

# FRED Reports

PROJECT REPORT  
Halibut Cove Lagoon Chinook Salmon,  
*Oncorhynchus tshawytscha*,  
Enhancement Project, 1973-1984

by Nick Dudiak,  
Mark Dickson, and William J. Hauser

Number 78



**Alaska Department of Fish & Game**  
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## ABSTRACT

Between 1977 and 1984, the Halibut Cove Lagoon chinook salmon, *Oncorhynchus tshawytscha*, enhancement project has provided an estimated 11,280 adult chinook salmon for harvest. Between 1982 and 1984, an estimated 2,500 fish have been harvested annually. The average survival rate for all smolts stocked into Halibut Cove Lagoon is 2.3%, but it has ranged from 0.3% to 5.7%. The average survival rate of "healthy" smolts is 3.4%. Good survival of chinook salmon smolts can be expected if healthy smolts weighing at least 17.0 g are released between 1 and 15 June. The average age-class composition and size of chinook salmon harvested from Halibut Cove Lagoon are similar to those harvested from Crooked Creek, the donor stock.

KEY WORDS: chinook salmon, *Oncorhynchus tshawytscha*, smolts, survival rate, southcentral Alaska.

## INTRODUCTION

The Halibut Cove Lagoon Saltwater Rearing Facility was established in 1973 by the Alaska Department of Fish and Game (ADF&G), Fisheries Rehabilitation, Enhancement, and Development (FRED) Division to provide additional sport fishing opportunities for the people of the Kachemak Bay area. During the early years of development, all five species of Pacific salmon were experimentally reared there; some, for as long as 12 months.

Since 1979, however, the lagoon has served only as a chinook salmon, *Oncorhynchus tshawytscha*, smolt imprinting and release site. The objective of these releases was to provide chinook salmon for harvest by anglers in the Kachemak Bay area.

## Study Area

Halibut Cove Lagoon is located on the southern shoreline of Kachemak Bay, approximately 19 km southeast of the Homer Spit (Figure 1). The saltwater rearing facility was located on the south edge of the lagoon, adjacent to a small freshwater stream (Figure 2):

The lagoon encompasses 228 ha and has a maximal depth of over 91 m. The shoreline is generally composed of steep rock outcroppings, with very few gravel beaches. Access to the lagoon is through a shallow intertidal channel and is restricted to high-tide periods. Tides range from -1.2 to over 7.0 m. Salinity in Halibut Cove Lagoon ranges from 10 to 30 ppt. Usually, a 30-cm, brackish water lens of 10 to 16 ppt salinity is present where the stream enters the lagoon.

Fresh water for imprinting and rearing is obtained from a small, 2.8-ha lake located approximately 0.8 km above the lagoon (Figure 2). Falls Creek has also been used as a water source for rearing in previous years (Figure 2).

## METHODS AND MATERIALS

The chinook salmon brood stock is from Crooked Creek, a tributary to the Kasilof River located approximately 96 km north of Homer. Typically, eggs are taken at the Crooked Creek Hatchery and transported to Fort Richardson Hatchery or Elmendorf Hatchery in Anchorage for incubation and rearing. Heated water from power plants is used to accelerate the development so that full-sized smolts are produced in about 11 months.

