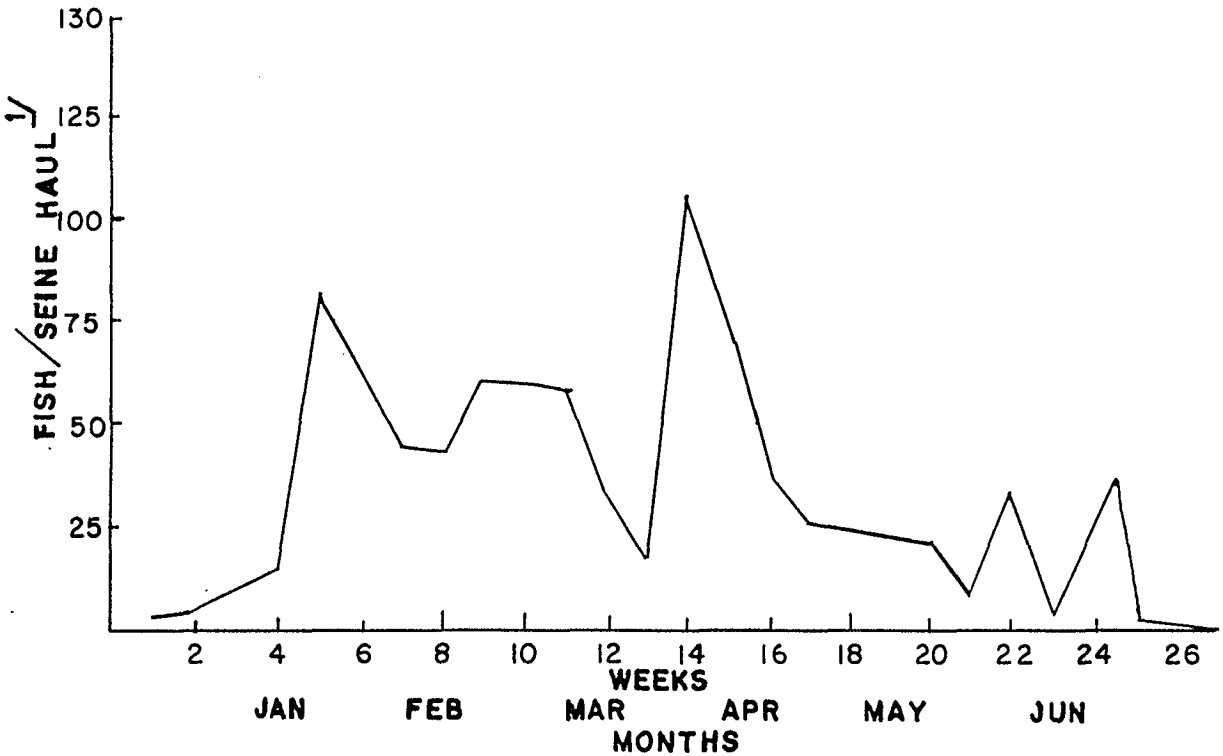


FIGURE 4. AVERAGE WEEKLY SEINE CATCHES OF chinook salmon at YOLO COUNTY BOAT RAMP. JANUARY - JUNE 1974.

1/ The estimated average volume of water sampled per seine haul was 200 m^3 (7000 ft^3).

78 fish/seine haul. This peak followed a minor peak in the midwater trawl catches. Catches declined irregularly to 17 fish/seine haul until mid-March when a second major peak of 104 fish/seine haul occurred. This peak followed an increase in river flow from 1,560 to 2,410 m^3/s (55,000 to 85,000 cfs). Catches decreased after this peak, never reaching more than 50 fish/seine haul after mid-April. No salmon were taken by beach seine after July 1.

Midwater trawl catches during the second week of January averaged over 0.2 fish/1,000 m^3, up from near zero through December (Figure 5). From late January to early March, catches of salmon fluctuated between 0.8 and 2.3 salmon/1,000 m^3. A high of 5.1 fish/1,000 m^3 occurred in mid-March. Trawl catches dropped to near zero in late March, then increased to a second major peak of 3.8 fish/1,000 m^3 in mid-May. Catches dropped sharply in late June, reaching near zero by late July. A small peak was observed in mid-July following unseasonable rains and a slight increase in river flow.

Salmon Size During Migration

Midwater Trawl - During both years of the survey, three distinct size groups of chinook salmon were captured by the midwater trawl (Appendices A-D):

1. Fry, averaging 37 mm (1.5 in.) FL, were present at the beginning of the survey in late February 1973. These fry were abundant until mid-March. During January 1974, fry were again taken and were dominant in catches until the end of March.

2. In February of both years, small numbers of larger salmon, 95 to 160 mm (3.7 to 6.3 in.) FL, were collected. These larger fish were discernable as a separate size class until late April of both years.

3. In mid-March 1973, and mid-April 1974, salmon 75 to 90 mm (2.9 to 3.5 in.) FL began to dominate trawl catches. The apparent 1973 migration peak during April and May (not sampled completely) and the second migration peak during April, May, and June 1974 were almost entirely composed of this group. During these migration peaks (May-June), the weekly mean size of outmigrants was remarkably constant, ranging from 75 to 87 mm (2.9 to 3.4 in.) FL.

The size of outmigrants passing Hood after the major migrations gradually increased in size throughout the latter half of 1973.

Beach Seine - Average size of fish taken in January 1974 was 42 mm (1.6 in.) FL. As the number of fish increased, average size decreased to 38 mm (1.5 in.) FL, remaining constant until mid-March. After mid-March, average size increased from 38 to 78 mm (1.5-3.1 in.) FL until mid-June when fish were last collected (Figure 6).

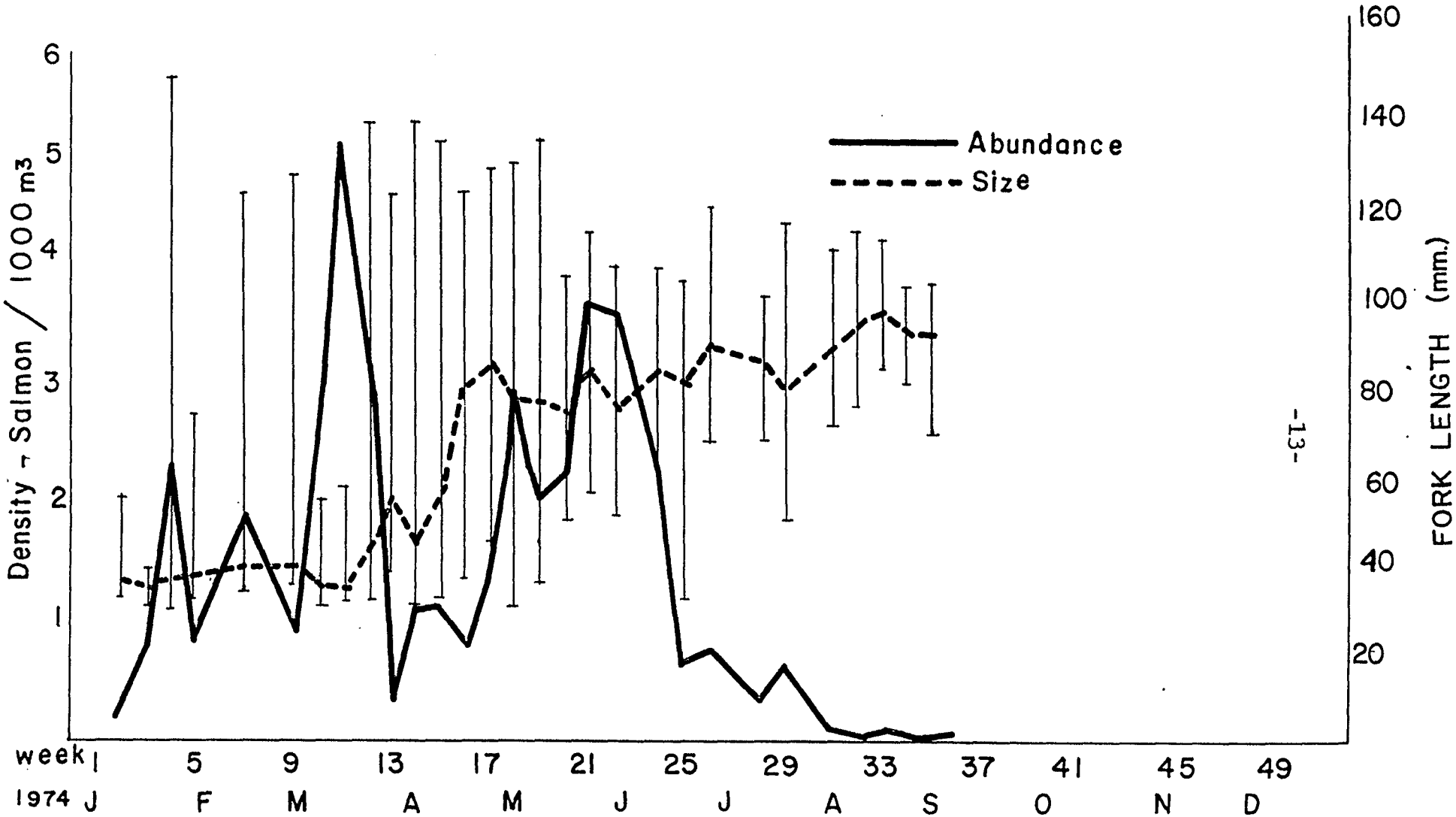


FIGURE 5. Chinook salmon - Weekly average abundance, mean fork length, and range in the Sacramento River between Clarksburg Bend and Walnut Grove, January to September, 1974.

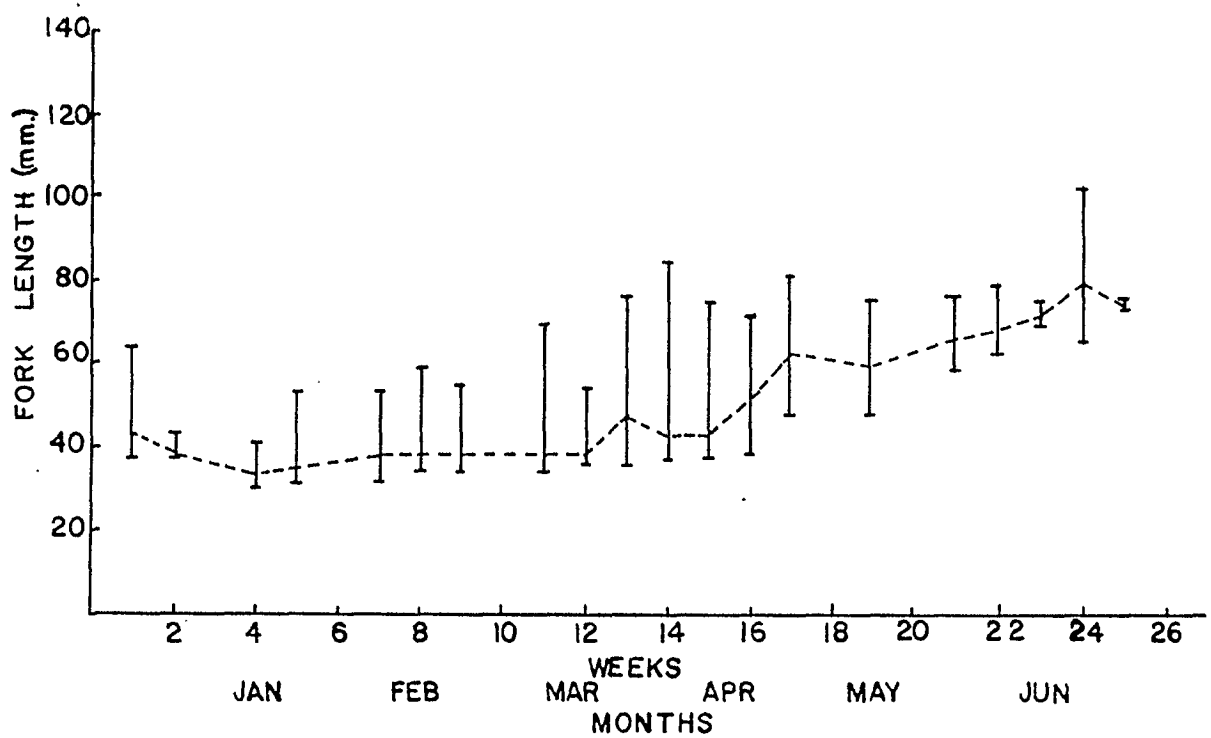


FIGURE 6. Chinook salmon mean fork length and range, average over weekly periods, collected in beach seine at Yolo County boat ramp. January - June, 1974

Average size of fish collected from January to mid-March was similar to the average size collected by the midwater trawl, but did not increase as sharply thereafter, not reaching 70 mm (2.7 in.) until late May (Appendices E-F). Only a single salmon, collected during March, was comparable in size to the largest group of outmigrants sampled by the midwater trawl during the first quarter.

Vertical Distribution of Chinook Salmon

Measurements of vertical distributions of chinook salmon at Hood and Clarksburg in 1973 suggested these fish concentrated in surface layers during daylight, but large amounts of submerged debris and lateral currents in these areas hindered attempts to measure subsurface concentrations of fish.

In 1974, sampling station eight in the straight portion of the river above Walnut Grove and the Delta Cross Channel provided a debris-free area where the entire water column could be sampled. A towed remote fathometer transducer verified net performance during subsurface tows.

During 13 paired daylight and 12 paired night tows (2-4 hours after sunset) a definite vertical movement was noted. During daylight, 96% of all salmon were taken in the surface 2 m (7 ft) of water. Similar night sampling yielded only 11% of the total catch from this top 25% of the water column. Concentrations of salmon calculated from night otter trawl sampling were not different from concentrations calculated from midwater trawl catches taken from a depth of 5 to 7 m (16 to 23 ft), indicating that salmon do not become benthic during darkness, but do concentrate in the lower portions of the water column.

Sampling with the 30.5 X 1.8 m (100 X 6 ft) beach seine at three locations indicated salmon abundance in seine areas declines to near zero after sunset (Figure 7).

Horizontal Distribution of Chinook Salmon at Hood

Trawl catches of chinook salmon were greatest in the river center and near the east bank at Hood (Figures 8 and 9). Sampling was between March 20 and June 27, 1973, when most fish exceeded 70 mm (2.8 in.). Figure 8 gives approximate locations of the center of all Hood trawl transects but actually right and left bank stations of each transect ranged between 15-20 m (50-65 ft) offshore. If high concentrations of fish were very close to shore, they would not have been collected by the midwater trawl. The pattern of salmon distribution in the channel (Figure 9) suggests the portion of the channel with highest river velocity contains the highest density of salmon.

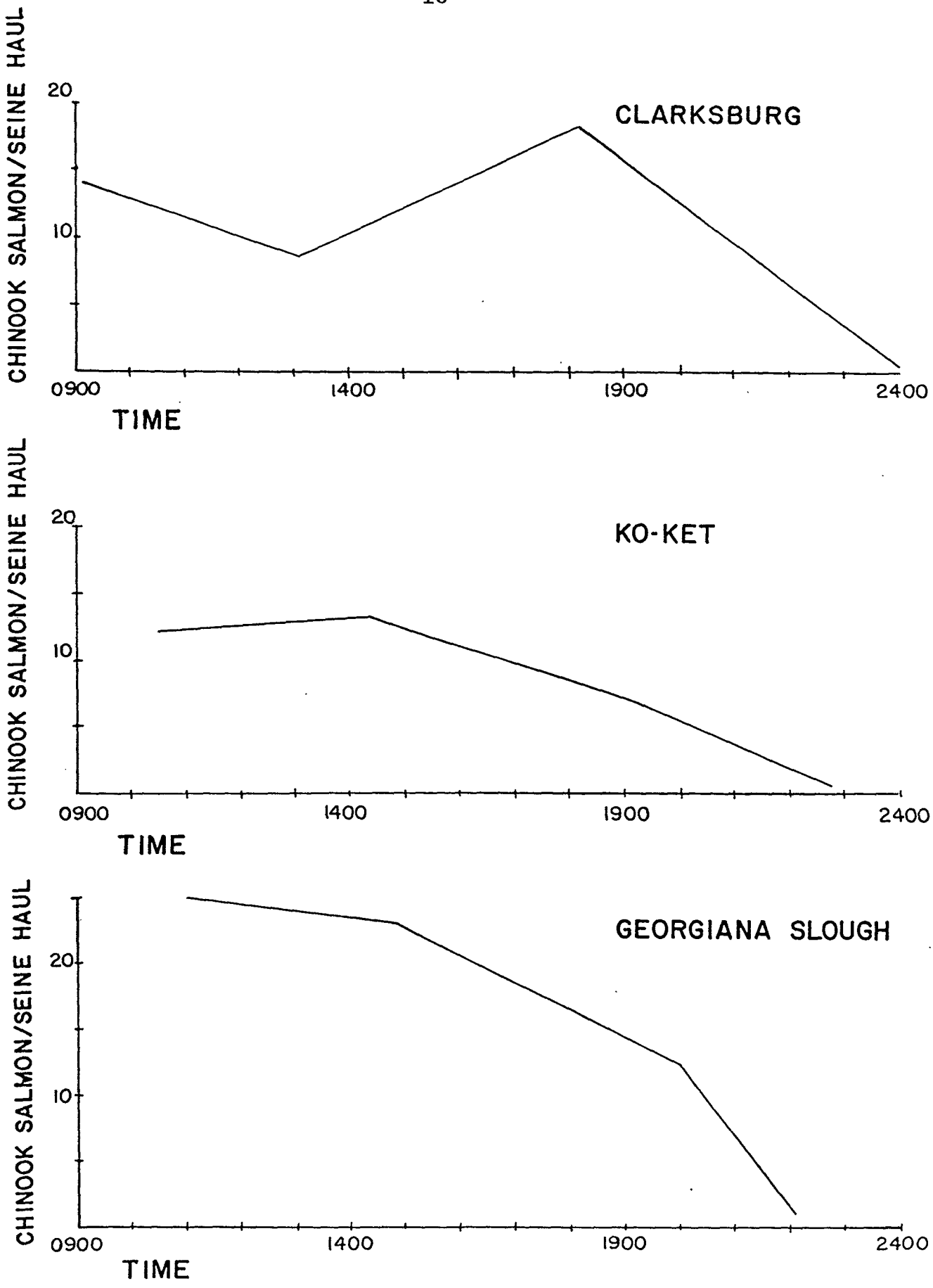
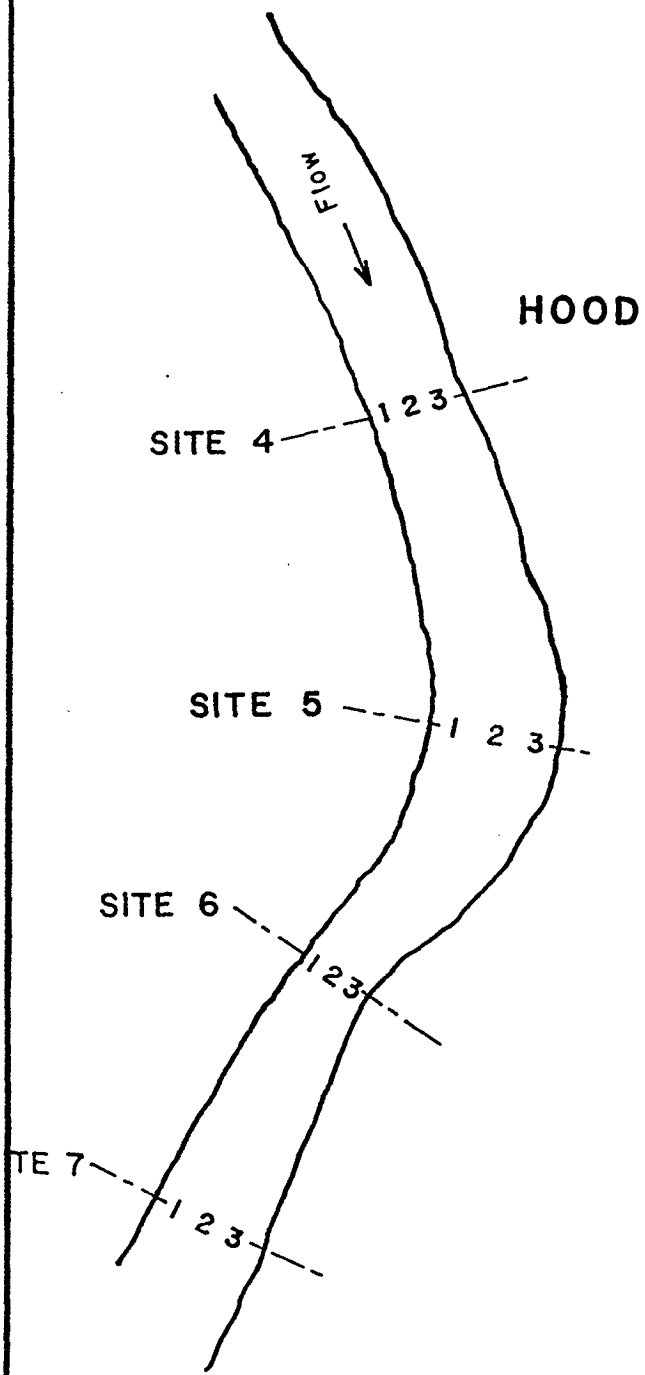


FIGURE 7. BEACH SEINE CATCHES AT CLARKSBURG, KOKET AND GEORGIANA SLOUGH demonstrating a decline in catches after sunset. Legal sunset WAS APPROXIMATELY 20 30 HRS.



IGURE 8. MAP OF THE SACRAMENTO IVER NEAR HOOD SHOWING LOCATION OF OOD TRAWL STATIONS.

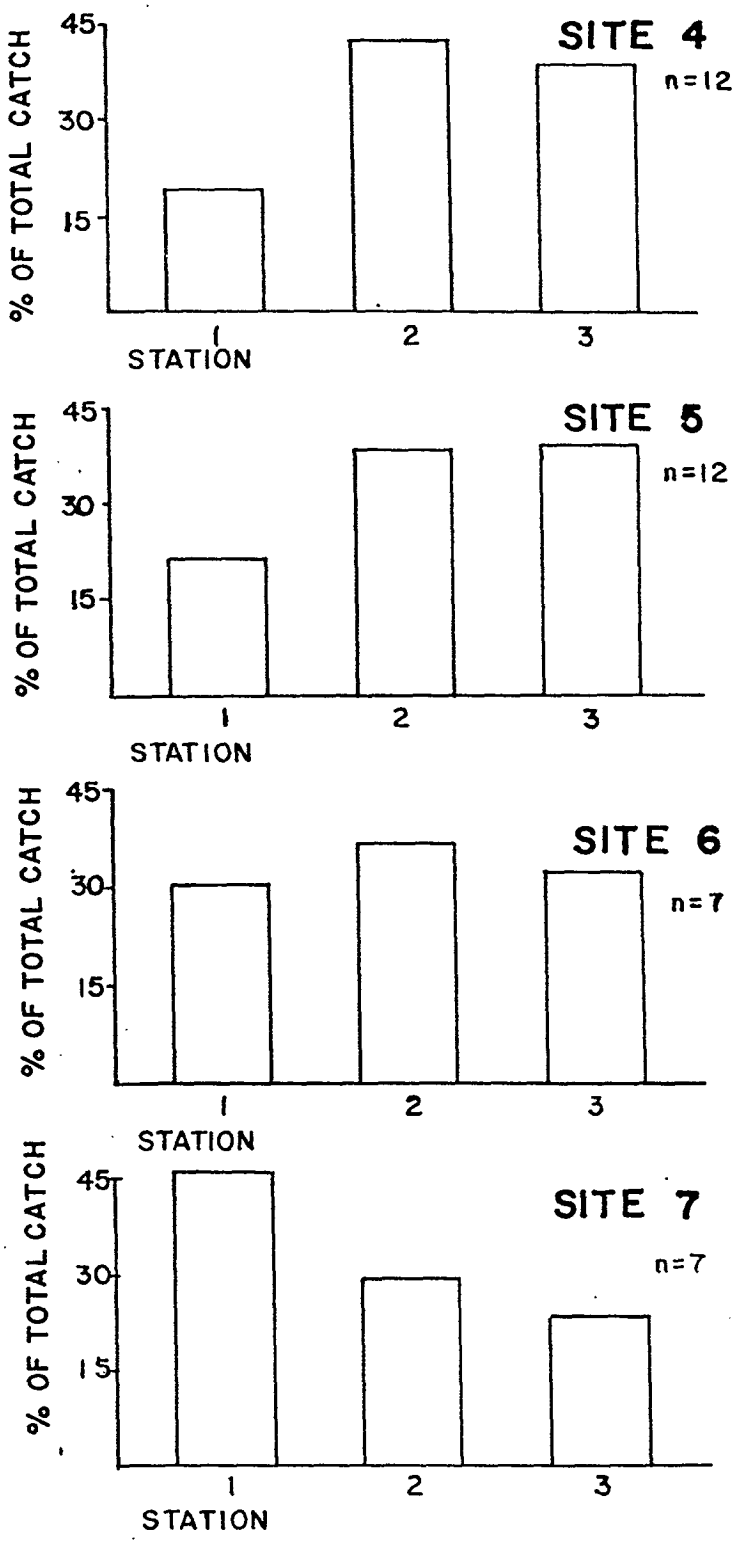


FIGURE 9. Lateral distribution of chi nook SALMON CAPTURED IN MIDWATER TRAWL. BARS REPRESENT PERCENTAGE OF TOTAL collected WITHIN EACH SITE. SAMPLING CONDUCTED BETWEEN MARCH 20 AND JUNE 27, 1973.

Salmon Abundance in the Delta Cross Channel and Georgiana Slough

During spring of 1973, surface tows were made to compare the concentrations of chinook salmon in the Delta Cross Channel and Georgiana Slough with concentrations in the Sacramento River channel upstream of both channels.

Mean ratios of salmon densities in the channels/salmon densities in the Sacramento River were 0.99 for the Delta Cross Channel and 0.69 for Georgiana Slough, based on four days sampling at each side channel (Table 4). These ratios were not statistically different from unity, suggesting that salmon are drawn into these channels in proportion to the water volumes entering each channel.

Comparisons With Previous Lower Sacramento River Surveys

The relationships between fish size and downstream migration timing have been reported in five previous studies conducted in the lower Sacramento River (Rutter 1903, Hatton 1940; Hatton and Clark 1942; Erkkila et al. 1950; Sasaki 1966a) (Table 5). The findings of this study support the hypothesis of Sasaki that differences in gear were at least partially responsible for the differences in timing and size of outmigrants captured between his and earlier studies. Beach seine collections during this study indicate an early spring migration pattern similar to that described by Rutter and Hatton, who fished anchored hoop and fyke nets placed within 21.3 m (70 ft) of the shoreline. Our trawl net collections, without the 5.52 efficiency compensation for smaller fish, described a May-June migration similar to Sasaki's.

While four runs of chinook salmon are recognized in the Sacramento River system (Table 6), resulting in spawning and emergence from the gravel nearly every month of the year, most fish that emerge after March remain in the river until the following winter. Neither this survey nor Sasaki's (1966a) found a major fall salmon migration, but substantial fall outmigrations of salmon in Carquinez Strait (Messersmith 1966), San Pablo and Suisun bays (Ganssle 1966), and San Francisco Bay (Alpin 1967) have been reported.

Steelhead Rainbow Trout

During 1973 and 1974, 404 juvenile steelhead rainbow trout were collected by the midwater trawl. Peak abundance was February-May in the Sacramento River between Clarksburg and Walnut Grove (Figure 10). Only one fish was collected between June and October. Seven fall outmigrants were caught between November 1973 and January 1974.

The smallest fish collected was 131 mm (5.2 in.) FL. No young-of-the-year were seen. A wide size distribution, with few larger than 230 mm (9.1 in.) FL, was evident during 1973 and 1974 migration peaks. Average size of the smolts was 15 mm (0.6 in.) longer in 1973 than 1974 (Figures 11 and 12).

Five fish taken at Clarksburg Bend in March 1973 had marks indicating they had been planted in the Mokelumne River at Thornton, a 24.1 km (15 mile) upstream movement from the Delta Cross Channel, their probable entry point into the Sacramento River.

TABLE 4. Chinook Salmon Concentrations in the Delta Cross Channel and Georgiana Slough Compared With Concentrations in the Sacramento River at Transect 9, Immediately Upstream From the Delta Cross Channel.

Date	[Fish/1,000 m^3] Sac River	[Fish/1,000 m^3] Delta Cross Channel	Ratio [Delta Cross Channel / Sac River]
4 April 73	0.278	0.365	1.313
5 April 73	0.694	0.511	0.737
11 April 73	1.770	2.213	1.250
26 April 73	8.290	6.581	0.794
		$\bar{X}$ =	0.99[1/]

Date	[Fish/1,000 m^3] Sac River	[Fish/1,000 m^3] Georgiana Slough	Ratio [Georgiana Slough / Sac River]
19 March 73	0.264	0.134	0.508
23 March 73	0.509	0.191	0.375
29 March 73	1.229	0.763	0.621
5 April 73	0.694	1.302	1.876
		$\bar{X}$ =	0.69[1/]

1/ For statistical tests ratios were transformed to logarithms before calculation of mean; $\bar{X}$ = antilog of mean log ratios.

TABLE 5. Comparison of Information on Peak Migration of Young Chinook Salmon for Several Years in the Lower Sacramento River.[1/]

Year	Reference	Gear[2/]	Mesh (inches)	Location	Peak migration	Average length
1899	Rutter (1903)	Circular bag 4' diameter	1/2 stretch	Walnut Grove	March	44 mm FL
1939	Hatton (1940)	Fyke net 5' diameter	1/2 stretch	Hood	March	39 mm FL
1940	Hatton & Clark (1942)	Fyke net 5' diameter	1/2 stretch	Hood	February-March	40 mm FL
1941	Hatton & Clark (1942)	Fyke net 5' diameter	1/2 stretch	Hood	February-March April-May	40 mm FL 65 mm FL
1949	Erkkila et al. (1950)	Tow net 5' diameter	1/2 stretch	5 stations on Sacto River from Walnut Grove to Pittsburg	March	38 mm FL
1964	Sasaki (1966a)	Midwater trawl 15'X15'	3/4 stretch	Isleton and Rio Vista	May-June	83 mm FL
1973	Fish Occurrence and Distribution Study	Midwater trawl 6'X12'	Var. 8"-1/2" stretch	Hood and Walnut Grove	May	79 mm FL
1974	Fish Occurrence and Distribution Study	Midwater trawl 6'X12'	Var. 8"-1/2" stretch	Hood and Walnut Grove	March May-June	38 mm FL 81 mm FL
1974	Fish Occurrence and Distribution Study	Beach seine 42'X4'	1/8" Delta	Hood	February-March April	38 mm FL 46 mm FL

1/ Chart modified from Sasaki (1966a).

2/ Variation in sampling gear may account for differences in peak migration timing.

TABLE 6. Recognized Runs of Sacramento Chinook Salmon.[1/]

Run	Adult upmigration	Spawning
Fall	August-November	Mid-October-December
Late Fall	December-January	January-March
Winter	January-May	April-July
Spring	April-June	September-October

1/ From Richard Hallock (unpublished data) and Steven N. Taylor (1973).

