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Migrations of Juvenile Coho Salmon, *Oncorhynchus kisutch*, into the Columbia River Estuary, 1966-71

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August **1985**

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ABSTRACT

Beach seine sampling of juvenile coho salmon, *Oncorhynchus kisutch,* in the lower Columbia River is described for 1966 through 1971. Major migrations into the estuary occurred between late April and late May in each year of the study; peak catches occurred between 6 and 16 May. Release of marked hatchery fish at various upriver sites indicated that movement and recovery rates of downstream migrants in the estuary were related to time of release and distance from the estuary. Recoveries of individual groups of marked coho salmon released from March to May at Ice Harbor Dam in 1967 and 1968 revealed that later releases moved downstream more swiftly than did early releases.

Length frequency data show that larger coho salmon (>125 mm) arrived in the estuary first and that progressively smaller coho salmon arrive after the peak of migration. The average size of coho salmon increased during the 6 years of this study. Relations between hatchery practices, movement, and size of fish entering the estuary are discussed.

CONTENTS

INTRODUCTION

The coho salmon, Oncorhynchus kisutch, is an important commercial and recreational species inhabiting the Columbia River and its tributaries for spawning and presmolt rearing. Drawing from several sources, Pruter (1966) devised a table which showed the annual average coho salmon landings in terms of pounds from 1893 to 1963. The peak landings of coho salmon occurred between 1921 and 1930, with an average of 6,000,000 pounds (2,722,000 kg) taken annually. Landings decreased progressively until 1956-60; when an average of only 300,000 pounds (136,000 kg) were taken. Assuming an approximate average weight of 10 lb (4.5 ,kg). per fish, coho salmon landings were reduced from 600,000 to 30,000 fish.

Many factors together with the commercial harvest affected the Columbia River coho salmon stocks. Silt-choked gravel beds and log jams in streams from early forest harvesting reduced the spawning areas and limited food production during the rearing period. Low head hydroelectric dams impaired adult and juvenile migrations directly and indirectly, whereas multipurpose high head storage dams completely blocked adult spawning migrations. Commercial trolling and recreational ocean fishing contributed to losses, since many immature, sublegal fish are caught, and mortally injured before being released (Parker et al. 1959; Milne and Ball 1956). Additional causes for the decline in the number of coho salmon include municipal and industrial pollution, pesticide usage, nitrogen supersaturation, and hydrothermal conditions. Despite these negative factors, the decline in coho salmon numbers was reversed in the early 1960s. The run has stibsequently averaged 265,000 fish landed from 1964 to 1974, with a high of 521,000 fish in 1970 and a low of-125,000 fish in 1968.

An improved hatchery diet which sustained the juvenile fish until their yearling migration is credited as the single most important factor in the improved coho salmon runs. Cleaver (1969) determined the benefits from various coho salmon hatcheries in the Columbia River system appeared to be well in excess of their costs. Haw and Mathews (1969) reported that the technological advances in the rearing of coho salmon resulted in returns far exceeding the rearing capacity of the hatcheries.

Since the early 196Os, the number of coho salmon returning to hatcheries has increased substantially while their presence in selected natural spawning tributaries has decreased according to tables prepared by Gunsolus and Wendler (1975). Pollution control, restricted use of pesticides, improved forest harvesting techniques, updated designs for fish passage facilities at dams, and reduction in supersaturation of dissolved atmospheric gas in the water downstream from dams are all continuing improvements that should result in increased survival of coho salmon. However, while coho salmon have increased numerically from their low point in the. 1950s, they have not reached the magnitude of earlier runs. One possibility for the apparent leveling off of the coho salmon resurgence might be attributed to problems encountered by smolts during their migration to the sea.

In 1966, the Bureau of Commercial Fisheries [now the National Marine Fisheries Service (NMFS)] initiated a program to study the downstream migration of juvenile Pacific salmon, Oncorhynchus spp., and steelhead, Salmo gairdneri, in the Columbia River estuary. The purpose was to provide basic information on the seasonal distribution, migrational timing, and size of the various. species of juvenile salmon in the estuary. This paper presents data on juvenile coho salmon migrations collected/from 1966 through 1971.

SAMPLING GEAR, PROCEDURE, AND SITES

Beach seines were used to capture samples of juvenile coho salmon in the Columbia River. In general, the seine was 100 m long and ranged in depth from 3 m at each wing end to 4 m at the bag. Stretched mesh size ranged from 12 to 19 mm in the wings and was 6 mm in the bag. The standard method of seining was to leave one end anchored on shore and, using a motorized boat, tow the other end through a 180" sweep of the adjacent water. The net was retrieved at the end of the sweep, and enclosed fish were worked to the bag. A detailed description of. the net and technique used to make sets is given by Sims and Johnsen (1974).

Sampling sites for the study are shown in Figure 1. The locations varied during 1966 and 1967, but from 1968 through 1971, the primary site was at Jones Beach. Jones Beach is located on the Oregon shore of the Columbia River approximately 75 km upstream from the river mouth. The river is 1.6 km wide at this point, and a tidal fluctuation of up to 2 m occurs at the site. Jones Beach is 30 to 35 km above saline intrusion and is on the last constriction of the Columbia River before it broadens into the central estuary. Beach topography is gradually sloped with a hard sand bottom. It was possible to sample at this site every month through nearly all weather, flow, and tidal conditions.

Sites at nearby Puget Island and Cape Horn Beach on the Washington shore were sampled frequently during the first 3 years of the study (Table 1). Seining at those locations consistently resulted in a smaller catch

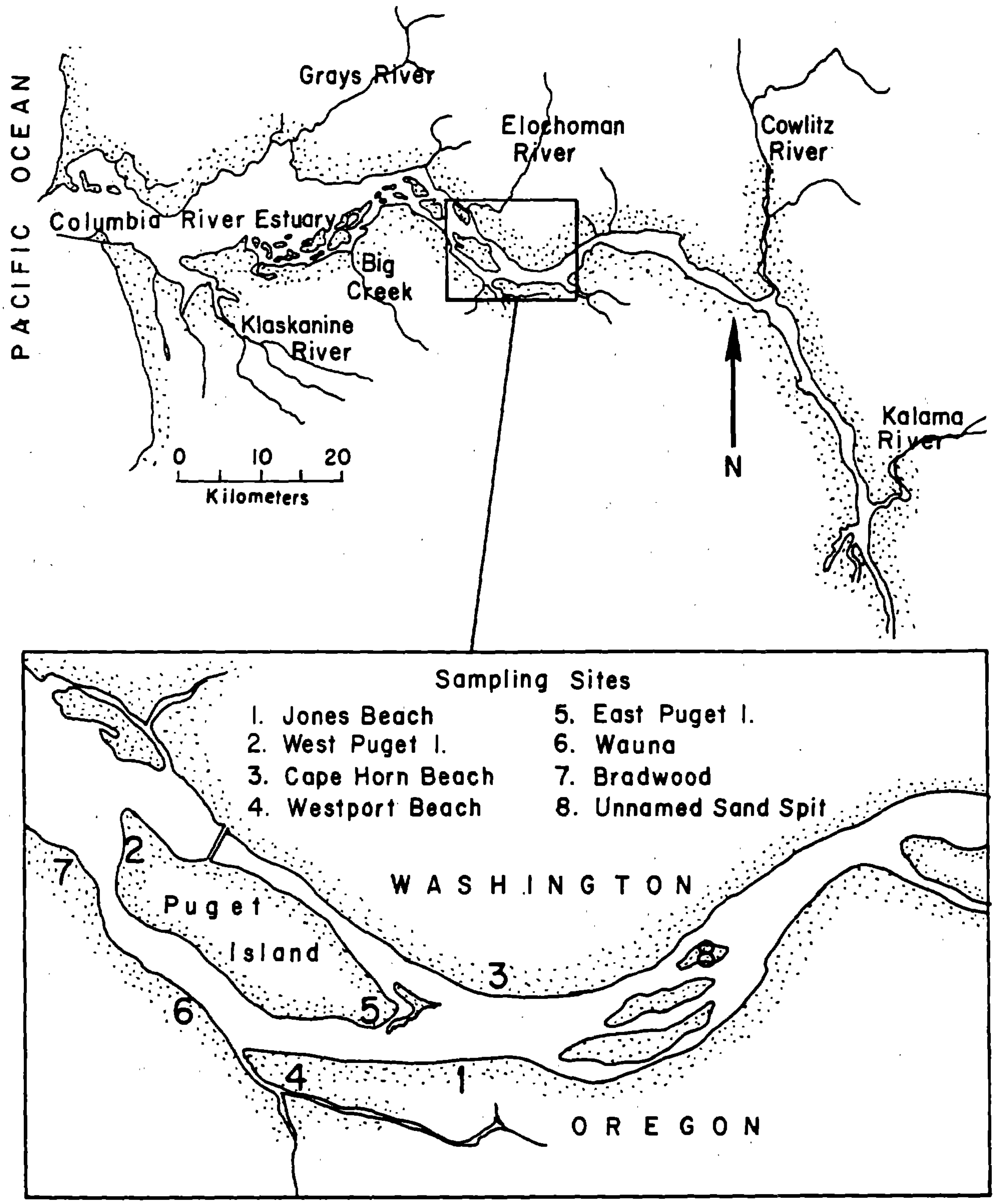

Figure 1.--Map of lower Columbia River with inset showing location of sampling sites used in the upper estuary between 1966 and 1971.