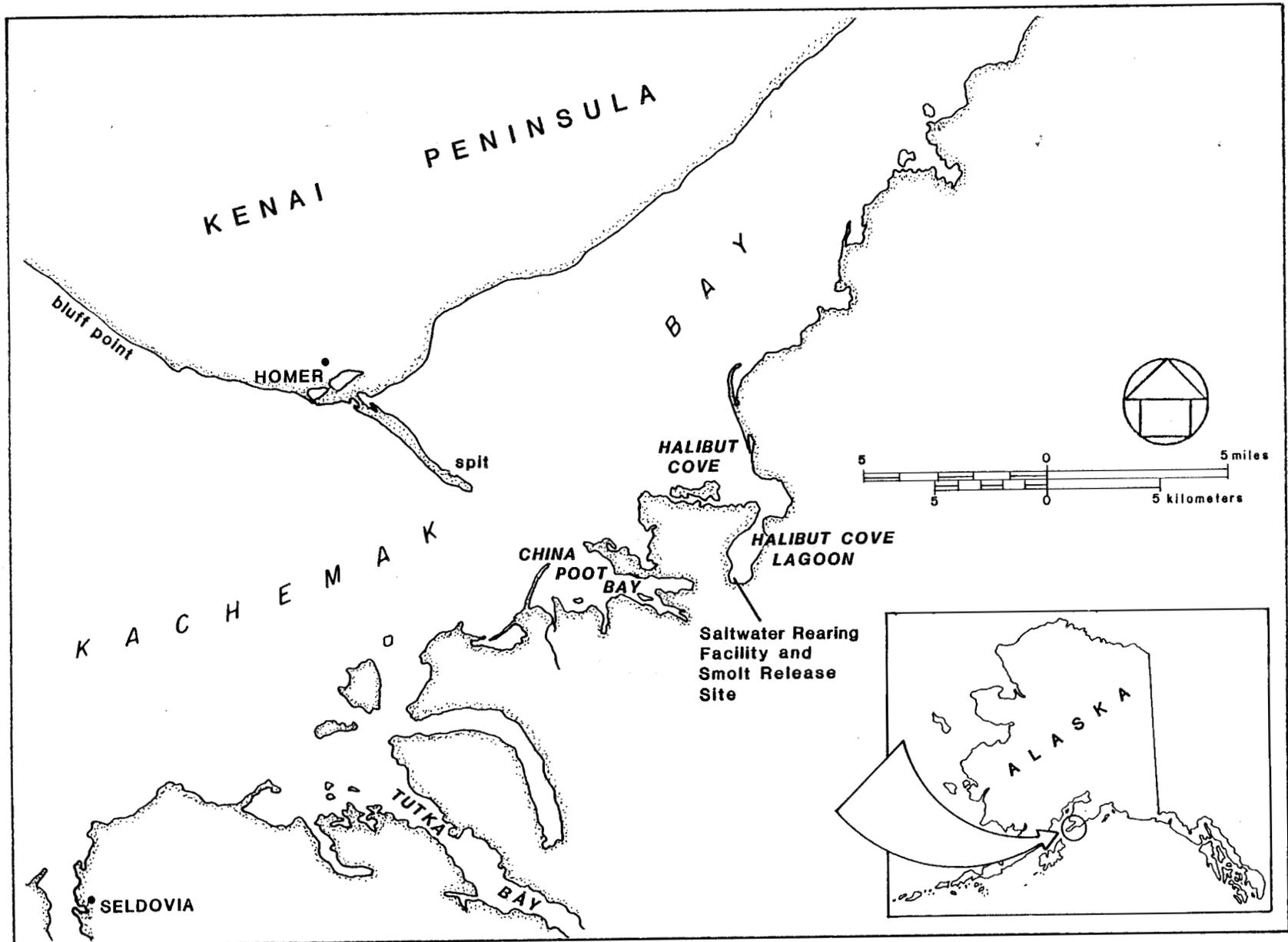


Figure 1. Location of Halibut Cove Lagoon.