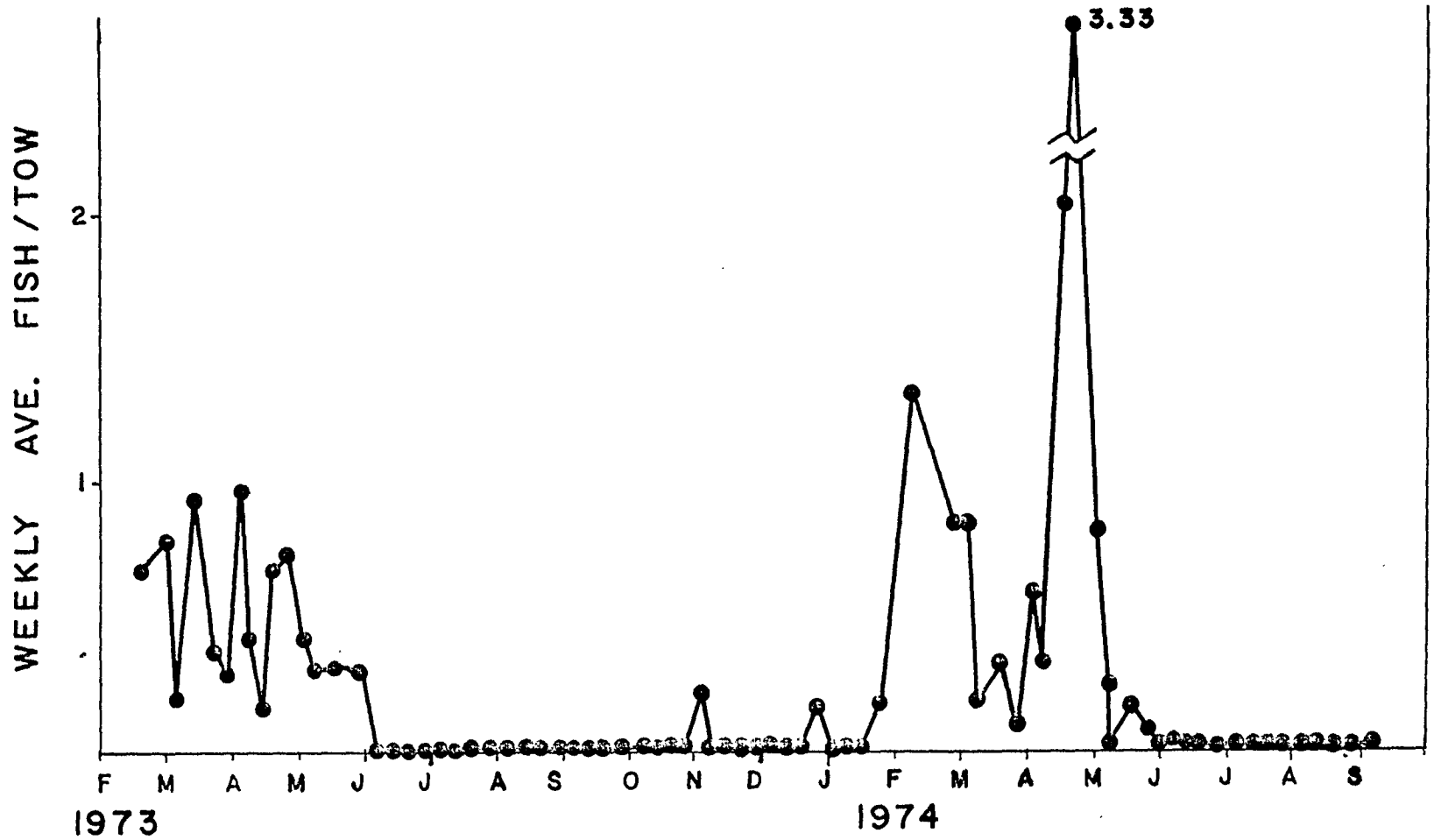


FIGURE 10. STEELHEAD rainbow trout. Weekly average fish/10 minute trawl in the SACRAMENTO RIVER BETWEEN CLARKSBURG BEND AND WALNUT GROVE. FEBRUARY 21, 1973 - SEPTEMBER 3, 1974.

C-045767

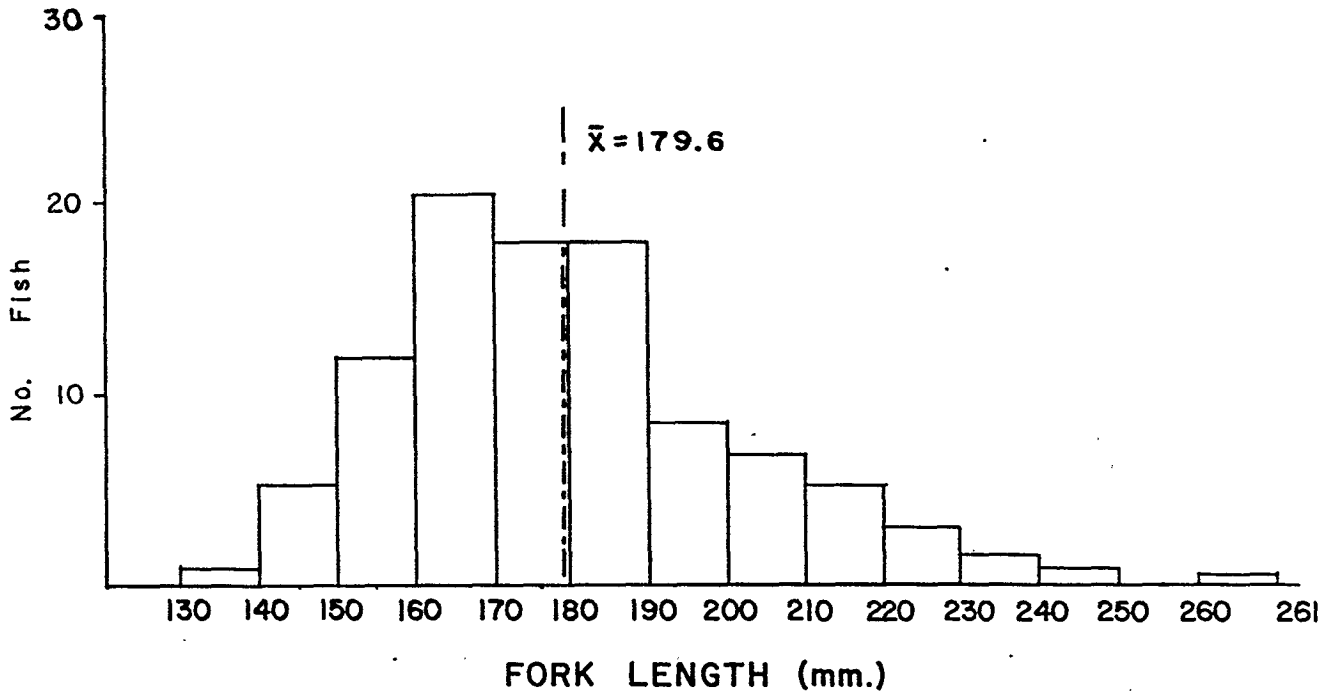


FIGURE 11. Length frequency of steelhead rainbow trout collected from February 21 through December 31, 1973. N = 235

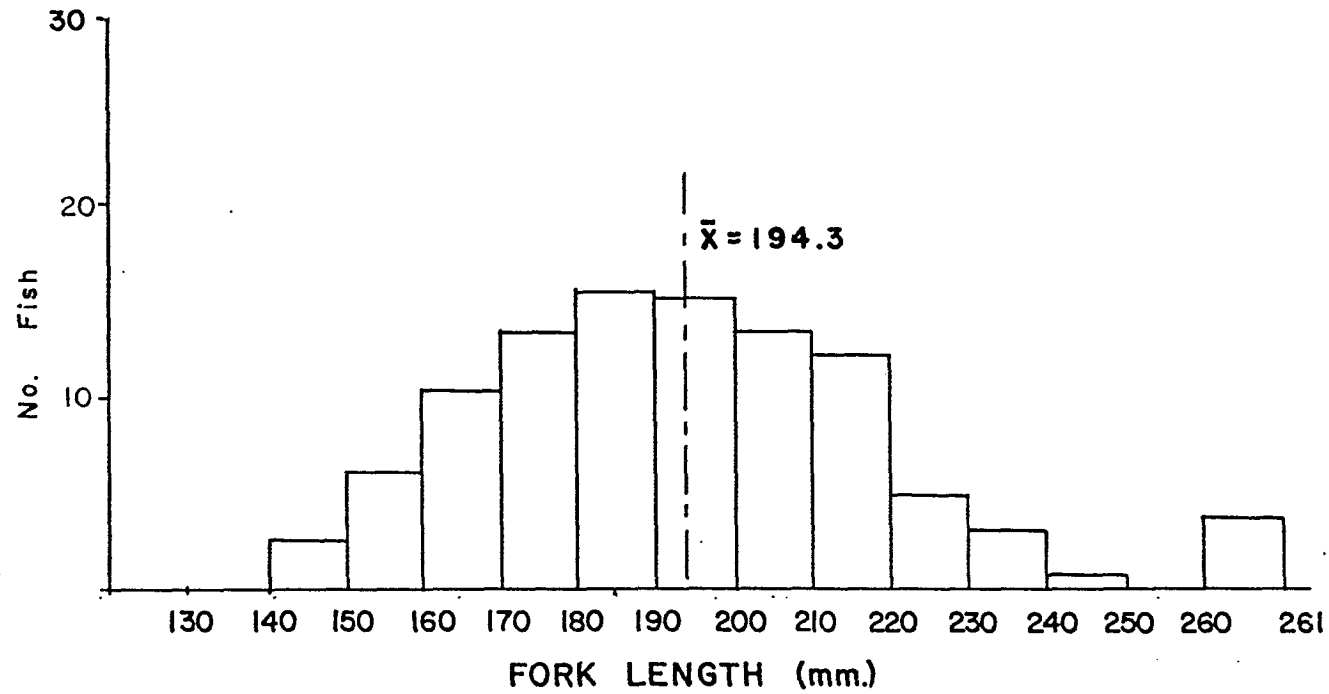


FIGURE 12. Length frequency of steelhead rainbow trout collected from January 1 through September 3, 1974. N = 167

Only two steelhead were taken during paired surface - mid-depth and bottom tows, both during subsurface midwater trawls at night. While these data were insufficient to determine vertical distributions, it suggests that diel movements similar to chinook salmon may occur. Catches suggest steelhead behave similarly to yearling chinook salmon in their downstream migration pattern, i.e. most reside "up river" until late winter or early spring rather than moving out with increased fall flows.

Striped Bass

A total 764 striped bass were collected during the survey. Peak catches, averaging near one fish per 10 min trawl occurred during summer and early fall, with near zero catches occurring in the winter and early spring (Table 7).

Eighty-two percent of all striped bass taken were between 90 and 200 mm (3.5-7.9 in.) FL (Appendices G-H), a length bass usually attain between their first and second winters (Sasaki 1966b). Only 7.8% of all bass taken were classed by length as young-of-the-year.

Striped bass were probably more abundant in the study area than indicated by the midwater trawl catches. Net evaluation tests against a small mesh gill net found an otter trawl, constructed of maximum 3.8 cm (1.5 in.) heavy mesh, to be 4.7 times as efficient as a midwater trawl, constructed of lighter 12.7 cm (5 in.) "guiding" mesh (Sasaki 1966b). The smaller striped bass, due to poor swimming ability or lack of response to the guiding mesh, evidently passed through the large mesh at the mouth of our midwater trawl.

Sasaki also reported that striped bass, after their second winter, are large enough and have developed sufficient swimming ability to totally avoid both otter and midwater trawls. He also found that young striped bass tended to be concentrated near the bottom, where they were not vulnerable to the midwater trawl. This tendency was most apparent during fall and winter. Insufficient numbers of striped bass were taken in paired surface-bottom tows to verify this seasonal shift in vertical distributions, however seasonal distribution could partially explain the zero catches in the study area during winter months.

American Shad

American shad eggs were taken on all of 11 days sampled near Hood between May 1 and June 28, 1973 (Figure 13). Peak catches of 28 and 34 eggs/m^3 (0.79 and 0.96 eggs/ft^3) were noted on May 21 and 24.

TABLE 7. Quarterly Striped Bass Catches: Clarksburg, Hood, and Walnut Grove.

Area and year	Season[1]	Number of trawls	Catch per trawl		
			Age 0[2]	Age 1	Age 2+
Clarksburg					
1973	Spring	89	0	0.022	0.011
	Summer	33	0.030	1.181	0.030
	Fall	79	0.063	0.532	0.025
	Winter	42	0	0	0
1974	Spring	Not sampled			
	Summer	Not sampled			
Hood					
1973	Spring	100	0	0.110	0
	Summer	95	0.032	1.053	0.052
	Fall	45	0.111	0.933	0.066
	Winter	Not sampled			
1974	Spring	Not sampled			
	Summer	6	0	0.666	0
Walnut Grove					
1973	Spring	99	0	0.212	0.252
	Summer	4	0	0	0
	Fall	Not sampled			
	Winter	Not sampled			
1974	Spring	250	0	0.404	0.080
	Summer	222	0.216	1.063	0.067

1/ Spring - March, April, May
Summer - June, July, August
Fall - September, October, November
Winter - December, January, February

2/ Ages estimated from fork length, using age length curves from Sasaki (1966a

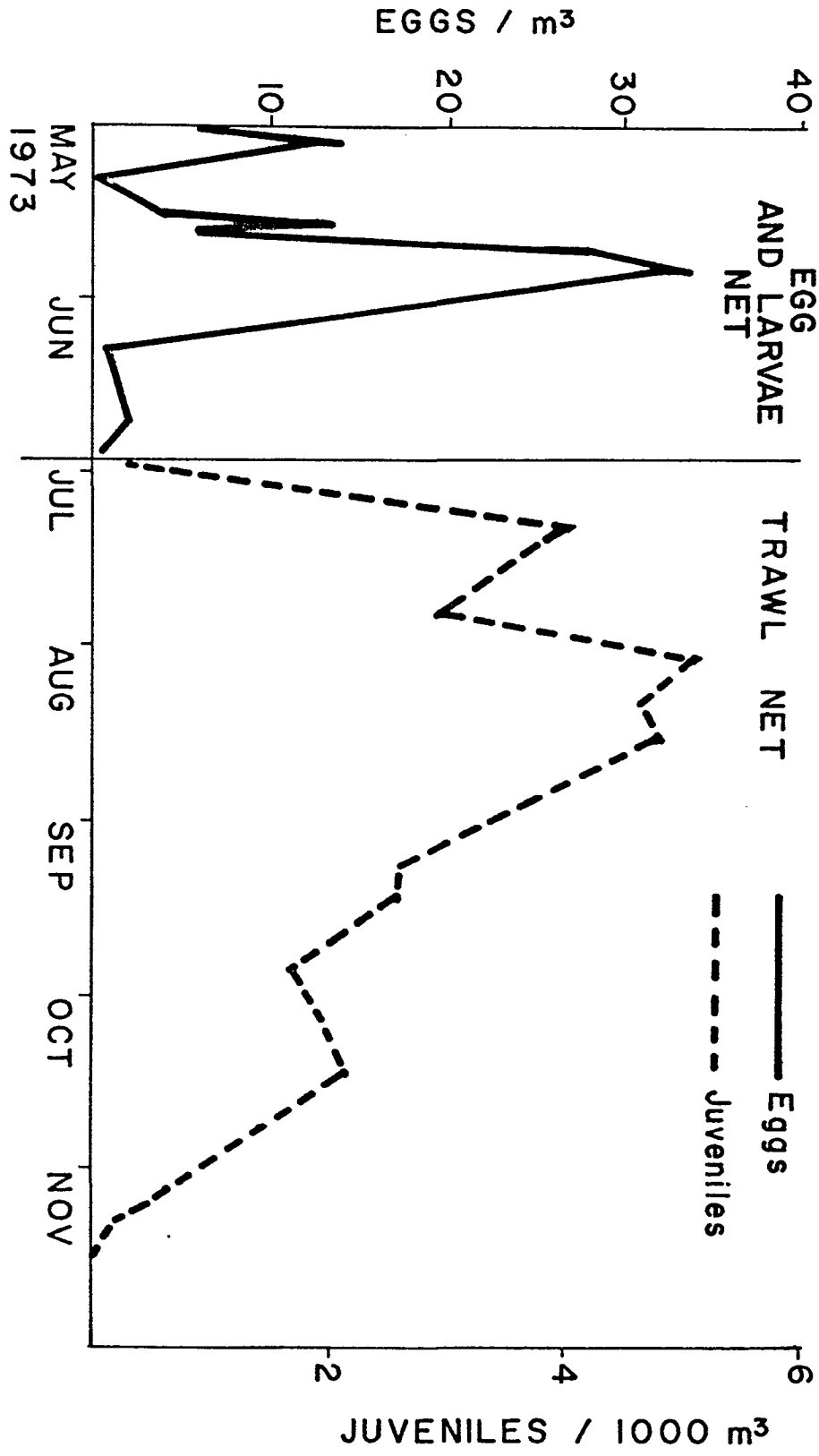


FIGURE 13. American shad. Eggs and juvenile collected from May through November, 1973.

C-045771

This may have been the result of the higher water velocities accompanying flow increases from 408 m^3/s (14,400 ft^3/s) to 626 m^3/s (22,100 ft^3/s) that occurred between May 17 and 24. Although routine sampling ended on June 28, a few shad eggs were taken in exploratory sampling near Clarksburg on August 17. Water temperature during this survey ranged from 17.4 to 22.5°C (63.4 to 72.6°F). Peak collections (May 24) were taken at water temperatures of 22.1 C (67.3°F).

Two 21 mm (0.83 in.) shad larvae were found in the bobbinet cod end of the trawl net on June 5. The colorless larvae were probably much more numerous but either passed through the trawl net or were unnoticed in sample sorting. On June 21, 1973, 110 metamorphosed shad averaging 28.0 mm (1.1 in.) FL were caught in 10 trawls. The average size of American shad caught increased rapidly, reaching an average of 53.3 mm (2.1 in.) by the second week of July (Figure 14).

Shad catches at Hood increased through July, reaching a maximum during the first week of August. Through the remainder of the summer and early fall, catches declined. No shad were taken after the second week of November when storms raised river flows to over 1,700 m^3/s (60,000 ft^3/s) (Appendix I).

Young shad were concentrated along the shallower west bank at Hood. Between July 13 and November 9, 53.4% of all shad captured in the trawl corridor through the Hood transect were taken near the west bank. Only 13.5% were caught along the deeper east bank (Figure 15).

Forty adult shad were collected during May and June 1973, 35 of these were collected on two trawls made after dark on May 3. No yearling American shad were taken.

Although large numbers of American shad eggs were taken near Hood, spawning primarily occurred upstream. Egg and larvae sampling of the Sacramento River during May and June 1973 between RK 225 (RM 140) near Meridian and RK 0 (RM 0) at Collinsville found 85% of all shad eggs sampled upstream from Hood with peak catches made between May 7 and June 6 (Lee W. Miller, unpublisued data). High numbers of eggs were also taken in the Feather River near Oroville between May 11 and June 11 (Richard Painter, unpublished data).

In the Connecticut River most shad spawning activity was noticed over sand or sand and gravel in water less than 3.7 m (12 ft) deep (Marcy 1969). While eggs can be taken in other habitat types, this habitat is consistent with other successful collections of shad eggs (Leim 1924). This type of habitat occurs in the Sacramento River and major tributaries above Sacramento.

The period of peak abundance of shad eggs sampled by this survey (May 11-June 7) and the aforementioned surveys indicates shad spawning is generally concurrent with striped bass spawning. Evidence suggests that shad sampled at Hood were slowly moving downstream rather than resident in the area. The apparent increase in size of young shad at Hood of 0.35 mm/day (0.01 in./day) was considerably less than the 1.29 mm/day (0.05 in./day) reported by Marcy (1969) and 0.56 to 1.44 mm/day (0.02 to 0.06 in./day) reported by Watson

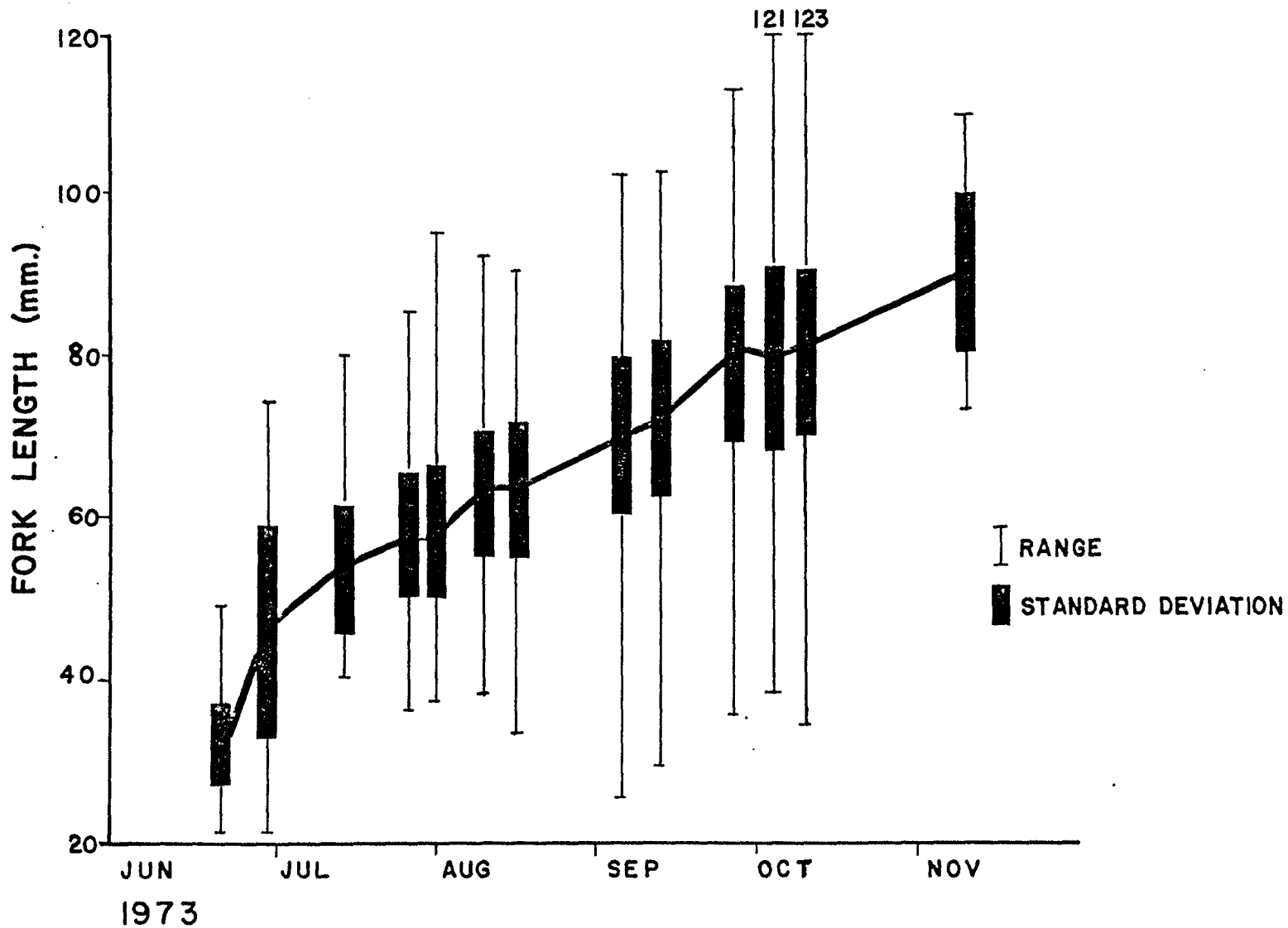


FIGURE 14. American shad. Weekly mean F.L., range, and 1 standard deviation of mean.

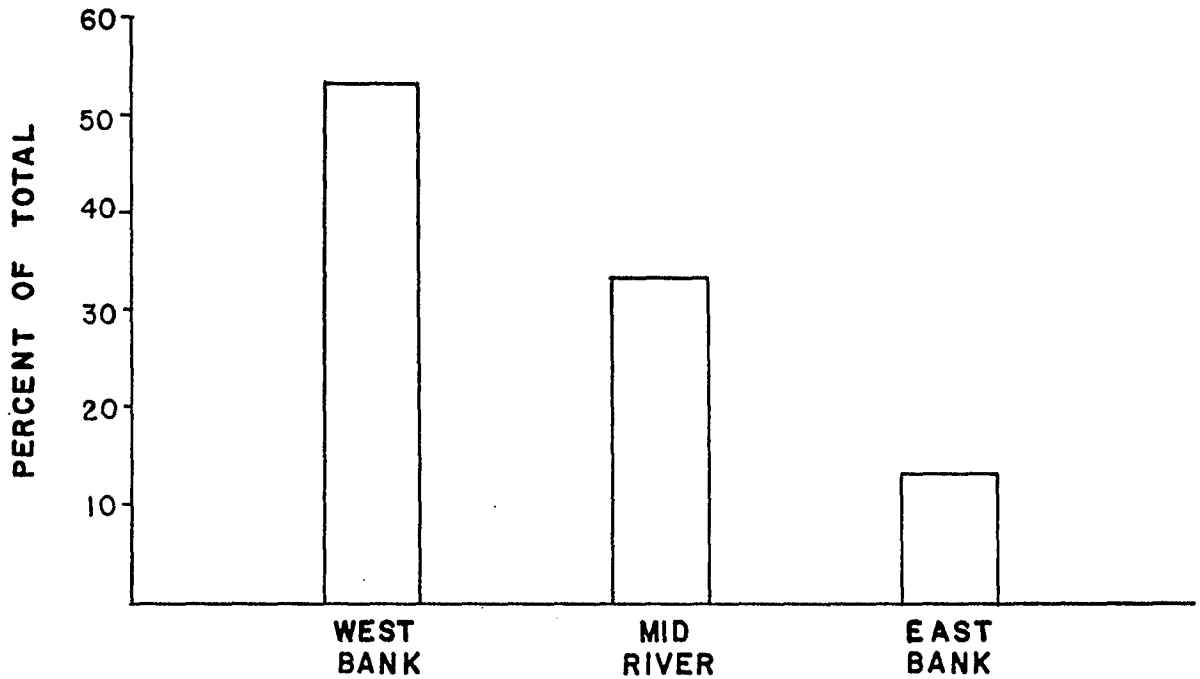


Figure 15. LATERAL DISTRIBUTION OF AMERICAN SHAD IN THE SACRAMENTO RIVER AT HOOD.

(1970), both from the Connecticut River (Figure 16). While this difference in apparent growth rate may be a result of intraspecific competition, it can also be the result of smaller, younger shad moving in from upriver locations while larger shad are moving downstream to salt water. Shad found in the center trawl corridor were statistically larger than shad found in the bank stations (Table 8). Downstream displacement by river flow would move them at a higher rate than the smaller fish found nearer the banks.

This downstream movement is also demonstrated by the shift of greatest juvenile shad density as the season progresses. The peak abundance of shad in the Feather River during 1973 was July 1 to August 15 (Richard Painter, unpublished data). Peak abundance at Hood was July 10 to September 15. Stevens (1966) reported peak shad catches at Fulton and Pt. Sacramento (below Hood) during September and October, indicating that the center of the shad population moves slowly downstream during the summer and fall months.

Insufficient numbers of American shad were captured during the surface-bottom tow series to allow identification of vertical distribution patterns. Young shad have been reported to reside near the bottom during daylight and in the upper 1.2 m (4 ft) during darkness (Marcy 1969).

Threadfin Shad

Threadfin shad, Dorosoma petenense, catches were low throughout the survey with peak catches in late summer and early fall (Figure 17). Except during peak abundance periods, threadfin shad were usually taken singly or in pairs, suggesting fish were "scattered" rather than present in schools. However, during August and September 1973, 10 min trawl tows caught from 0 to 57 on one day at adjacent locations, indicating a "schooled" distribution.

The mean length of all threadfin shad was 80.7 mm (3.2 in.) with a range of 21-146 mm (0.8-5.7 in.). The size distribution about this mean was skewed slightly toward smaller fish (Figure 18).

In the 1963-64 survey of the Delta, threadfin shad concentrations in the Sacramento River were among the lowest encountered in the Delta (Turner 1966d), with catches of over 1,000 fish per trawl were made in deadend sloughs. This compared to a maximum of 57 taken in a similar trawl at Clarksburg August 23, 1973. Threadfin shad are reported to prefer some current (Burns 1966a), but velocities in the main Sacramento River are probably too fast to attract large populations. Over 400 larvae taken during an extensive striped bass egg and larval survey in May and June of 1973 near Hood were identified as threadfin shad, indicating some spawning occurs above Hood.

C-045775

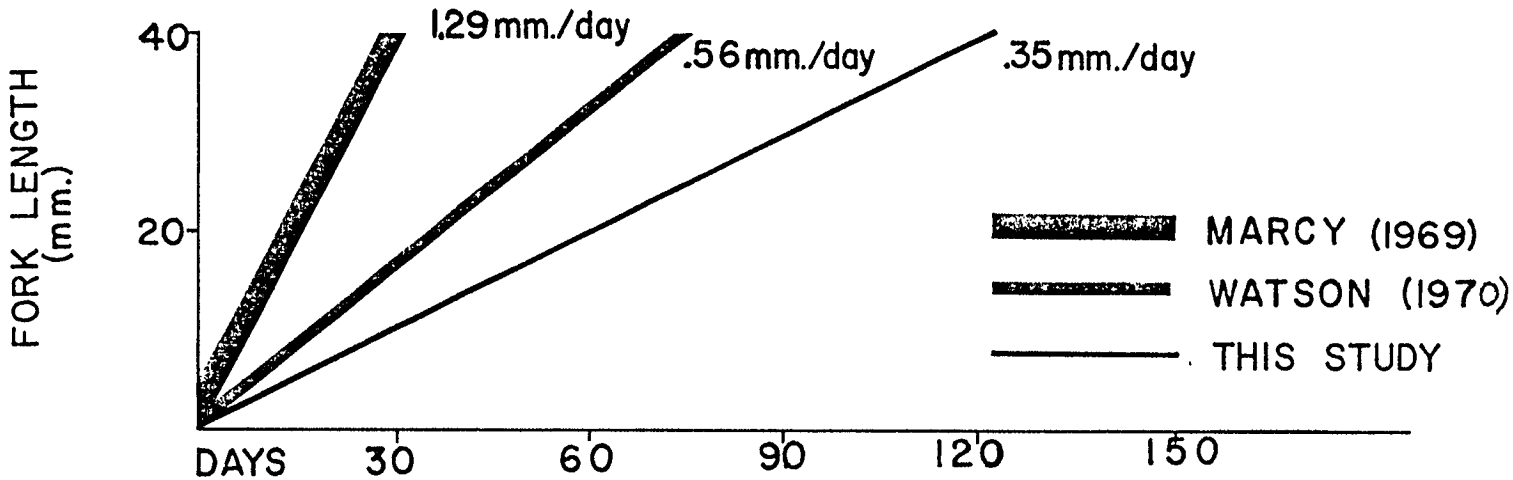


FIGURE 16. Average apparent growth rates of American shad in the Connecticut River (Marcy 1969, Watson 1970) and the Sacramento River, 1973.

C-045776

TABLE 8. Mean Lengths of American Shad Taken at the East, Center, and West Sample Sites at Transect Five at Hood with Test for Homogeneity of Ranks.

Date (1973)	Mean length (mm) East (rank)	Mean length (mm) Center (rank)	Mean length (mm) West (rank)
July 15	53.19(3)	54.65(1)	54.00(2)
25	56.95(2)	61.04(1)	54.50(3)
30	57.93(2)	59.30(1)	55.44(3)
Aug 7	58.34(2)	60.62(1)	55.42(3)
9	62.32(2)	64.86(1)	61.84(3)
15	62.26(3)	64.68(1)	62.63(2)
22	67.34(2)	68.44(1)	65.89(3)
Sep 5	72.06(1)	71.00(2)	69.29(3)
12[1/]	71.45(3)	72.38(1)	71.82(2)
12[1/]	76.92(2)	79.00(1)	73.85(3)
13	70.96(3)	72.60(1)	71.00(2)
26	82.13(1)	77.50(2)	70.85(3)
Oct 3	80.57(2)	81.04(1)	76.70(3)
11	79.42(2)	84.40(1)	78.50(3)
Rank Summary	30	16	38
Final Rank	2	1	3

X^2 for homogeneity of ranks = 39.33[2/]

1/ On September 12, two sets of tows were run on the Hood transect, with the second set of tows made during dusk-darkness period.

2/ Significant at 99% level.