Table 1.--Sampling effort in the upper Columbia River estuary, April through June, 1966-71.

Year	Principal sampling sites	Secondary sampling sites	No. of work shifts	Daily sampling period (h)	Sampling days per week	Sets per day
1966	West. Puget Is.	Westport Beach Jones Beach Unnamed Sand Spit	2	0800-1600	5	3 to 10
1967	West. Puget Is. Jones, Beach	East Puget Is. Bradwood Beach Westport Beach Wuana Cape Horn Beach	2	0800-1600	5	3 to 10
1968	Jones Beach Cape Horn Beach	West. Puget Is. East. Puget Is.	2	(0800-1600 until mid-May) (0500-1100 after mid-May)	5 7	9 9
1969	Jones Beach	Cape Horn Beach	1	(0800-1600 until mid-May) (0500-1100 after mid-May)	5 7	12 12
1970	Jones Beach	Cape Horn Beach	2	0500-1200 1300-2000	7	24
1971	Jones Beach	None	1	0500-1200	5	12

per set than at Jones Beach. Size range, species composition, and other catch characteristics were similar at all sites.,

Until April 1968, the seine crew examined and recorded their catch. Beginning in May 1968, a separate crew was used to process fish and record data. In both situations, all juvenile salmon and trout were anesthetized with MS-222 (tricaine n-ethanesulfonate), identified, enumerated by species, and examined for marks; individuals from a subsample were measured for fork length. Fish were held until they appeared fully recovered from the anesthetic and then were returned to the river. Use of a separate processing crew resulted in a greater number of sets being made at a site and reduced the time that the fish were held under stress.

Juvenile coho salmon were also taken by purse seining in the navigation channel of the river adjacent to Jones Beach (Johnsen and Sims 1973). Purse seining effort was consistent for only 2 years in the area and for that reason little information from that effort is included in this report. Coho salmon data from purse seine catches were in agreement with those from the beach seine catches.

RESULTS

Annual and Monthly Catches

Juvenile coho salmon are abundant in the Columbia River estuary from mid-April to early June and are present in small numbers through the remainder of the year. Beach seining captured 110,421 juvenile coho salmon between 1966 and 1971. Monthly and annual catches are presented in Table 2. Our largest annual catch was in 1970 when 45,146 fish were caught, and the least was in 1967 when we took only 5,792 coho salmon. Sampling

Table Z.--Results of beach seine sampling for juvenile coho salmon in the Columbia River estuary, 1966.

	1966			1967			1968			1969			1970			1971		
Month	No. sets	No. coho	CPS[a]	No. sets	No. coho	CPS	No. sets	No. coho	CPS	No. sets	No. coho	CPS	No. sets	No. coho	CPS	No. sets	No. coho	CPS
Jan	--	--	--	--	--	--	4	0	0.0	19	0	0.0	--	--	--	--	--	--
Feb	--	--	--	50	1	0.0	12	1	0.1	31	3	0.1	--	--	--	--	--	--
Mar	66	0	0.0	92	14	0.2	69	78	1.1	60	3	0.1	--	--	--	--	--	--
Apr	217	3,547	16.3	104	271	2.6	227	1,831	8.1	165	4,831	29.3	386	9,826	25.5	80	3,017	37.7
May	320	3,851	12.0	104	5,283	50.8	372	6,172	16.6	320	18,973	59.3	673	34,771	51.7	168	10,484	62.4
Jun	398	86	0.2	405	185	0.5	525	255	0.5	637	1,114	1.7	674	510	0.8	240	118	0.5
Jul	83	7	0.1	315	37	0.1	589	68	0.1	697	79	0.1	597	29	0.0	187	55	0.3
Aug	--	--	--	17	1	0.1	214	1	0.0	406	4,745	11.6	178	10	0.1	--	--	--
Sep	--	--	--	--	--	--	--	--	--	163	67	0.4	--	--	--	--	--	--
Oct	--	--	--	--	--	--	--	--	--	78	27	0.3	--	--	--	--	--	--
Nov	11	3	0.3	--	--	--	48	25	0.5	33	0	0.0	--	--	--	--	--	--
Dec	9	38	4.2	--	--	--	34	4	0.1	12	0	0.0	--	--	--	--	--	--
Total	1,104	7,532	6.8[b]	1,087	5,792	5.3	2,094	8,435	4.0[b]	2,621	29,842	11.4[b]	2,508	45,146	18.0[b]	675	13,674	20.3[b]

a/ CPS = catch per set.

b/ Total catch/total number sets.

effort, in seine sets per month, provides a basis for annual comparison, but caution is advised in interpreting these results. Catch alone should not be construed as an annual index 'of abundance. Major considerations in this study are the variation in seine sites in 1966 and 1967 and the frequency of seine sets during the period of maximum availability. Monthly averages show that most coho salmon were caught in May followed by April and June in that order. The large monthly catch in August 1969 was a result of a large release of hatchery fish (subyearling coho salmon) in late July by the Washington Department of Fisheries into the Columbia River above our sampling site. With this exception, our catch records show consistently high capture relative to expended effort in the spring of each year, but relatively insignificant numbers during winter, summer, and fall.

Annual and Monthly Catches

The annual peak in the daily catch per set (CPS) of coho salmon (averages of all seine sets in that day) occurred within a 12-day period over the 6-year study (Fig. 2). Peak CPS occurred in the upper estuary of the Columbia River between 5 and 16 May of each year; 10 May most likely approximates the average, as all annual peaks occurred within 6 days before or after this date.

The date of peak migration may be determined on a basis other than CPS. Figure 3 shows daily total catches in percentages of the annual total catch. Less than 5% of the coho salmon reached our sampling sites before 17 April. Each year, the midpoint of the migration was reached between 2 and 13 May. The yearling smolt migration was 95% complete between 19 and 31 May. Thus, on the whole, both the daily percentage of the total catch and the average daily CPS indicated that the annual migration of coho