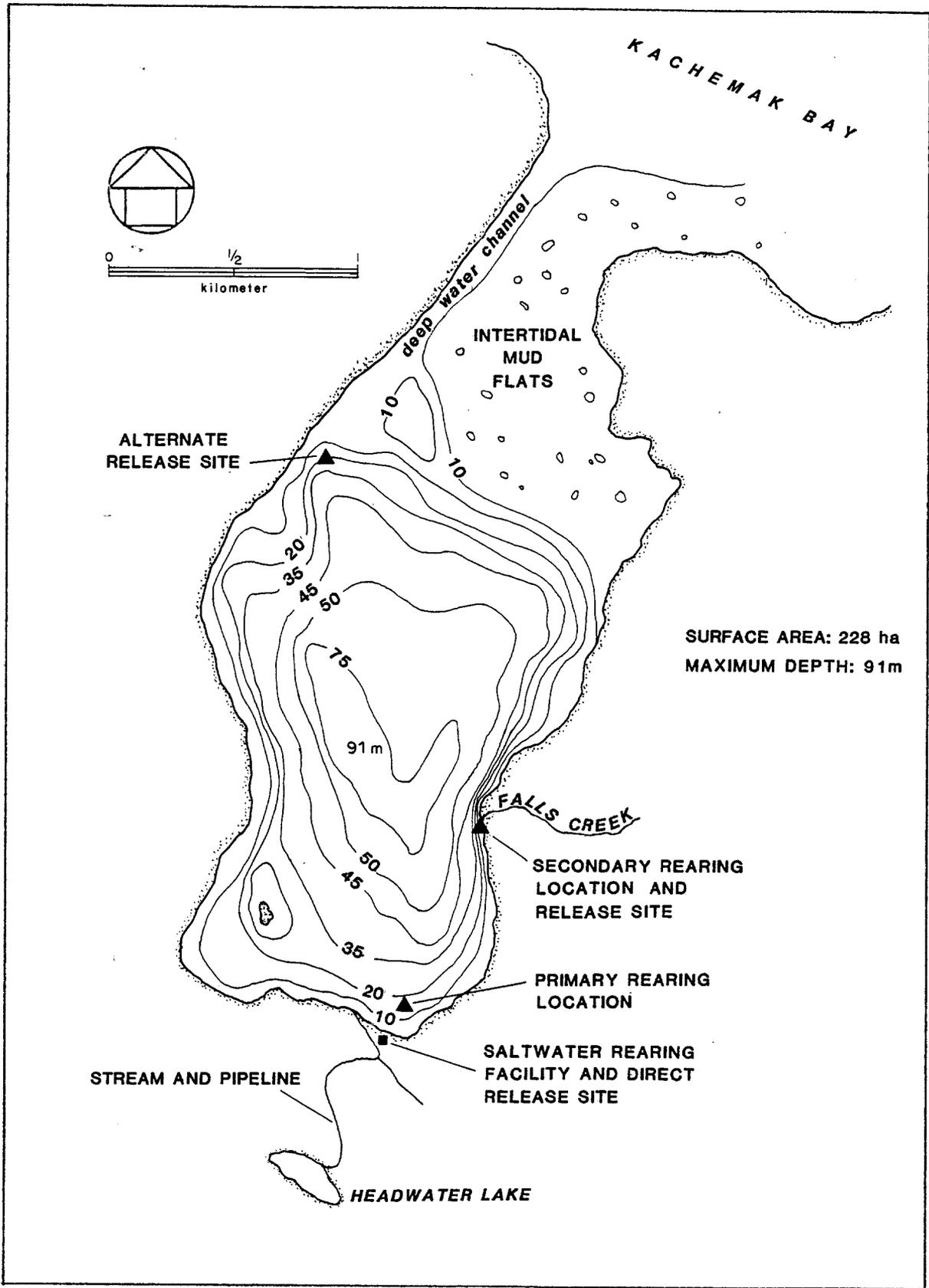


Figure 2. Bathymetric map of Halibut Cove Lagoon with project features.

During most years, some or all of the smolts were marked to identify release lots, determine ages of adult fish, estimate survival rates, or evaluate differences between treatment groups (Table 1).

The smolts were transported to Homer in 1,890-liter fish-transport tanks mounted on flatbed trucks. Smolts were generally loaded at a density of approximately 0.1 kg/liter of water with a maximal biomass of 136 kg of fish per tank. In Homer, the transport vehicles were driven onto landing-craft barges for the 1-h-long trip across Kachemak Bay to Halibut Cove Lagoon where the smolts were either transferred into floating rearing pens or released directly into the estuary.