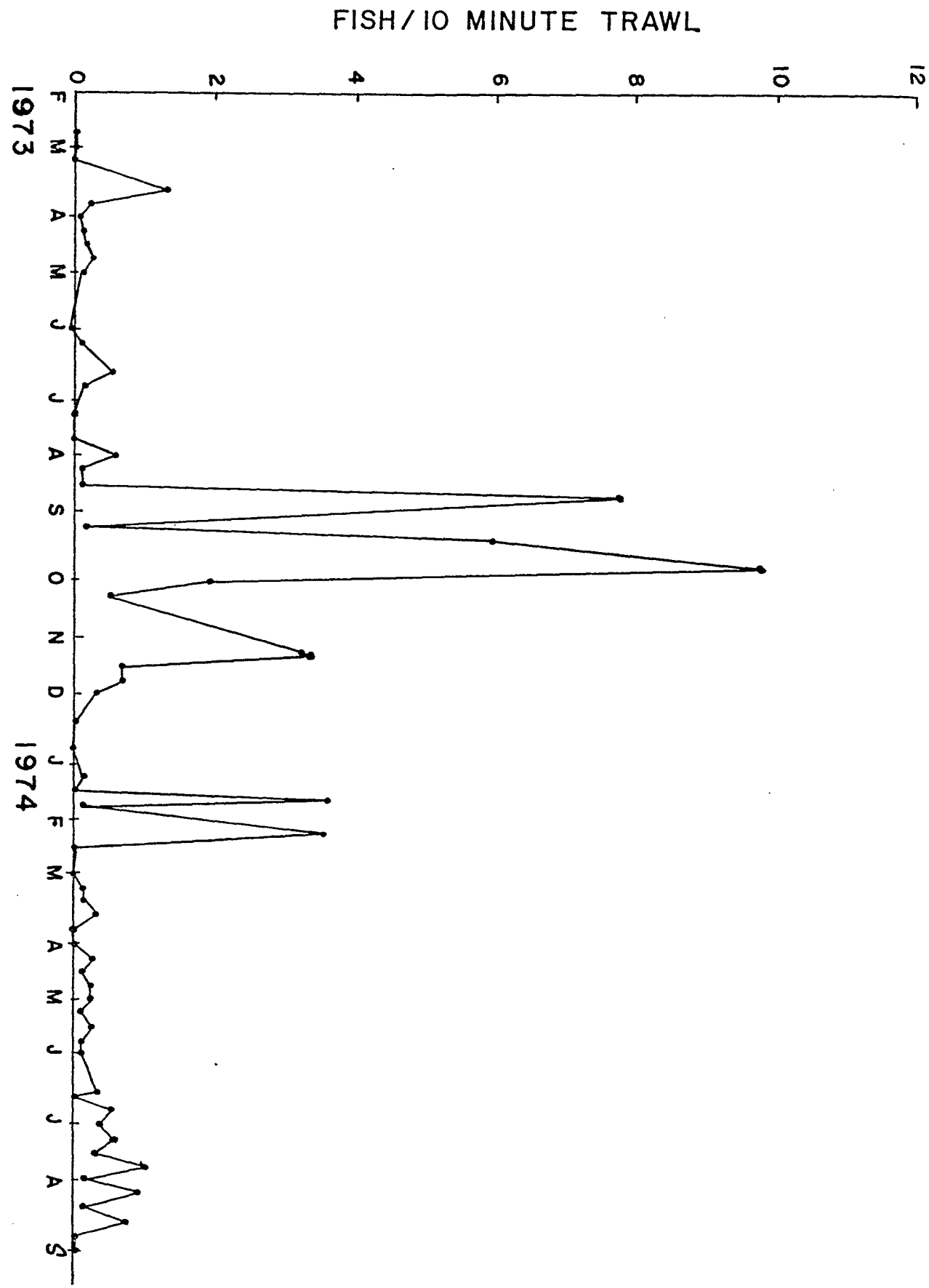


FIGURE 17. Average weekly collection of threadfin shad in the Sacramento River.

C-045778

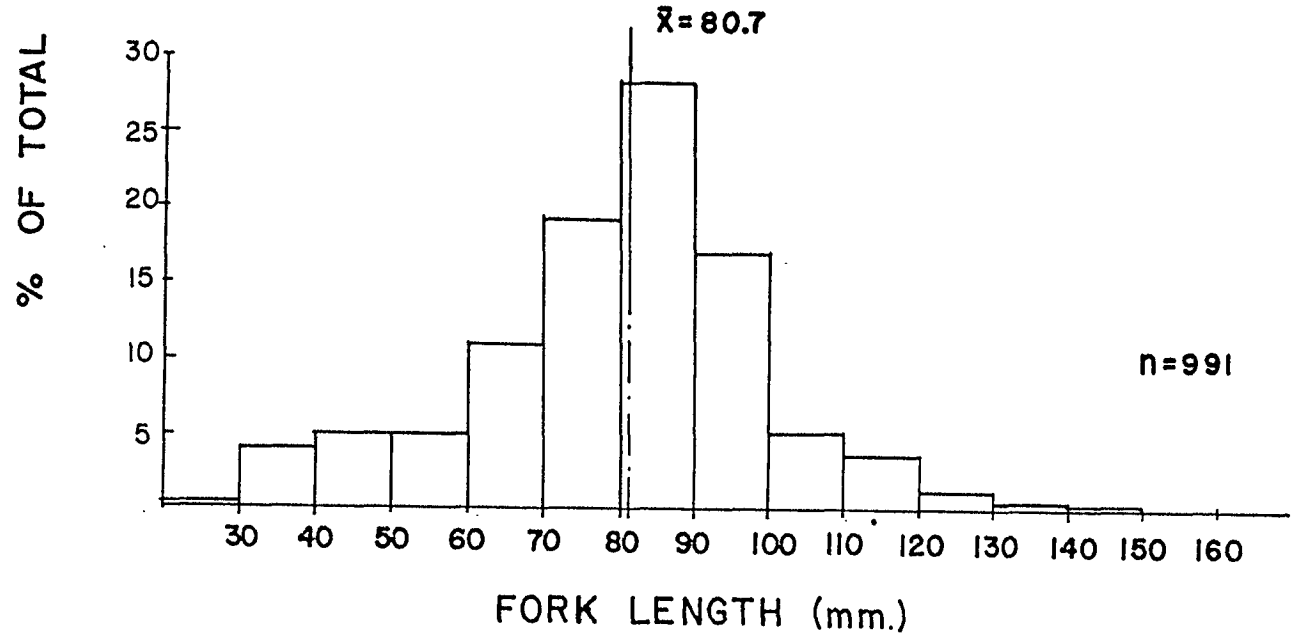


FIGURE 18. Length frequency of threadfin shad collected from March, 1973 to September, 1974.

Spiny-Rayed Fishes

Only 58 centrarchid (spiny-rayed) fish were taken by the midwater trawl. Thirty-five were collected in the river near Hood (Table 9). Of all species taken, only black crappie, Pomoxis nigromaculatus, and white crappie, P. annularis, were of sufficient size to be sexually mature, suggesting that other species taken were young transported into the area from upstream. Two smallmouth bass, Micropterus dolomieui, fry were collected during 1974 beach seining operations at the Yolo County boat ramp. No horizontal or vertical distribution patterns could be identified.

The lower Sacramento River does not provide the cover, slow clear water, or firm substrate usually associated with centrarchid habitat. In previous Delta surveys, only deadend sloughs, with still water and riparian vegetation on the banks, provided large catches of crappie, bluegills, Lepomis macrochirus, and warmouth bass, Chaenobryttus gulosus, in otter and midwater trawl sampling (Turner 1966b). Twenty-four of 32 largemouth bass, M. salmoides, taken by gill nets during these surveys were from deadend sloughs.

Sacramento Squawfish

A total of 102 Sacramento squawfish, Ptychocheilus grandis, were taken in the midwater trawl survey. Squawfish were collected during most months and were most prevalent during late winter and early spring (Figure 19). Ninety percent of the squawfish collected were less than 200 mm (8 in.) (Figures 20 and 21). Greater numbers of squawfish less than 200 mm were evident at beach seine locations. As many as eight fish/seine haul were collected during spring and early summer. Horizontal and vertical distribution patterns could not be identified.

The Sacramento River is the source of most squawfish in the Delta (Turner 1966c). Adult squawfish move from tributary streams into larger rivers during winter and probably move downstream during high winter flows. Young-of-the-year are also probably displaced by high flows. Squawfish greater than 200 mm (8 in.) are often captured during April and May in traps operated by the California Department of Fish and Game designed to capture upstream migrant striped bass (John Grant, unpublished data). These fish are probably migrating upstream to spawn.

Carp and Goldfish

Near Hood, most carp, Cyprinus carpio, were collected in late winter and spring of 1973 and 1974, with infrequent catches during late summer and fall (Figure 22). Ninety percent of all carp collected were between 325-500 mm (12.8-19.7 in.) FL (Figure 23). Four young-of-the-year fish were taken in May, July, and August of 1974.

TABLE 9. Catches of Centrarchid Fishes in the Sacramento River Near Hood and Clarksburg. Catches from Walnut Grove and Other Delta Channels are Excluded. This Catch is Based on 524 10 Min Surface Trawls.

Species	Adults	Juveniles
Black crappie, Pomoxis nigromaculatus	1	2
White crappie, P. annularis	-	2
Bluegill, Lepomis macrochirus	-	4
Green sunfish, L. cyanellus	-	4
Warmouth bass, Chaenobryttus gulosus	-	1
Smallmouth bass, Micropterus dolomieui	-	13
Largemouth bass, M. salmoides	-	3
Unidentified Centrarchids	1	4

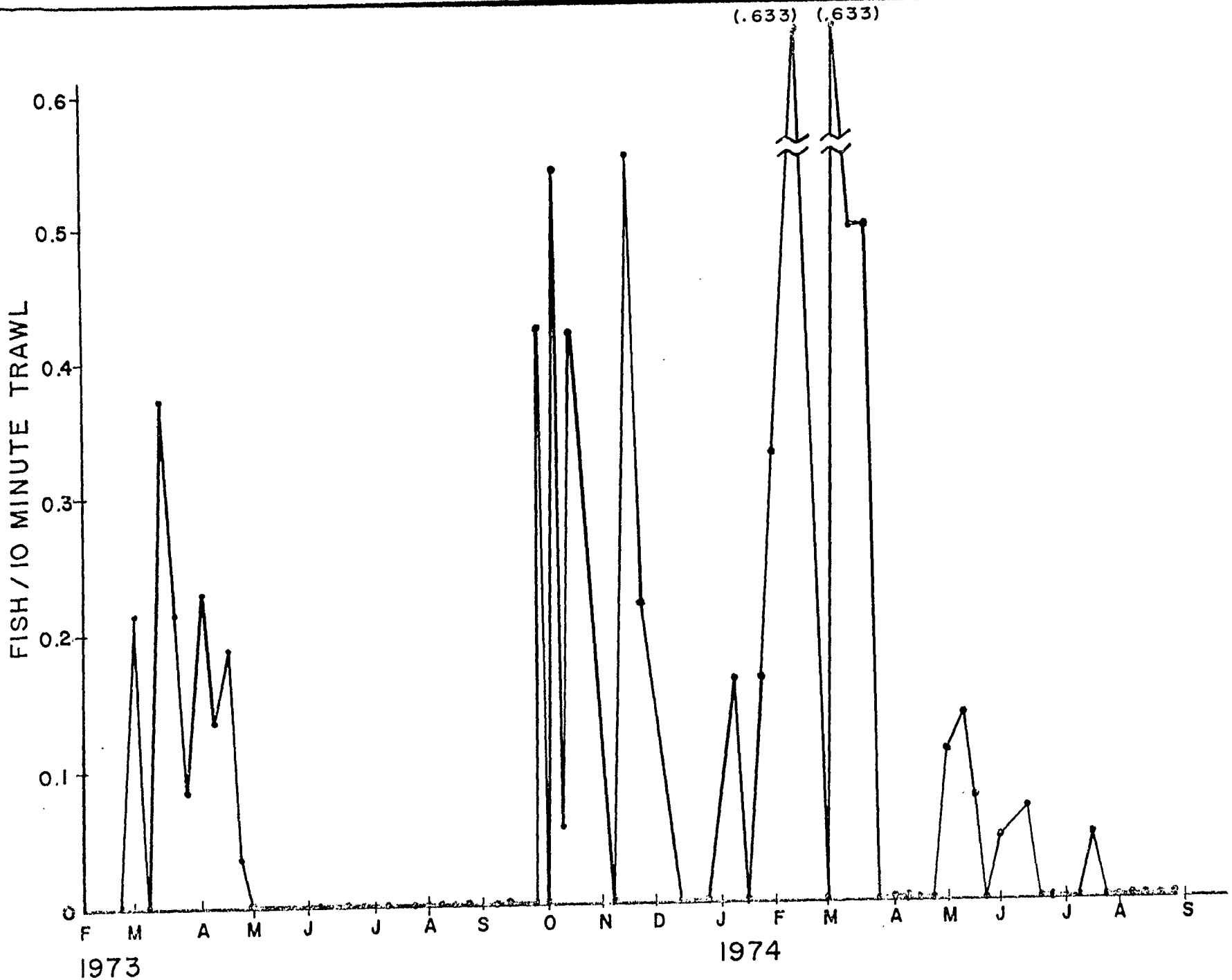


FIGURE 19. Sacramento squawfish collected by surface trawling in the Sacramento River from Clarksburg Bend to Walnut Grove.

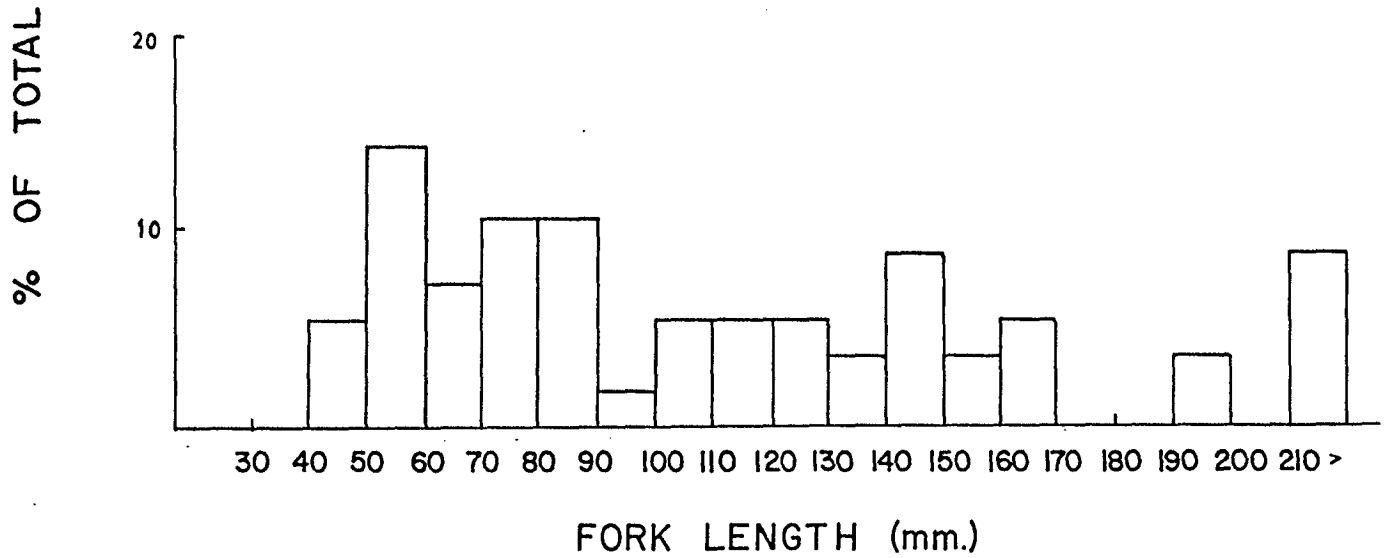


FIGURE 20. LENGTH FREQUENCY OF SACRAMENTO SQUAWFISH collected from FEBRUARY 21, 1973 to DECEMBER 31, 1973.

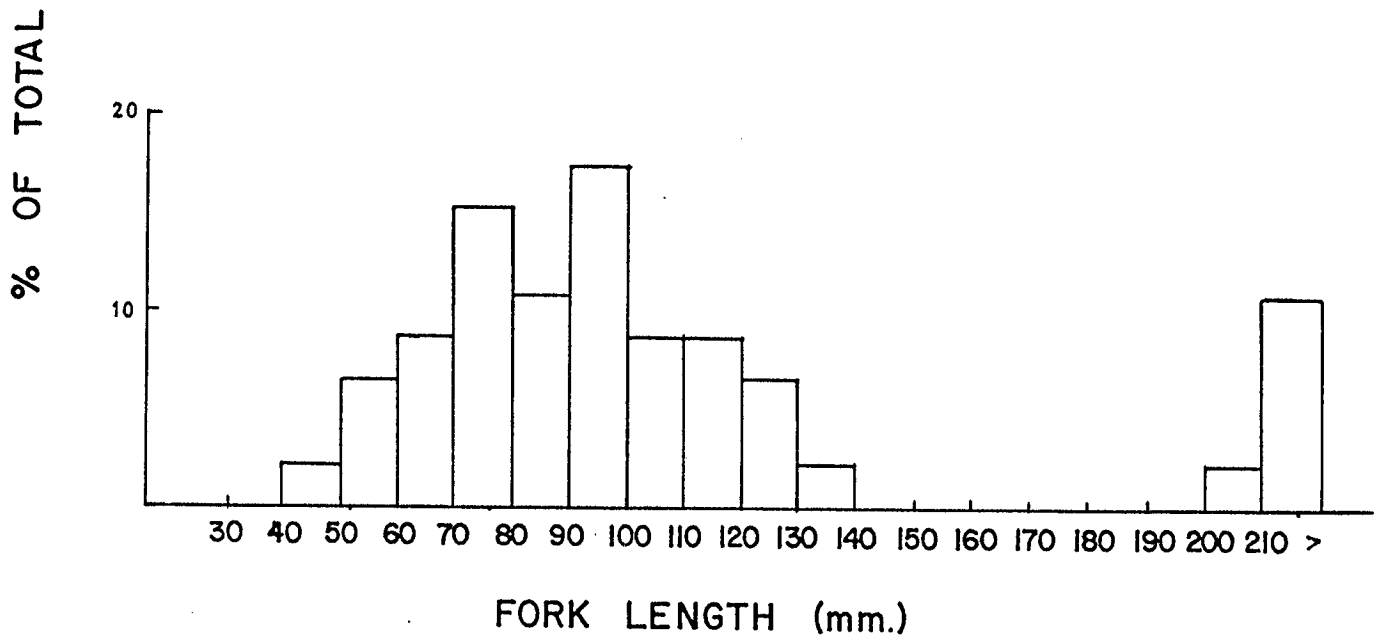


FIGURE 21. LENGTH FREQUENCY OF SACRAMENTO SQUAWFISH collected from JANUARY 1, 1974 to SEPTEMBER 3, 1974.

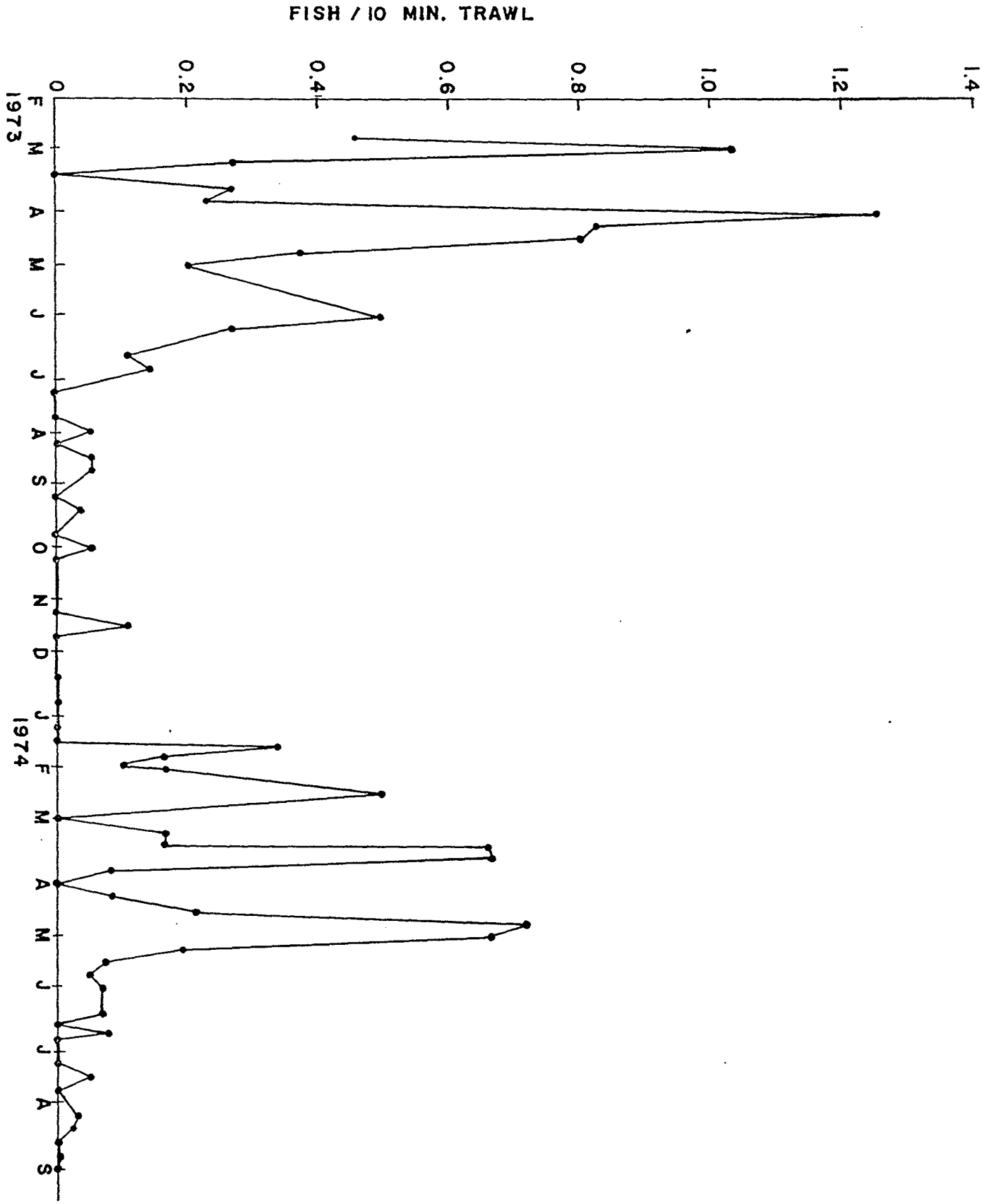


FIGURE 22. Average weekly collections of carp (Cyprinus carpio) from Clarksburg Bend to Walnut Grove, February 1972 to [illegible]

FIGURE 22. Average weekly collections of carp (Cyprinus carpio) from Clarksburg Bend to Walnut Grove, February, 1973 to September, 1974.

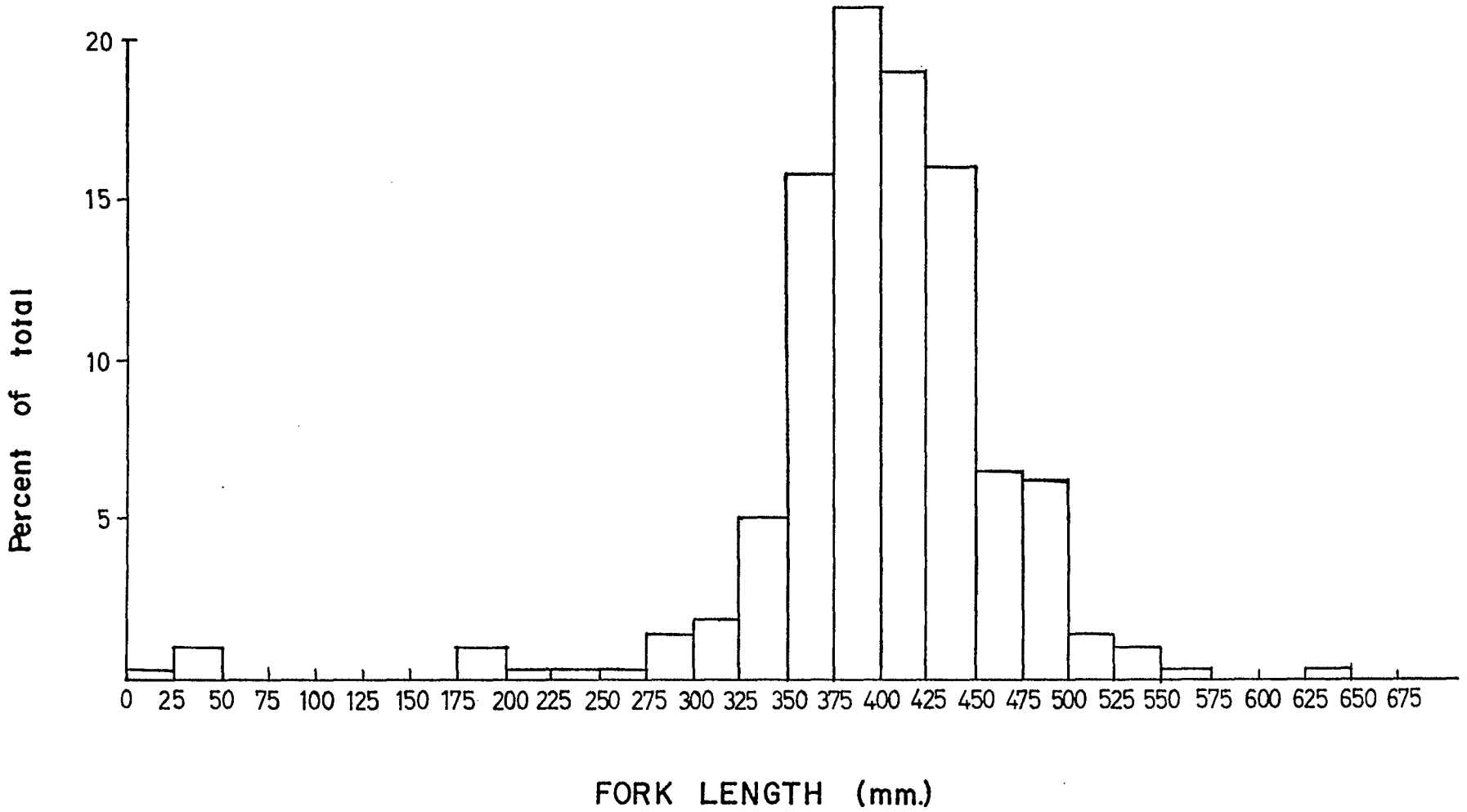


FIGURE 23. Length-frequency distribution of carp collected from February, 1973 to September, 1974.

The narrow size range is similar to that reported in the 1963-64 Delta-wide surveys by Turner (1966c). Carp reproduction in the Delta is probably low due a lack of shallow areas with submerged vegetation, but carp are long-lived (Burns 1966b) and not highly exploited in the Delta, allowing a substantial adult population to be maintained by limited reproduction within the Delta and minor immigration from other areas.

One goldfish, Crassius auratus, 250 mm (9.8 in.) FL, was collected at Hood during November 1973.

Splittail

Fifty-six splittail, Pogonichthys macrolepidotus, were collected with peak catches during March and April of 1973 and April and May of 1974 (Figure 24). Catches in March and April were adult fish, ranging from 200-325 mm (7.9-12.8 in.) FL (Figure 25). May, June, and July catches ranged from 26-60 mm (1.0-2.4 in.) FL. The presence of young-of-the-year fish in 1973 suggest spawning areas exist in the Sacramento River upstream from Hood.

Sacramento Blackfish

One Sacramento blackfish, Orthondon microlepidotus, 383 mm (15.1 in.) FL, was taken on May 29, 1973.

Delta Smelt

Delta smelt, Hypomesus transpacificus, were first collected on March 19 and 20, 1973 at Walnut Grove and Hood, respectively. Water temperature on both days was 10.8°C (51.4°F). Peak abundance occurred in April and May, 1973 (Figure 26). All fish collected prior to July were probably 1972 year class fish. On July 25, 1973, two young-of-the-year were taken at Hood.

In 1974, 1973 year class Delta smelt were taken between April 25 (water temperature 12.8°C (55.2°F)) and July 16 (water temperature 20.9°C (69.6°F)) with peak abundance during May and June (Figure 27). All 157 fish caught were 1973 year class. One young-of-the-year fish was taken at Hood on August 12, 1974.

In previous surveys, highest catches of Delta smelt were in fall in the Sacramento River below Isleton and Suisun Bay to Martinez (Stevens 1966; Ganssle 1966). Smelt apparently move upstream into the central and eastern Delta during February and March (Erkkila et al. 1950; Radtke 1966) and into the Sacramento River above Isleton during March, April, and May to spawn. A small portion of this population migrates at least as far upstream as Clarksburg in the Sacramento River. In June the new year class moves into Suisun Bay and the lower Sacramento River (James Broadway, unpublished data).

C-045787

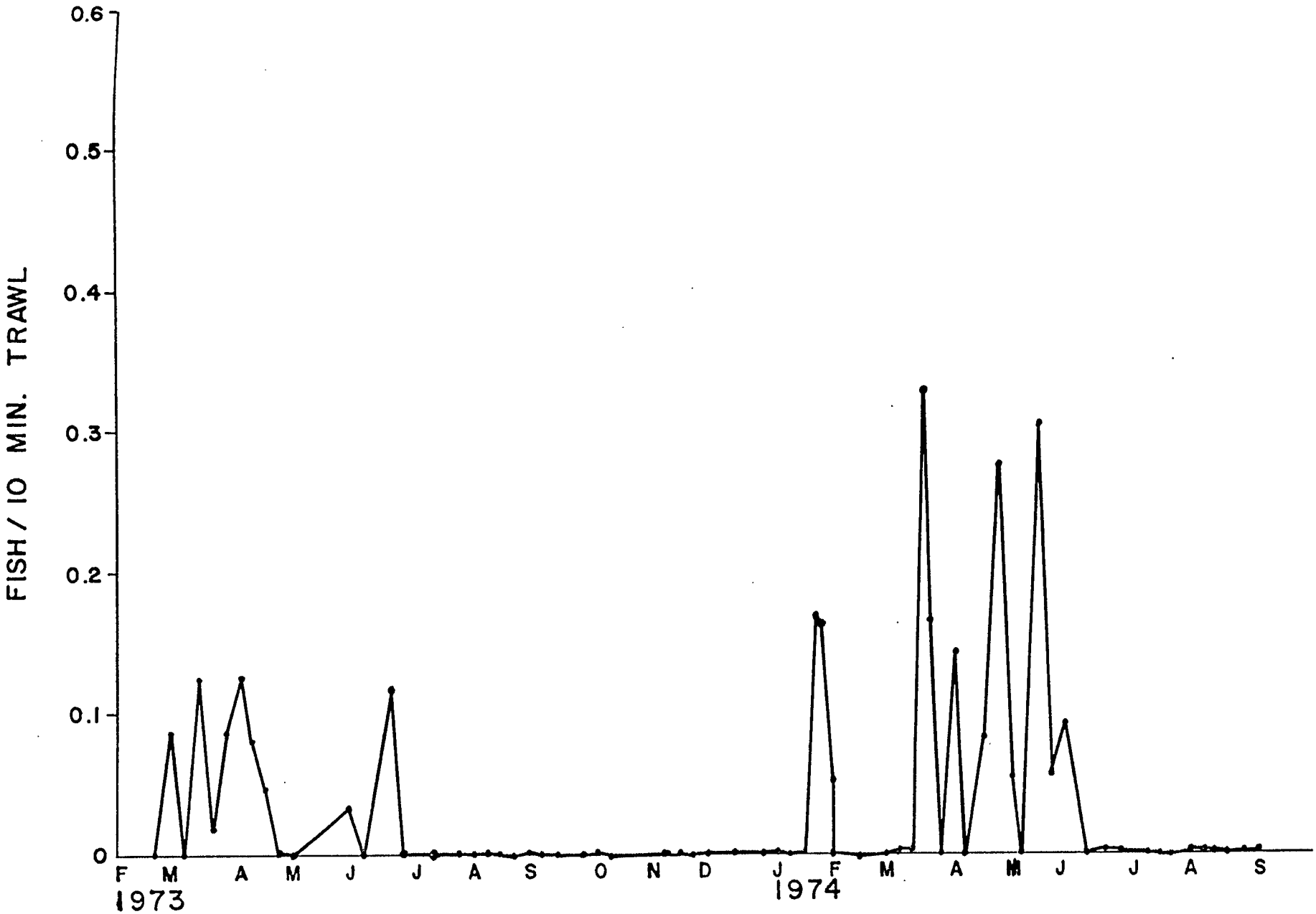


FIGURE 24. Average weekly collection of splittail from February 1973 to September, 1974.