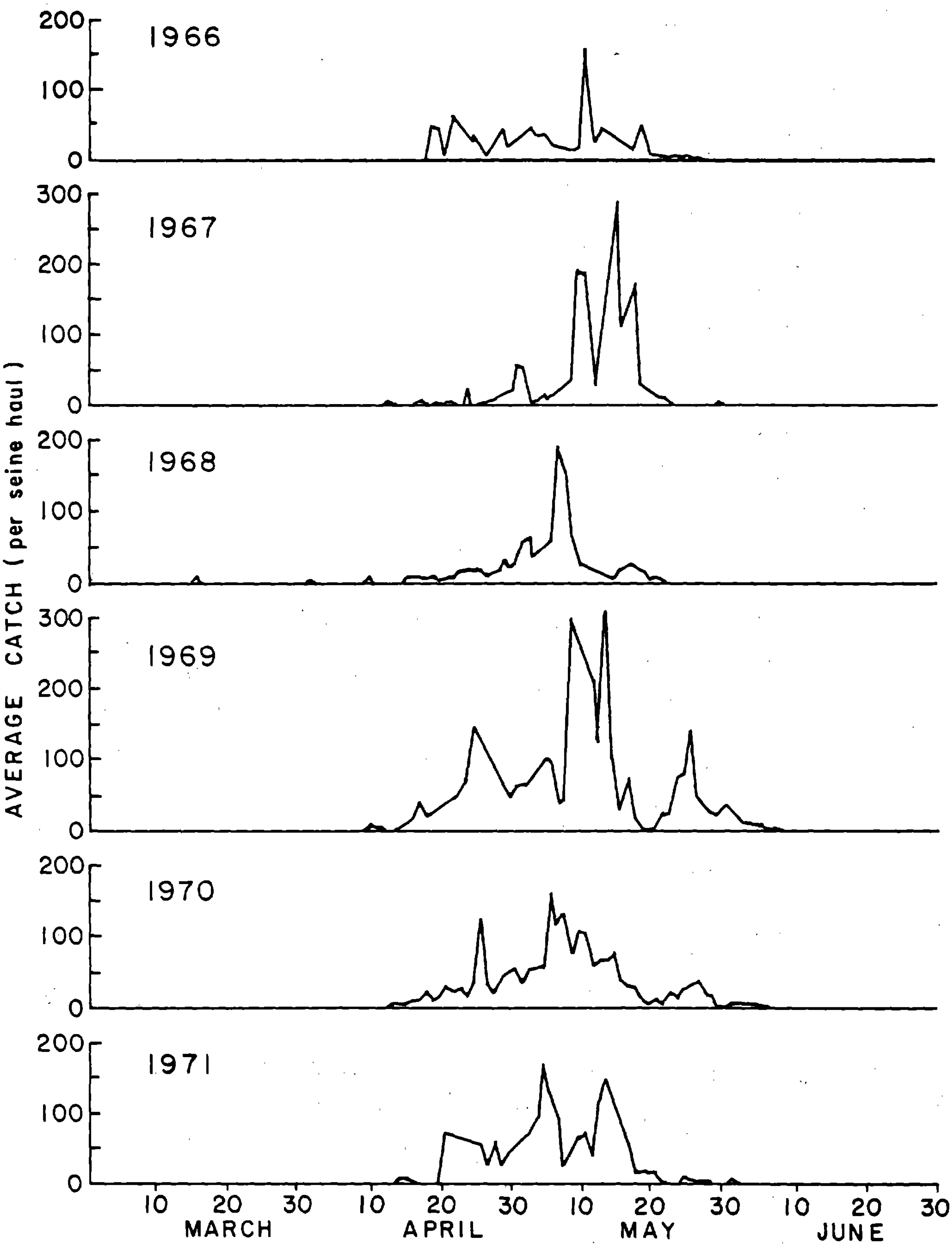

Figure 2. --Average daily beach seine catches of juvenile coho salmon at sites in the upper Columbia River estuary (1966-71).

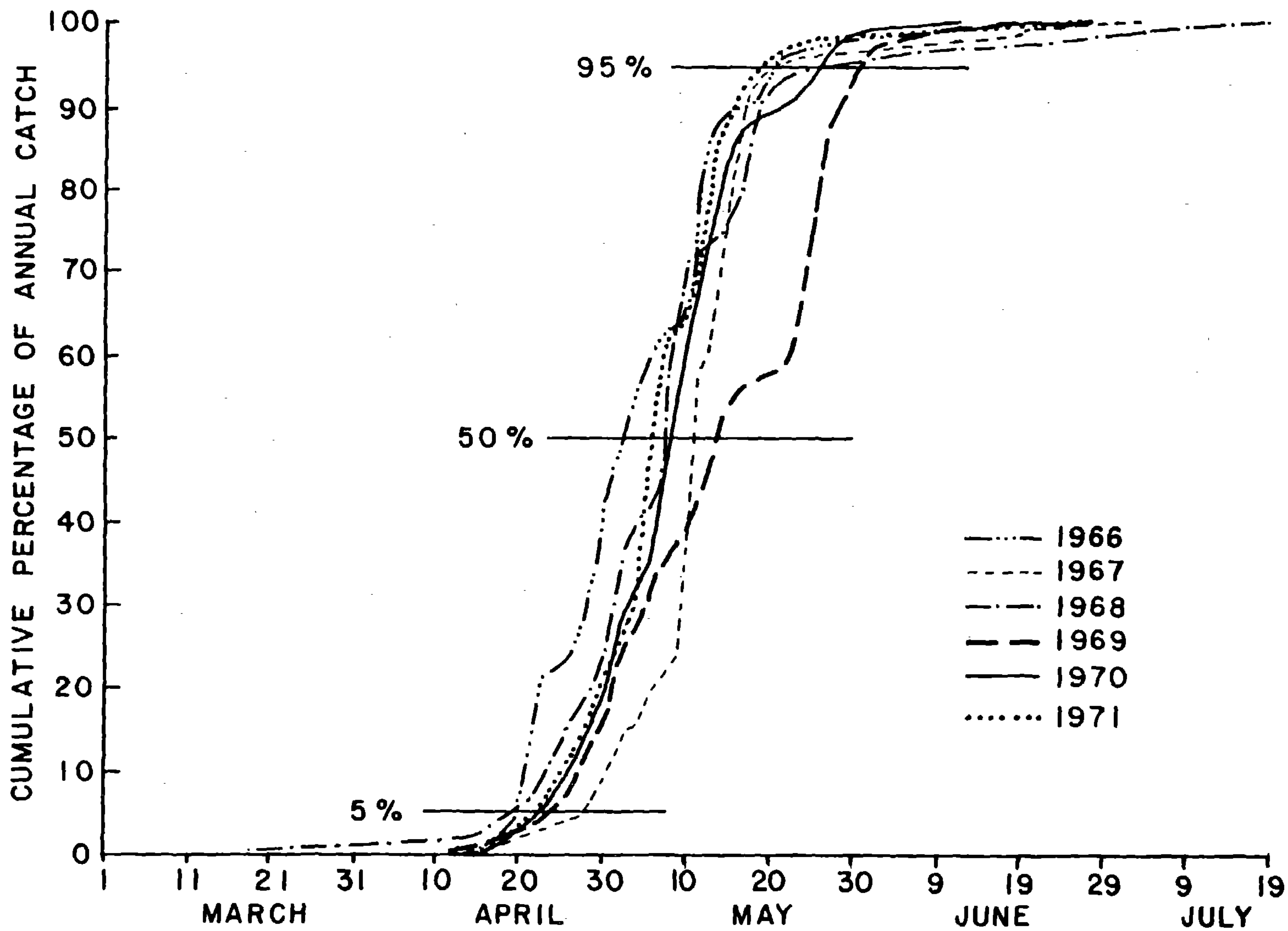

Figure 3.--Daily total seine catch of juvenile coho salmon in the upper Columbia River estuary (expressed in percentage of the annual catch), 1966-71.

salmon smolts in the Columbia River was compact, consistent, and comparable through the 6-year investigation.

The chronological similarity of annual peak catches in the upper estuary is particularly interesting since many widely separated hatcheries and tributaries contribute to the total migration. Fulton (1970) listed 39 Columbia River streams and 62 of their tributaries that now have or have had spawning runs of coho salmon. He also reported that 78 of these presently have spawning areas. More important numerically are coho salmon reared at as many as 19 different Columbia River hatcheries, though not all of these hatcheries produce coho salmon every year. Considering the number of diverse systems contributing to the migration and the differences in river discharge between years, it is remarkable that coho salmon smolt migrations into the estuary were so consistent in their timing.

The timing of migrations of juvenile coho salmon coincides with movement reported in other widely separate geographic areas. Shapovalov and Taft (1954) presented tables showing that the peak migration of juvenile coho salmon occurred from 6 to 12 May during a 9-Year study of Waddell Creek, California. Chamberlain (1907) reported a heavy migration of yearling coho salmon into seawater in May of 1903 and 1904 in southeastern Alaska. Peck (1970) found that most coho salmon smelts left a Lake Superior tributary within a week of planting on 16 and 17 May. Salo (1955) reported the peak seaward migration of juvenile coho salmon in Minter Creek, a tributary of Puget Sound in Washington, occurred in early May.