#### Smolt Rearing

From 1974 to 1978, the chinook salmon smolts were reared and imprinted for 2-6 weeks. Floating net-pen collars were constructed from styrofoam logs and lumber and hung with 9-mm nylon mesh netting with 24 or 49 m<sup>3</sup> of rearing space per net pen. Fabric salinity barriers were installed around the pens to create an artificially brackish water lens in the upper 1 or 2 m of the rearing pens.

Fresh water was piped 0.8 km to the primary rearing area from the small lake located 152 m above seawater. Usually, the fresh water was supplied from the lake at a rate of 22 liters/s and mixed with salt water so that each pen received 3.8-4.4 liters/s of brackish (10-12 ppt) water. Aeration devices on each pen injected air into the water and caused a counterclockwise circulation. Maximal rearing density was approximately 205 smolts/m<sup>3</sup>.

Two locations were utilized for rearing. The primary rearing area, near the south end of the lagoon, had eight large pens. The second rearing area was comprised of four large pens

Table 1. Chinook salmon smolt releases, Halibut Cove Lagoon, 1974-1984.<sup>a/</sup>

Release year	Production facility	Transport			Number released		Average size (g)		Rearing (# of days)	Release date	Disease conditions		
		Method	Date	Mortality	Total	Marked	Delivered	Released			Mortality	Diagnosis	Comments
1974	ND	ND	ND	ND	3,872	3,872	ND	73.2	ND	ND	ND	ND	
1975	Fire Lake	aircraft	10 Jun	none	3,679	3,679	9.4	27.0	53	3 Aug	0.8%	ND	-released at mouth of lagoon
1976	Ft Richardson	aircraft	11-13 May	10%	16,183	16,183	19.7	21.6	25	5 Jun	0	ND	-fed medicated feed
1977	Ft Richardson	truck/ barge	25-28 May	none	48,900	29,344	23.8	28.4	14	8-10 Jun	2.0% (hemorrhaging)	bacteria (stress)	-fed medicated feed
1978	Elmendorf	truck/ barge	19-21 Jun	ND	26,500 99,800	15,043 14,485	14.9 33.6	ND ND	30 30	19 Jul 19 Jul	26% (both lots)	Furunculosis <sup>a/</sup>	-fed medicated feed -release approved
1979	Ft Richardson	truck/ barge	12-14 Jun	ND	225,000	25,902	18.1	18.1	0	12-14 Jun	minimal	ND	-16% HCL broodstock
1980	Ft Richardson	truck/ barge	13 May	slight	155,800	49,813	16.0	16.0	0	13 May	NA	-many gill parasites <sup>b/</sup> -ERM <sup>c/</sup>	-highly variable sizes -80% mortality (7 days at 24-28 ppt)
1981	Elmendorf	truck/ barge	1 Jun 1 Jun	slight	50,000 51,400	25,389 24,577	17.2 15.3	17.2 17.3	0 14	1 Jun 14 Jun	NA 7.0%	NA ND	
1982					0								
1983	Elmendorf	truck/ barge	25-26 May	slight	126,400 74,600	19,780 0	9.9 11.2	9.9 11.2	0 0	25-26 May	none none	NA NA	- in situ bioassay mortality=44%; most dead fish had parr marks.
1984	Elmendorf	truck/ barge	13 Jun	slight	84,000	0	16.8	16.8	0	13 Jun	none	NA	

<sup>a/</sup> Areomonas salmonicida.

<sup>b/</sup> Dermocystidium loma

<sup>c/</sup> ERM = Enteric Red Mouth, (Yersinia ruckeri).

anchored near the mouth of Falls Creek, 0.4 km from the primary float system (Figure 2).

At Falls Creek, fresh water was collected behind a small dam located just above the high-tide line, and about 3.2 liters/s was delivered through 76-mm-diameter plastic pipe to each pen. The amount of fresh water entering each pen varied with tidal stage because high tides reduced the amount of head. The exchange rate in the upper 2 m of each pen was approximately six times per hour.