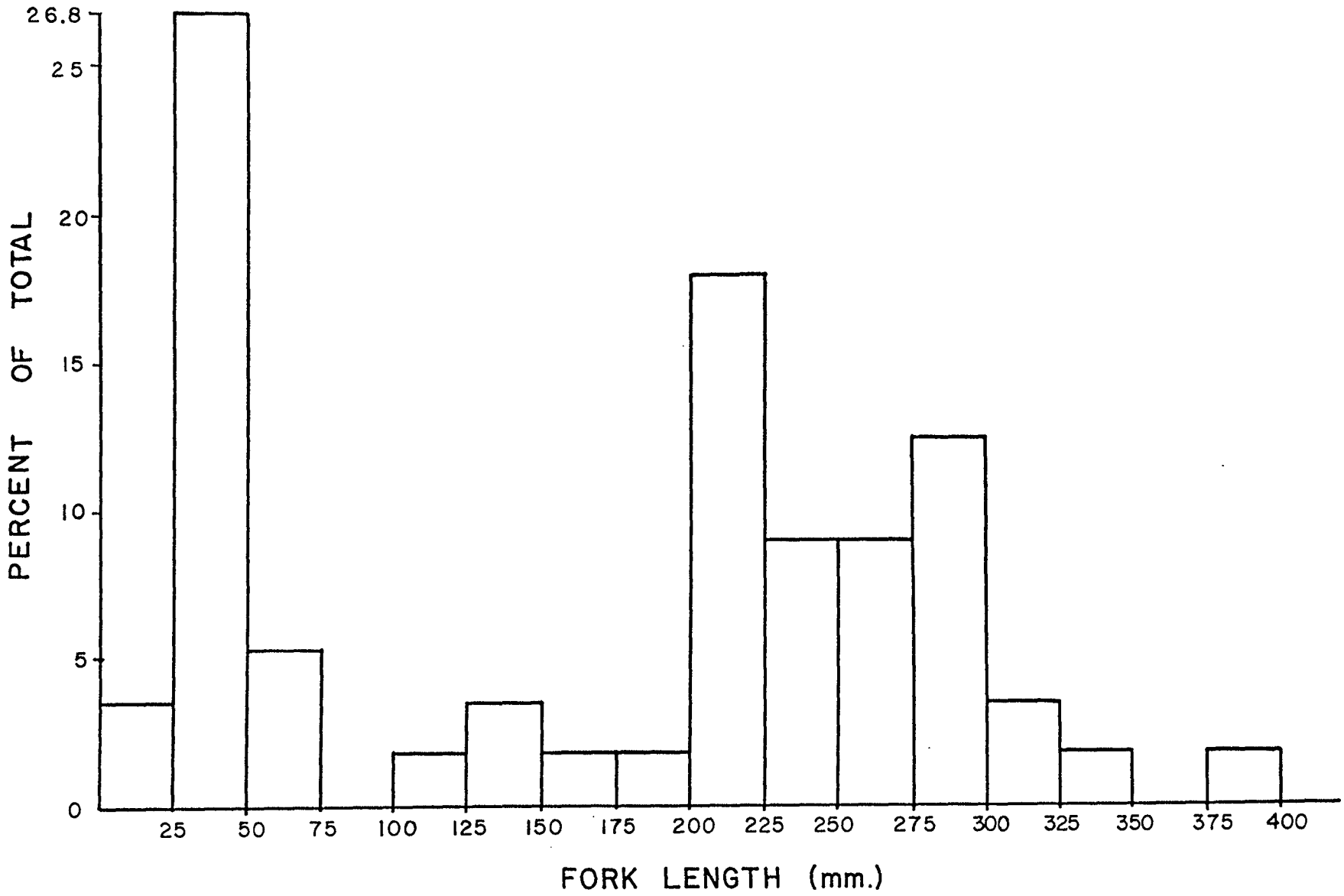


FIGURE 25. Length frequency of splittail collected between February 21, 1973 and September 3, 1974.

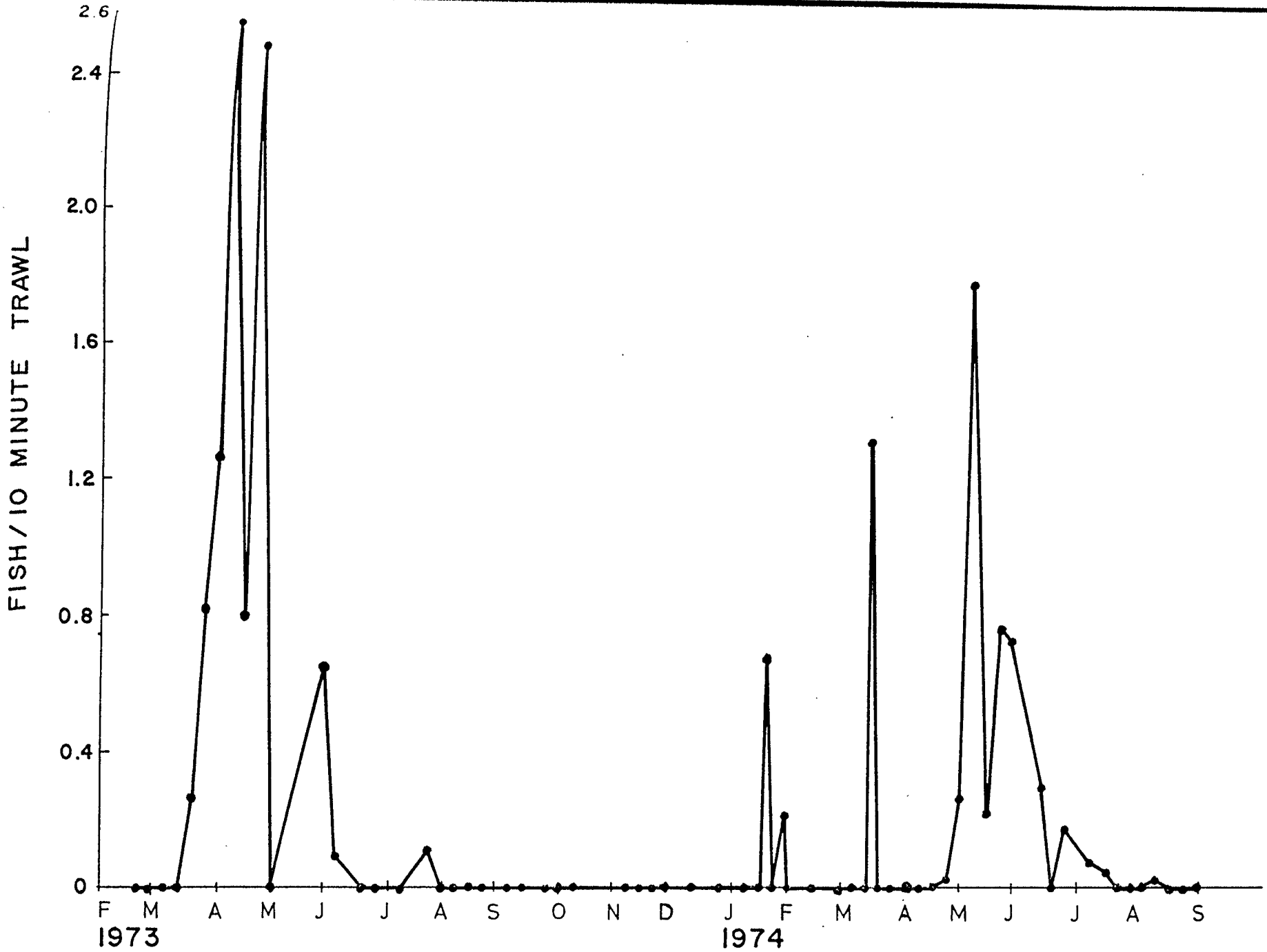


FIGURE 26. Average weekly collection of Delta smelt from February 1973 to September 1974

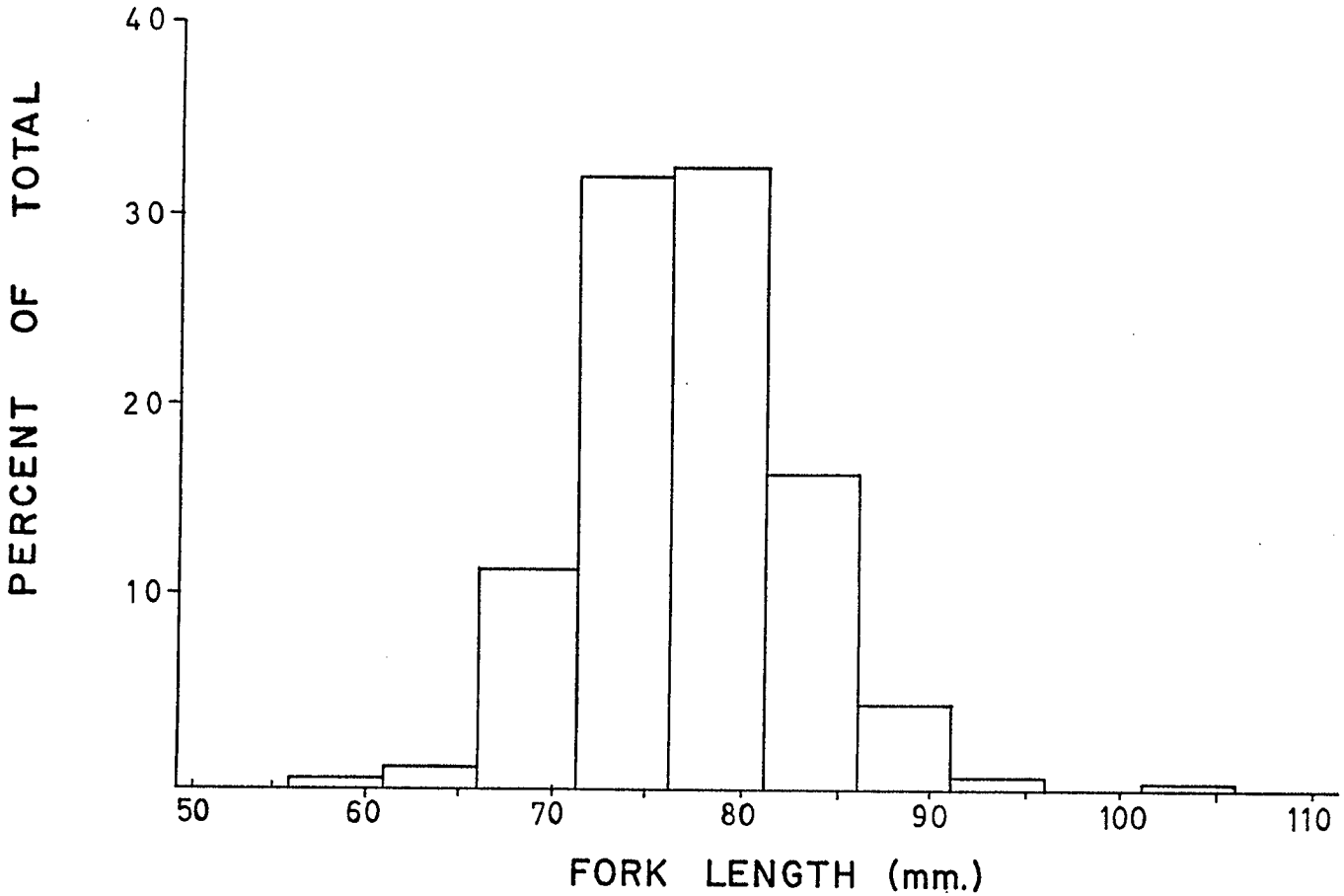


FIGURE 27. LENGTH FREQUENCY OF DELTA SMELT collected between FEBRUARY 21, 1973 AND SEPTEMBER 3, 1974.

Stevens (1966) and Erkkila et al. (1950) found Delta smelt in the eastern and southern Delta much earlier than they appeared in the Sacramento River at Hood and Walnut Grove. This may indicate upstream movement was restricted by greater net downstream flows.

Longfin Smelt

Twelve longfin smelt, Spirinchus thaleichthys, were taken in 1973. Nine adult fish, ranging from 110-125 mm (4.3-4.9 in.) FL, were captured during March and April. Three young-of-the-year, 25, 23, and 18 mm (1.0, 0.9, and 0.7 in.) FL, were caught in June and July.

No Sacramento smelt were taken during the high outflow year of 1974.

Hood is considerably upstream from the primary spawning area of longfin smelt under present salinity and flow conditions. Even under reduced outflows it is doubtful that appreciable numbers would migrate upstream as far as Hood.

Ictalurid Fishes

This fish occurrence and distribution study, designed primarily to sample salmon and shad, utilized gear and procedures that were inefficient in sampling benthic species. As only daylight surface trawls were made on a continuous basis, trawl catches provide a very poor estimate of ictalurid fishes.

Only 12 white catfish, Ictalurus catus, were taken during surface tows during the months of May through August. The average fork length was 183 mm (7.2 in.) with a range of 103-262 mm (4.1-10.4 in.).

During September of 1974, while attempting to sample vertical distributions of American shad, 10 young-of-the-year channel catfish, I. punctatus, ranging from 46 to 59 mm FL (1.8-2.3 in.) were taken at Walnut Grove sample sites with the small otter trawl.

In a previous Delta-wide survey, Turner (1966a) found very low populations of ictalurids in the Sacramento River near Isleton and Rio Vista. A combination of high current velocities, lack of spawning substrate, and high turbidity renders the habitat marginal for ictalurids.

A resident population of channel catfish is present in the main river near Verona and in the Sutter bypass (McCammon and LaFaunce 1961). This population probably gave rise to the young-of-the-year fish taken at Walnut Grove, fish which were transported by the above average spring and summer flows of 1974. The importance of this "stocking" from upstream areas to the channel catfish populations in the Delta is unknown.

White catfish are found in higher salinities in the Delta than other species of ictalurids, and are the most abundant ictalurid in the Delta. Tagging studies have demonstrated significant upstream movement of white catfish from the Delta to the Sacramento weir above Sacramento (Borgeson and McCammon 1967). Young white catfish are also probably carried downstream past Hood from upriver spawning areas, but information on the numbers and sizes of fish is lacking.

Sturgeon

Although no sturgeon were collected during this survey the majority of spawning occurs in the Sacramento River above Knights Landing during mid-February to late May (Kohlhorst 1976). All the larvae and juveniles pass Hood on the way to the nursery in the estuary.

CONCLUSIONS

Chinook Salmon

1. Large numbers of young-of-the-year and yearling chinook salmon can be expected at Hood between early January and mid-July.

2. A substantial salmon fry (less than 50 mm (2 in.)) migration begins in early January. These fish remain inshore and drift downstream slower than the current. High populations decrease during April and May as these fish grow and leave.

3. Small numbers of yearling salmon migrate downstream rapidly during February, March, and April. Fork length of these fish is over 100 mm (4 in.). These fish do not concentrate onshore.

4. The primary salmon smolt migration occurs April through July. These fish remain offshore, and move downriver rapidly. Average fork length of these fish is 80 mm (3.3 in.).

5. Smolting salmon remain in the top 2 m (6.5 ft) of water during daylight but disperse to lower levels during darkness.

6. Smolting salmon concentrate in swift portions of the river near Hood.

7. Smolting salmon are probably diverted down Delta channels branching off the Sacramento River in proportion to the water diverted.

8. Four runs of chinook salmon produce young nearly every month of the year. The fall outmigration of salmon in 1973 was minor compared with late winter and spring outmigrations.

C-045793

Steelhead

9. The majority of young steelhead trout currently present at Hood are one year old smolts.

10. The steelhead outmigration is concurrent with the main salmon migration (February-May). Only a small portion of the population passes Hood during fall.

Striped Bass

11. Juvenile striped bass populations near Hood are small compared with other downstream Delta areas. Most of these bass are larger than 40 mm (1.5 in.).

American Shad

12. American shad spawning in the Sacramento River is concurrent with striped bass spawning.

13. American shad do not undergo a "smolting" migration past Hood as do salmon. Young shad drift past Hood from late June through mid-November. Average size ranges from less than 30 mm (1.2 in.) FL in July to 90 mm (3.5 in.) FL in November.

14. American shad prefer calm, inshore water areas such as on the inside of the Hood bend.

Other Fishes

15. Threadfin shad are abundant at Hood in fall, but populations are smaller than summer American shad populations. Size range of adults passing Hood is from 21-146 mm (0.8-5.8 in.) FL.

16. Delta smelt are the most abundant smelt at Hood.

17. Abundance of bottom dwelling fish such as sturgeon, carp, and catfish was not adequately sampled. Few young-of-the-year were taken.

18. Spiny-rayed fishes, centrarchids, are not common near Hood.

ACKNOWLEDGEMENTS

Most of the success of this study is due to Jim Swanson who aided in both the field sampling and data reduction phases of this study. Ed Whitesel provided supervision and inspiration; John Skinner, Glenn Delisle, Dan Odenweller, and Alan Pickard provided considerable editorial assitance. Barby Allen typed the final copy as well as numerous drafts and Ismael Solorio and Robert Kano drew the illustrations. Special thanks must go to the numerous seasonal aids who provided most of the field labor during the two years of this study.

C-045794

REFERENCES

Alpin, J. S. 1967. Biological survey of San Francisco Bay 1963-1966. Calif. Dept. Fish Game, Mar. Res. Oper. Br. Rept. 67(4):1-131.

Borgeson, D. P. and G. W. McCammon. 1967. White catfish (Ictalurus catus) of the Sacramento-San Joaquin Delta. Calif. Fish Game 53(4):254-263.

Burns, J. W. 1966a. Threadfin Shad. In: A. Calhoun (ed.). Inland Fisheries Management. Calif. Dept. Fish Game:481-488.

———————— 1966b. Carp. In: A. Calhoun (ed.). Inland Fisheries Management. Calif. Dept. Fish Game:510-515.

Erkkila, L. F., J. B. Moffitt, O. B. Cope, B. R. Smith, and R. S. Nielson. 1950. Sacramento-San Joaquin Delta fishery resources: Effects of Tracy Pumping Plant and Delta Cross Channel. U. S. Fish and Wildlife Service, Spec. Rept. - Fisheries, 56:109.

Ganssle, David. 1966. Fishes and decapods of San Pablo and Suisun bays. In: D. W. Kelley (compiler). Ecological studies of the Sacramento-San Joaquin Estuary. Part I. Calif. Dept. Fish Game, Fish Bull. 133:64-94.

Hatton, S. R. 1940. Progress report on the Central Valley fisheries investigations, 1939. Calif. Fish Game 26(4):334-373.

———————— and G. H. Clark. 1942. A second progress report on the Central Valley fisheries investigation. Calif. Fish Game 28(2):116-123.

Kohlhorst, David W. 1976. Sturgeon spawning in the Sacramento River in 1973, as determined by distribution of larvae. Calif. Fish Game 62(1):32-40.

Liem, A. H. 1924. The life history of the shad, Alosa sapidissima (Wilson), with special reference to the factors limiting its abundance. Cont. to Can. Biol., N. S. 2, Vol. 11, pp. 163-284.

Marcy, B. C. Jr. 1969. Shad (early life histories) and resident fishes. In: The Connecticut River Investigation, 8th Seminar. Prog. Rept. 1+99 pp.

McCammon, G. W. and D. A. LaFaunce. 1961. Mortality rates and movement of the channel catfish population of the Sacramento Valley. Calif. Fish Game 47(1):5-26.

Messersmith, James. 1966. Fishes collected in Carquinez Strait in 1961-62. In: D. W. Kelley (compiler). Ecological studies of the Sacramento-San Joaquin Estuary. Part I. Calif. Dept. Fish Game, Fish Bull. 133:57-63.

Radtke, Larry D. 1966. Distribution of smelt, sturgeon, and starry flounder in the Sacramento-San Joaquin Delta with observations on food of sturgeon. In: J. L. Turner and D. W. Kelley (eds.). Ecological studies of the Sacramento-San Joaquin Delta. Part II. Calif. Dept. Fish Game, Fish Bull. 136:115-129.

Rutter, C. 1903. Natural history of the quinnat salmon. A report of investigations in the Sacramento River, 1896-1901. U. S. Fish. Comm., Bull. 22:65-141.

Sasaki, Shoken. 1966a. Distribution and food habits of king salmon, Oncorhynchus tshawytscha, and steelhead rainbow trout, Salmo gairdnerii, in the Sacramento-San Joaquin Delta. In: J. L. Turner and D. W. Kelley (eds.). Ecological studies of the Sacramento-San Joaquin Delta. Part II. Calif. Dept. Fish Game, Fish Bull. 136:108-114.

———— 1966b. Distribution of juvenile striped bass, Roccus saxatilis, in the Sacramento-San Joaquin Delta. In: J. L. Turner and D. W. Kelley (eds.). Ecological studies of the Sacramento-San Joaquin Delta. Part II. Calif. Dept. Fish and Game, Fish Bull. 136:59-67.

Stevens, D. E. 1966. Distribution and food habits of the American shad, Alosa sapidissima, in the Sacramento-San Joaquin Delta. In: J. L. Turner and D. W. Kelley(eds.). Ecological studies of the Sacramento-San Joaquin Delta. Part II. Calif. Dept. Fish Game, Fish Bull. 136:97-107.

Taylor, S. N. (Editor). 1973. King (chinook) salmon spawning stocks in California's Central Valley, 1971. Calif. Dept. Fish Game, Anad. Fish. Br. Admin. Rept. No. 73-2. 36 p.

Turner, J. L. 1966a. Distribution and food habits of Ictalurid fishes in the Sacramento-San Joaquin Delta. In: J. L. Turner and D. W. Kelley (eds.). Ecological studies of the Sacramento-San Joaquin Delta. Part II. Calif. Dept. Fish Game, Fish Bull. 136:130-143.

———— 1966b. Distribution and food habits of Centrarchid fishes in the Sacramento-San Joaquin Delta. In: J. L. Turner and D. W. Kelley (eds.). Ecological studies of the Sacramento-San Joaquin Delta. Part II. Calif. Dept. Fish Game, Fish. Bull. 136:144-153.

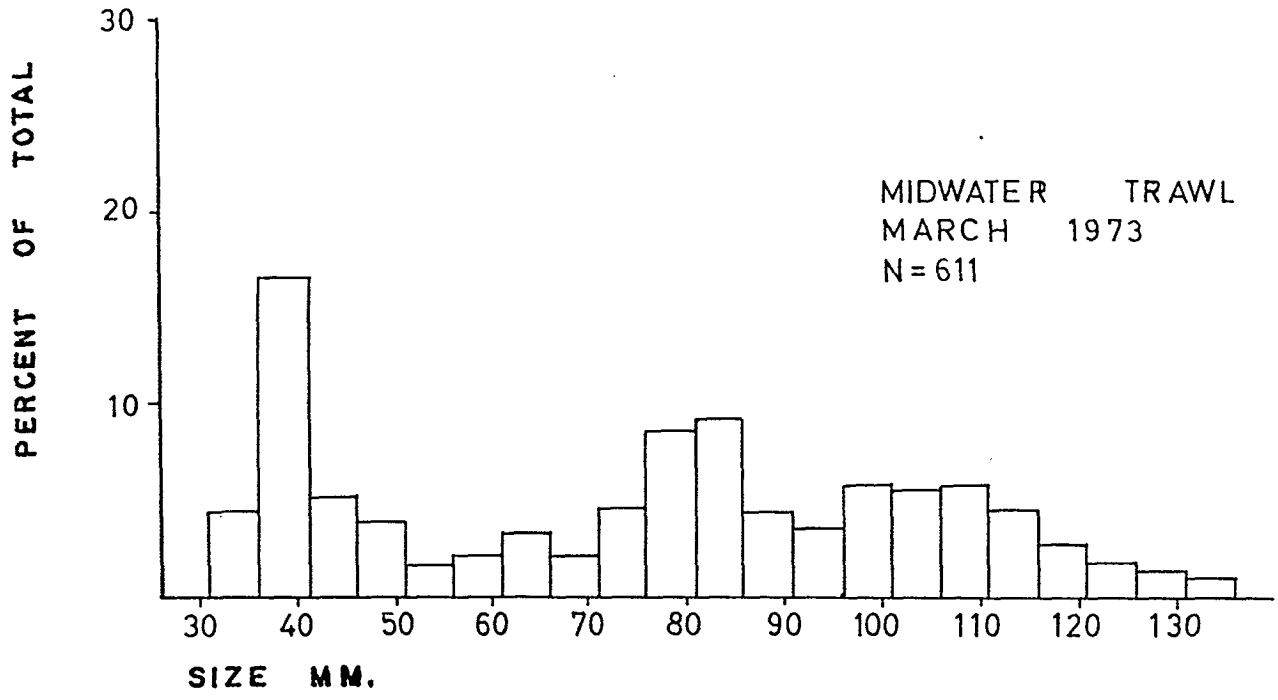
———— 1966c. Distribution of Cyprinid fishes in the Sacramento-San Joaquin Delta. In: J. L. Turner and D. W. Kelley (eds.). Ecological studies of the Sacramento-San Joaquin Delta. Part II. Calif. Dept. Fish Game, Fish Bull. 136:154-159.

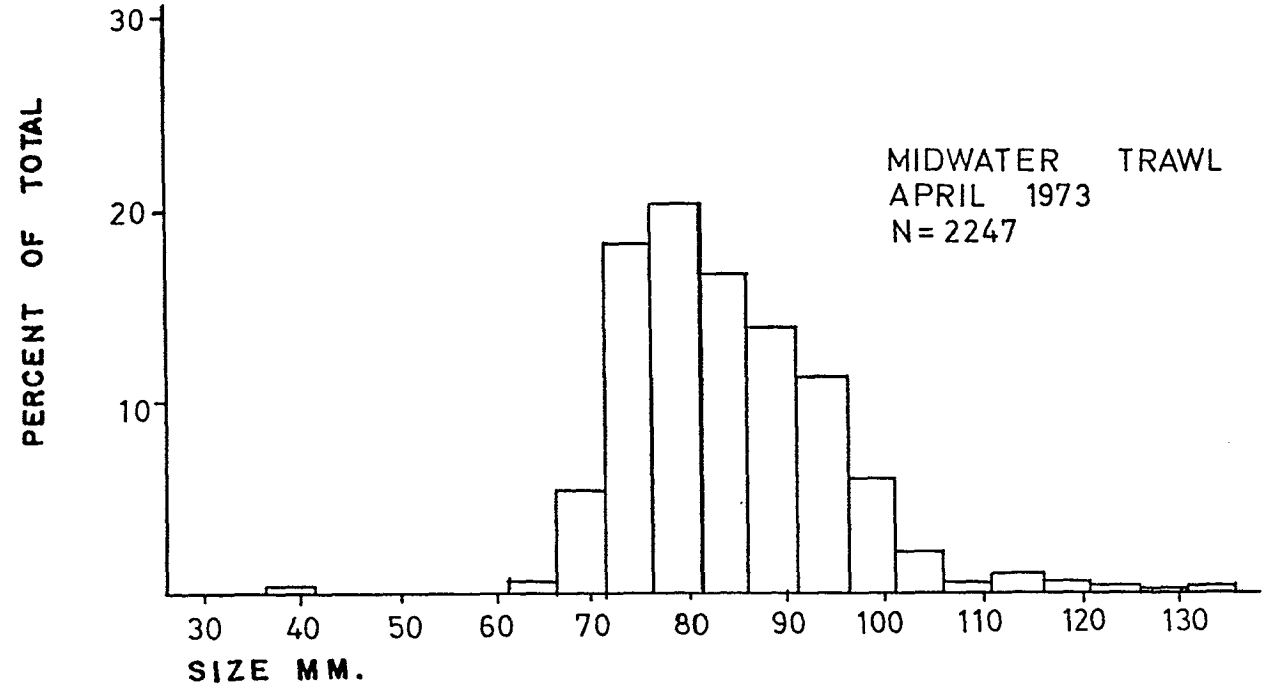
Turner, J. L. 1966d. Distribution of threadfin shad, Dorosoma petenense, tule perch, Hysterocarpus traskii, sculpin spp., and crayfish spp. in the Sacramento-San Joaquin Delta. In: J. L. Turner and D. W. Kelley (eds.). Ecological studies of the Sacramento-San Joaquin Delta. Part II. Calif. Dept. Fish Game, Fish Bull. 136:160-168.

Watson, J. F. 1970. Distribution and population dynamics of American shad, Alosa sapidissima (Wilson), in the Connecticut River above Holyoke Dam, Massachusetts. Univ. of Mass. Ph.D. diss.: 104.

VonGeldern, C. E. 1972. A midwater trawl for threadfin shad, Dorosoma petenense. Calif. Fish Game 58(4):268-276.

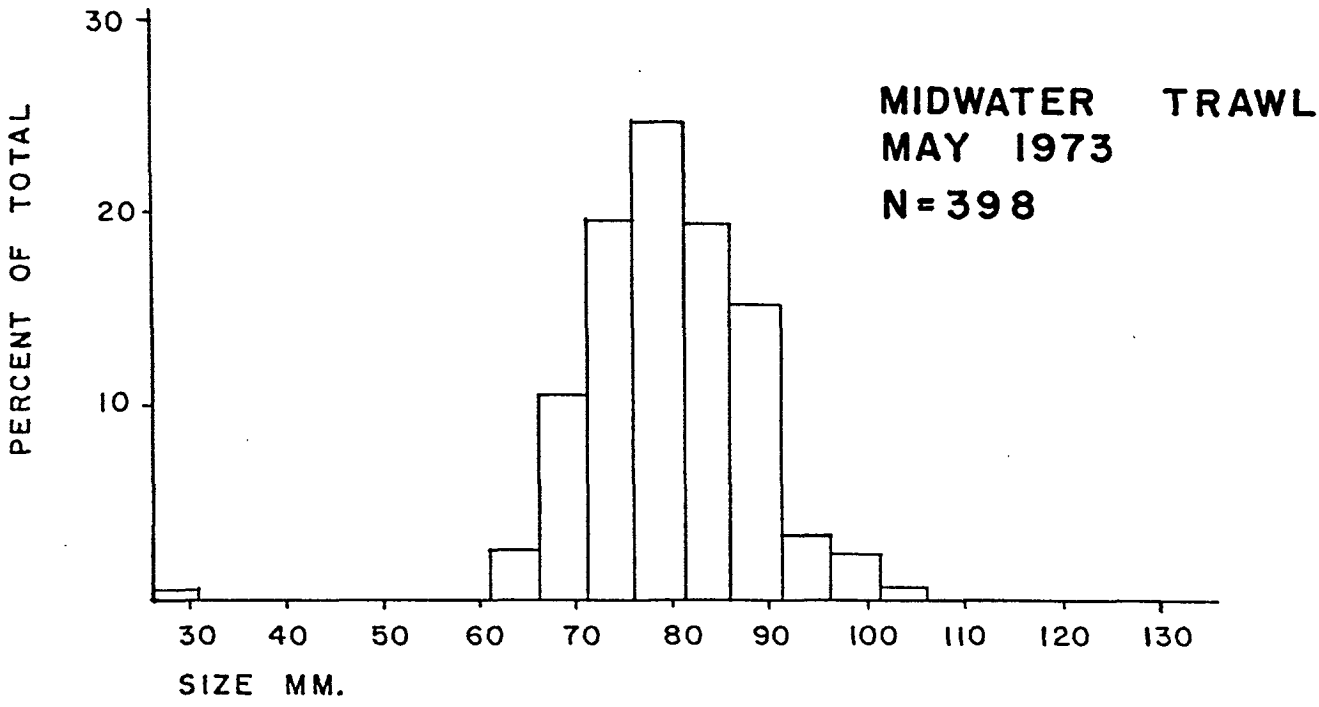
1973 Monthly Size Distribution - Chinook Salmon

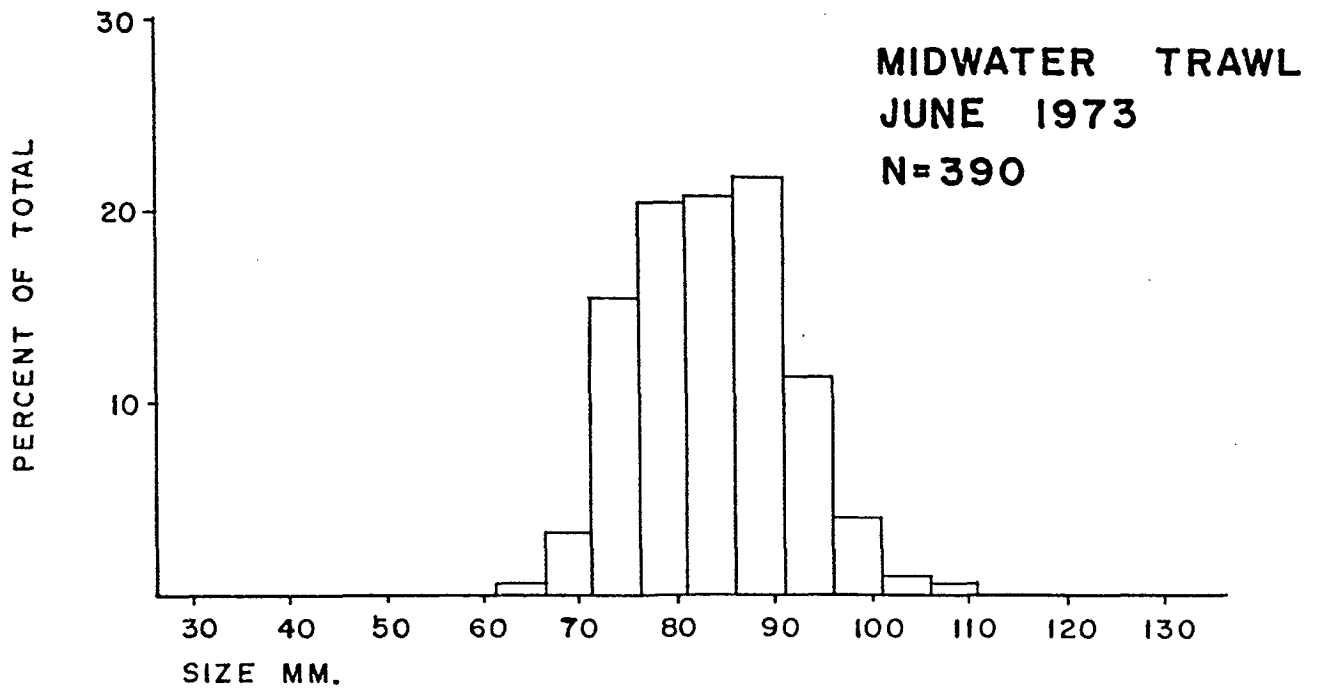




C-045798

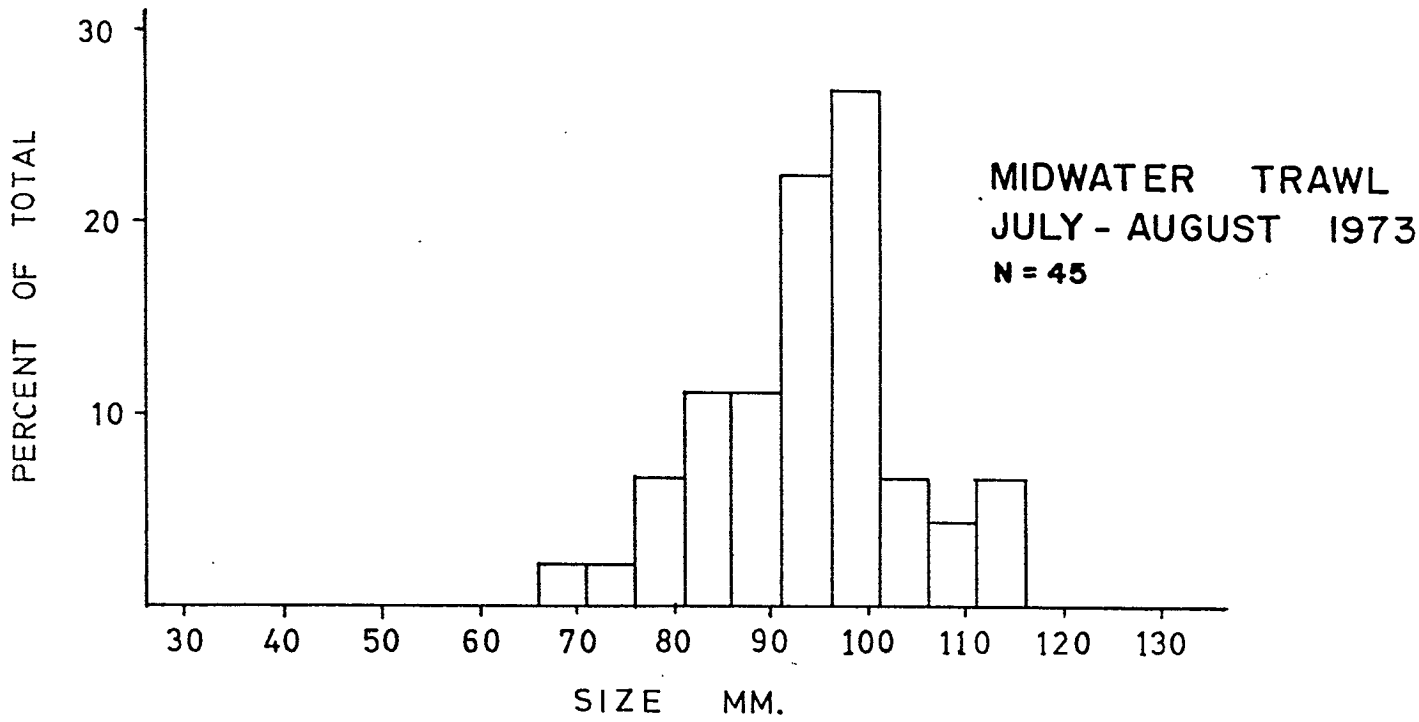
1973 Monthly Size Distribution - Chinook Salmon

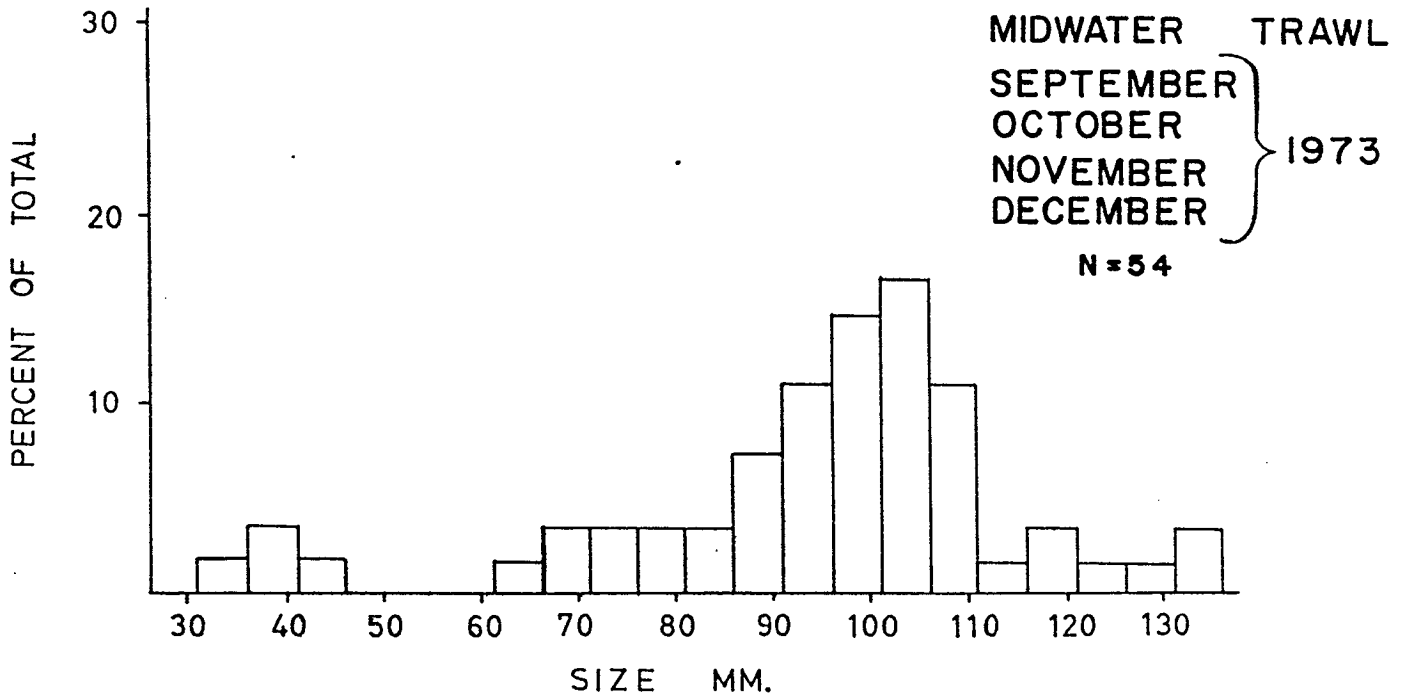




C-045799

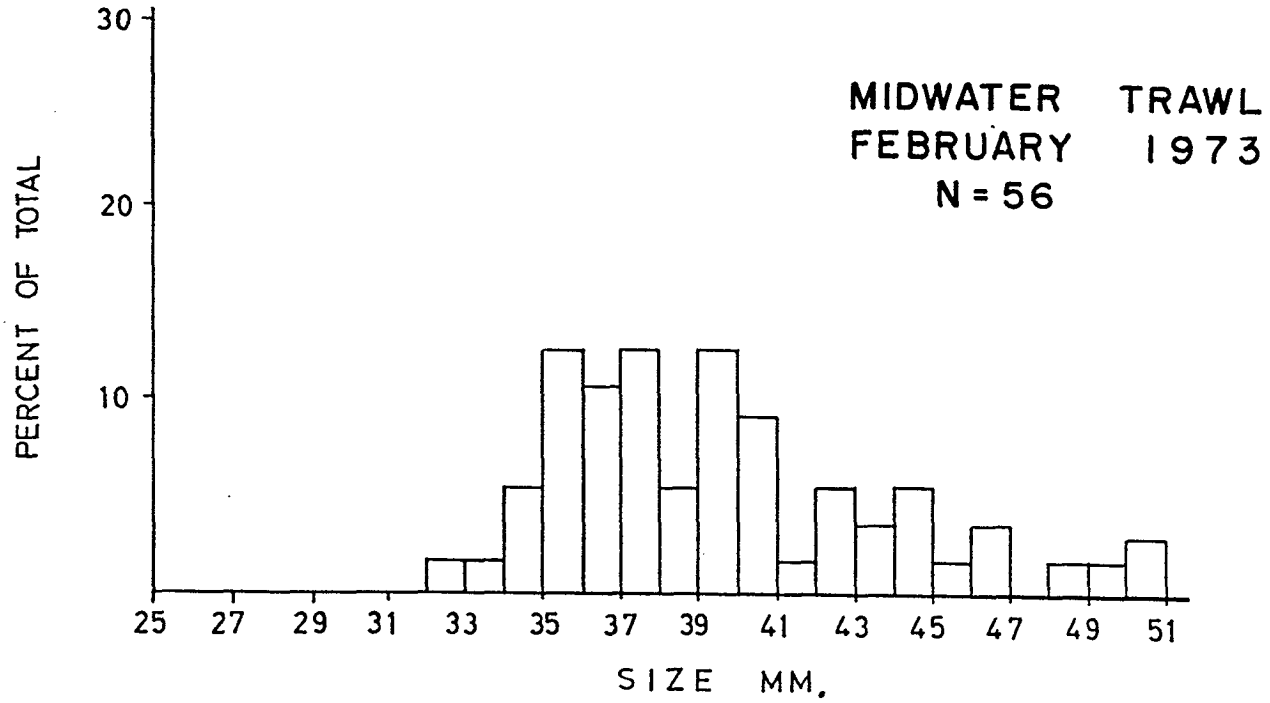
1973 Monthly Size Distribution - Chinook Salmon

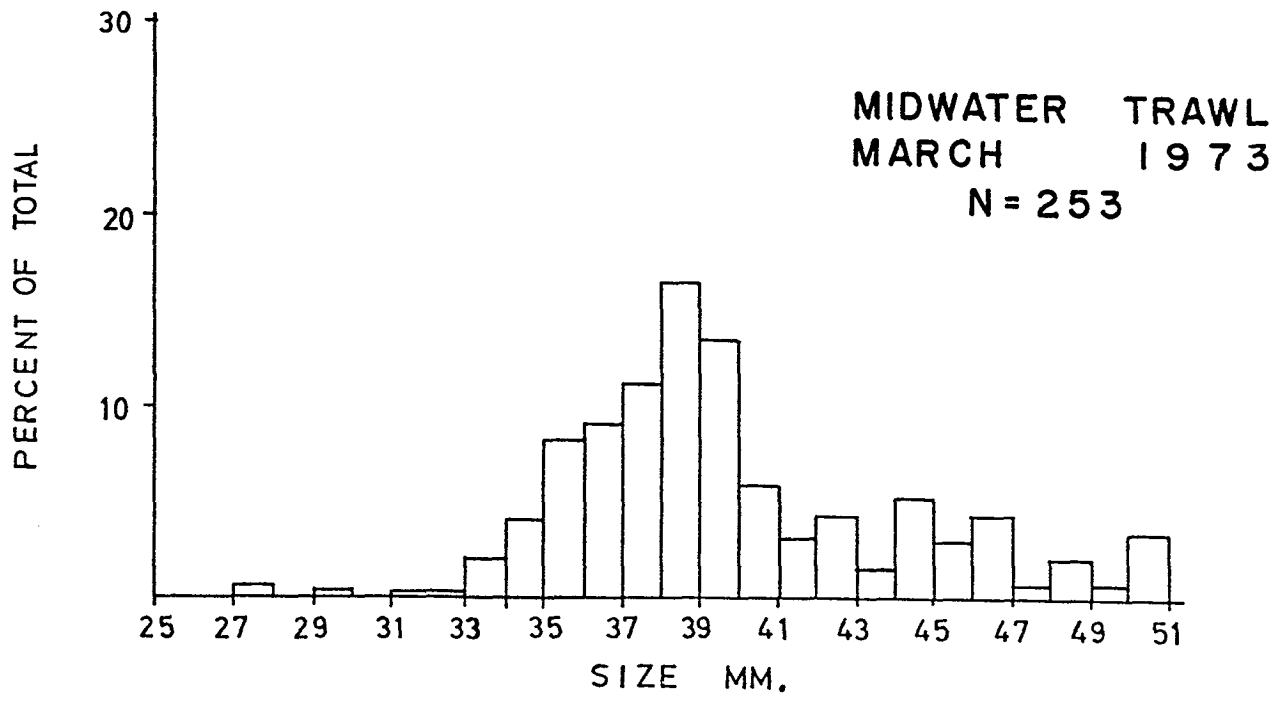




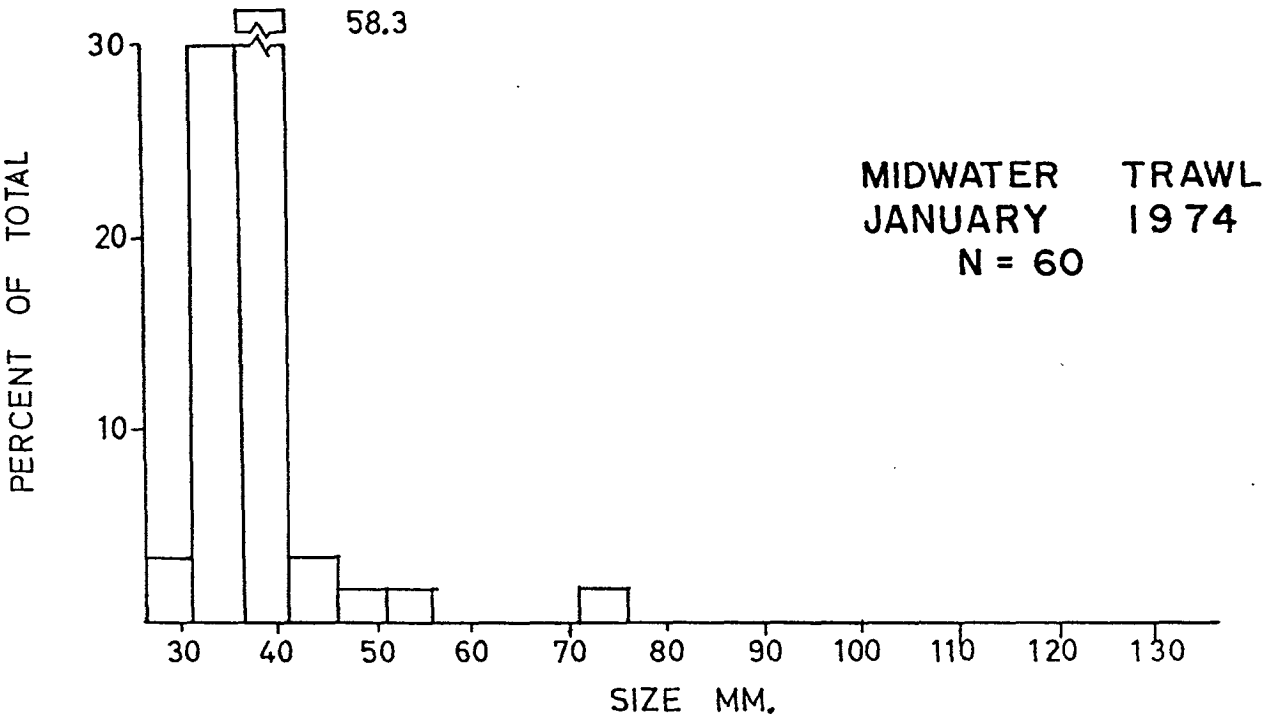
APPENDIX B

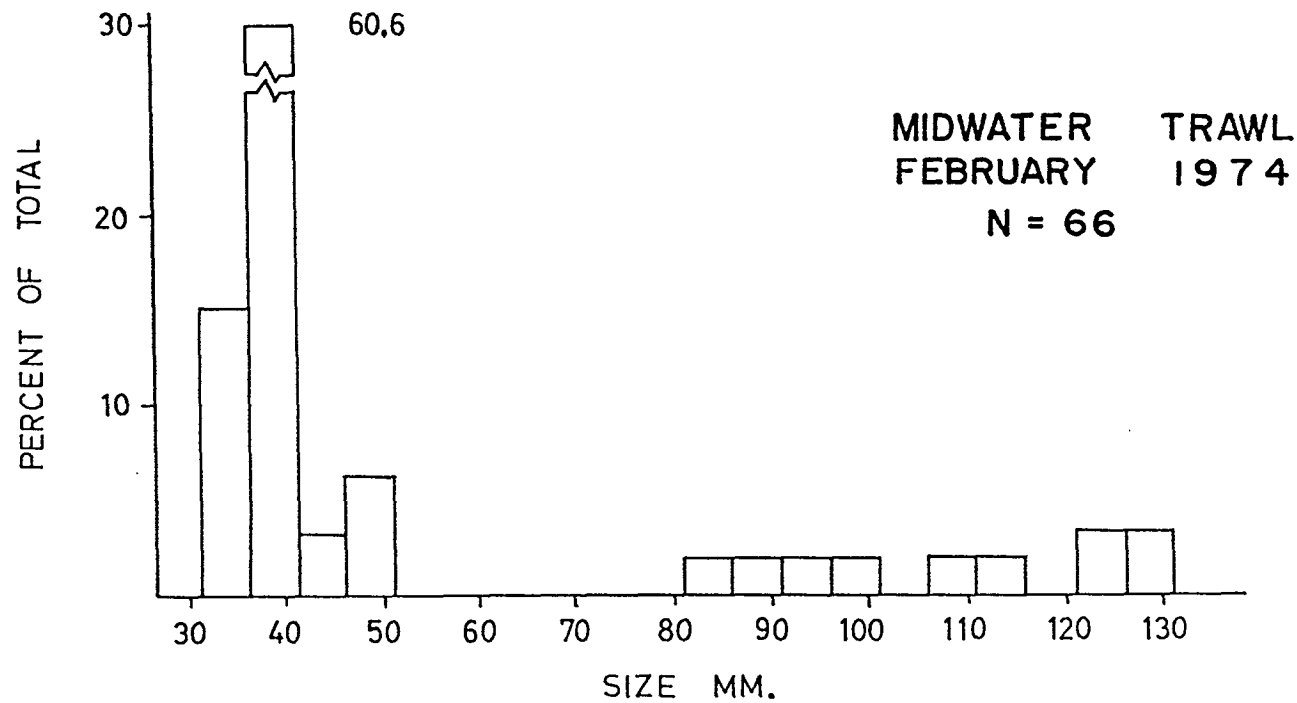
1973 Monthly Size Distribution - Chinook Salmon Less Than 50 mm





1974 Monthly Size Distribution - Chinook Salmon

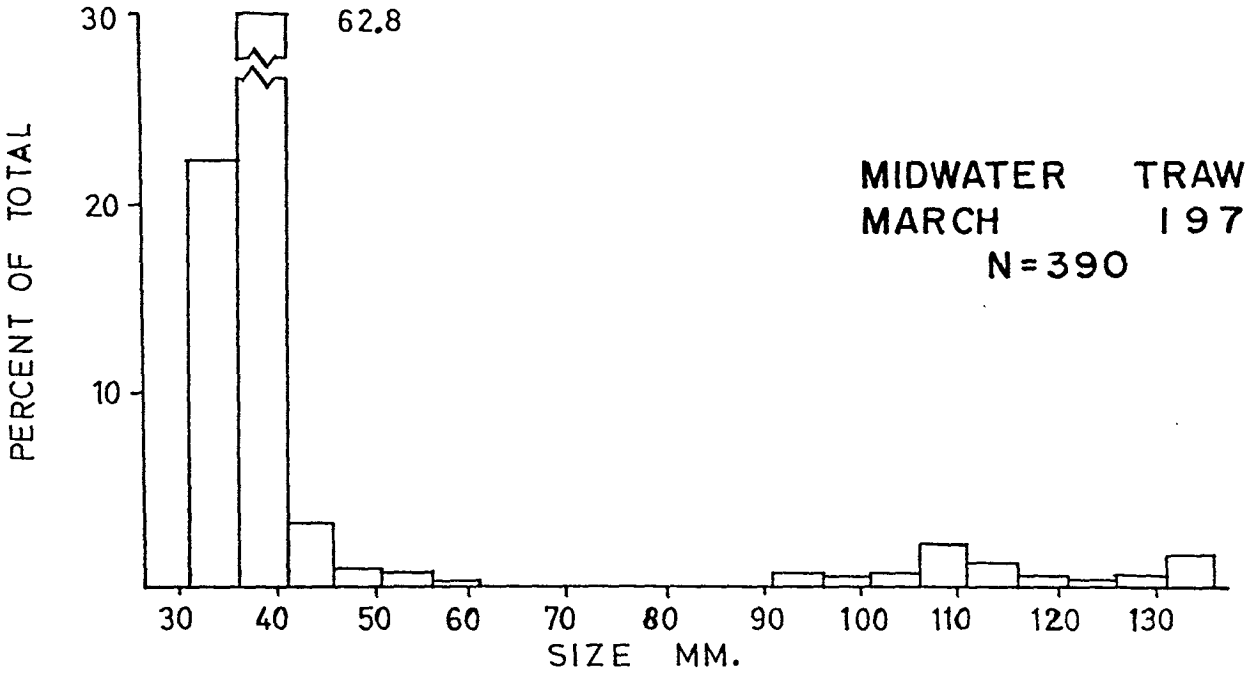


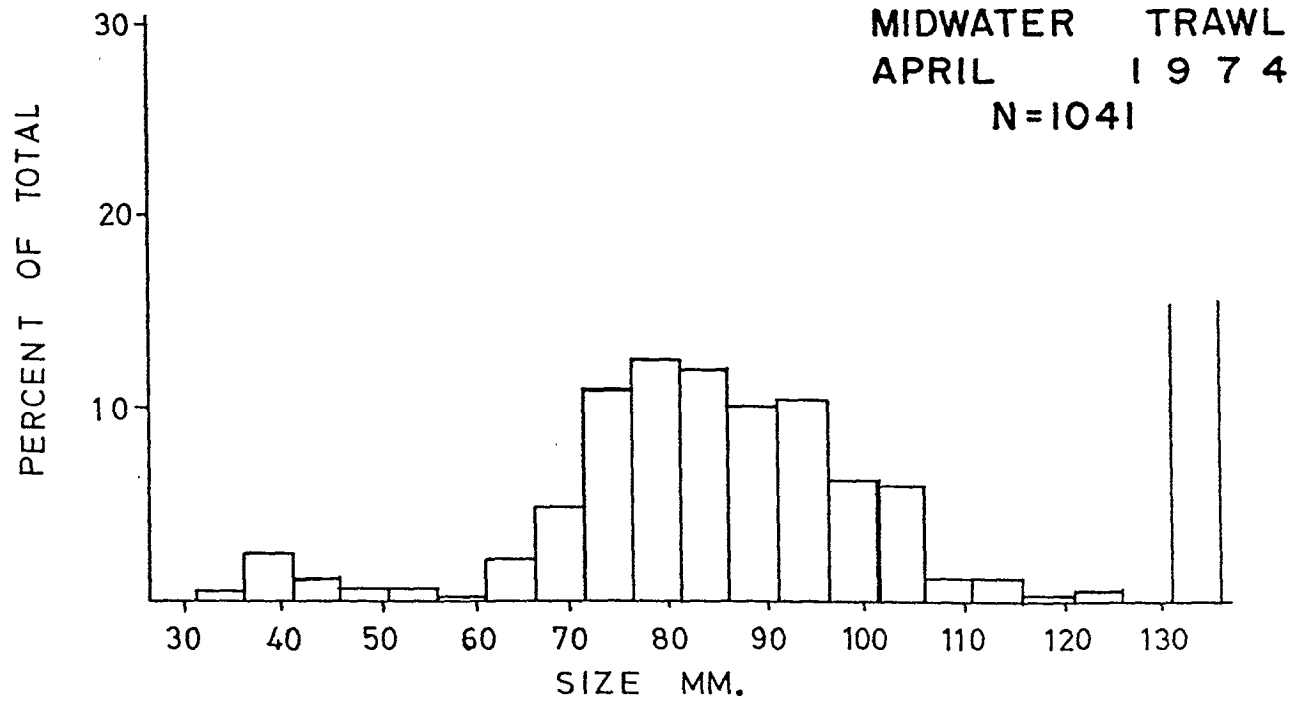


C-045802

APPENDIX C

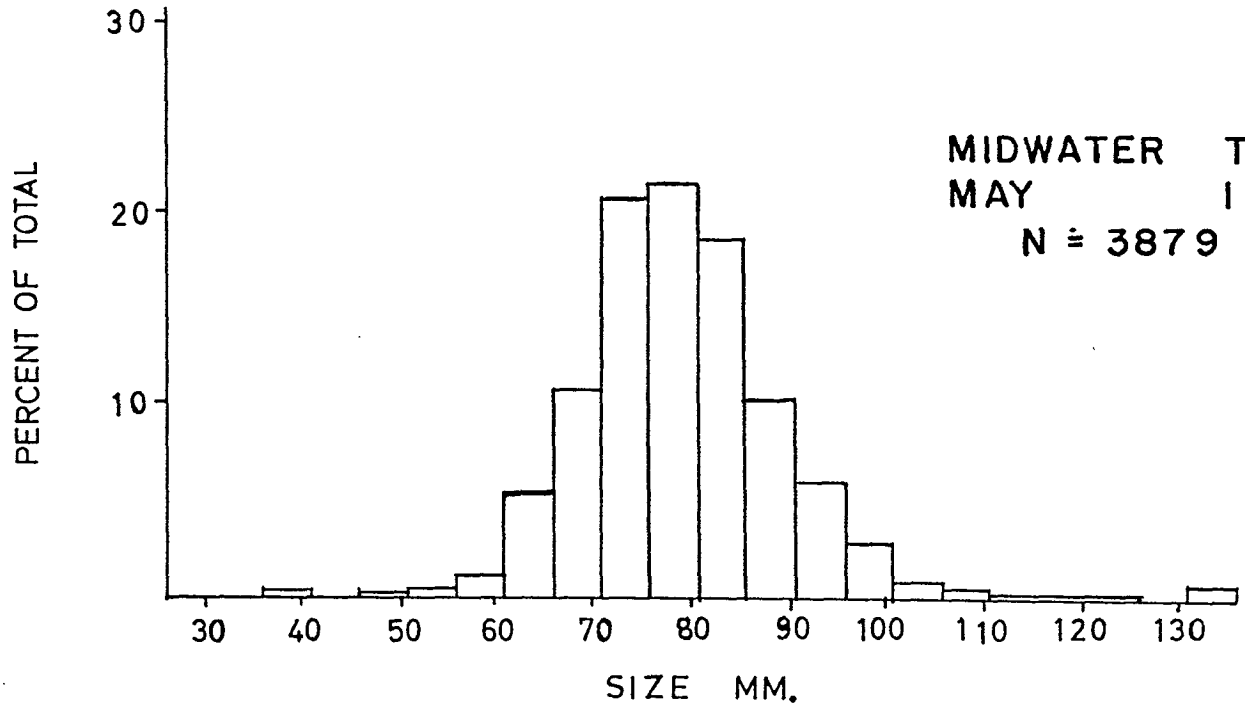
1974 Monthly Size Distribution - Chinook Salmon

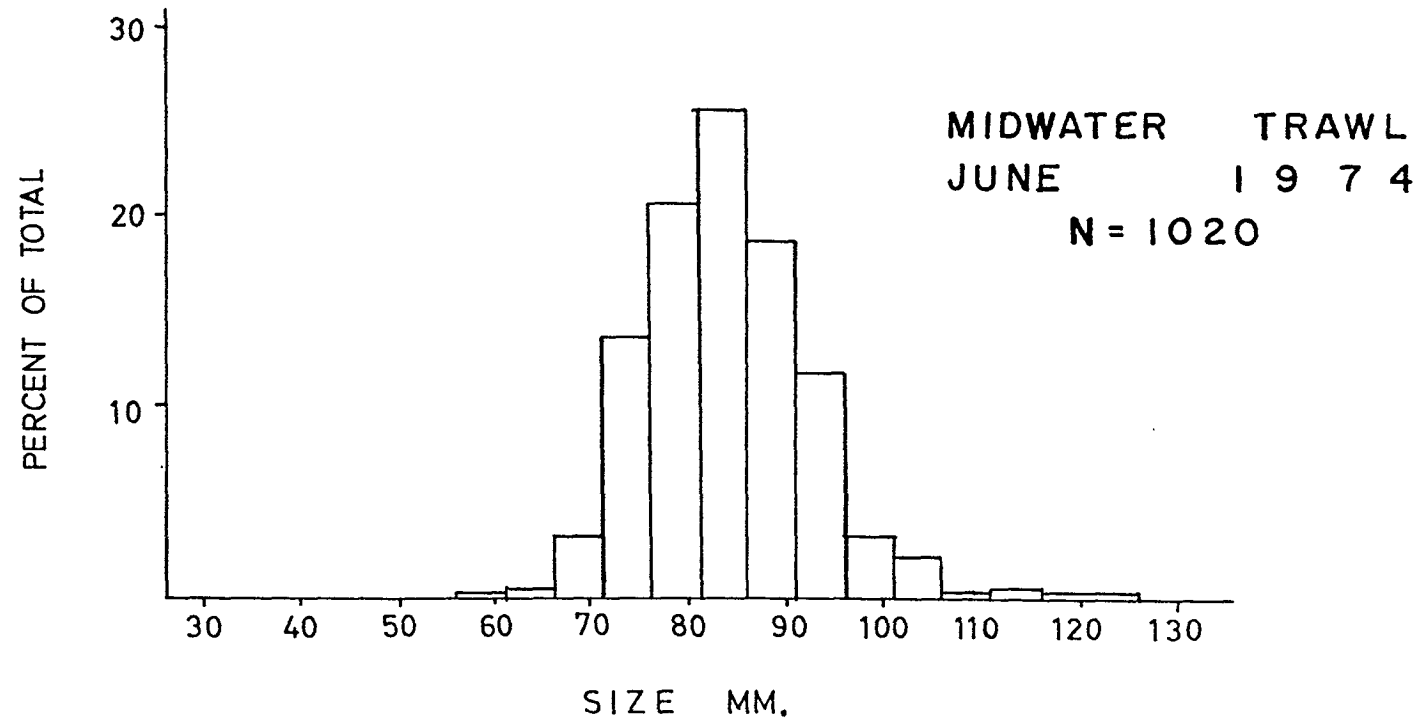




C-045803

1974 Monthly Size Distribution - **Chinook Salmon**

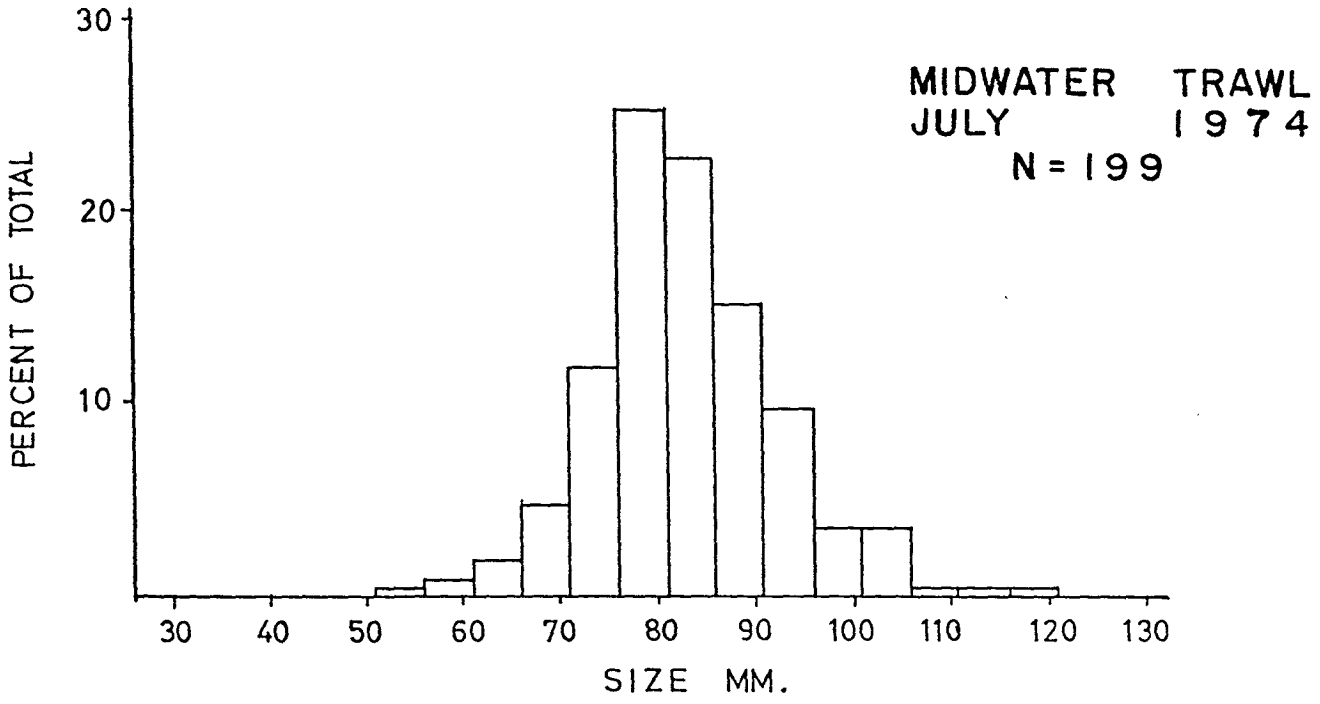


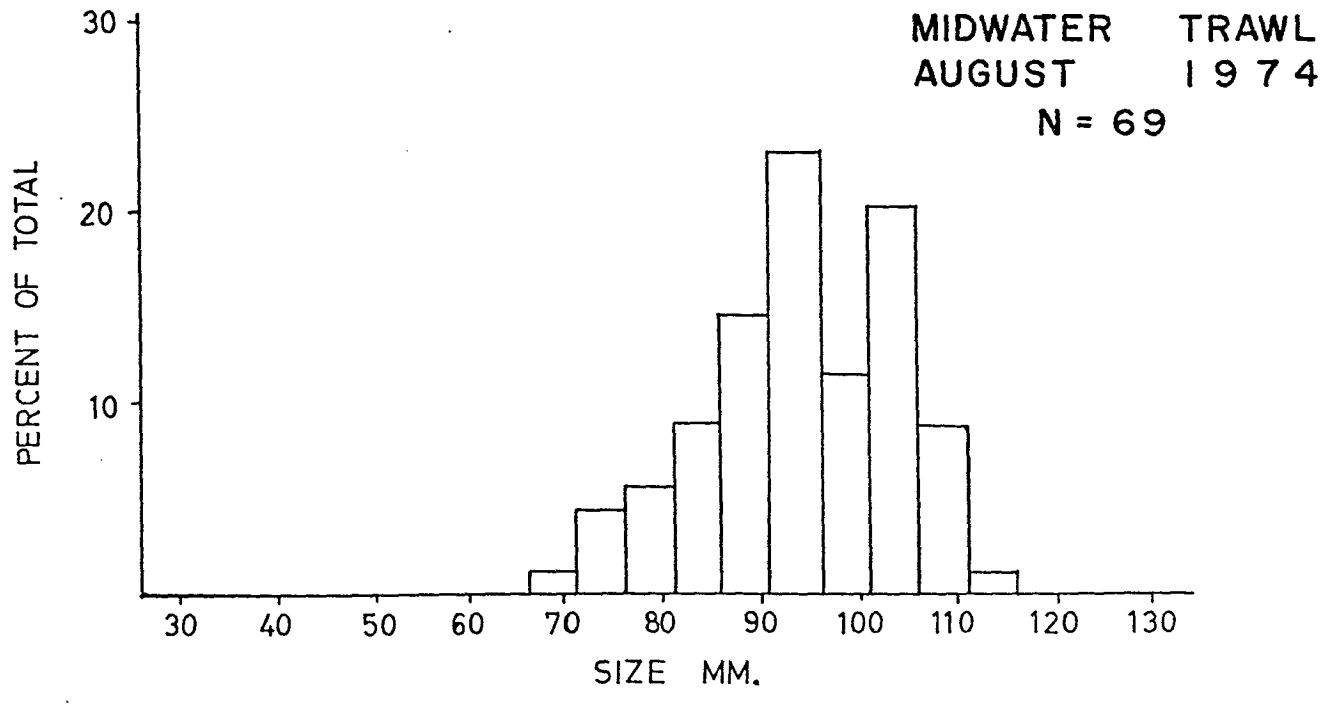


C-045804

APPENDIX C

1974 Monthly Size Distribution - Chinook Salmon

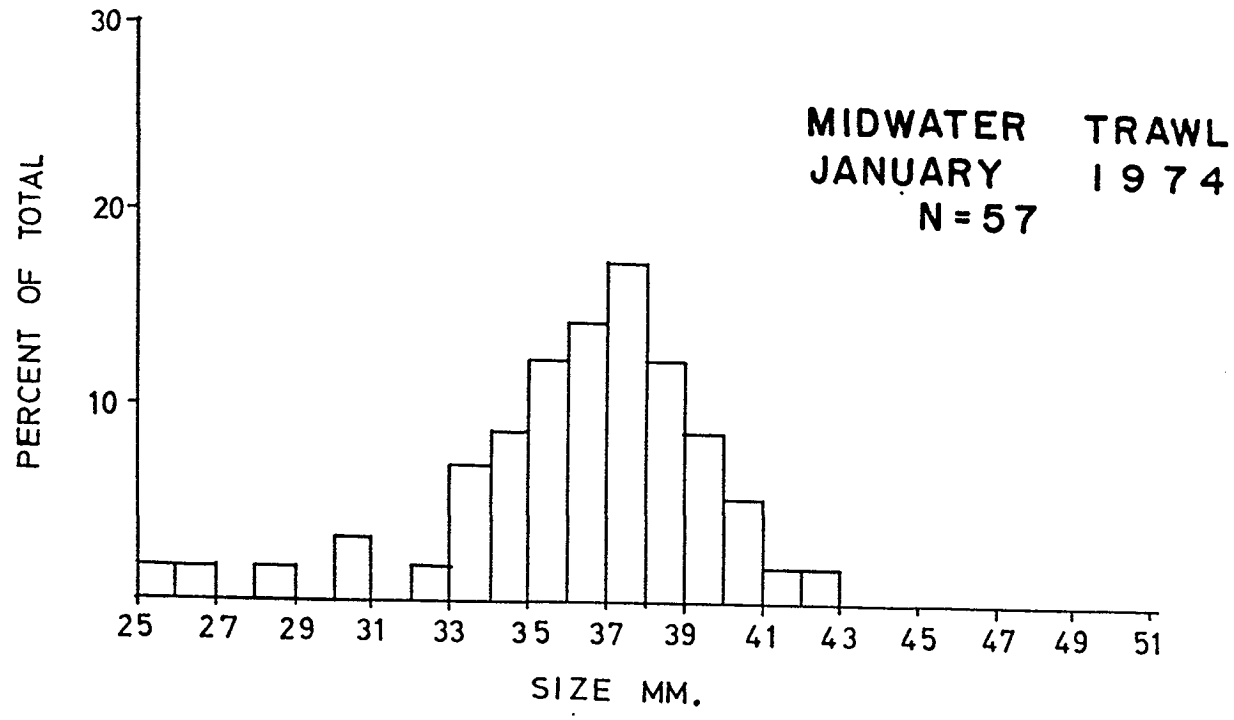


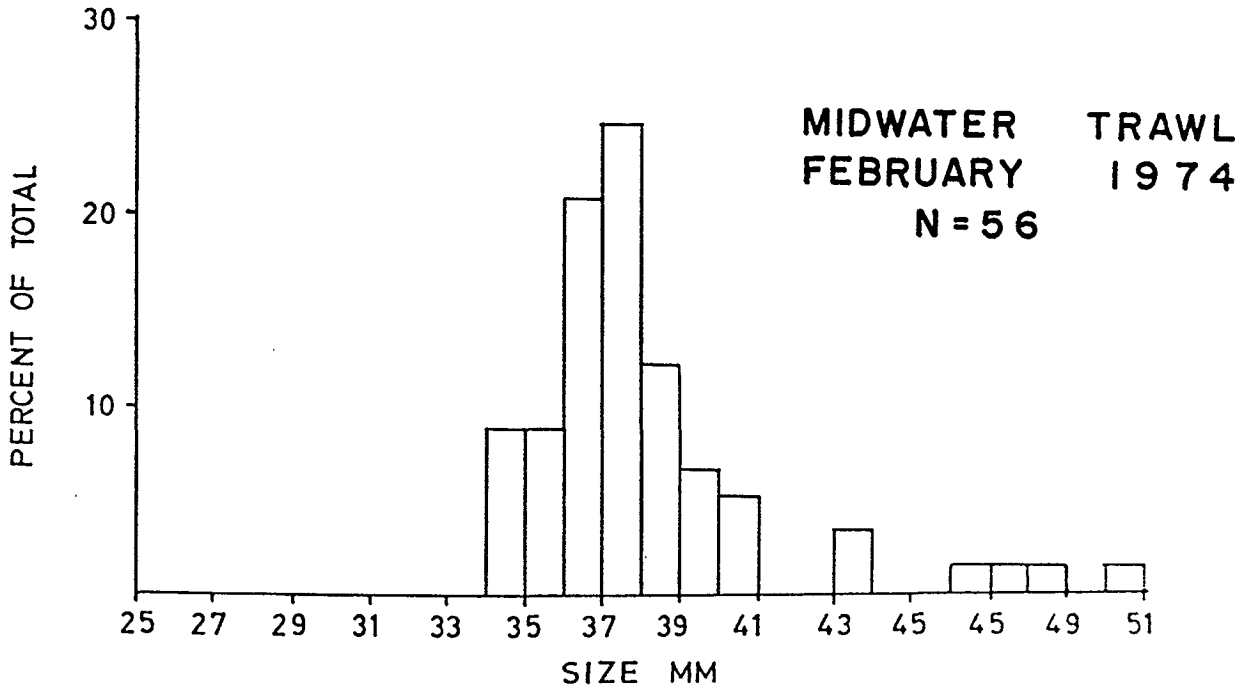


C-045805

APPENDIX D

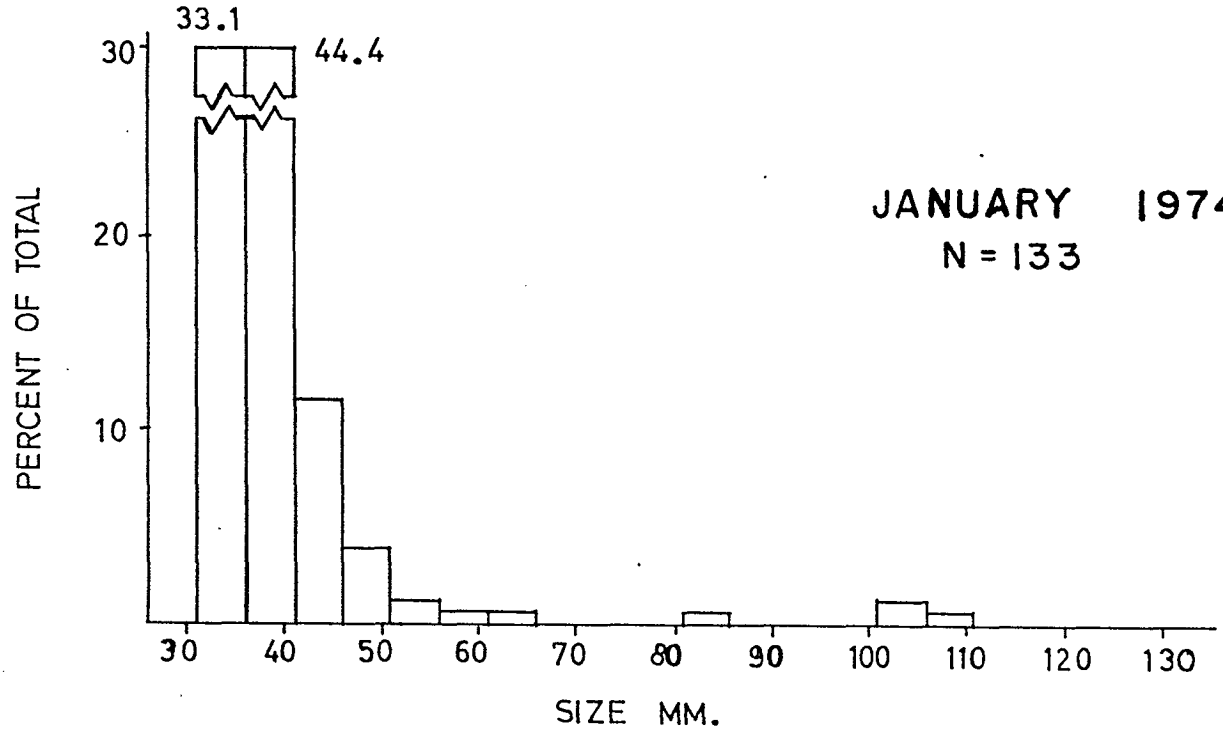
1974 Monthly Size Distribution - Chinook Salmon Less Than 50 mm

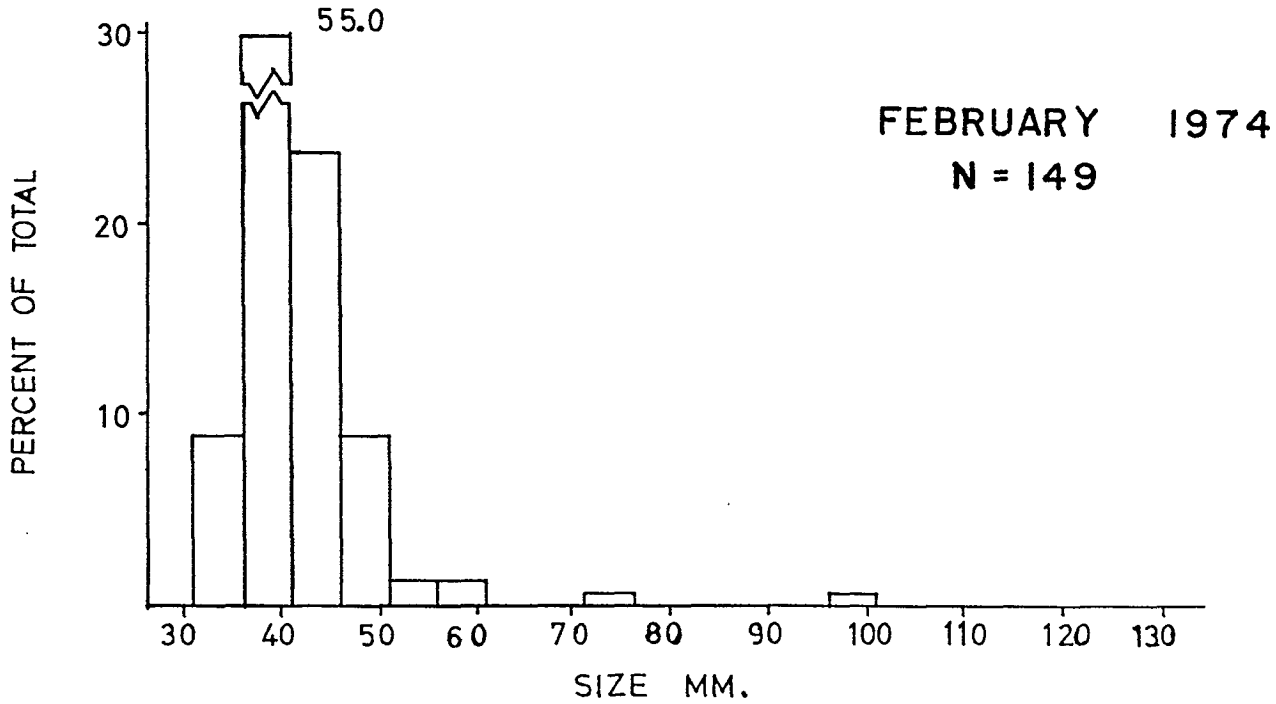




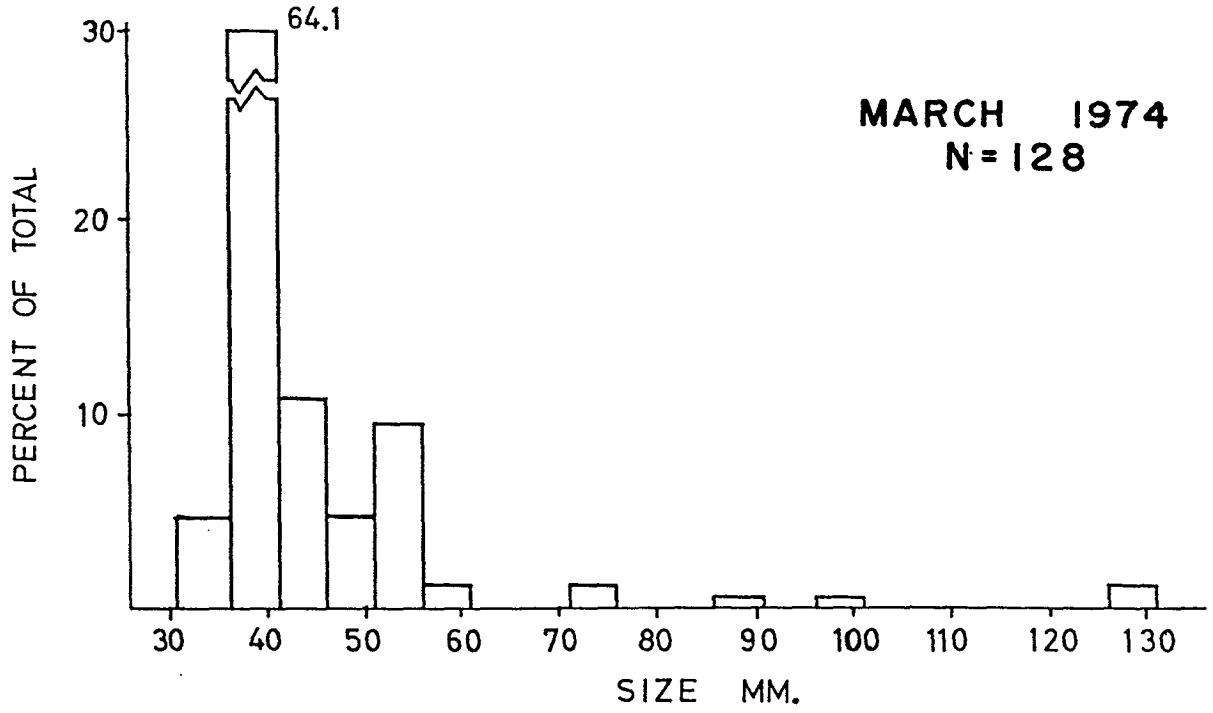
C-045806

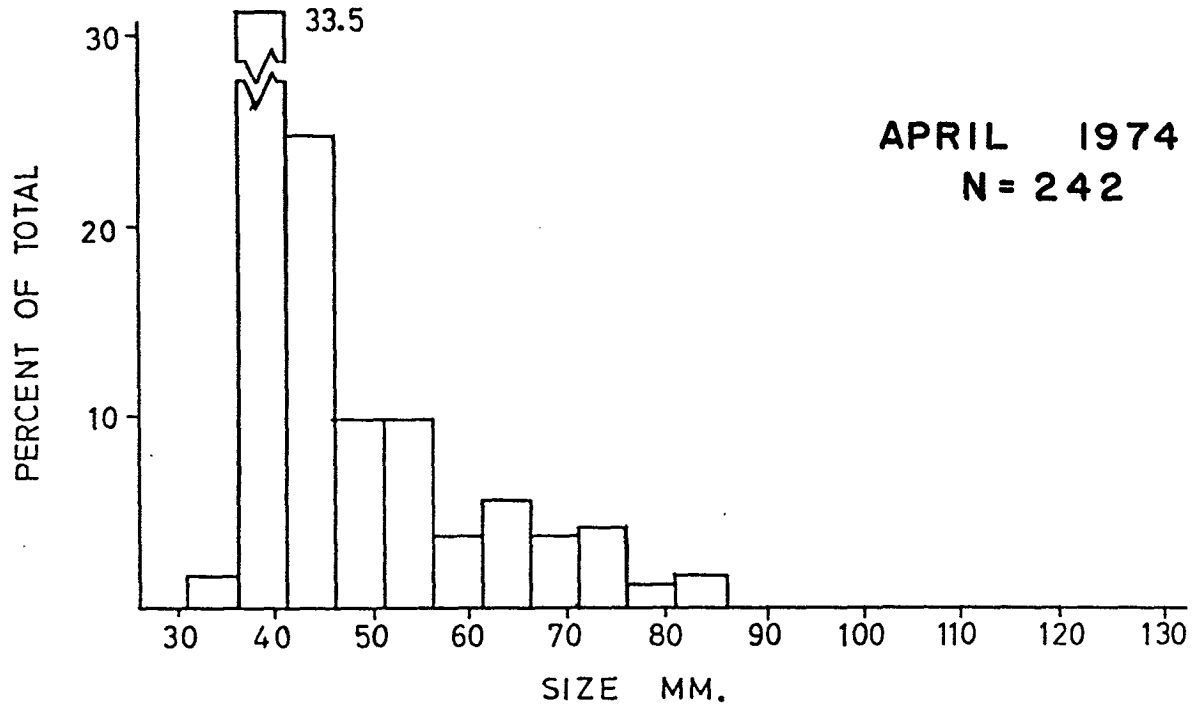
1974 Monthly Size Distribution - **Chinook Salmon** - Beach Seine
Yolo County Boat Ramp





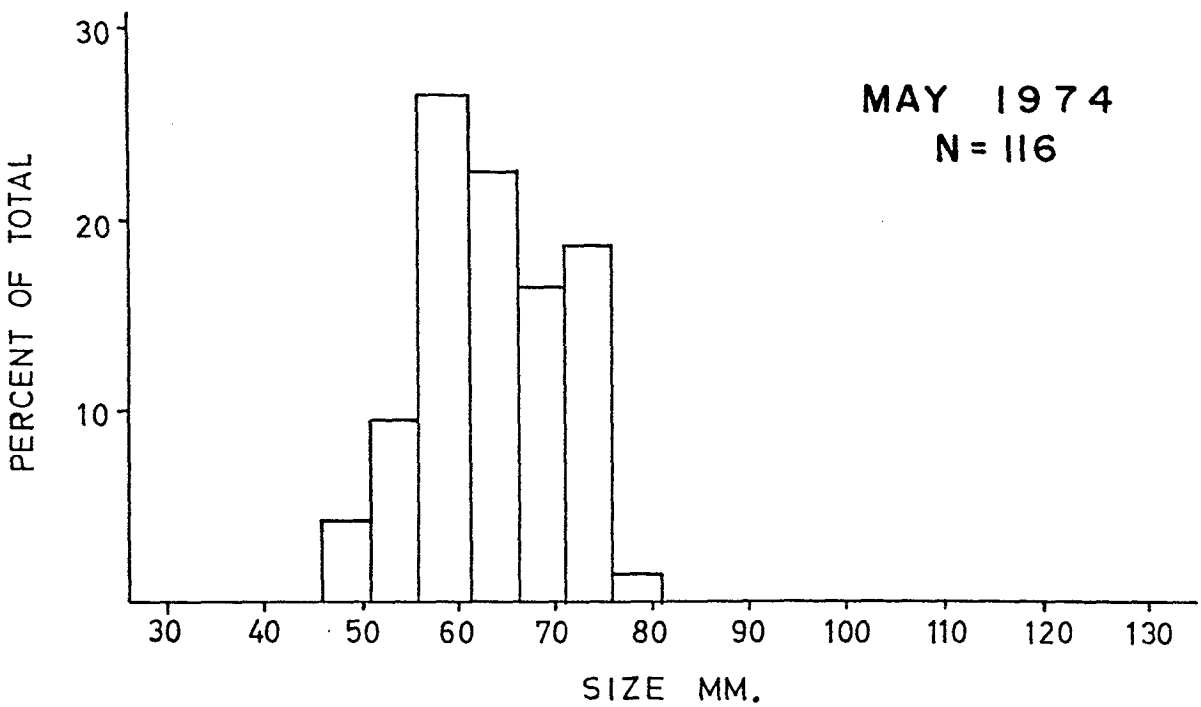
1974 Monthly Size Distribution - **Chinook Salmon** - Beach Seine
Yolo County Boat Ramp





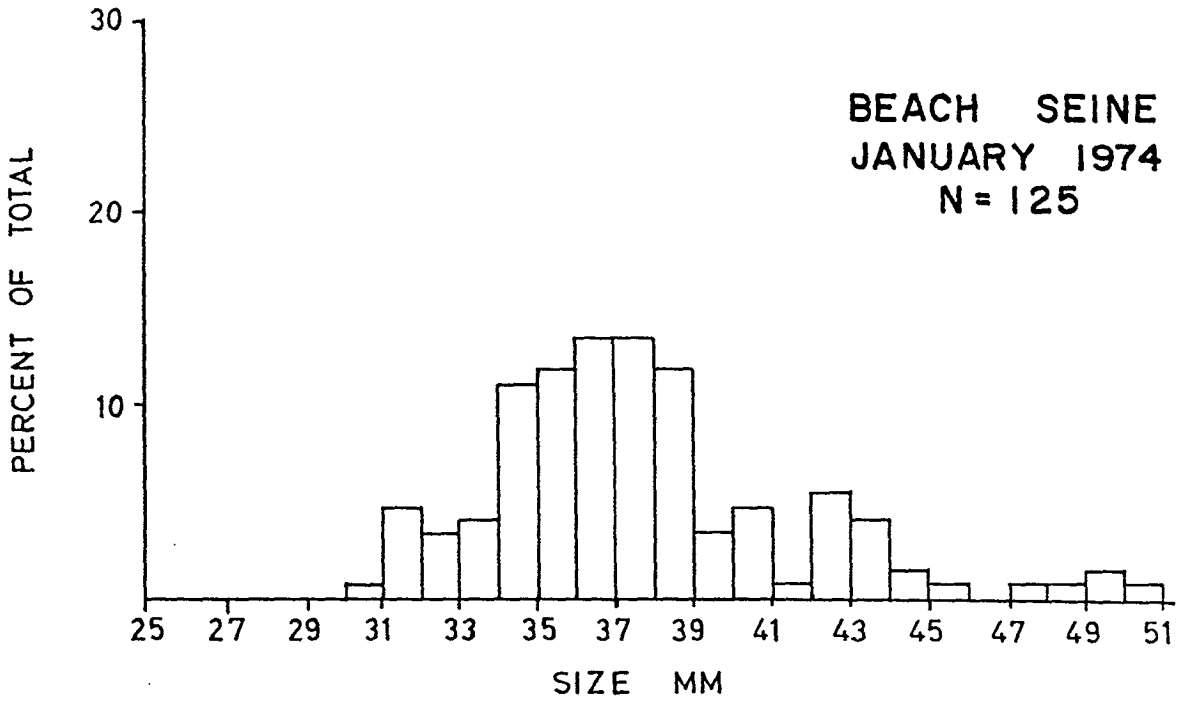
C-045808

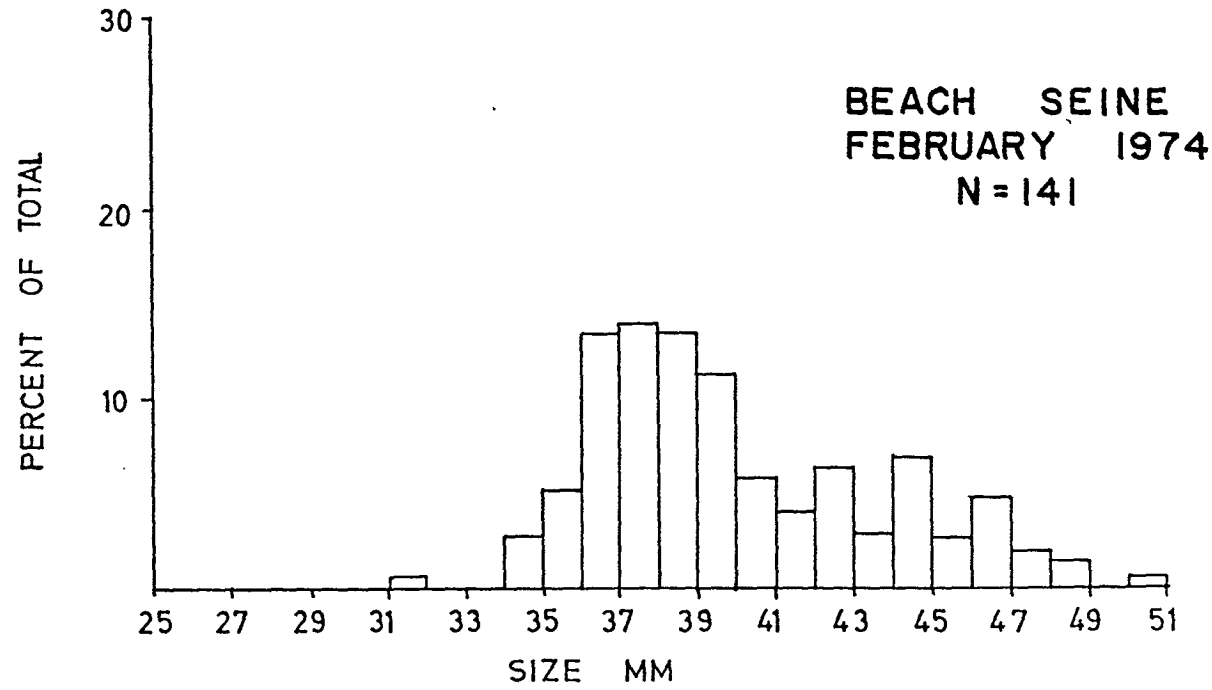
1974 Monthly Size Distribution - **Chinook Salmon** - Beach Seine
Yolo County Boat Ramp



C-045809

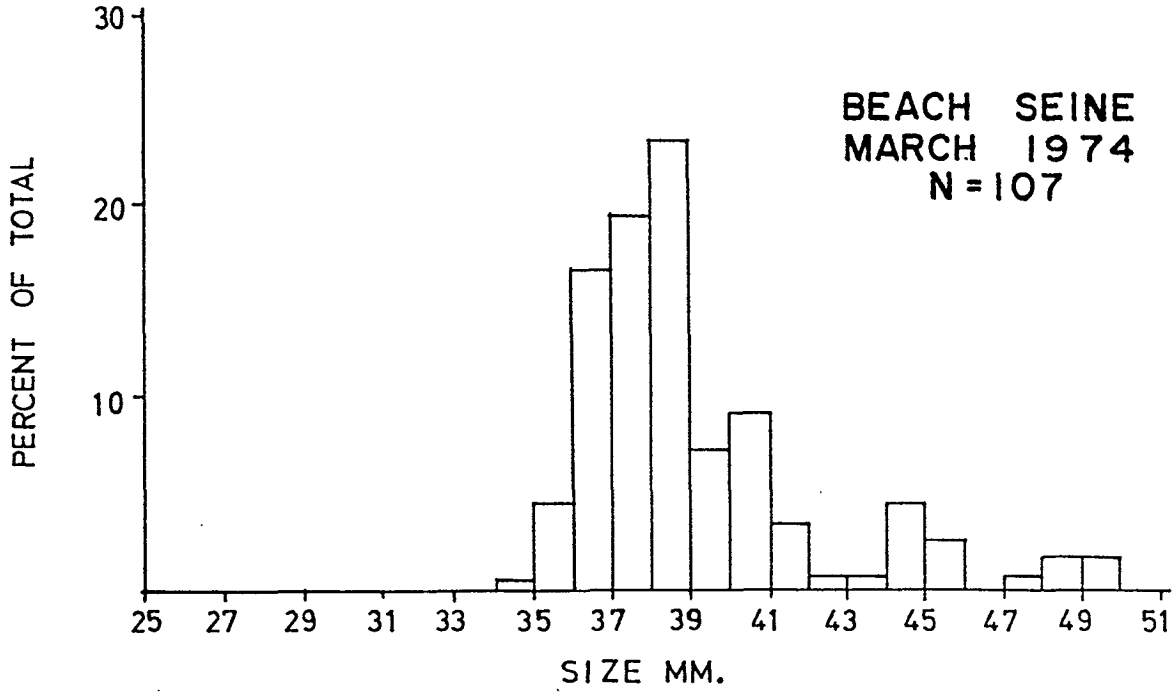
1974 Monthly Size Distribution - **Chinook Salmon Less Than 50 mm**

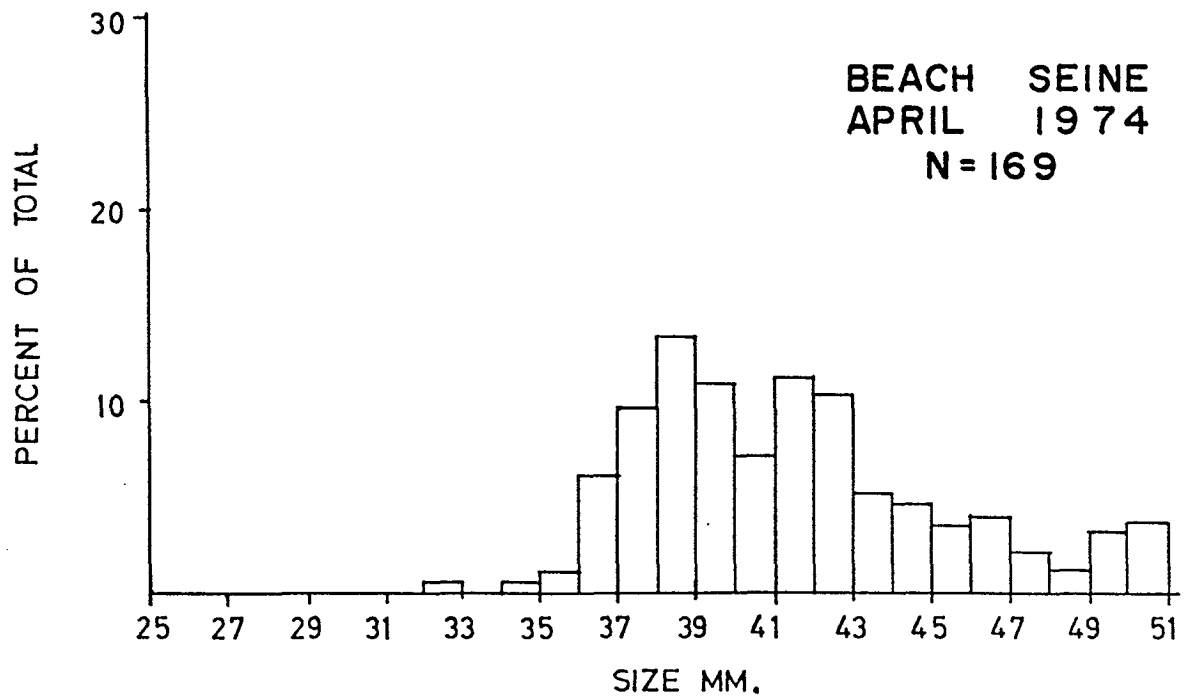




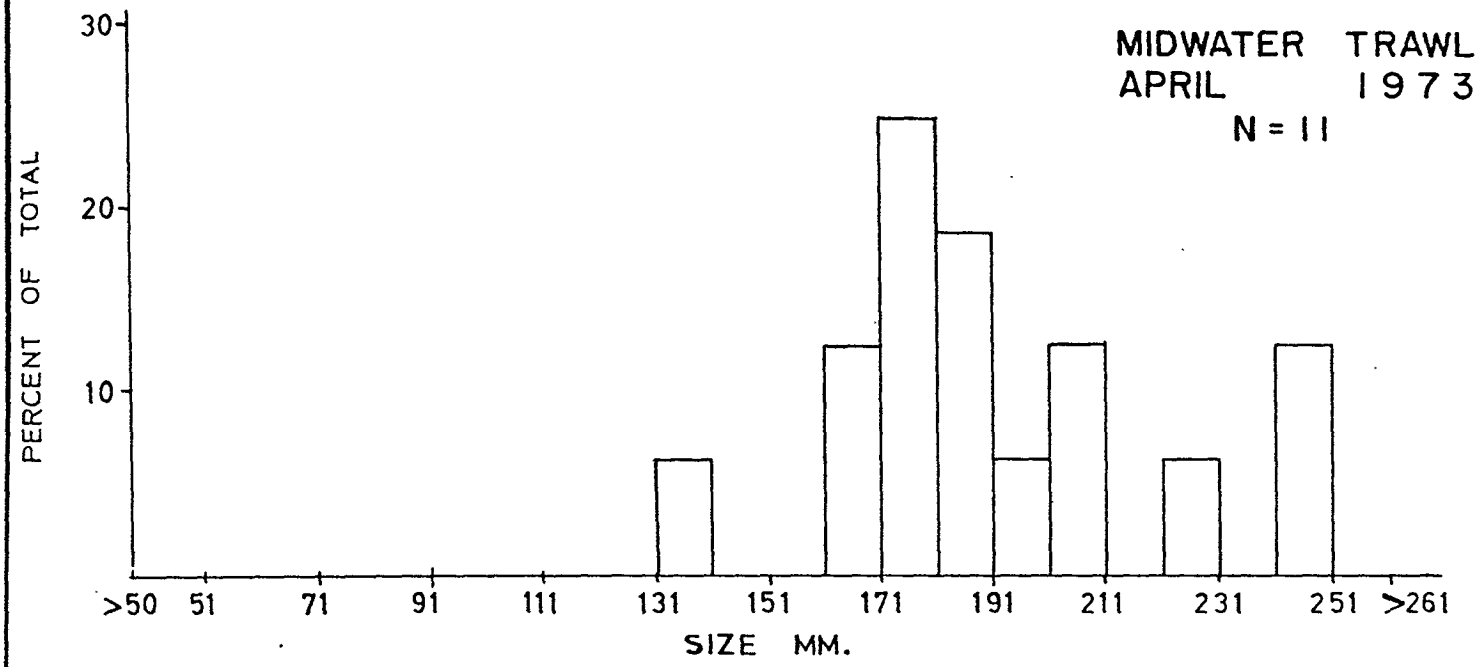
C-045810

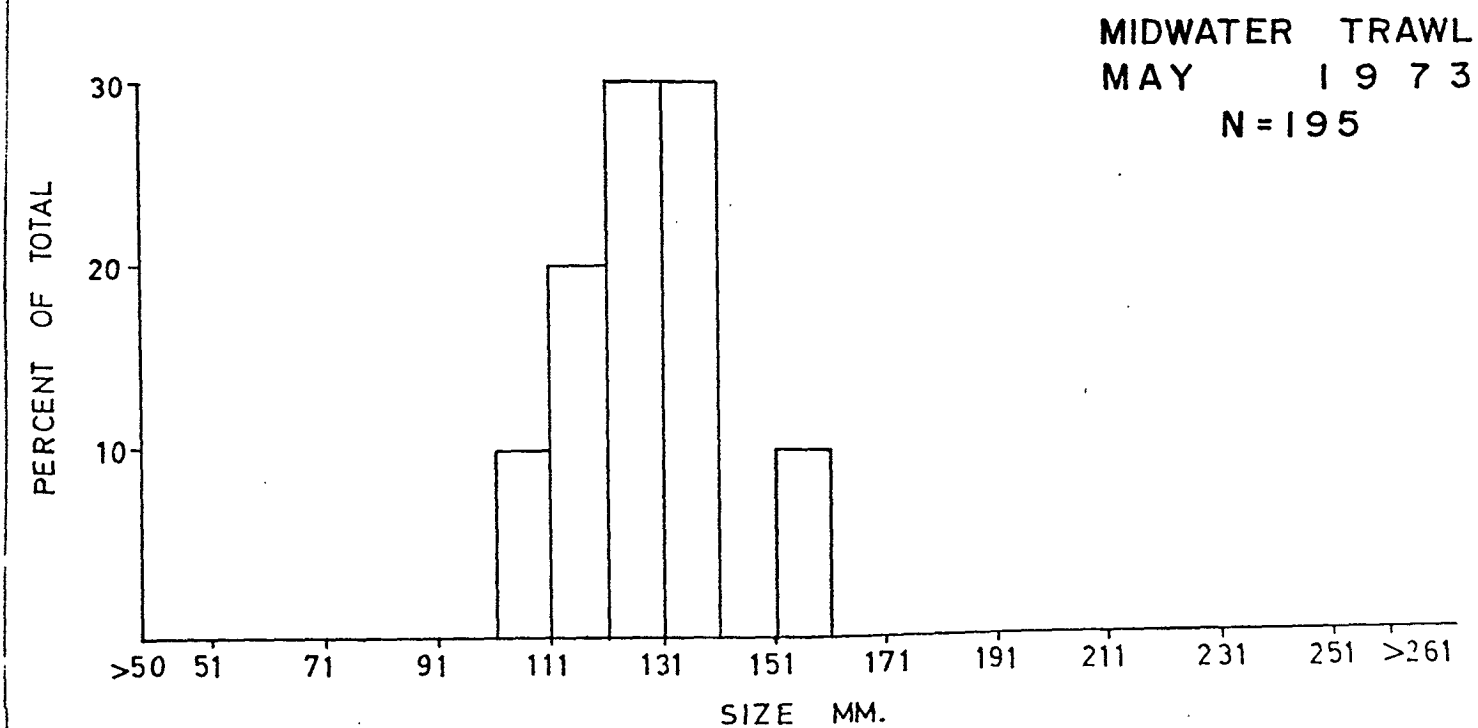
1974 Monthly Size Distribution - **Chinook Salmon Less Than 50 mm**



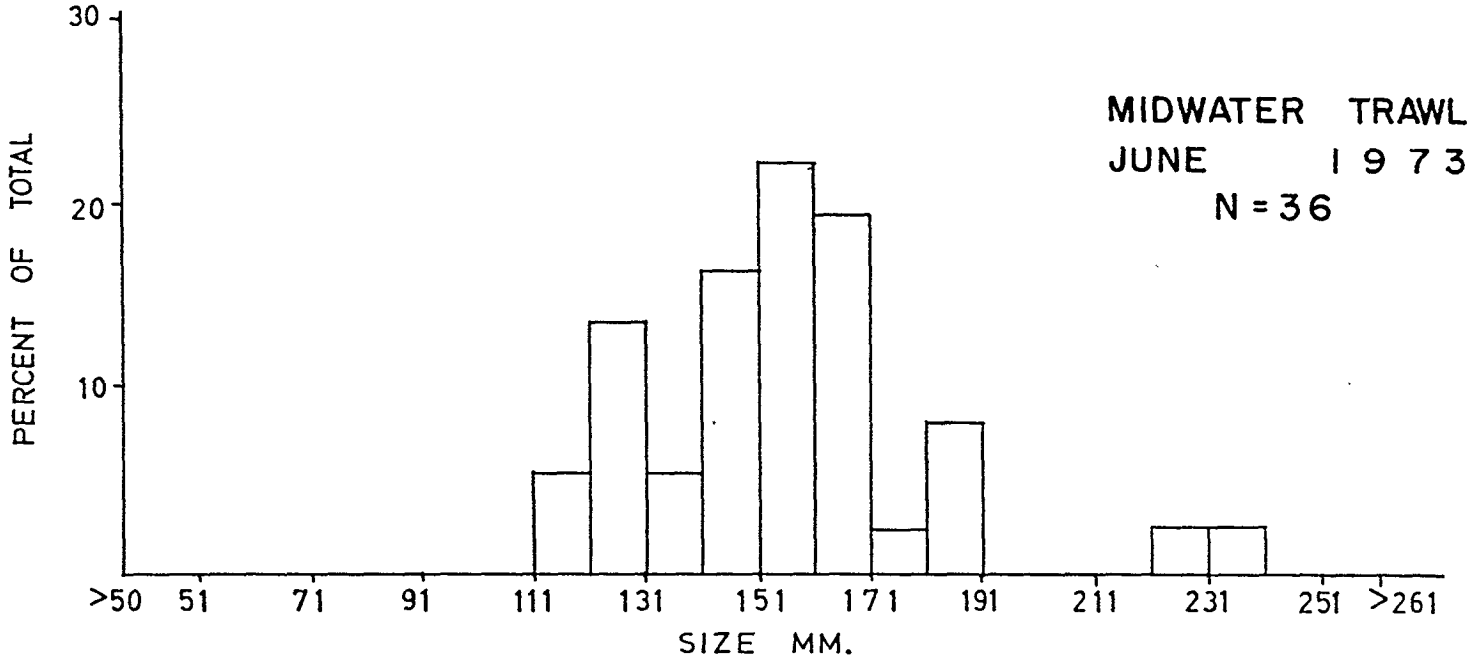


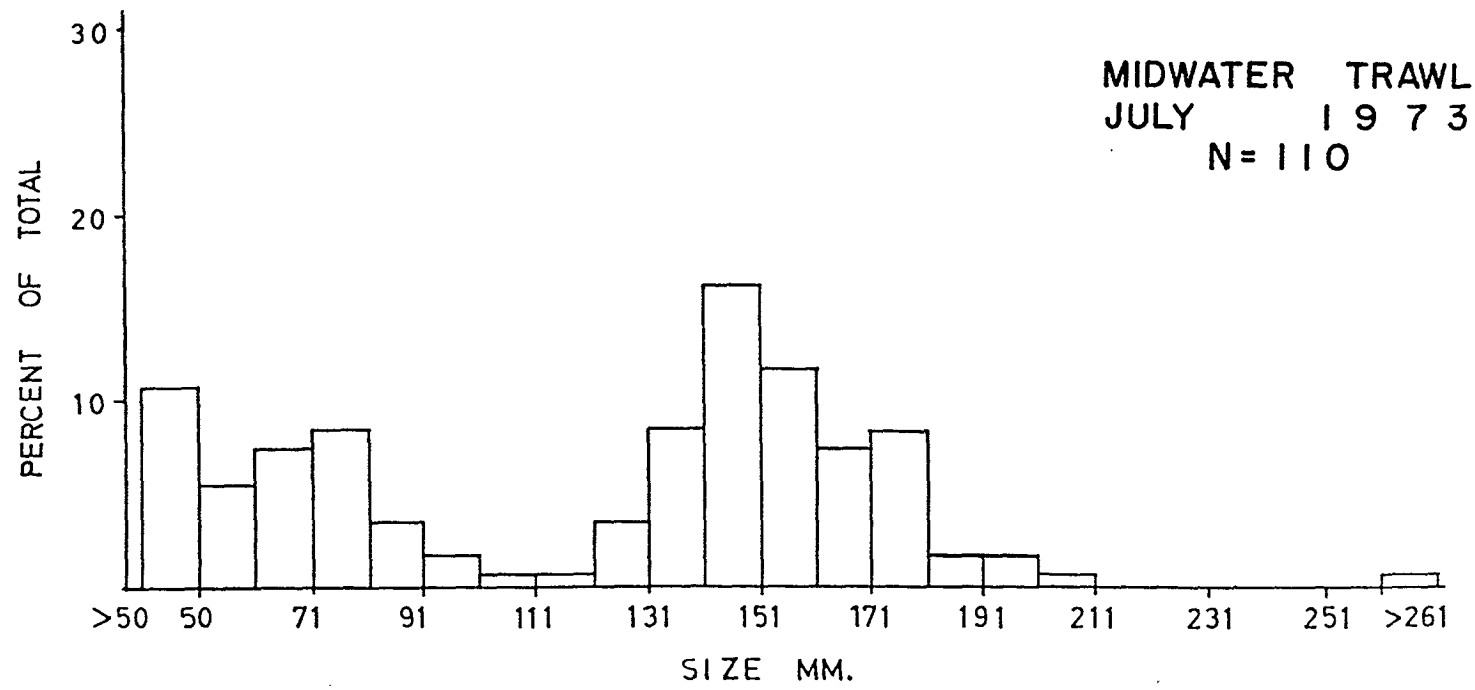
1973 Monthly Size Distribution - Striped Bass





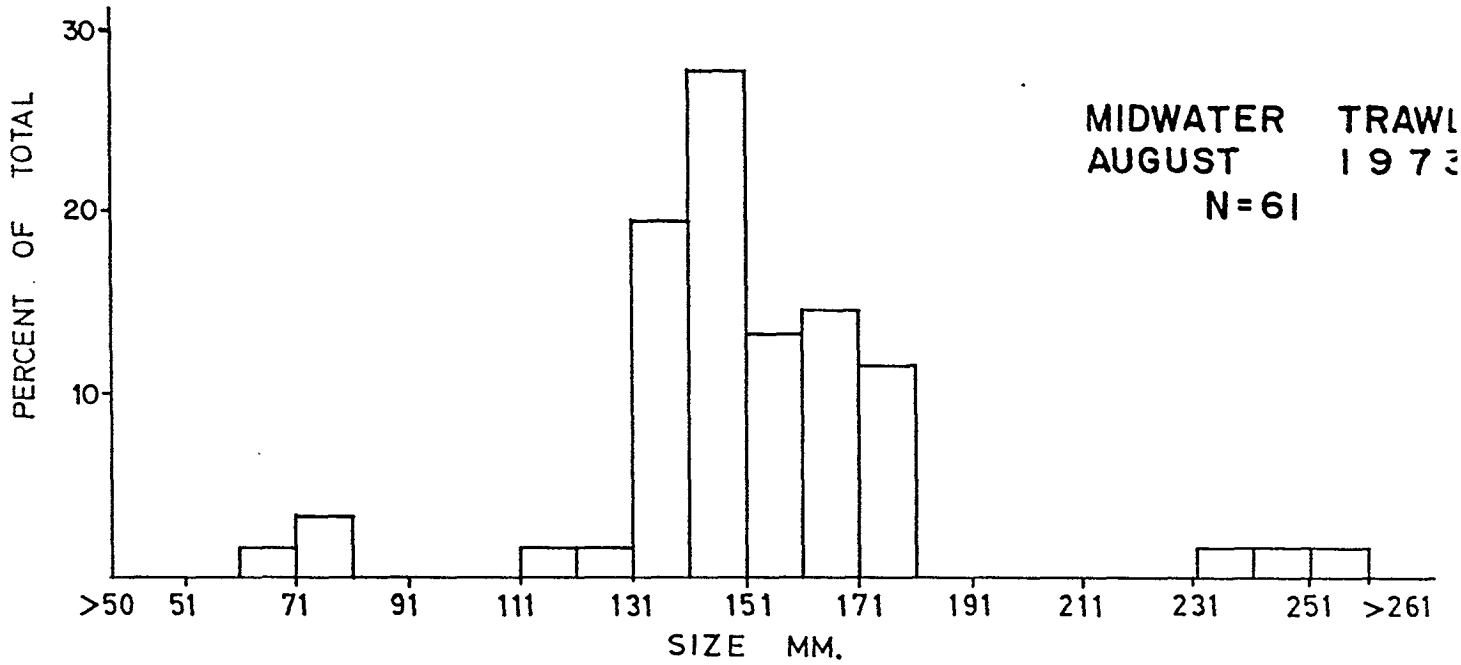
1973 Monthly Size Distribution - Striped Bass

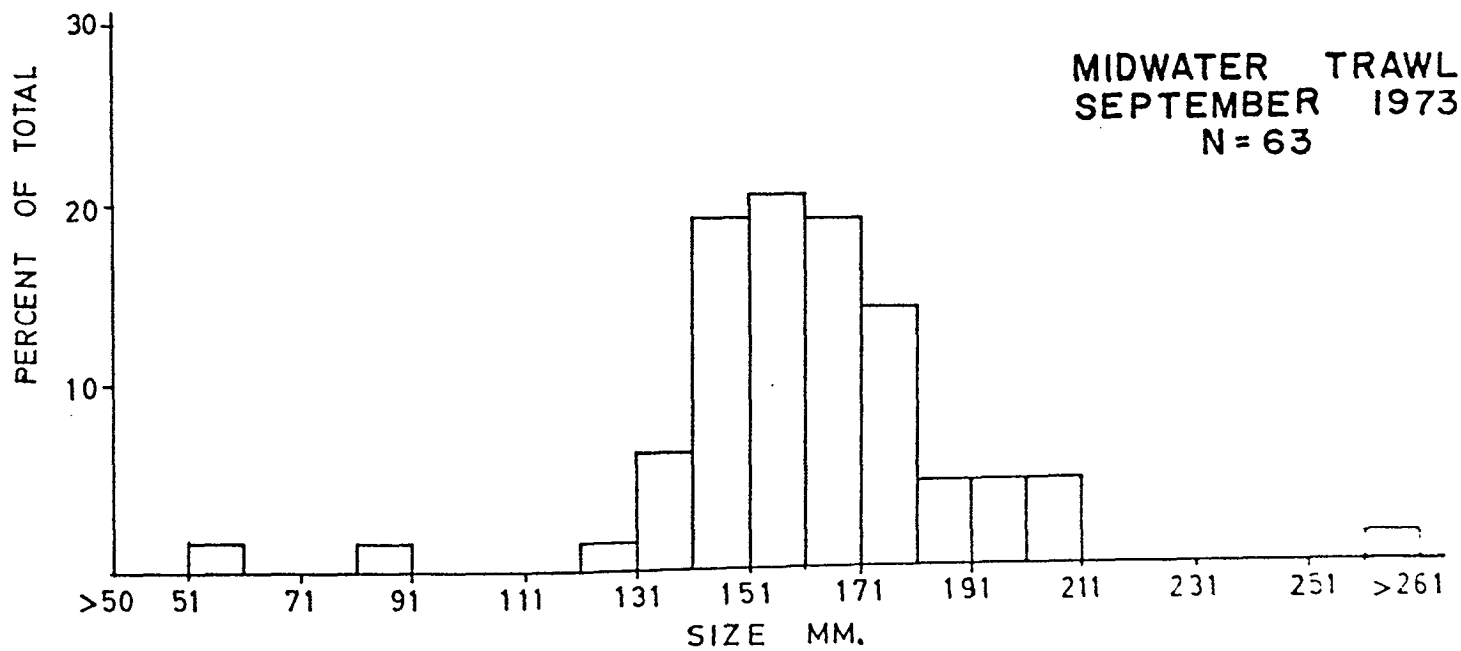




C-045813

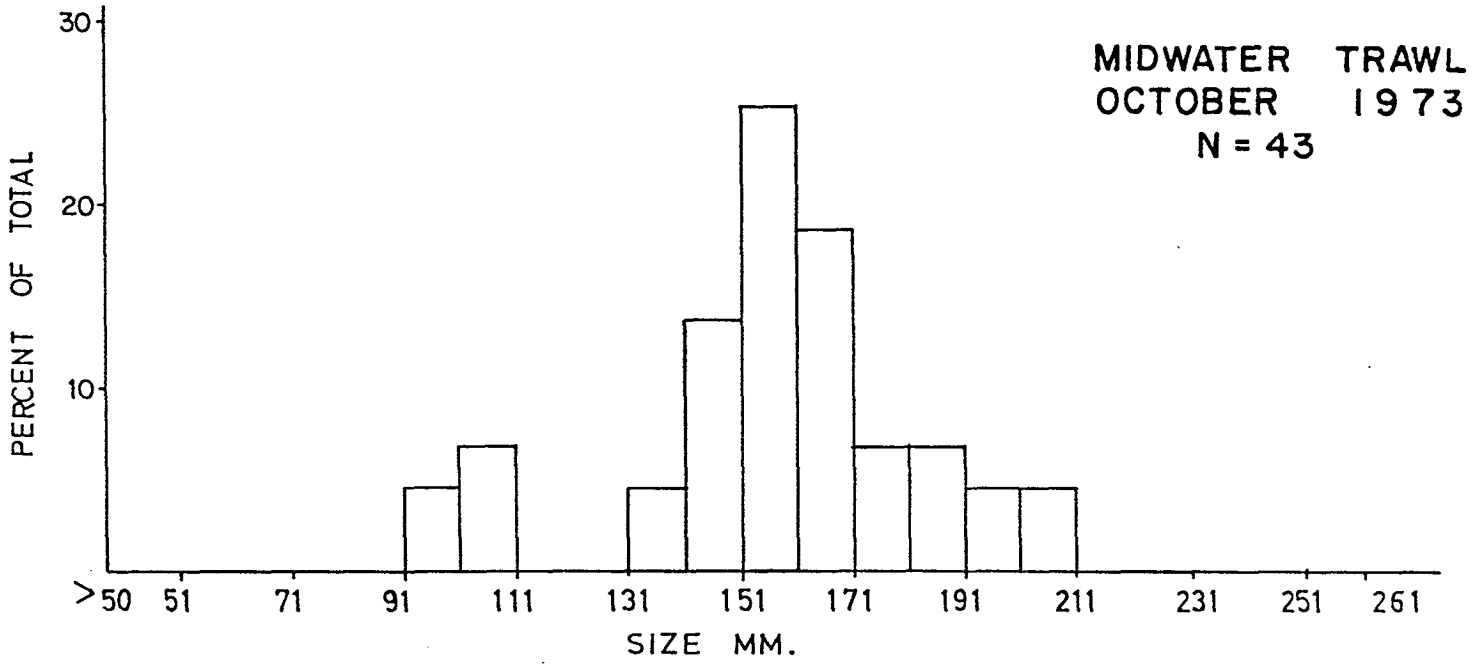
1973 Monthly Size Distribution - Striped Bass

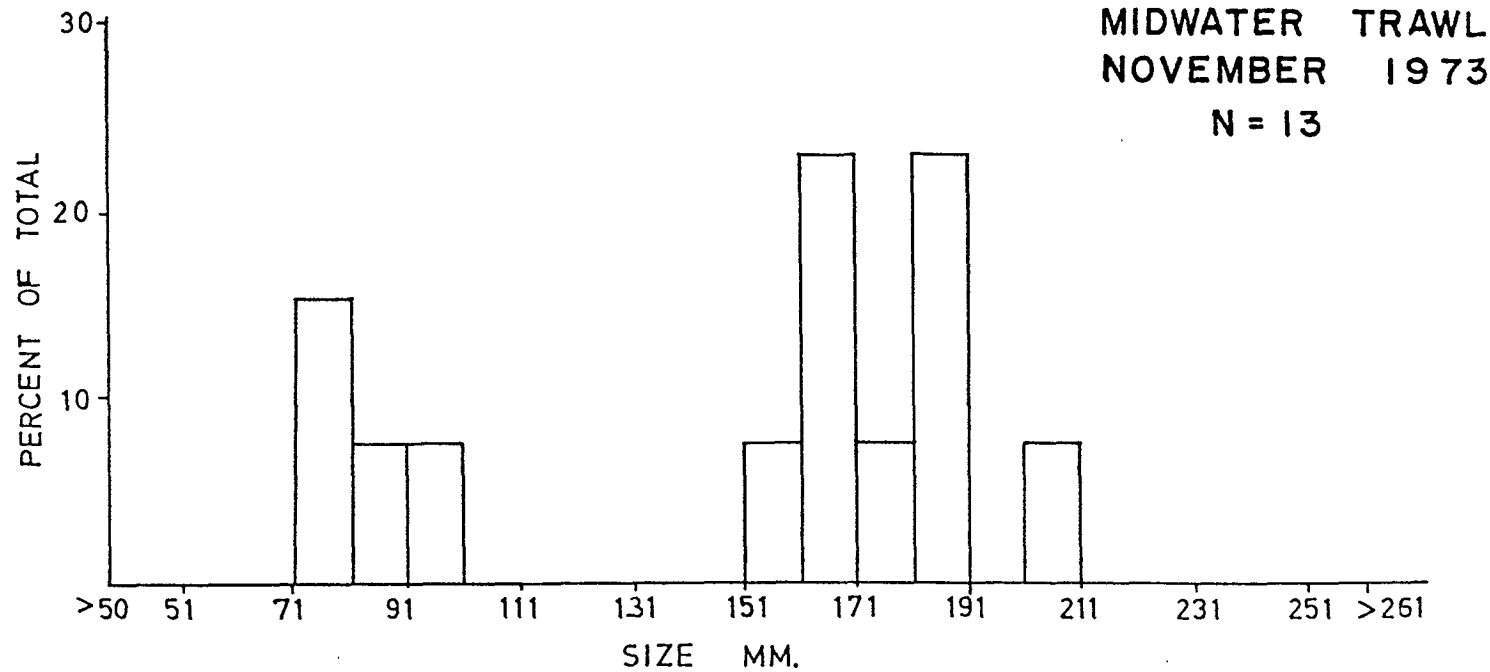




C-045814

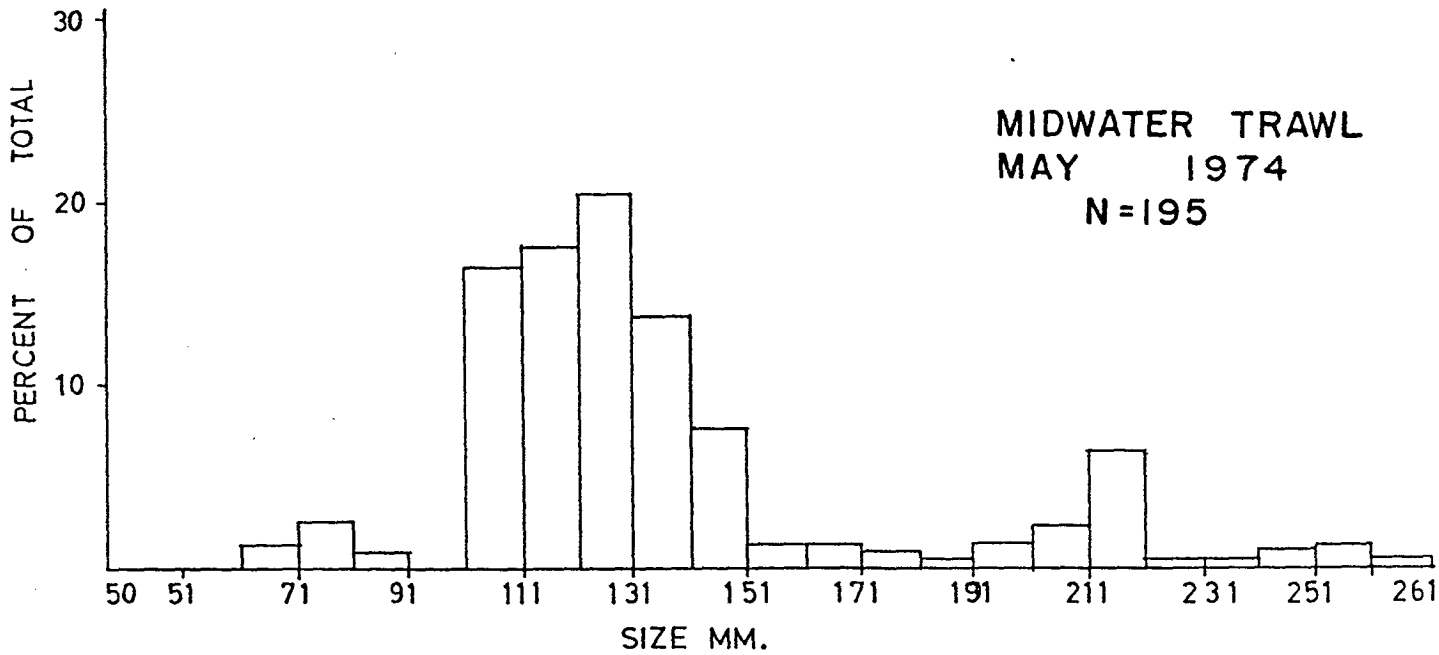
1973 Monthly Size Distribution - Striped Bass

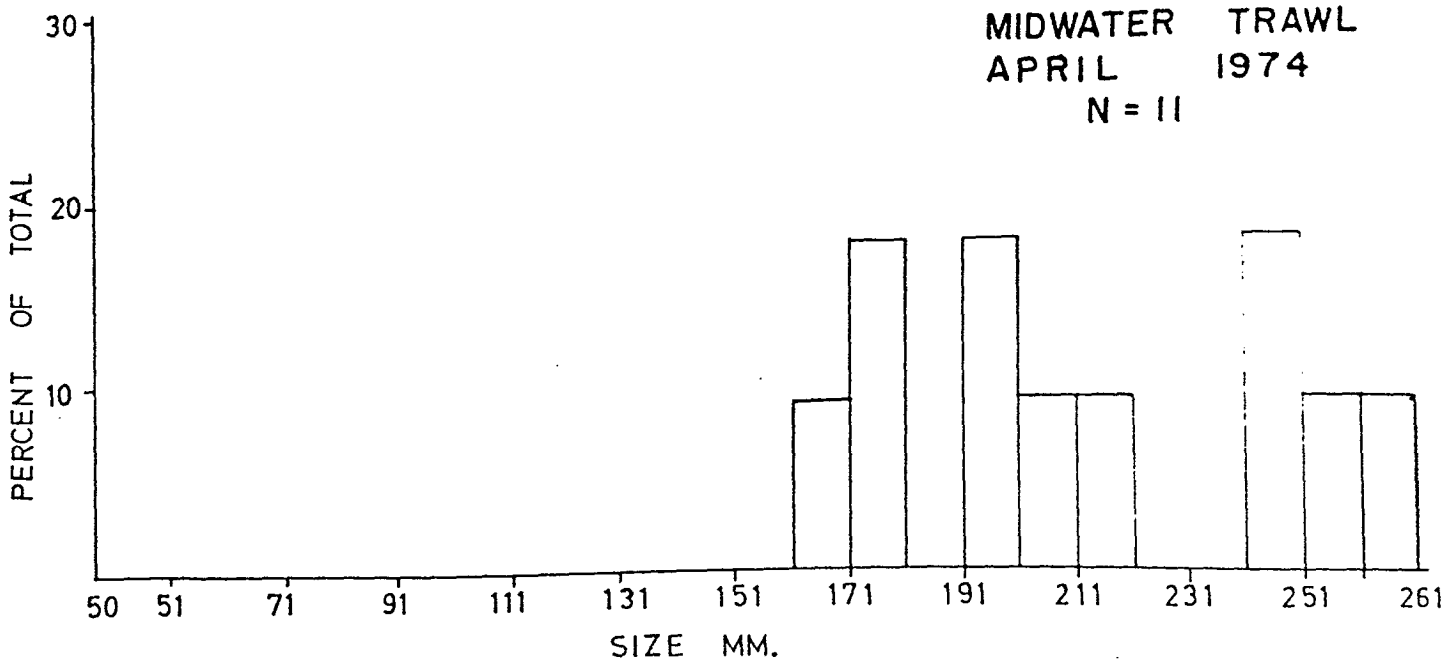




C-045815

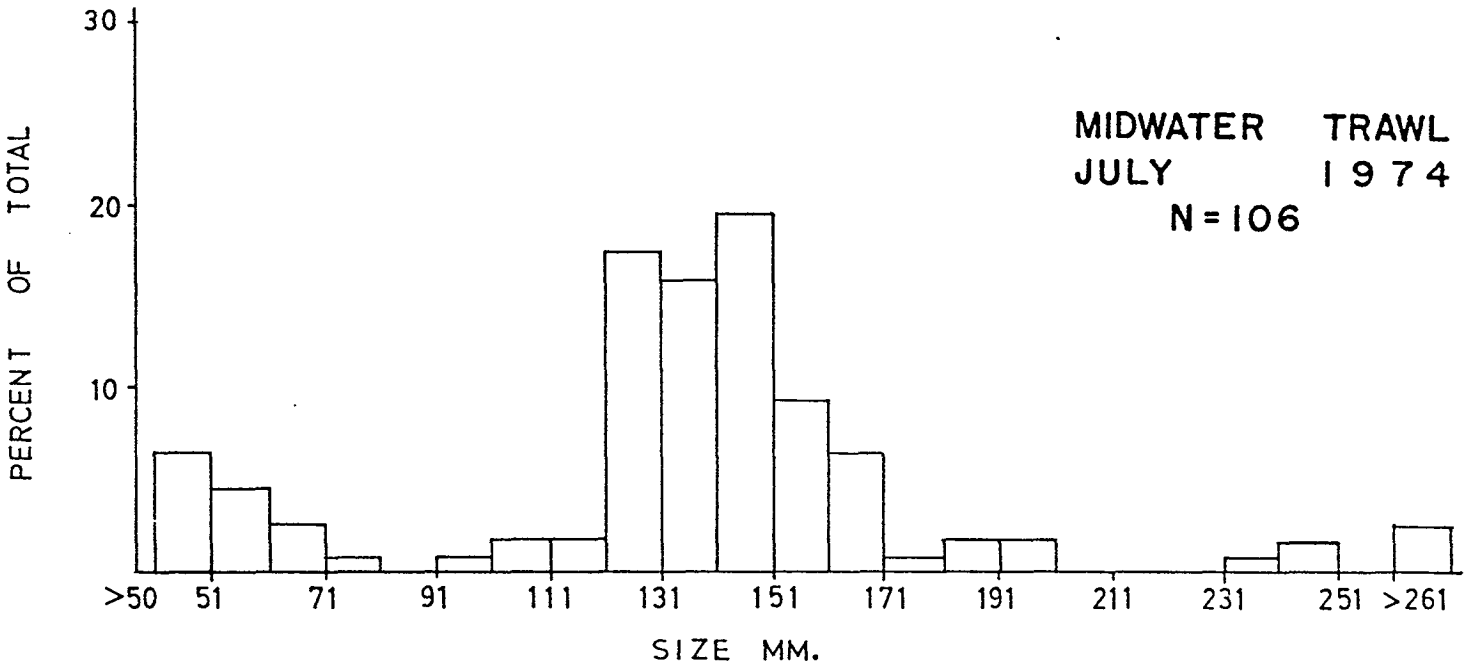
1974 Monthly Size Distribution - Striped Bass

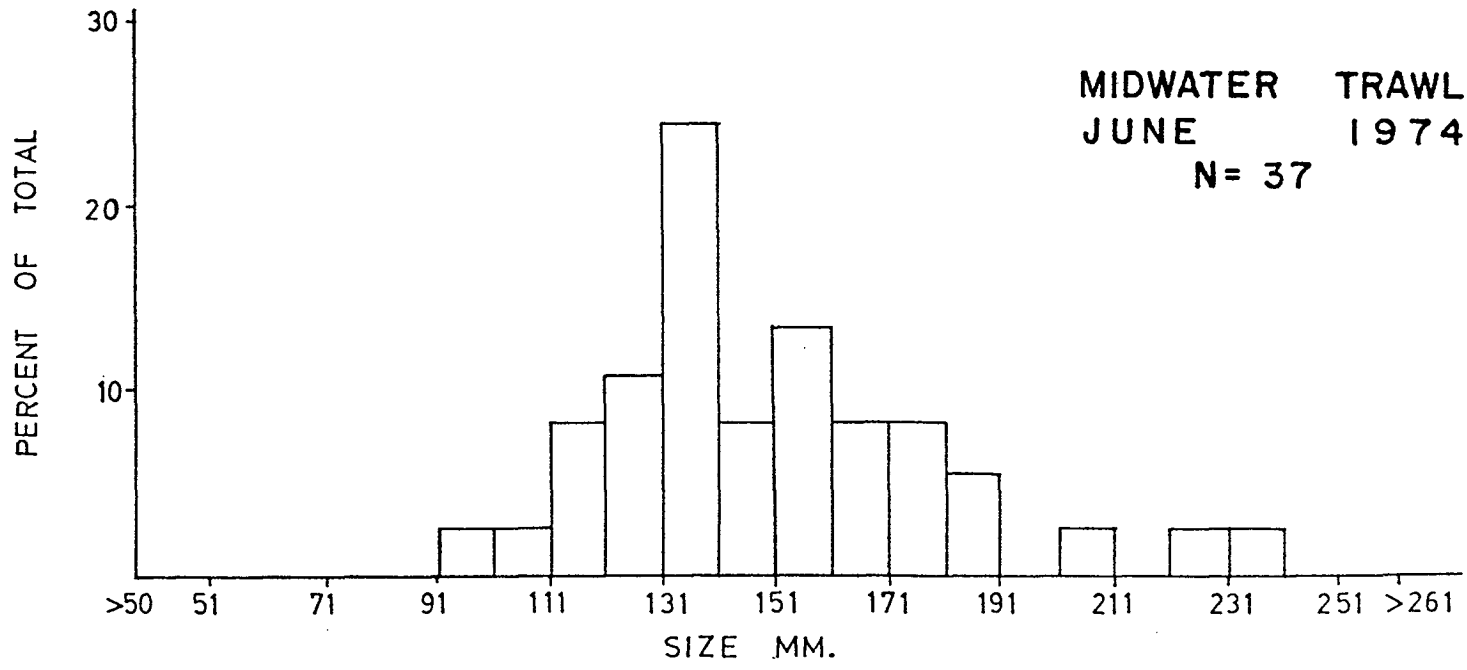




C-045816

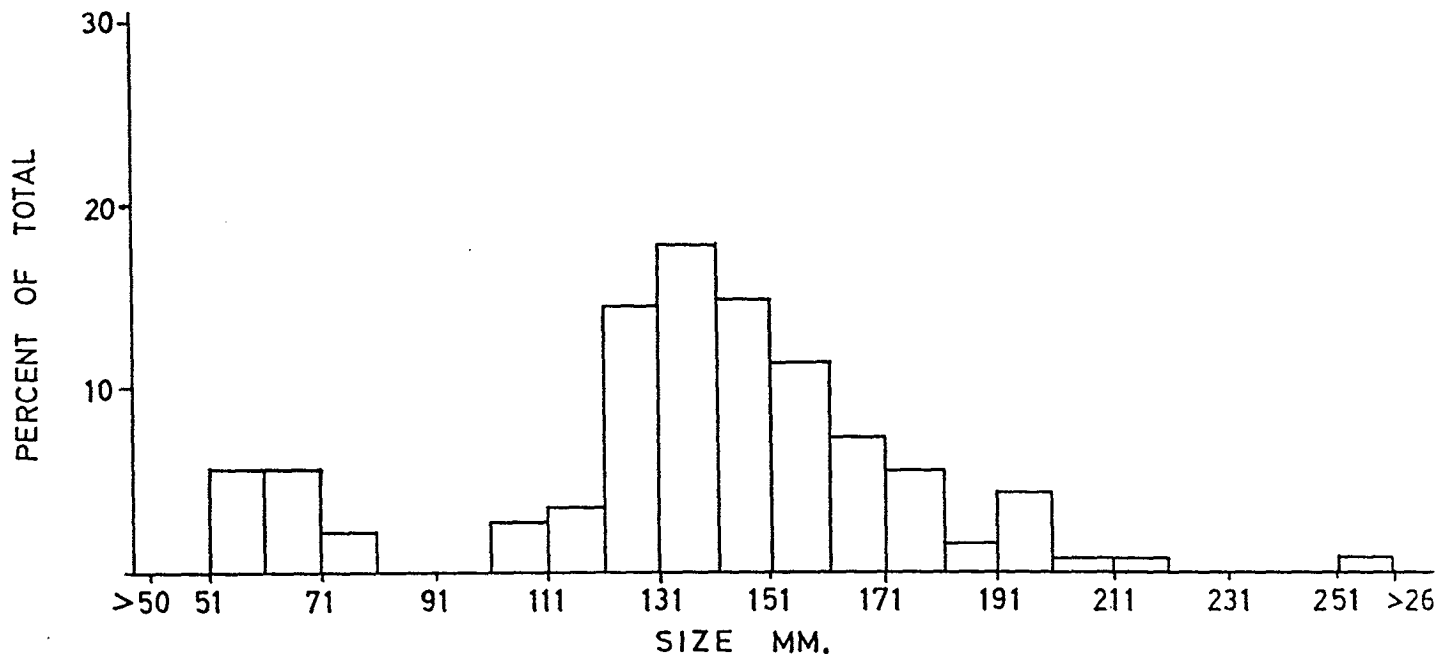
1974 Monthly Size Distribution - Striped Bass





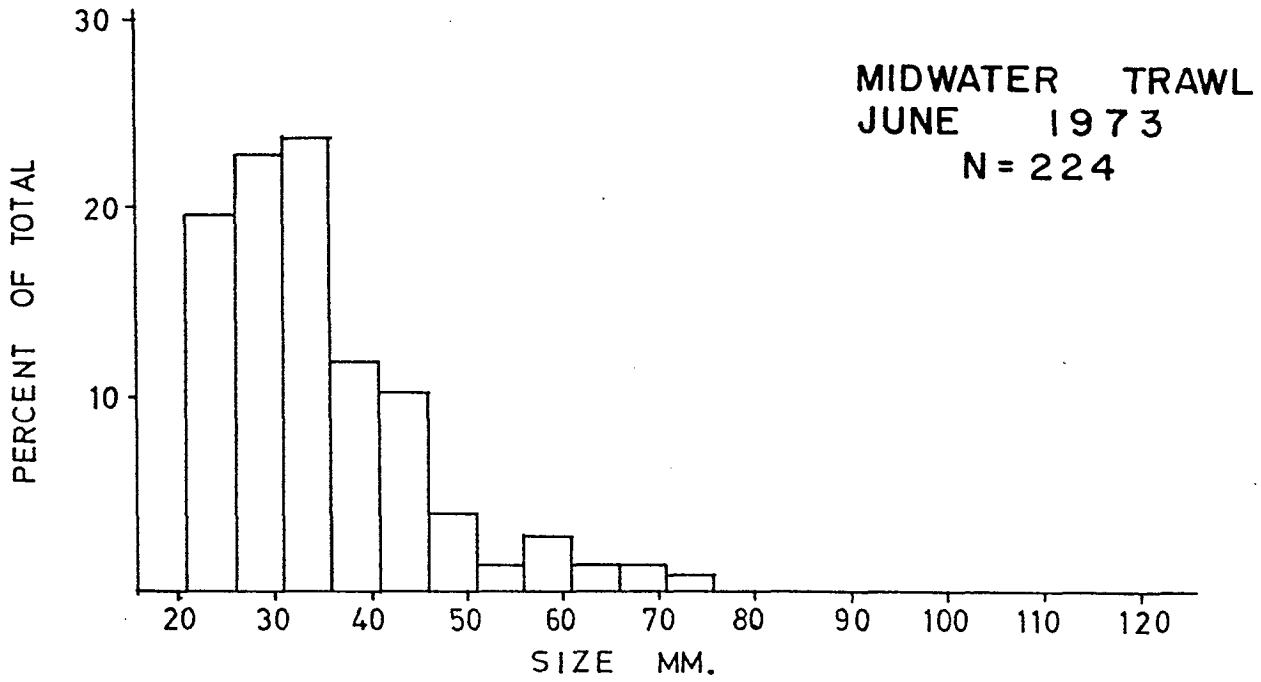
C-045817

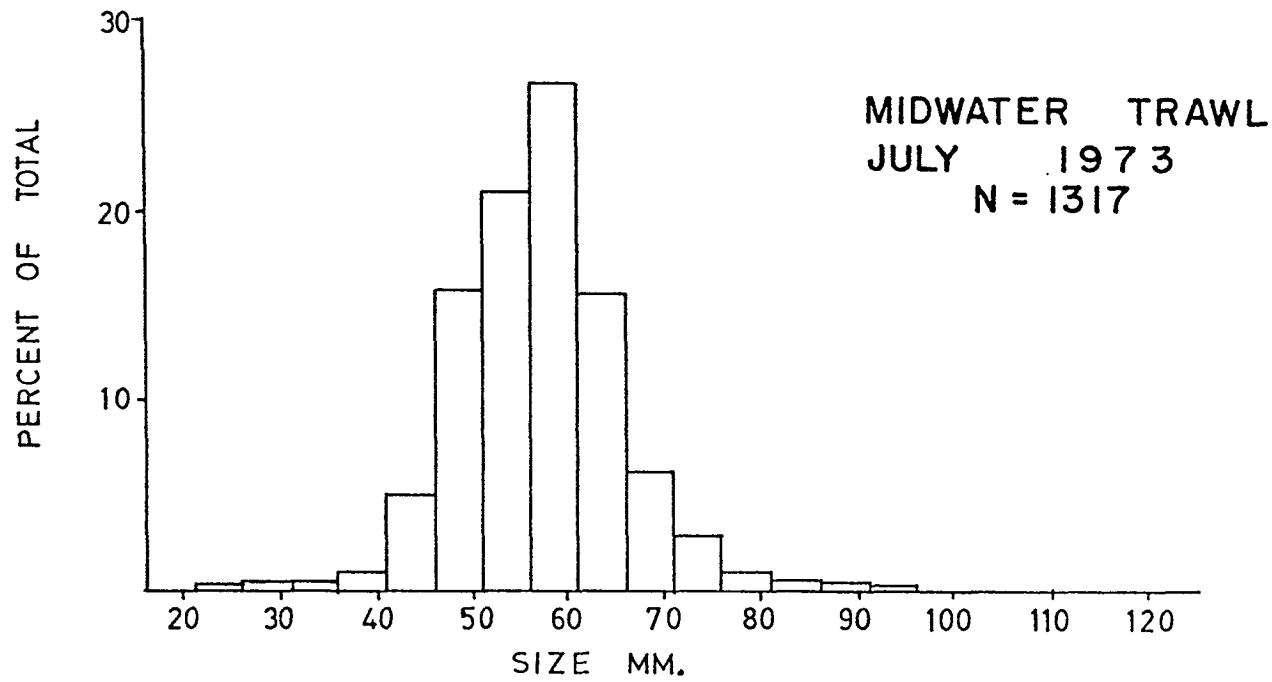
1974 Monthly Size Distribution - Striped Bass



MIDWATER TRAWL
AUGUST 1974
N = 61

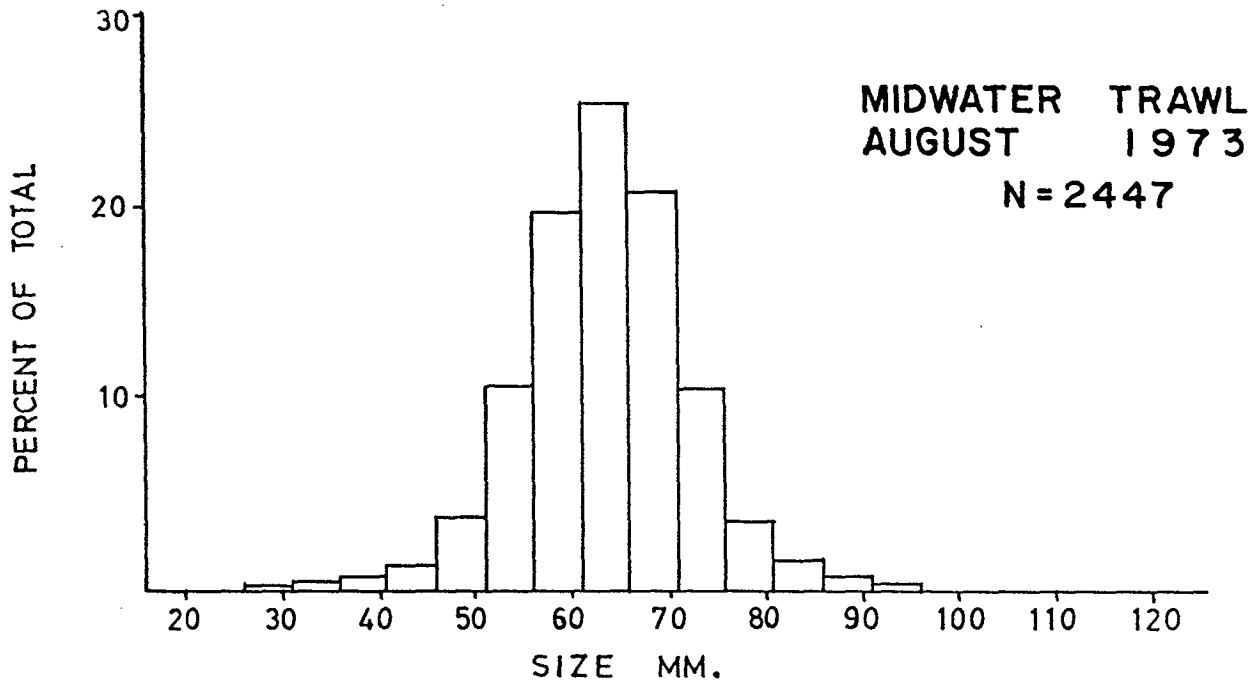
1973 Monthly Size Distribution - American Shad

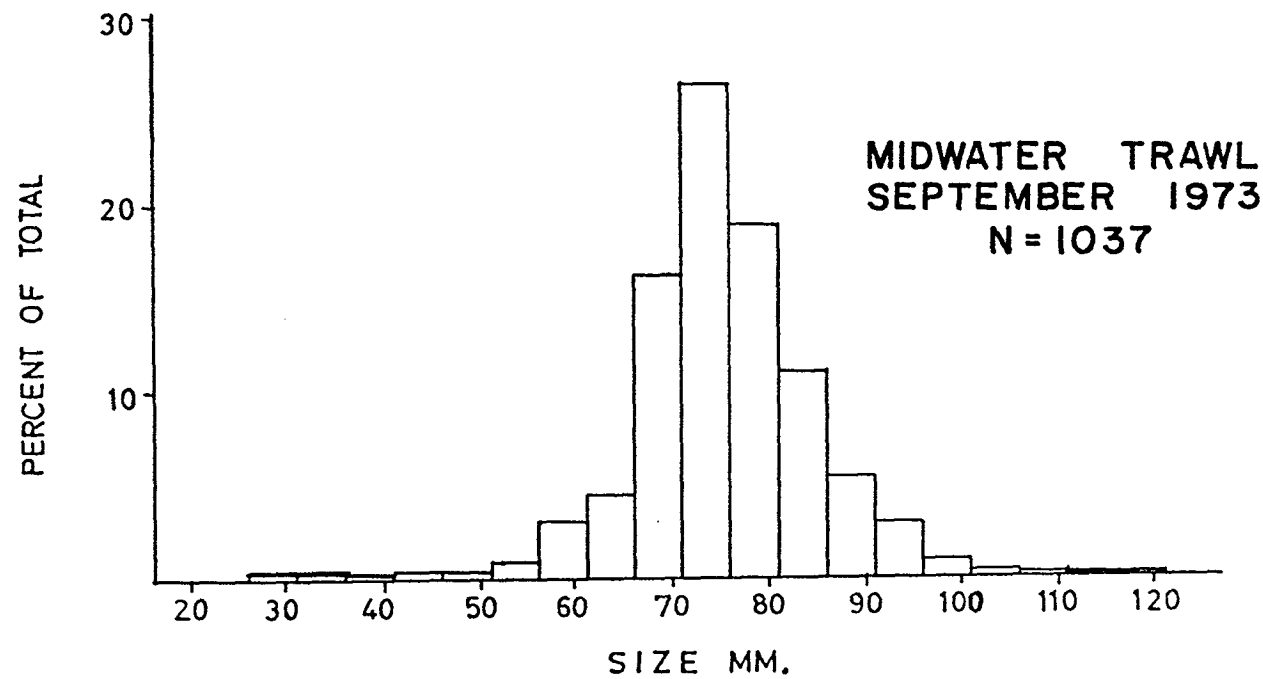




C-045819

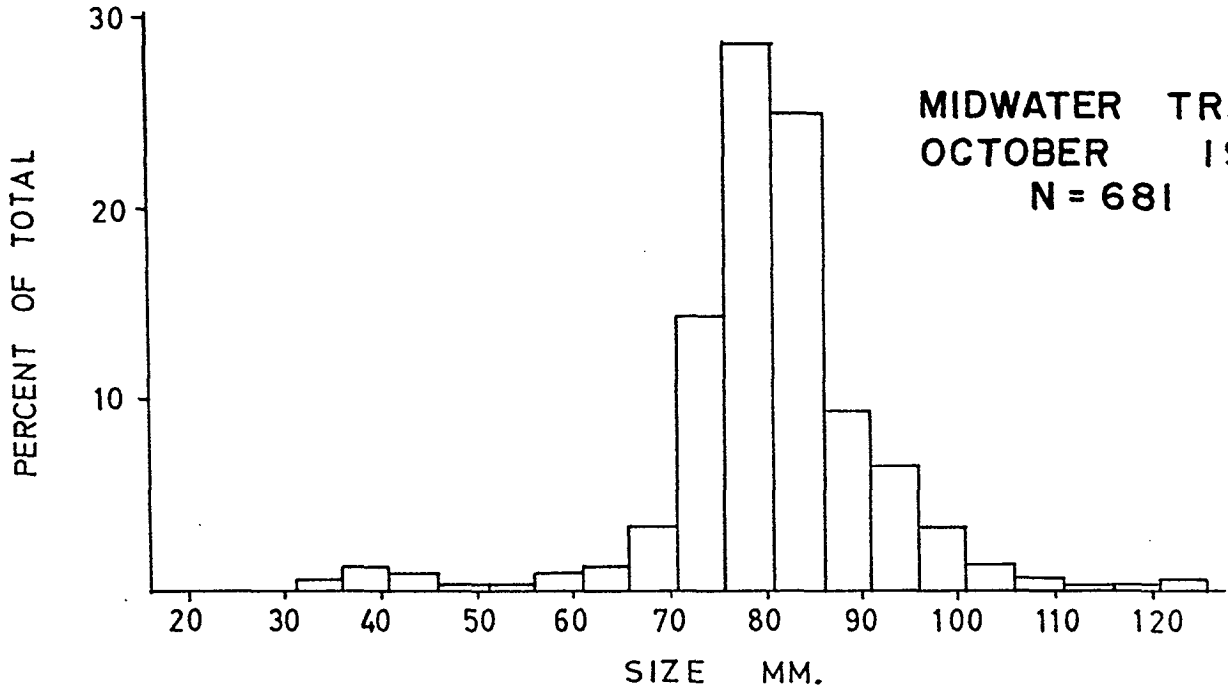
1973 Monthly Size Distribution - American Shad

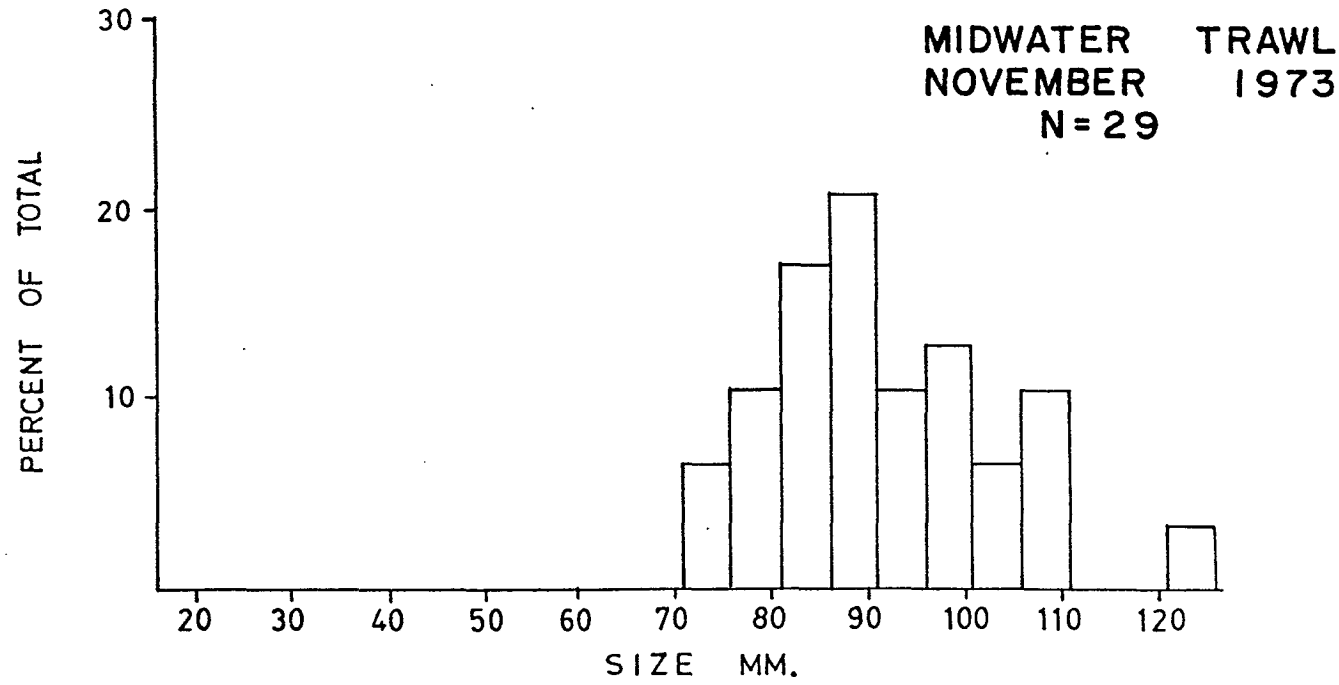




C-045820

1973 Monthly Size Distribution - American Shad





C-045821