Hartman et al. (1967) compared timing of sockeye salmon, 0. *nerka,* smolts with the latitude of their nursery areas and determined photoperiodism to be an overriding stimulus for downstream migration. Such a relation for coho salmon smolts is not apparent because their migration seems to occur at a similar time irrespective of latitude.

Water temperature may be a factor that influences the timing and movement rate of coho salmon smolts (Fig. 4). During the study, water temperatures would generally rise from approximately 10° C in early. April to 16°-18° C in late June. Temperatures at peak migrations ranged from 11.3° C (1970) to 14.7°C (1967). Water temperatures in 1969 generally lagged behind those in other study years; coincidently, progression of the smolt migration in that year was somewhat later, on the whole, than in other years of this study (Fig. 3). The relation of temperature to timing of migration, however, is not precise and can only be inferred.

No consistent relation was found between flow volume of the Columbia River and timing of juvenile coho salmon (Fig. 4). In 1966, 1969, and 1971, the period of peak arrival of coho salmon generally corresponded with increasing river flows. In 1967, 1968, and 1970, however, increased river flows began after the migratory peak had passed. Recovery of marked coho salmon released from Cowlitz Hatchery in 1969, 1970, and 1971 indicated variation in rate of movement of only 2 km per day for seven separate groups of coho salmon. It appears, therefore, that since the timing of coho salmon migration was generally consistent over the study period and the volume of river flow was substantially different during the 6-year investigative period, timing of the migration is not dependent upon volume of river flow.

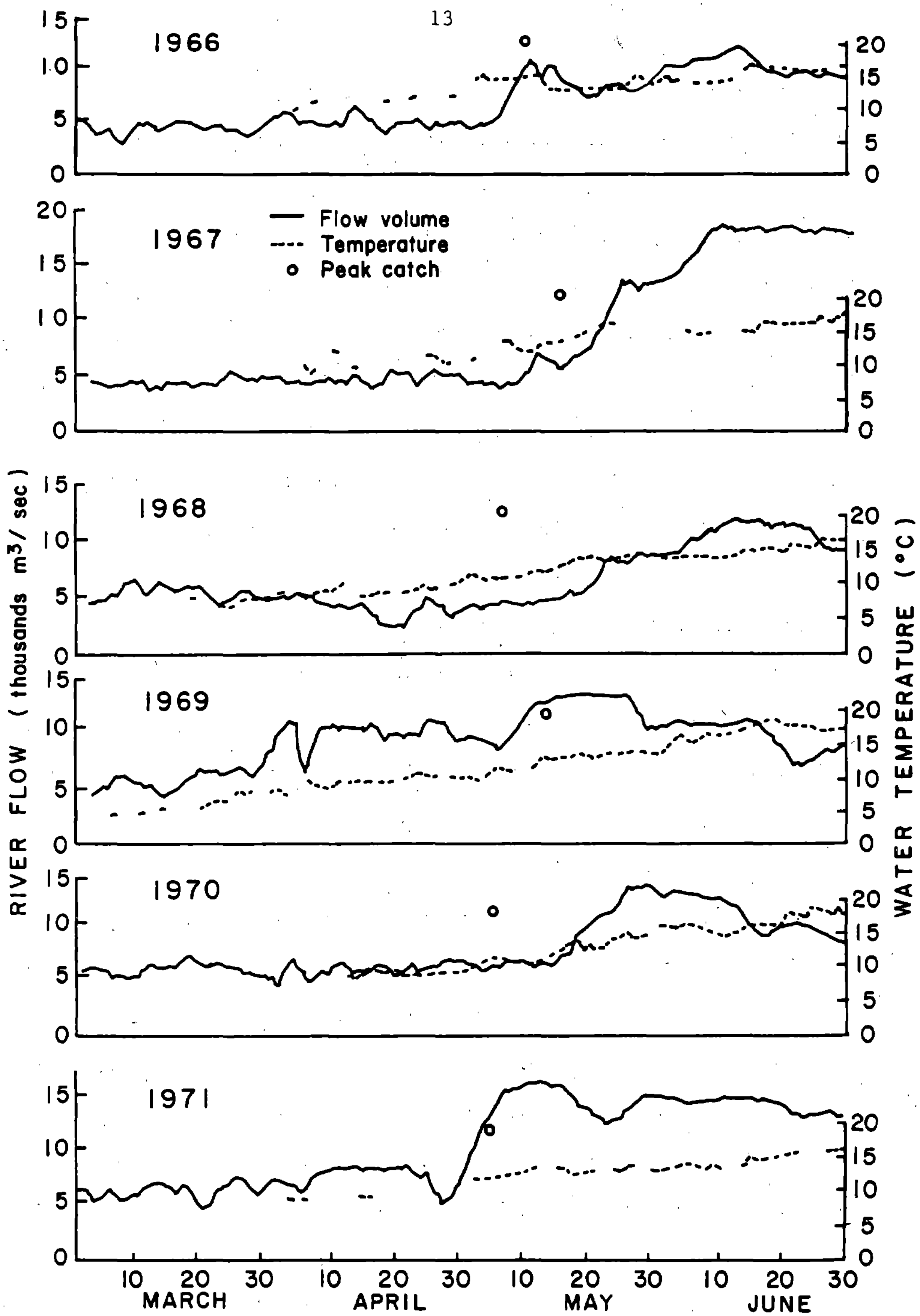

Figure 4.--Columbia River flows (U.S. Geological Survey, 1965-71), water temperatures, and dates of peak catch for the spring migration of juvenile coho salmon at Jones Beach, 1966-71.

The possibility that the, time of release of coho salmon from the various hatcheries influenced the time of peak migration into the estuary also was examined. Timing of releases from the 19 coho salmon hatcheries varied considerably within and between years. Major releases ranged from January to May. March was the principal month for juvenile releases in 1966 and 1967, whereas the major releases from 1968 to 1971 were in April. Based on recoveries at Jones Beach, early release of coho salmon from the hatcheries failed to result in a correspondingly early seaward migration. For this reason, the March to May release time suggested by Wallis (1968) for hatchery coho salmon might be modified to a mid-April to May schedule if direct seaward migration is desired.

Zaugg (1970) discussed the migratory timing of juvenile coho salmon in several Pacific Northwest streams and found a corresponding seasonal change in gill Na^+-K^+ ATPase. He interpreted increases of Na^+-K^+ ATPase (in late March) as an indication of biological readiness for seawater and decreases (July) as indicative of a loss of urge to move seaward. The timing data from our catches of yearling coho salmon entering the Columbia River estuary are generally in agreement with this observation. However, subyearling coho salmon reared in a hatchery and released in late July also moved toward the estuary in large numbers. On 28 July 1969, the Washington Department of Fisheries released 742,218 subyearling coho salmon at Rainier, Oregon, 28 km above Jones Beach. We captured 4,817 of these fish in the following few weeks.. The fish averaged 80 mm in length (range: 50 to 100 mm). These fish were identifiable as juveniles by their small size and dates of recovery, however, since these fish were not marked and were released directly into the Columbia River, evaluation of their adult contribution to the fisheries was not possible.

Since many hatchery releases of yearling coho salmon made before mid-April apparently did not move directly and rapidly to the estuary, their behavior during the interim period is of interest. Chapman (1962) found that aggressive behavior caused some wild coho salon (i.e., nonhatchery fish) in small streams to migrate downstream early. Chapman (1965) also noted that relatively large freshets in small streams caused downstream movement of wild coho salmon. Continuance of such movement to the estuary was not indicated at Jones Beach. We did learn that some hatchery reared coho salmon released before May in tributary streams downstream from Jones Beach moved upstream. Recovery of these marked fish at Jones Beach is shown in Table 3. Unfortunately, there were no distinctively marked fish released after 1 May below Jones Beach. Jones Beach is from 10 to 80 km upstream from the indicated release sites of hatcheries. No marked coho salmon were released below our sampling sites in 1966, but from 1967 through 1970 marked fish were released in the lower area, and upstream movement was indicated each year. Although coho salon were released in the lower estuary in 1971, no assessment was made since the only marked release made below our site also coincided with similarly marked coho salmon released upstream.

Rates of Movement

Many groups of juvenile coho salmon were marked and released at various state and federal hatcheries during this study. Average rates of movement to the estuary based on distance traveled and time of release have been determined from the analysis of recovery data at the Jones Beach sampling site (Table 4). Releases of identifiable fish ranged from about 63,000 to 742,000 fish. The largest release was the group of unmarked

Table 3.--Releases and recoveries of marked yearling coho salmon moving upstream to Jones Beach.

Hatchery and release point[a]	Km from Jones Beach (approx.)	Release date	No. marked fish Released	No. marked fish Recovered	Type of finclip mark[b]
Grays River-WDF	75	23 April 1967	35,068	1	D-LV
Grays River-WDF	75	23 April 1967	36,344	1	D-RV
Elochoman-WDF	75	23 April 1967	107,227	18	AD-RM
Grays River-WDF	20	1 January 1967	118,365		
Big Creek-ODFW	35	27 February 1968	123,343	69	
Clatskanine-ODFW	80	7 March 1968	113,316	69	AD-RM
Grays River-WDF	75	15 April 1968	63,150	69	
Elochoman-WDF	20	16 April 1968	88,515	69	
Cathlamet-Trans. from Cowlitz-WDF	10	14 April 1969	314,639	9	AD-LP
Big Creek-ODFW	35	15 April 1969	80,957	121	AD and wire tag
Big Creek-ODFW	35	15 March 1970	73,920	123	AD
Grays River-WDF	75	2 April 1970	232,081	123	
Youngs Bay-Trans. from Little White Salmon-FWS	60	23, 29 April 1970	100,662	13	LV

a/ WDF designates Washington Department of Fisheries, ODFW the Oregon Department of Fish and Wildlife, and FWS the U.S. Fish and Wildlife Service.

b/ AD designates that the adipose fin was removed, D the dorsal fin; RM the right maxillary bone, LP left pectoral fin, LV left ventral fin, RV the right ventral fin.

Table 4.--Rate of movement (from area of release to the Jones Beach sampling site) for various releases of marked hatchery-reared juvenile coho salmon, 1967-71.

Origin of stock	Agency a/	Km. to Jones Beach	Mark	Release date	No. released	No. recovered	Rate of recovery Per 10,000	Average no. days to Jones Beach	Movement rate km/ day
Leavenworth	FWS	730	D-AD	3/1/67	200,000	5	0.25	81	9.0
Ringold Ponds	WDF	490	LV-LM	3/24-27/70	80,215	6	0.75	22	20.0
Ice Harbor	NMFS	461	BRAND	3/24-5/15/67	643,123	90	1.40	26	17.7
Ice Harbor	NMFS	461	BRAND	3/28-5/1/68	505,840	152	3.00	29	15.7
Little White	FWS	190	RV	5/12/70	100,367	112	11.16	12	15.8
Cascade	ODFW	166	1/2 D-LP	4/5/71	88,000	41	4.66	36	4.6
Cascade	ODFW	166	1/2 D-P	4/5/71	81,000	36	4.44	34	4.7
Leavenworth (Trans. to Bonn. Dam)	FWS	162	D-AD-LM	3/10/68	97,000	41	4.23	53	3.1
Cascade (Trans. To Tanner Cr.)	ODFW	162	RV-RM	3/29/71	100,000	28	2.80	37	4.4
Eagle Creek	FWS	140	AN	4/1/68	87,000	39	4.48	46	3.0
Sandy River	ODFW	138	D-LM	2/20-24/67	171,435	19	1.11	40	3.5
Ringold Ponds (Trans. to Washougal)	WDF	132	LV-RM	4/14/70	63,293	93	14.69	5	26.4
Washougal	WDF	132	RV	4/9/71	87,876	65	7.40	26	5.1
Washougal	WDF	132	LV	4/9/71	87,824	47	5.35	26	5.1
Cowlitz	WDF	110	AD-RV	4/14/69	335,681	308	9.18	32	3.5
Cowlitz	WDF	110	AD-LV	4/15/69	348,754	422	12.10	22	5.0
Cowlitz	WDF	110	AD-LV	4/6/70	285,000	428	15.02	27	4.0
Cowlitz	WDF	110	AD-RV	4/6/70	326,000	527	16.17	31	3.5
Cowlitz	WDF	110	AD-RP	4/1/71	303,365	63	2.08	37	3.0
Cowlitz	WDF	110	AD-LP	4/1/71	266,695	117	4.39	34	3.2
Cowlitz	WDF	110	D	4/1/71	302,695	89	2.94	37	3.0
Kalama (Trans. to Rainier, OR)	WDF	36	b/	7/28/69	742,218	4,817	64.90	7	5.1
Abernathy	FWS	28	AD	5/28/69	78,000	1,540	197.44	3	9.3

a/ FWS designates the U.S. Fish and Wildlife Service, WDF the Washington Department of Fisheries, NMFS the National Marine Fisheries Service, and ODFW the Oregon Department of Fish and Wildlife.

b/ Not marked but readily identifiable because of small size (O-age). All other releases were yearling fish.

subyearling coho salmon from Lower Kalama Hatchery of the Washington Department of Fisheries. Their distinctive small size and time of release in late July 1969 made it possible to readily identify these fish upon recovery. Recoveries of groups of marked fish ranged from 5 to 4,817 individuals. Average travel time to Jones Beach among the 24 specific groups ranged from 3 to 81 days. Average rate of travel ranged from 3 to 26 km per day. Rate of movement was associated with distance traveled. Generally, we found that coho salmon released above Bonneville Dam moved more: rapidly than those released at sites below the dam. In an unusual example of travel rate over an extended distance, Witty (1966) found juvenile coho salmon moved from the Wallowa River to Bonneville Dam (about 700 km) at an average rate of 71.3 km per day.

Time of release was another factor influencing the movement rate. Releases of a single stock of marked juvenile coho salmon made in the spring over a 2-month period at Ice Harbor Dam in 1967 and 1968 provided examples of changing rates of movement in relation to time of release. Subsequent recovery of these fish at Jones Beach enabled determinations of travel time. Scientists studying the effects of turbines on salmon smolts released 643,123 marked juvenile coho salmon during an 8-week period in 1967. These coho salmon were released at various times (Table 5) at four sites near Ice Harbor Dam, 461 km above Jones Beach. Recoveries of marked fish indicated that the average number of days required to reach Jones Beach decreased by 30 days from late March to mid-May, resulting in an increase in rate of movement from 11.5 km/day to 46.1 km/day (Krcma et al.1/). Therefore, the average coho salmon released in late March at Ice

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1/ Krcma, R. F., C. W. Long, and W. M. Marquette, Fishery Biologists, Northwest and Alaska Fisheries Center, Coastal Zone and Estuarine Studies Division, NMFS, NOAA, Seattle, WA 98112, pers. commun. and unpubl. data.

Table 5.--Rate of movement and recovery of marked coho salmon fingerlings released at Ice Harbor Dam between 24 March and 15 May 1967 and subsequently recovered at Jones Beach.

Release period	Number of coho released	Number recovered at Jones Beach	Recovery rate per 10,000 released	Range of days recovered	Days to Jones Beach: Average	Days to Jones Beach: Standard deviation	Average km/day
24-27 March	37,790	5	1.3	31-54	40.2	8.4	11.5
30 March-3 April	87,770	15	1.7	32-53	38.9	7.2	11.8
6-10 April	97,051	21	2.2	20-46	32.3	7.5	14.9
14-17 April	87,295	10	1.1	23-40	31.2	5.6	14.9
21-24 April	91,304	12	1.3	17-41	23.4	6.9	20.0
28 April-1 May	89,895	5	0.6	16-25	19.0	3.5	24.3
5-8 May	84,574	7	0.8	12-17	13.9	1.9	32.9
12-15 May	67,444	15	2.2	3-13	9.7	2.7	46.1
Totals	643,123	90					
Grand avg.			1.4		26.1		17.7

Harbor Dam would have arrived at Jones Beach in early May; coho salmon released in mid-April would have arrived in mid-May; and those released in mid-May would have arrived in late May. The range of the recovery period was broad for early release groups and narrow for late releases.

An additional 505,840 marked coho salmon were released at Ice Harbor Dam in 1968 (Table 6). Though fewer fish were released, our beach seine effort doubled and, as a result, more marked fish were recovered than in 1967. The release schedule in 1968 began slightly later, was interrupted for 13 days in mid-April, and was completed 2 weeks earlier than in 1967. The average late March releases appeared at Jones Beach in early May, whereas releases in late April and early May arrived in late May. The range of travel time for each group was again broad for early releases and narrow for late releases. Once again, the rate of movement to the estuary increased as the migratory season progressed, but in 1968, the change was more abrupt between early and late April. The overall average rate of movement decreased slightly in 1968 (15.7 km/day) compared with 1967 (17.7 km/day). Completion of John Day Dam in spring 1968 impounded over 100 km of free-flowing river and no doubt accounted, in part, for the slower movement of the migration in 1968. Raymond (1968) indicated that rate of movement of yearling chinook salmon, 0. *tshawytscha*, through McNary Reservoir was about one-third the rate of movement in free-flowing reaches of the river.

Movement of the 1967 and 1968 releases at Ice Harbor Dam is compared in Figure 5. Plotting the time of release against the average number of days to reach Jones Beach for each of the groups of coho salmon indicates a

Table 6.--Rate of movement and recovery of marked coho salmon fingerlings released at Ice Harbor Dam between 28 March and 1 May 1968 and subsequently recovered at Jones Reach.

Release date	Number of coho released	Number recovered at Jones Beach	Recovery rate per 10,000 released	Range of days recovered	Days to Jones Beach		Average km/day
					Average	Standard deviation	
28 March	41,987	13	3.1	13 to 59	36.2	13.5	12.8
1 April	34,744	8	2.3	32 to 53	39.9	7.9	11.2
2 April	34,776	5	1.4	21 to 48	35.6	10.5	13.2
3 April	34,786	4	1.1	30 to 51	39.0	9.2	11.8
4 April	34,744	11	3.2	27 to 48	36.7	8.5	12.8
5 April	34,779	7	2.0	31 to 45	35.9	5.5	12.8
9 April	34,789	5	1.4	36 to 45	39.2	3.8	12.5
10 April	33,966	5	1.5	34 to 44	40.8	4.2	11.8
23 April	62,587	16	2.6	22 to 35	28.9	3.8	15.9
25 April	35,971	17	4.7	19 to 33	26.0	3.9	17.7
26 April	35,935	20.	5.6	18 to 32	24.0	3.6	19.2
20 April	32,344	11	3.4	21 to 25	22.7	1.6	20.0
30 April	11,982	2	1.7	23 to 24	23.5	0.7	20.0
1 May	42,450	28	6.6	19 to 28	21.9	1.9	21.0
Totals	505,840.	152.					
Grand avg.			3.0		29.4		15.7

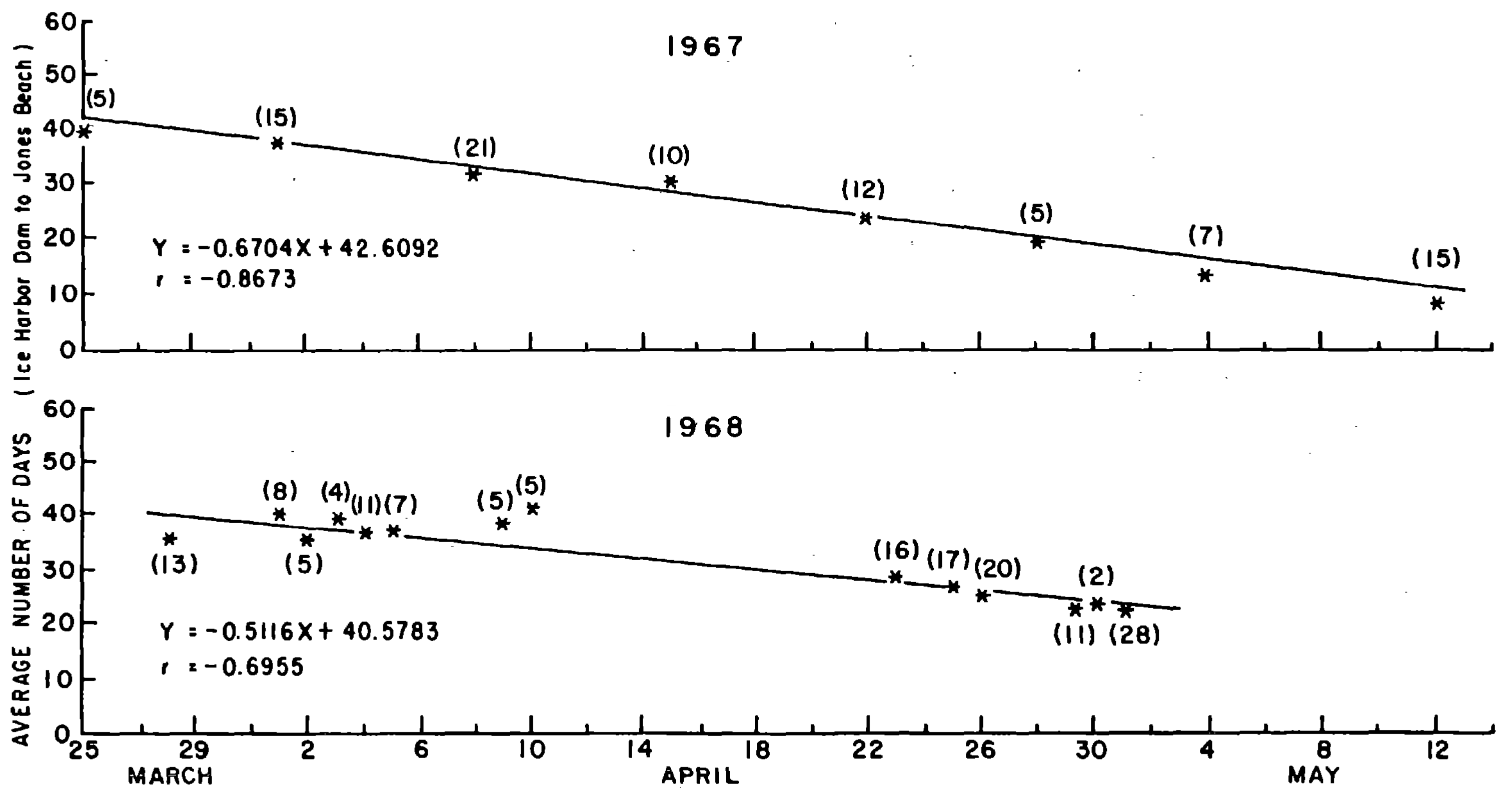

Figure 5.--Relation between rate of migration (i.e., the average number of days from time of release at Ice Harbor Dam to time of recovery at Jones Beach) of juvenile coho salmon and the date of their release at Ice Harbor Dam, 1967-68. The number of coho. salmon recovered from each release group is shown in parentheses; their average travel time is marked with an asterisk.

close agreement between the 2 years of travel times that apparently are a function of time of release.

Variation in Hourly Seine Catches

It was apparent from the sampling at Jones Beach that coho salmon smolts were present in greater numbers during midday than dawn or dusk--there was no sampling at night. In 1970, it was possible to assess hourly variations in the catch from 0600 to 1930 h each day throughout the coho salmon migration. The coho salmon were separated from other salmon, and the total averaged for each 30-minute seine haul during the principal 3 weeks (26 April-16 May) of the outmigration (Fig. 6). During these 21 sampling days, 34,537 coho salmon were captured, which was 76.5% of the 1970 total catch of that species. Coho salmon were the dominant species of salmon taken in the 3-week period, comprising 65.2% of all salmon captured. Inspection of Figure 6 indicates that coho salmon smolts were captured most frequently between 0830 and 1430 h, and the largest catches occurred at midday. Samples of coho salmon were marked and released in the area, and with negligible recoveries. We assume, therefore, that coho salmon smolts are not milling in the area but are migrating seaward actively during midday.

Fish Length in Relation to Seaward Migration

Fork length samples of coho salmon were taken daily and averaged for each year from 1966 through 1971 (Fig. 7). The trend of increasing smolt size is very likely a reflection of the changing rearing techniques at state and federal hatcheries.

Differences in the average length of early and late migrating coho salmon smolts were also apparent. Larger fish (>125 mm) consistently

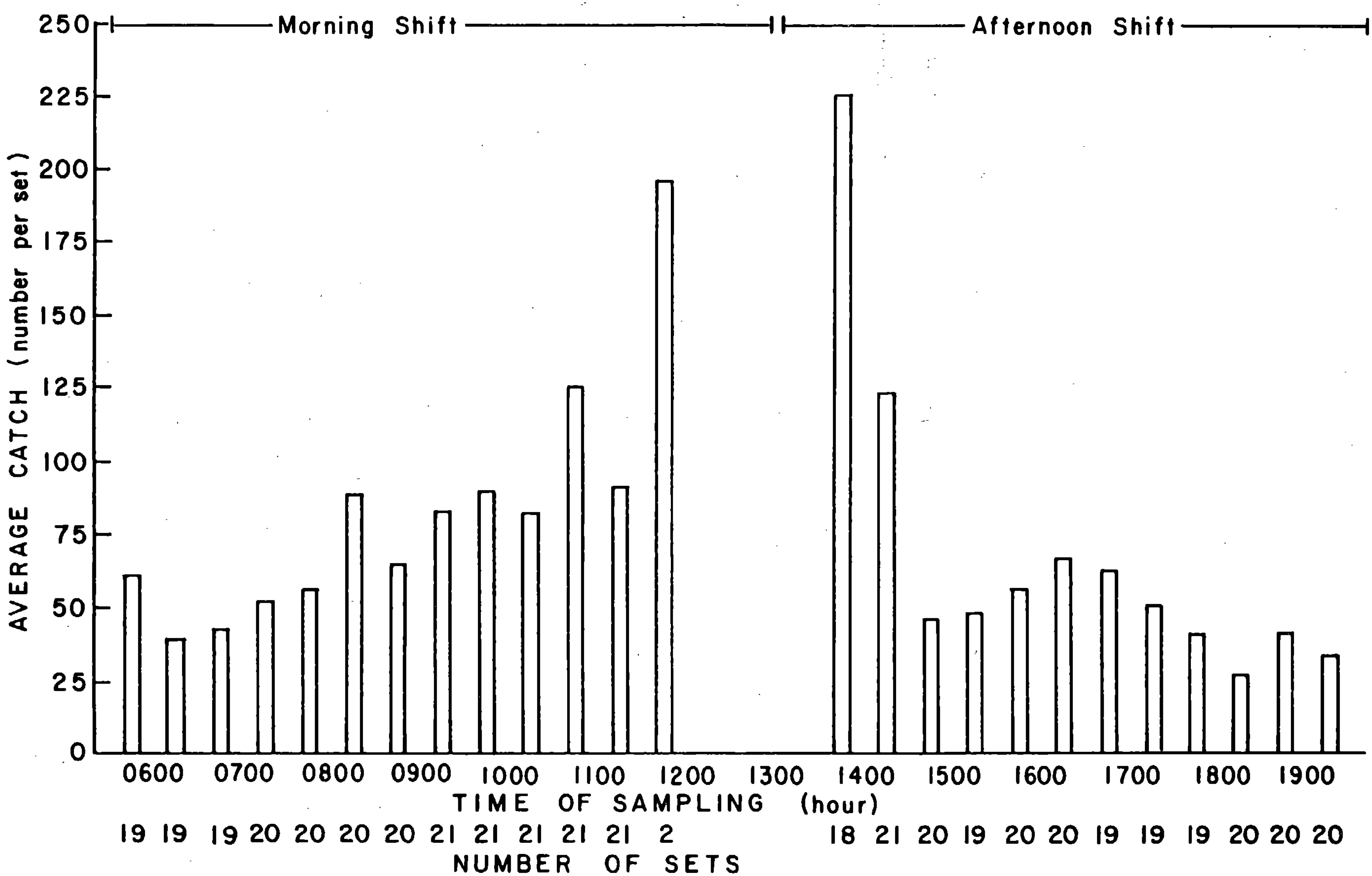

Figure 6.--Average seine catches of juvenile coho salmon per half hour for the 3-week period of maximum availability between 26 April and 16 May 1970.

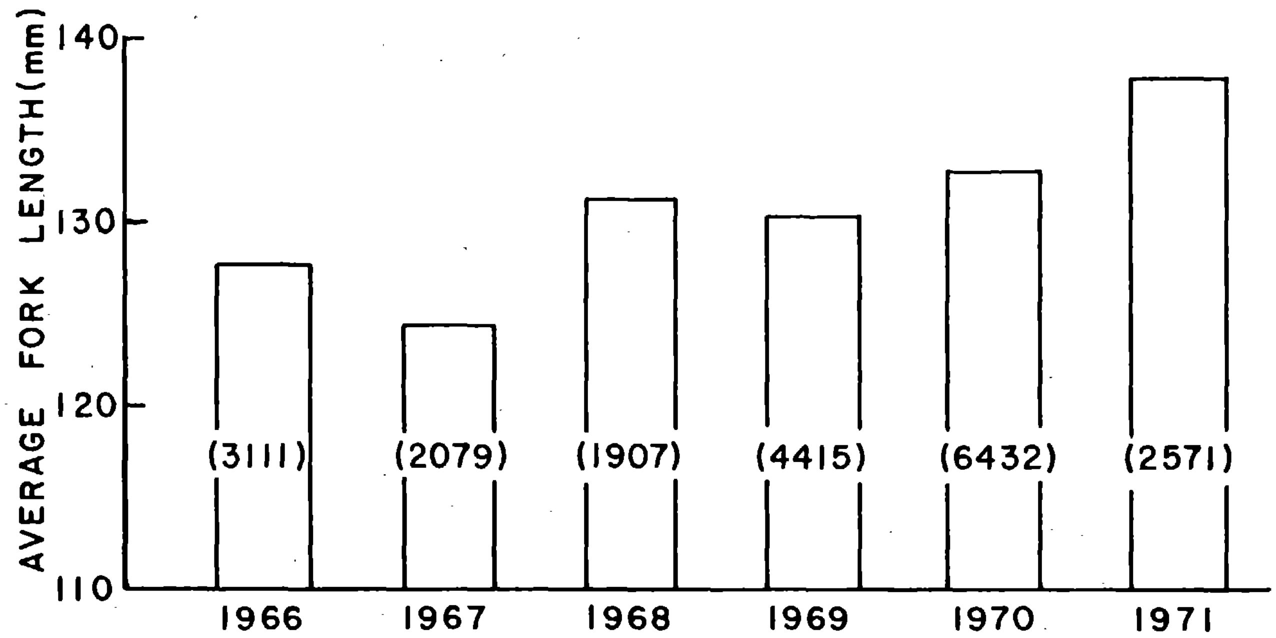

Figure 7.--Average fork lengths of juvenile coho salmon at time of migration through the upper Columbia River estuary, 1966-71 (sample size in parentheses).

migrated earlier than the smaller migrants (Fig. 8). Shapovalov and Taft (1954), in a 9-year study of Waddell Creek, California, reported a similar gradual decrease in the average size of coho salmon migrants as the season progressed. Salo and Bayliff (1958), in a coho salmon life history study on Minter Creek, Washington, also found large individuals migrating earlier than small fish. Apparently this characteristic is not confined to one species since Shapovalov and Taft noted a similar phenomenon for juvenile steelhead trout of a given age class, and Hartman et al. (1967) reported that they and other investigators observed a tendency for larger juvenile sockeye salmon to migrate earlier in the season than smaller sockeye salmon.

The trend toward releasing larger coho salmon in recent years has resulted in earlier timing of the peak migrations as well (Fig. 8). For example, fish migrating in 1971 (mean annual fork length, 138 mm) peaked on 5 May, 10 days earlier than those migrating in 1967 (122 mm). Similar relations were also evident in the other years as shown in Figure 9. The strong relation (correlation coefficient, r = 0.85) suggests that the mean annual fork length of coho salmon is a factor in the time that they migrate seaward.

SUMMARY

The annual seward migration of coho salmon smelts was sampled intensively in the upper Columbia River estuary between April and June (and periodically in other months) over a 6-year period from 1966 to 1971. Approximately 110,000 juvenile coho salmon were taken during this period to obtain information on the dates and rates of migration and the size of the

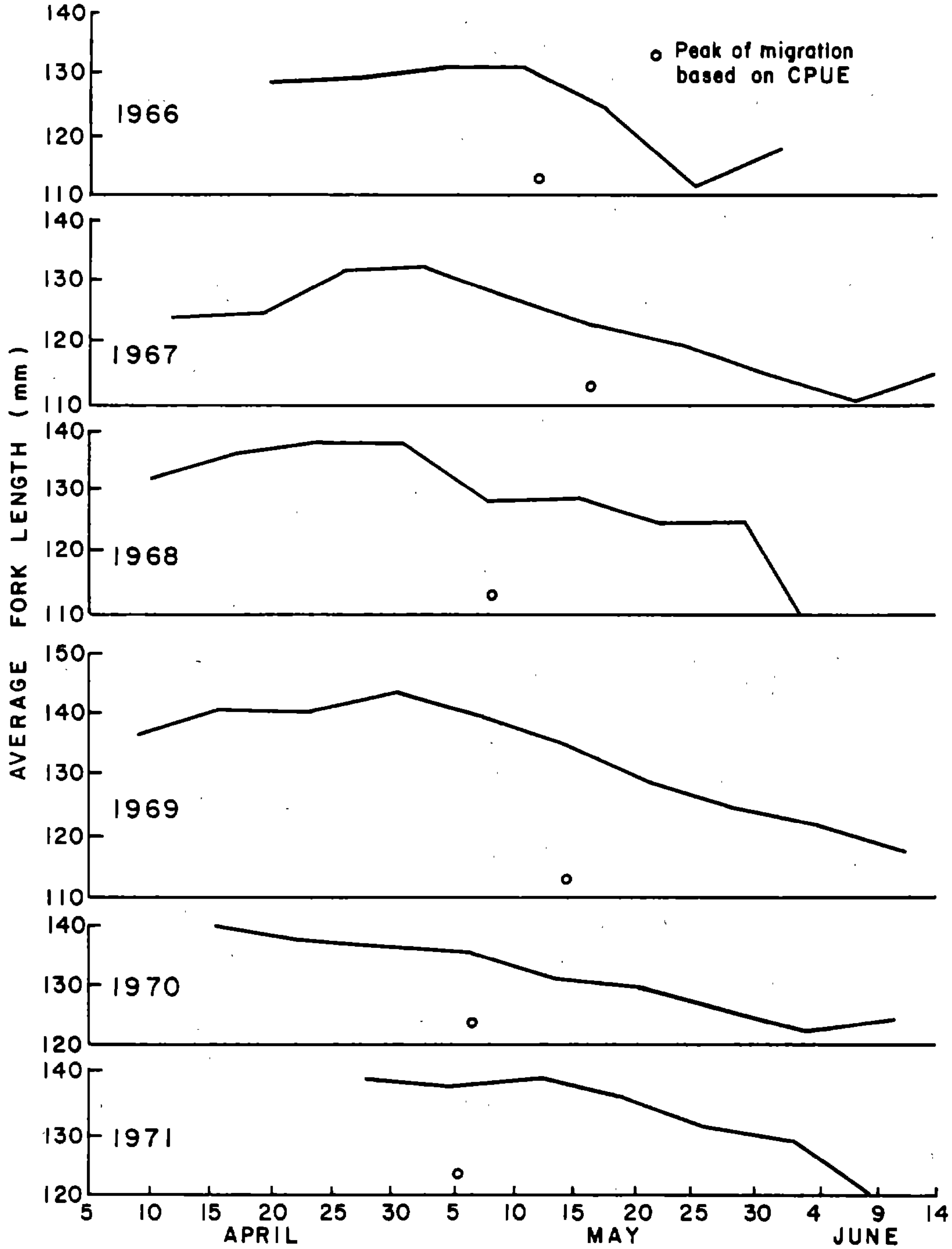

Figure 8.--Average fork lengths of juvenile cohb salmon captured in the upper Columbia River estuary for each weekly period of the annual smolt migration, 1966-71.

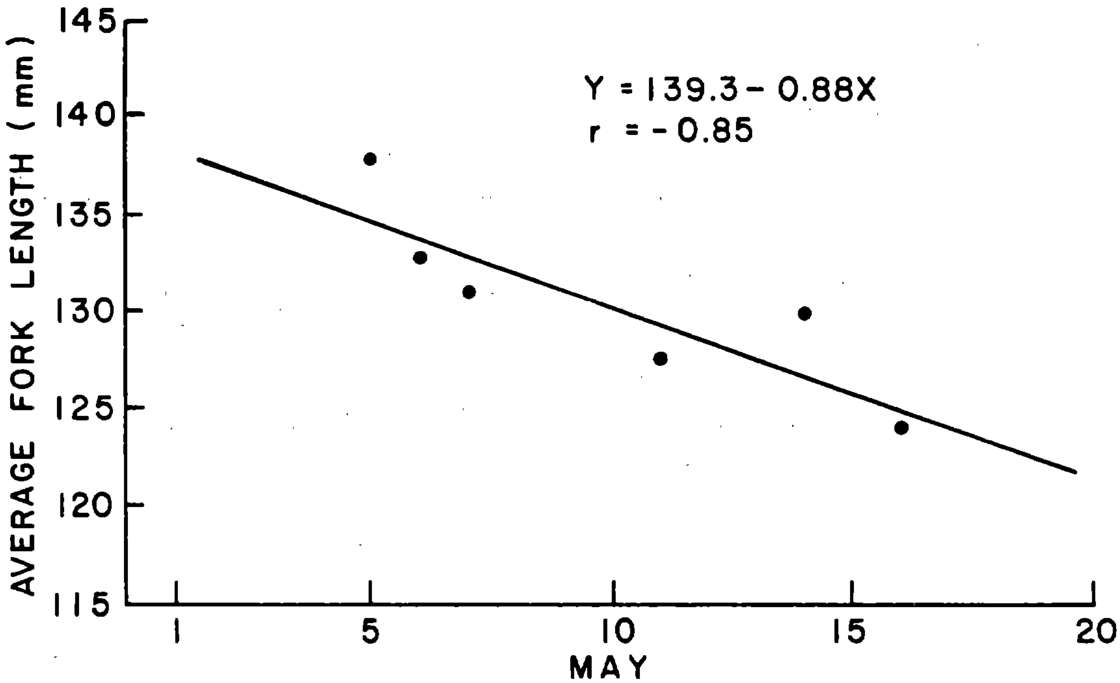

Figure 9.--Relation between annual average fork length of coho salmon smolts and date of annual peak catches at Jones Beach (1966-71).

fish. Primary sampling equipment was a 100-m long beach seine. Sampling sets per day ranged from 3 to 24. The primary sampling site was at Jones Beach on the Oregon shore, but other nearby beaches on the islands and the Washington shore were also seined.

The seaward migration of yearling coho salmon is made up of fish from as many as 19 hatcheries and 39 tributary streams of the Columbia River. Nearly all of the fish migrated into the upper estuary between mid-April and late May. Peak catches in all years of the study were, from 5 to 16 May.

Recoveries of marked yearlings from releases in 1967 through 1971 indicate a relation between the rate of seaward movement and the time of release and the distance migrated to the estuary. Generally, coho salmon released in upper reaches of the Columbia River system moved downstream more rapidly than those released near our sampling site. Also, fingerlings released before mid-April moved at a slower rate than those released in late April or May.

Some marked coho salmon released from hatcheries downstream from our sampling site and others transported and released in the lower estuary moved upstream and were captured at Jones Beach in 1967-70.

Plotting catches of coho salmon taken at Jones Beach in 1970 (0600 to 2000 h) showed that maximum abundance occurred around midday.

Average annual fork length of coho salmon smelts entering the upper estuary increased about 10% during this study. This increase in size is probably due to improvements in rearing techniques and diet at Columbia River hatcheries.

During migration, larger coho salmon smolts (> 125 mm fork length) were the first to arrive in the upper estuary and were followed by smaller individuals. (< 125 mm). This trend occurred each year of the study and appears to be characteristic of the coho salmon migration.

Timing of the annual peak of migration of coho salmon varied in association with annual mean fork length; overall average size for the migrating population increased through the 6 years of study, and the peak of migration came progressively earlier.

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