Smolts were fed Oregon Moist Pellet (OMP). Rations were calculated based on fish size and water temperature, and the pellets were broadcast manually into the net pens. On some occasions, fish were fed *ad libitum* and the weight of feed was calculated after the rearing period.

Dead fish were removed and counted daily; whenever possible, these fish were examined for marks so that the numbers of marked and unmarked ones to be actually released could be adjusted. Periodically, fish samples were sent to the FRED Division Pathology Laboratory in Anchorage for analyses, especially when mortality rates exceeded 0.5% per day. If diseases were diagnosed, treatments were prescribed and administered.

Water temperatures (°C) and dissolved-oxygen concentrations (ppm) were measured daily (1 m below the surface) with a Yellow Springs Instrument Model-57 D.O. meter. Salinities (ppt) were measured daily with a Y.S.I. Model-33 salinity meter at the surface, at 1 m below the surface, and at the bottom of each rearing pen.

#### Direct Releases

Since 1979 all except one production group and several test groups of chinook salmon smolts at Halibut Cove Lagoon have been released directly into seawater, rather than into pens for rearing. At high tide, the smolts were released from the transport barge

directly into the mouth of the small inlet stream (Figure 2) where the natural freshwater lens provides an imprinting source.

When possible, *in situ* (96-164 hours) saltwater bioassay tests were conducted with a sample of smolts that were released directly into the estuary. Several hundred randomly selected smolts were held in the pens and fed OMP. Number of dead fish, water temperature, dissolved oxygen, and salinity were monitored daily.

#### Adult Return Evaluation

Adult chinook salmon returning to Halibut Cove Lagoon were sampled from the sport and commercial fisheries and local fish-processing plants. Numbers of sport fishermen and their harvest of chinook salmon in Halibut Cove Lagoon were monitored by a creel census. FRED Division personnel counted the numbers of boats and the numbers of anglers per boat daily, except during 1983 and 1984 when counts were made less regularly. Anglers reported their catches and times fished. Harvest rates (fish/angler-hour) were calculated and the total harvest was estimated. The sex of each fish was noted; each one was then examined for marks, weighed to the nearest .01 kg, and measured from mideye to fork in millimeters.

Commercial set-net fishermen were asked to examine the chinook salmon they caught for marks. Twice weekly, FRED Division personnel visited set-net sites to collect information and samples. The public was kept informed by news releases and radio broadcasts describing fish with clipped adipose fins released in Halibut Cove Lagoon.

Snouts from chinook salmon adults that had no adipose fins were collected and passed through a metal detector. A positive reaction of the metal detector confirmed the presence of a coded-wire tag. The tag was extracted, cleaned, and decoded so that the history

of the fish could be determined. Scales from a random sample of fish were also collected throughout each year's return.

To determine the run size when creel censuses were incomplete or not done, the majority of returning fish were seined. Consequently, we were able to estimate the contribution of the different release groups by expanding the recoveries of coded-wire tags. Variances of these estimates were then computed (Appendix A).

## RESULTS

### Smolt Release

Between 1974 and 1984, thirteen lots of chinook salmon smolts (numbering approximately 3,600 to 225,000 annually) have been released into Halibut Cove Lagoon (*see* Table 1). The average size at the time of release has ranged from 6.0 to 72.3 g. From 1974 through 1978, these smolts were held in net pens, fed from 14 to 53 days, and released. In 1979, 1980, 1983, and 1984, the smolts were released directly into the lagoon. In 1981, however, two treatment lots were released; one lot was held and fed for 14 days, and the other was released directly into the lagoon.

### Adult Returns

Chinook salmon returns to Halibut Cove Lagoon have been documented since 1977 (Table 2). The first substantial return was in 1979. From 1981 to 1984, the run strength has ranged from nearly 1,000 to over 3,300 fish. The estimated minimal survival rates of chinook salmon smolts released into Halibut Cove Lagoon have ranged from 0.3% to 5.7% (Table 3).

Table 2. Estimated number of chinook salmon returning to Halibut Cove Lagoon, 1974-1984.

Release year	Estimated number of fish during return year								Total
	1977 <u>a/</u>	1978	1979	1980	1981	1982	1983	1984	
1974	32	15							47
1975	6	36	18						60
1976	335	140	327	12					814
1977		88	84	77	49				298
1978			135	67	210	81			493
1979				67	668	2,145	1,923		4,803
1980					29	116	495	30	670
1981						162	936	3,000	4,098
Total	373	279	564	223	956	2,504	3,354	3,030	11,283

a/ Although there was virtually no creel census, the adults were seined to make a minimal estimate of the run size.

Table 3. Estimated minimal survival rates and 95% confidence intervals of chinook salmon smolts released into Halibut Cove Lagoon, 1974-1981.

Release year	Treatment	Estimated survival rate (%)	Confidence interval
1974	reared	1.2 <sup>a/</sup>	0.8 - 1.6
1975	reared	1.6 <sup>b/</sup>	1.4 - 1.9
1976	reared	4.6	4.3 - 4.9
	reared	5.7	5.3 - 6.2
1977	reared	0.6	0.6 - 0.7
1978	"small" sized	0.6	0.5 - 0.7
	"large" sized	0.3	0.3 - 0.4
1979	direct release	2.1	1.9 - 2.3
1980	direct release	0.4	0.3 - 0.5
1981	reared	4.9 <sup>c/</sup>	4.5 - 5.4
	direct release	3.4 <sup>c/</sup>	3.0 - 3.8

<sup>a/</sup> includes ages 0.3 and 0.4

<sup>b/</sup> includes ages 0.2, 0.3, and 0.4

<sup>c/</sup> includes ages 0.1, 0.2, and 0.3

## Harvest

Nearly all of the chinook salmon returning to Halibut Cove Lagoon are harvested by sport fishermen, and an estimated 20 to 600 fish are intercepted annually by commercial set-net fishermen. An estimated 11,280 chinook salmon have returned to Halibut Cove Lagoon between 1977 and 1984. Of these, an estimated 8,166 fish were harvested by over 12,000 sport fishermen. The annual catch rate has averaged 0.7 fish per angler (Table 4). Most anglers fish about 2.5-5.0 hours per day; i.e., one tidal cycle, since access to Halibut Cove Lagoon is restricted to high-tide periods. Consequently, the average annual harvest rate is 0.14 to 0.28 fish per angler-hour, or 3.6 to 7.1 hours per fish.

## Run Timing

Usually the first adult chinook salmon are caught in Halibut Cove Lagoon after 15 May, and most are harvested between 10 and 30 June (Table 5). Few fish are caught after the second week in July.

## Age and Size

Chinook salmon released into Halibut Cove Lagoon return 1-4 years after release; most (46%) returned at age 0.3, although the returns have been highly variable (Table 6).

The average lengths of chinook salmon harvested from Halibut Cove Lagoon range from 419 mm (age-0.1 fish) to 883 mm (age-0.4 fish). The average weight of age-0.1 chinook salmon harvested from Halibut Cove Lagoon is 1.4 kg; the average weight of age-0.4 fish is 11.0 kg (Table 7).

Table 4. Halibut Cove Lagoon chinook salmon creel-census data, 1977-1984.

Year	Estimated number of fish harvested	Number of boats	Number of anglers	Fish harvested per angler-day
1977	ND <sup>a/</sup>	ND	ND	ND
1978	100	ND	ND	NA
1979	500	452	1,331	0.38
1980	123	230	625	0.20
1981	689	399	1,086	0.63
1982	2,043	680	2,210	0.92
1983	2,171	1,071	3,018	0.72
1984	2,640	2,640	3,730	0.71
TOTAL (1979-84)	8,166	5,472	12,000	0.68

<sup>a/</sup> Unmeasured but small harvest. The minimal run size was estimated by seining the adult fish in the lagoon.

Table 5. Chinook salmon harvested from Halibut Cove Lagoon, 1979-1984.

Date	1979		1980		1981		1982		1983		1984	
	Number caught	% of total										
May 01-22		0.0		0.0		0.0		0.0	15	0.7	175	7.2
May 23-25		0.0		0.0		0.0		0.0	54	2.5		0.0
May 26-31		0.0		0.0		0.0		0.0	141	6.5		0.0
June 01-05	0	0.0	3	2.4	29	4.2	23	1.1	101	4.7	320	13.1
June 06-10	35	7.1	0	0.0	50	7.3	21	1.0	521	24.0	140	5.7
June 11-15	73	14.9	7	5.6	141	20.5	26	1.3	364	16.8	784	32.1
June 16-20	81	16.5	2	1.6	112	16.3	297	14.5	232	10.7	614	25.1
June 21-25	91	18.5	25	20.2	72	10.4	692	33.9	292	13.5	222	9.1
June 26-30	23	4.8	16	12.9	67	9.7	292	14.3	150	6.9	50	2.0
July 01-05	39	7.9	12	9.7	106	15.4	215	10.5	153	7.1	140	5.7
July 06-10	66	13.4	8	6.5	30	4.4	268	13.1	85	3.9		0.0
July 11-15	58	11.8	3	2.4	33	4.8	209	10.2	44	2.0		0.0
July 16-20	21	4.3	8	6.5	16	2.3		0.0	17	0.8		0.0
July 21-25	4	0.8	8	6.5	13	1.9		0.0	1	0.0		0.0
July 26-30		0.0	23	18.5	16	2.3		0.0		0.0		0.0
August 01-05		0.0	8	6.5	2	0.3		0.0		0.0		0.0
August 06-10		0.0	0	0.0	2	0.3		0.0		0.0		0.0
August 11-15		0.0	1	0.8		0.0		0.0		0.0		0.0
August 16-20		0.0		0.0		0.0		0.0		0.0		0.0
August 21-25		0.0		0.0		0.0		0.0		0.0		0.0
August 26-30		0.0		0.0		0.0		0.0		0.0		0.0
Total	491		124		689		2,043		2,170		2,445	

Table 6. Percentage of chinook salmon in each age-class returning to Halibut Cove Lagoon from smolts released in 1976-1980.

Release year	Percentage in each age-class			
	0.1	0.2	0.3	0.4
1976	41	17	40	2
1977	30	28	26	16
1978	27	14	43	16
1979	1	14	45	40
1980	4	17	74	5
Average	9	15	46	30

Table 7. Average sizes of chinook salmon harvested from Halibut Cove Lagoon, 1974-1981.

Release year	Age	Number of fish	Length (mm)	Weight (kg)
1974	0.1			
	0.2			
	0.3			
	0.4	ND	1,013	13.9
1975	0.1			
	0.2			
	0.3	ND	812	6.5
	0.4	ND	854	10.2
1976	0.1	0	413	1.2
	0.2	105	736	4.7
	0.3	237	792	8.5
	0.4	5	840	9.2
1977	0.1	43	446	1.3
	0.2	38	593	3.7
	0.3	20	714	5.4
	0.4	13	811	7.9
1978	0.1	24	371	1.6
	0.2	0	568	6.1
	0.3	38	742	6.7
	0.4	15	827	9.1
1979	0.1	3	401	1.3
	0.2	49	625	4.0
	0.3	126	799	8.6
	0.4	445	887	11.2
1980	0.1	6	441	1.6
	0.2	19	646	5.3
	0.3	183	800	8.4
	0.4	1	870	11.6
1981	0.1	41	416	1.4
	0.2	116	627	4.5
	0.3	170	784	8.4
	0.4	NA	NA	NA
1976 to 1981	0.1	117 <sup>a/</sup>	419	1.4
	0.2	327	659	4.4
	0.3	774	789	8.3
	0.4	479	883	11.0

<sup>a/</sup> Data from unknown sample sizes not included in calculation of average values.

## DISCUSSION

Chinook salmon returning to Halibut Cove Lagoon have provided a unique recreational opportunity for local and visiting anglers in Kachemak Bay since 1979. No similar fishery is available in the area, and no self-sustaining run can exist there; but through the stocking program, nearly 4,000 angler-days of effort are expended to harvest nearly 3,000 chinook salmon each year (see Table 4). Some anglers interviewed at Halibut Cove Lagoon have stated that they prefer to fish there rather than in some of the rivers on the lower Kenai Peninsula where there is intensive angler usage.

Typically, most fish harvested from Halibut Cove Lagoon are caught by snagging, which is legally acceptable in these waters. Some people feel that this technique is not aesthetic, and in recent years, many anglers have been using bait and lures, often with good success.

### Commercial Harvest

Although the Halibut Cove Lagoon project is intended to satisfy sport fishermen, some commercial harvesting does occur. Several commercial set-net sites are near the village of Halibut Cove, which is located outside the lagoon. Before 1978 few chinook salmon were harvested at these sites. Since then, a definite increase in set-net chinook salmon catches has occurred, corresponding with the first adult returns to Halibut Cove Lagoon. Between 1981 and 1983, catches have ranged from 200 to 600 fish per year. Although these catches have not been systematically sampled, it is reasonable to assume that most of the chinook salmon harvested in the Lower Cook Inlet Management Area, Southern District (statistical area 241) commercial set-net sites originated from smolts released into Halibut Cove Lagoon.

The proportion of marked chinook salmon caught in the set nets was similar to that observed in the Halibut Cove Lagoon fishery. The seasonal set-net catches coincided with the run into the lagoon. The average sizes of chinook salmon caught in both locations were similar, and while some of those caught in nets carried lures or snag hooks, many of the fish harvested in the lagoon had net marks.

### Survival Rates

The average minimal survival rate of all lots of chinook salmon smolts released into Halibut Cove Lagoon between 1974 and 1981 is 2.3%; this is a conservative estimate because several age classes were not counted in 1975 and 1976, and the 1985 returns are not included. The survival rates are extremely variable and range from 0.3% to 5.7% (*see* Table 3). The average estimated survival rate of chinook salmon smolts released into Crooked Creek between 1975 and 1981 is similar: 2.3% (Flagg, unpublished data).

The cause of the variability of the survival rates of smolts released into Halibut Cove Lagoon is not readily apparent, though many factors can affect the survival rates of salmonid smolts (Wedemeyer et al. 1980; Schreck et al. 1985; Bilton et al. 1980, 1982; Reisenbichler 1982; Wahle and Zaug 1982; Speckler and Schreck 1980; Houston 1961); however, the average estimated survival rate of chinook salmon smolts held and reared in net pens in Halibut Cove Lagoon was greater than the survival rate of those released directly into the lagoon. In 1981 two experimental lots of coded-wire tagged chinook salmon smolts were released into Halibut Cove Lagoon. One lot was released directly; the other was reared for 14 days. With three of the four age-classes of adults having returned, the survival of the reared smolts is significantly greater (statistically) than those released directly into the lagoon (*see* Table 3). During the rearing period, the smolts recovered from the stress of transport, acclimated to the estuarine conditions, and attained better imprinting. Because of

budget constraints, FRED Division can no longer rear smolts in Halibut Cove Lagoon; however, we are satisfied that a successful fishery can be provided simply by releasing smolts directly into the lagoon.

The average size of chinook salmon smolts released into Halibut Cove Lagoon has ranged from 9.9 to 73.2 g (*see* Table 1). Those weighing between about 17 and 22 g have had survival rates above 2.0% (Figure 3). