FF/BIO-4ATR/82-2

AN EVALUATION OF PREDATOR COMPOSITION AT THREE LOCATIONS ON THE SACRAMENTO RIVER

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Technical Report 2

September 1982

INTERAGENCY ECOLOGICAL STUDY PROGRAM FOR THE SACRAMENTO-SAN JOAQUIN ESTUARY

A Cooperative Study by the:

CALIFORNIA DEPARTMENT OF WATER RESOURCES
CALIFORNIA DEPARTMENT OF FISH AND GAME
U.S. BUREAU OF RECLAMATION
U.S. FISH AND WILDLIFE SERVICE

AN EVALUATION OF PREDATOR COMPOSITION

AT THREE LOCATIONS ON THE SACRAMENTO RIVER[1/]

by

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ABSTRACT

Gill net surveys were conducted at three locations in the lower Sacramento River from February 1976 to February 1978. Two sites at Horseshoe Bend were selected to measure differences in predation between a release site for juvenile fish salvaged from the pumping operations at the State Water Project near Byron, California, and a nearby control site. The third location was at Hood, California, the intake site for the proposed Peripheral Canal.

Striped bass, *Morone saxatilis*, was the most numerous predator at all three locations and the occurrence of striped bass fluctuated seasonally. The frequency of fish in the stomach samples and the mean volume of fish in the stomach samples of striped bass was greater at the release site than at the control site at Horseshoe Bend.

Sacramento squawfish, *Ptychocheilus grandis*, were more numerous at Horseshoe Bend than at Hood. Their occurrence at all three sites fluctuated seasonally. Squawfish occurred more frequently, were larger, and consumed more fish at the release site than at the control site.

Differences in the life histories and behavior of striped bass and Sacramento squawfish may contribute to their abilities to exploit the artificially abundant sources of food at the Horseshoe Bend fish salvage release site.

1/ Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary, Technical Report No. 2. September, 1982.

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INTRODUCTION

Fishes entrained to the California State Water Project's John E. Skinner Delta Fish Protective Facility near Byron, California, are collected and transported to the Sacramento River and released at Horseshoe Bend. It has been suggested that predation increases in an area where juvenile fish are stressed or concentrated (Hall 1979). Two study areas were selected to provide comparable data related to predation at Horseshoe Bend. One area was a regular release site for salvaged fish, and the second was a similar area where no releases were made. Both sites were subject to tidal flow reversals, a condition that would occur at the proposed Peripheral Canal intake. A third site was selected to provide data on predator occurrence at Hood, California, the intake site for the proposed Peripheral Canal.

Since the proposed Peripheral Canal fish screen facilities will utilize an off-river channel, and the screened fish will be concentrated and returned to the river from the channel, the objectives of this study were: (1) to evaluate predation at the release site as compared to a nearby control site at Horseshoe Bend, (2) to evaluate the effects of tidal flow reversal on predation, and (3) to determine the species composition and abundance of predators at Hood.

DESCRIPTION OF STUDY AREAS

Horseshoe Bend

Horseshoe Bend is located approximately 6.4 km (4 miles) downstream from the town of Rio Vista on the Sacramento River (Figure 1). It is approximately 3.2 km (2 miles) long and the channel width averages about 300 m (1,000 ft). The depth of the channel is relatively uniform, and averages about 5.5 m (18 ft). The substrate is mostly silt and compacted clay. The northwest (inside) bank of the bend is vegetated with rushes, *Scirpus sp.*, cattails, *Typha sp.*, willows *Salix sp.*, and alders, *Alnus sp.* The southeast (outside) bank of the bend is less extensively vegetated, and is leveed to provide the roadway for State Highway 160.

Channel flows are regulated by river flows and tidal action. Flow reversal occurs during almost all tide changes except when river flow exceeds about 1,700 m^3/s (60,000 cfs) (Larry Smith, Assoc. Engineer, Dept. Water Resources, pers. commun.). Channel velocities during high winter flow conditions may reach 2 m/s (7 ft/s), but are usually less than 1 m/s (3 ft/s) during most months.

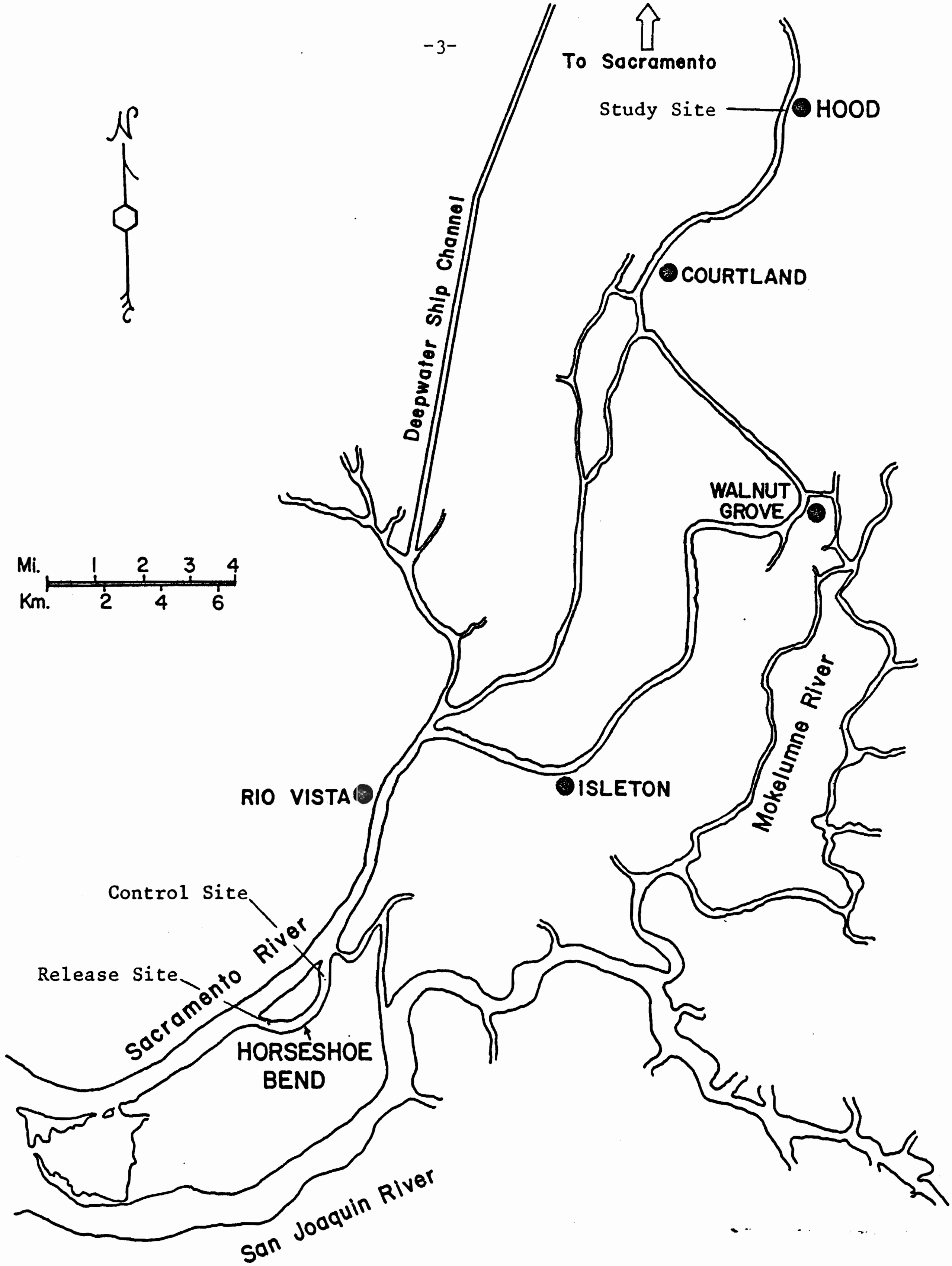

FIGURE 1. Study sites for lower Sacramento River predation study, 1976-1978.

Hood

Hood is approximately 24 km (15 miles) south of the City of Sacramento on the Sacramento River (Figure 1). The river channel at Hood is approximately 183 m (600 ft) wide. The average depth varies from 6 m (20 ft) at 340 m^3/s (12,000 cfs) to 11 m (35 ft) deep when the flow is 2,100 m^3/s (75,000 cfs). The substrate is largely compacted clay and the banks are riprapped levees. Several cottonwood trees, *Populus sp.*, grow along the eastern bank of the river near the study site. Channel velocities are determined by river flows with tidal flow reversals occurring only at flows less than approximately 225 m^3/s (8,000 cfs). The average monthly flows for the study period fluctuated from approximately 150 m^3/s (5,000 cfs) in October 1977 to over 2,100 m^3/s (75,000 cfs) in January 1978.

MATERIALS AND METHODS

Between February 1976 and February 1978, routine gill net surveys were conducted at each of three sites: Horseshoe Bend Experimental (HBX - the salvaged fish release site), Horseshoe Bend Control (HBC - nonrelease site), and Hood. At Horseshoe Bend, identical nets were fished at each site on 83 occasions. At Hood, 128 gill net surveys were conducted using two different nets simultaneously (Table 1). All nets were fished parallel to the flow of the river and were anchored on each end to concrete blocks and permanent buoys. Horseshoe Bend nets were fished for an average of 3 h, SD = 2.04 h. and Hood nets were fished for an average of 6.6 h, SD = 6.8 h. Most sampling was conducted during daylight hours, however a limited amount of sampling was conducted at night. Data collected when each net was set included: direction of flow, water temperature, and secchi disc transparency.

Each captured fish was recorded by species and measured to the nearest millimeter fork length (FL). In addition, stomach contents of all predatory species captured at both Horseshoe Bend sites were removed by the use of a hand operated stomach pump similar to that described by Seaburg (1957). Stomachs from a sample of predators were removed after pumping to determine the effectiveness of the stomach pump. Stomach contents and removed stomachs were preserved in 10% formalin for later laboratory analyses. After stomach contents were removed, fish were returned to the water.

Stomach contents and removed stomachs were analyzed in the laboratory to determine the composition of prey. Each prey item recovered was identified to the lowest possible taxonomic level. Volumes of prey items were determined by water displacement in a graduated cylinder and measured to the nearest 0.1 milliliter.

Capture frequencies were compared using chi-square (X^2) tests. Fishing effort was not the same for all seasons, therefore point estimates (Bhattcharyya and Johnson 1977) were made of the number of predators that

TABLE 1. Gill Net Specifications, Sacramento River Predation Study, 1976-1978.

Specification	Net Type 1 (Horseshoe Bend Control and Experimental)	Net Type 2 (Hood)	Net Type 3 (Hood)
Net length	91.4 m	53.3 m	36.6 m
Panel depth	8.3 m	3.7 m	2.7 m
Mesh size (Stretch)		Length of mesh size	
25 mm			7.3 m
38 mm			7.3 m
51 mm			7.3 m
76 mm	18.3 m	22.9 m	7.3 m
89 mm	18.3 m	7.6 m	
102 mm	18.3 m	7.6 m	7.3 m
114 mm	18.3 m	7.6 m	
127 mm	18.3 m	7.6 m	

would have been captured at a particular level of sampling effort. This was accomplished by the following formula:

$$P = \frac{C}{E_1} \times E_2$$

where: P = point estimate rounded to the nearest whole number
C = the total seasonal catch of a predator species
E_1 = the total effort (h) for the season
E_2 = the total effort (h) for the season with the least effort.

This method estimated catches per standard unit of effort.

Proportions of predators captured at HBX and HBC during each season were compared with X^2 tests (2 x 4 contingency table). Mean fork lengths of predators at the two Horseshoe Bend sites were compared with an approximate test of equality of the means (Sokal and Rohlf 1969).

The number of predators with fish in their stomach contents was analyzed by X^2 texts (2 x 2 contingency table) for each season and for the total samples combined. Volumes of all fish items, measured by water displacement, were summed for each stomach sample. T-tests were used to compare the differences in the mean volumes of stomach samples between HBX and HBC and between downstream flow (ebb tide) and upstream flow (flood tide). For purposes of this study, winter included December-February, spring included March-May, summer included June-August, and fall was considered to be September-November.

RESULTS

Horseshoe Bend

Six species of predators were captured during our surveys at Horseshoe Bend (Table 2). The total number of predators collected at HBX was significantly greater ($X^2 = 4.35$, $p < 0.05$) than the total collected at HBC. The most numerous predators were striped bass and Sacramento squawfish. Too few steelhead rainbow trout, _Salmo gairdneri_, white catfish, _Ictalurus catus_, channel catfish, _I. punctatus_, and black crappie, _Pomoxis nigromaculatus_, were collected to be included in statistical comparisons between HBX and HBC.

The occurrence of striped bass was not significantly different ($X^2 = 0.66$, $p > 0.5$), between HBX and HBC, but seasonal fluctuations at both sites were observed. Striped bass occurrence was lowest in summer and progressively increased through fall, winter, and spring (Table 3). The proportion of striped bass captured at HBX was not significantly different ($X^2 = 5.14$, $p > 0.1$) during the four seasons. The mean fork length of striped bass (Figure 2) was significantly larger ($t = 2.45$, $p < 0.02$) at HBX than at HBC.

TABLE 2. Seasonal Occurrence of Predators at Horseshoe Bend, February 1976 to February 1978.

Predator species	Winter		Spring		Summer		Fall		Total	
	HBX	HBC	HBX	HBC	HBX	HBC	HBX	HBC	HBX	HBC
Striped bass	51	36	31	48	26	21	47	43	155	148
Sacramento squawfish	41	3	10	6	12	13	24	11	87	33
Steelhead rainbow trout	2	1	0	0	3	7	12	11	17	19
White catfish	2	1	2	13	1	1	0	4	5	19
Channel catfish	0	0	2	0	0	0	0	0	2	0
Black crappie	0	0	0	0	1	0	0	0	1	0
Total	96	41	45	67	43	42	83	69	267	219

TABLE 3. Observed and Estimated Seasonal Occurrence of Striped bass at Horseshoe Bend, February 1976 to February 1978. Point Estimates Were Based on a Theoretical Standard Effort.

Striped Bass	Winter		Spring		Summer		Fall		Total	
	HBX	HBC	HBX	HBC	HBX	HBC	HBX	HBC	HBX	HBC
Observed	51	36	31	48	26	21	47	43	155	148
Point estimate	39	27	31	44	19	14	30	27	155	141
Total estimate	66		75		33		57			

TABLE 4. Observed and Estimated Seasonal Occurrence of Sacramento Squawfish at Horseshoe Bend, February 1976 to February 1978. Point Estimates Were Based on a Theoretical Standard Effort.

Sacramento Squawfish	Winter		Spring		Summer		Fall		Total	
	HBX	HBC	HBX	HBC	HBX	HBC	HBX	HBC	HBX	HBC
Observed	41	3	10	6	12	13	24	11	87	33
Point estimate	31	2	10	5	9	9	15	7	87	31
Total estimate	33		15		18		22			

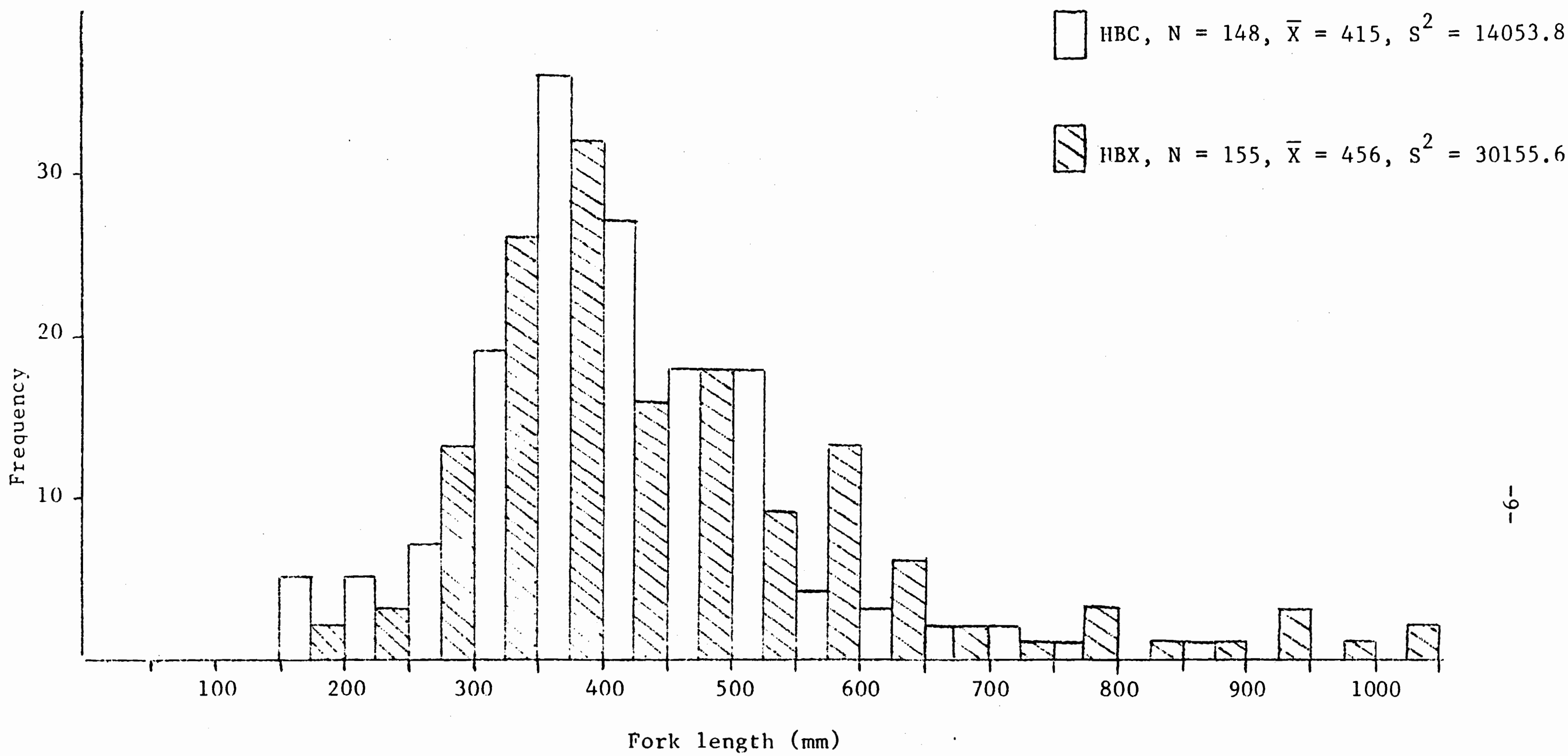

FIGURE 2. Size distribution of striped bass collected at Horseshoe Bend, February 1976 to February 1978. Fork lengths grouped in 50 mm intervals.

The total capture of Sacramento squawfish was significantly higher ($X^2 = 26.58$, $p < 0.005$) at HBX than at HBC. Winter, however, was the only season when a significant difference ($X^2 = 25.48$, $p < 0.005$) was observed between the two sites. Seasonal fluctuations were observed at HBX and in the total catches at both sites combined. Catches at both stations combined were lowest in spring and progressively increased through summer, fall, and winter (Table 4). The mean fork length of Sacramento squawfish (Figure 3) was significantly greater ($t = 3.09$, $p < 0.01$) at HBX than at HBC.

Our laboratory analyses indicated that the stomach pump was effective in removing essentially all stomach contents. The frequency of fish in the stomach samples of striped bass was significantly greater at HBX than at HBC during the fall ($X^2 = 6.24$, $p < 0.025$) and for all seasons combined ($X^2 = 8.09$, $p < 0.005$) (Table 5). The frequency of fish in the stomach samples of Sacramento squawfish was also significantly greater ($X^2 = 4.81$, $p < 0.05$) at HBX than at HBC for all seasons combined (Table 6).

Although the mean volumes of fish in the stomach samples taken at HBX were greater than those taken at HBC for both striped bass and Sacramento squawfish for most seasons, small sample sizes and very high variances made it difficult to describe any statistically significant differences between the two sites on a seasonal basis. However, the mean volume of fish consumed by Sacramento squawfish was significantly greater ($t = 1.82$, $p < 0.05$) at HBX than at HBC but the mean volume of fish consumed by striped bass was not significantly different ($t = 1.16$, $p > 0.1$) at HBX and HBC (Table 7).

The mean volume of fish in the stomach samples of striped bass and Sacramento squawfish was significantly greater ($t = 2.06$, $t = 2.03$ respectively, $p < 0.05$) during ebb tides than during flood tides when both sites were treated together. Also the mean volume of fish in the stomach samples of squawfish collected at HBX was significantly greater ($t = 2.07$, $p < 0.05$) during ebb tides than during flood tides (Table 8).

Hood

Five species of predators were captured at Hood (Table 9). Seasonal fluctuations were observed in the frequency of capture of striped bass and steelhead rainbow trout, the two most commonly captured predators. Striped bass were most numerous in the spring. Sacramento squawfish were not collected frequently, however more were collected during the spring than any other season.

DISCUSSION

The use of gill nets to sample fish populations is effective but not without sampling bias. Stevens (1966) compared gill nets, midwater trawls, and

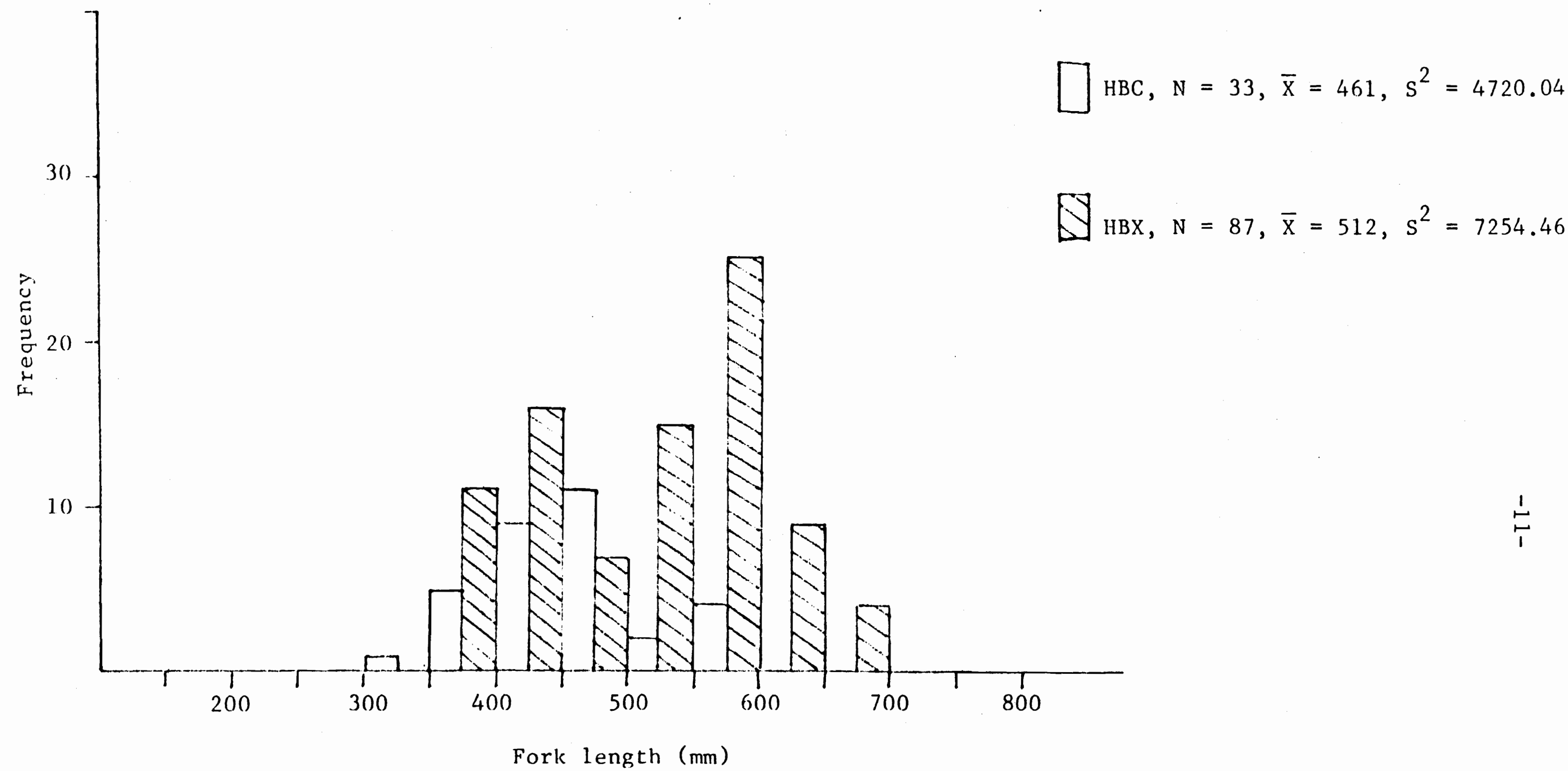

FIGURE 3. Size distribution of Sacramento squawfish collected at Horseshoe Bend, February 1976 to February 1978. Fork lengths grouped in 50 mm intervals.

TABLE 5. Frequency of Fish in Striped Bass Stomach Samples Collected at Horseshoe Bend, February 1976 to February 1978.

Striped bass	Winter		Spring		Summer		Fall		Total	
	HBX	HBC	HBX	HBC	HBX	HBC	HBX	HBC	HBX	HBC
No. stomachs examined	32	26	28	42	17	15	31	8	108	91
No. stomachs containing fish	23	22	8	10	10	3	27	3	68	38
X^2	0.71		0.03		3.5		6.24*		8.09**	

$*p < 0.025$

$**p < 0.005$

TABLE 6. Frequency of Fish in Sacramento Squawfish Stomach Samples Collected at Horseshoe Bend, February 1976 to February 1978.

Sacramento squawfish	Winter		Spring		Summer		Fall		Total	
	HBX	HBC	HBX	HBC	HBX	HBC	HBX	HBC	HBX	HBC
No. stomachs examined	33	3	10	6	14	11	24	6	81	26
No. stomachs containing fish	26	2	1	1	5	1	15	4	47	8
X^2	0.06		0.15		1.16		0.08		4.81*	

$* p < 0.05$

TABLE 7. Mean Volume of Fish in Stomach Samples of Sacramento Squawfish and Striped Bass Collected at Horseshoe Bend, 1976-1978.

	Sacramento squawfish			Striped Bass	
	HBX	HBC		HBX	HBC
N	47	8	N	68	38
$\bar{x}$ volume (ml)	8.12	2.61	$\bar{x}$ volume (ml)	5.28	2.98
s^2	369.10	10.73	s^2	167.21	55.83
	t = 1.82*			t = 1.16	

* $p < 0.05$

TABLE 8. Mean Volume of Fish in Stomach Samples of Striped Bass and Sacramento Squawfish Collected at Horseshoe Bend During Flood Tides and Ebb Tides, 1976-1978.

		Striped bass			Sacramento squawfish	
		Flood tide	Ebb tide		Flood tide	Ebb tide
HBX	N	36	32	N	24	23
	$\bar{x}$ volume (ml)	2.5	8.38	$\bar{x}$ volume (ml)	2.5	13.53
	s^2	52.6	283.44	s^2	8.98	671.49
		t = 1.03			t = 2.07*	
HBC	N	19	19	N	3	5
	$\bar{x}$ volume (ml)	1.77	4.19	$\bar{x}$ volume (ml)	2.8	2.5
	s^2	10.08	101.61	s^2	19.53	8.98
		t = 0.99			t = 0.10	
Both sites combined	N	55	51	N	27	28
	$\bar{x}$ volume (ml)	2.25	6.82	$\bar{x}$ volume (ml)	2.19	11.56
	s^2	37.57	216.51	s^2	26.83	566.99
		t = 2.06*			5 = 2.03*	

* $p < 0.05$

TABLE 9. Seasonal Occurrence of Predators at Hood, February 1976 to February 1978.

Predator species	Winter	Spring	Summer	Fall	Total
Striped bass	0	47	42	25	114
Steelhead rainbow trout	21	29	0	36	86
White catfish	1	10	17	3	31
Sacramento squawfish	3	7	1	3	14
Black crappie	0	2	0	0	2
Total	25	95	60	67	247

otter trawls with respect to the number of empty striped bass stomachs, and found that gill nets had the greatest proportion of empty stomachs. This difference may be due to digestion or regurgitation while in the net, but should not affect the Horseshoe Bend comparisons as the time that fish spent in the nets was similar at both sites.

Striped bass are large, introduced predators which are seasonably abundant in the Delta as adults. Although the smallest mesh in our gill nets at Horseshoe Bend (76 mm stretch) has been demonstrated to select for striped bass larger than 317 mm (12.5 in.) (Hassler, Hill and Brown 1981), the occurrence of sub-adult and juvenile striped bass has been reported throughout the Delta, including the Sacramento River near Horseshoe Bend, during all seasons (Stevens 1966). Fish is reported to be an important constituent in the diet of juvenile striped bass and increases its importance as striped bass grow (Stevens 1966, Thomas 1967).

Adult striped bass migrate in the spring (April-May) from San Francisco Bay, San Pablo Bay, and the Delta up the Sacramento and San Joaquin Rivers to spawn (Radtke 1966). After spawning, they move back downstream into the Delta and bays. The occurrence of striped bass at Hood was greatest during spring and summer. The occurrence of striped bass at Horseshoe Bend also was highest during the spring spawning migration.

Striped bass did not appear to congregate around the release site at HBX to take advantage of the regularly abundant food supply. The same conclusion was also reached in 1966 and 1967 when a similar study was conducted at the Sherman Island fish release site for the U. S. Bureau of Reclamation Tracy Fish Collection Facility (Dept. Fish and Game unpublished). This may be a result of striped bass foraging strategy as a roving schooling predator that may occasionally take advantage of a single clumped food source, rather than a strategy of establishing a territory and lying in ambush at a location, such as at the release site. Thus, if a school of striped bass encountered a single release of salvaged fish, the school could feed until foraging efficiency in the area was sufficiently reduced or they were satiated.

Juvenile and sub-adult striped bass are the groups that are most likely to establish residency and they were not adequately sampled at Horseshoe Bend. The size distribution of striped bass collected at Hood (Figure 4) indicates that juvenile and sub-adult bass were abundant and they may be a significant predator at the proposed Peripheral Canal intake.

Sacramento squawfish are relatively large native predatory cyprinids found throughout the Sacramento-San Joaquin River system. Several investigators have concluded that squawfish are most abundant in the permanent foothill streams of the Sierra Nevada between 100 and 650 m (328 and 2131 ft) elevation (Taft and Murphy 1950; Moyle and Nichols 1973). However, this conclusion may be attributable to the fact that they are more visible in the smaller streams and adequate information is not yet available on their abundance and distribution in the main Sacramento and San Joaquin rivers.

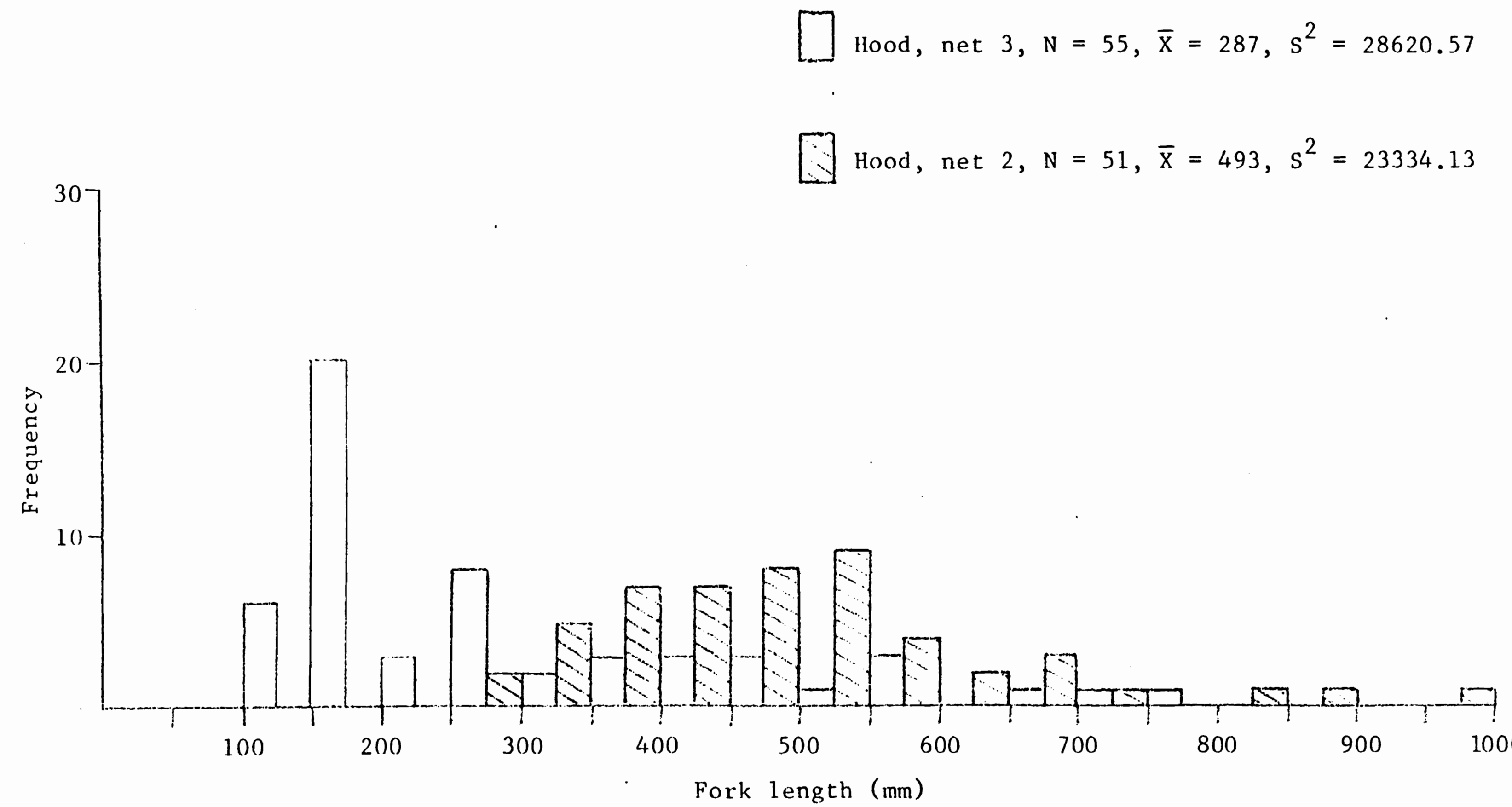

FIGURE 4. Size distribution of striped bass collected at Hood, February 1976 to February 1978. Fork lengths grouped in 50 mm intervals. See Table 1 for description of nets.

In streams, small Sacramento squawfish tend to form schools, while larger squawfish are solitary and tend to lay in deeper pools to ambush smaller fish, particularly in the evening (Moyle 1976). While evaluating predation at the Red Bluff Diversion Dam (Calif. Dept. Fish and Game unpublished) and at the Hallwood-Cordua fish screen on the Yuba River near Marysville (Hall 1979), Sacramento squawfish have been observed to actively feed during mid-day. Their behavior is probably due to the opportunistic nature of squawfish to take advantage of a concentration of prey.

Temporal distributions of Sacramento squawfish in the Sacramento River system are poorly understood. While more than 20,000 adult squawfish are counted annually migrating past Red Bluff Diversion Dam on the Sacramento River, little is known about their movement other than that they migrate upstream to spawn in the spring (Moyle 1976). In May 1980, two squawfish were collected at Red Bluff Diversion Dam that were tagged in April 1979 at Clarksburg, over 320 km (200 miles) downstream (Calif. Dept. Fish and Game unpublished). Long migrations have been reported for the northern squawfish, *Ptychocheilus oregonensis*, in Idaho rivers (Falter 1969; Craig MacPhee, University of Idaho, pers. commun.). The implication for the proposed Peripheral Canal is that squawfish may be attracted to an artificial concentration of fish at the fish facilities, especially if stress to downstream migrants cannot be avoided.

In contrast to striped bass, the occurrence of Sacramento squawfish at HBX was significantly greater than at HBC. Some factor, such as availability of food, must cause squawfish to be more numerous at the release site. It appears that squawfish move into the Horseshoe Bend area in the summer, continue to increase in numbers through the winter, and leave again in the spring. The proportion of squawfish at the release site compared to the control site also increased from summer, when it was nearly equal; to fall, when there were about twice as many captures at the release site; to winter when there were over ten times as many captures at the release site than at the control site. From these relationships, it appears that squawfish enter Horseshoe Bend, discover the location of the release site, and the food supply associated with it, and congregate in that area.

Predator size can be used to determine if larger, more dominant individuals occur to a greater extent at the release site than at the control site. The size distributions of squawfish were significantly different between the two sites at Horseshoe Bend. This relationship indicates that larger Sacramento squawfish prefer the release site and smaller squawfish either do not prefer HBX or they are discouraged from occupying the area by the presence of large squawfish. A similar distribution was not observed for striped bass.

Since the frequency of occurrence of fish in the stomachs of Sacramento squawfish and striped bass was significantly greater at the release site (HBX) than at the control site (HBC), and since the mean volume of fish consumed was greater at HBX than HBC for Sacramento squawfish, it may be concluded that if prey fish are stressed or concentrated, predators are more effective in capturing them. This appears to be particularly true for Sacramento squawfish.

The effects of tidal fluctuations on predation were not adequately tested but there appears to be an influence due to the tide cycle. When all samples were combined, predation during ebb tides was significantly greater than during flood tides for both striped bass and Sacramento squawfish.

In conclusion, we feel that adult striped bass will substantially contribute to predation at the fish facilities for the proposed Peripheral Canal although their impact may be seasonal. Juvenile and sub-adult striped bass are likely to be significant predators during all seasons. Sacramento squawfish appear to respond to an artificial abundance of food and they are likely to contribute to predation on a permanent basis.

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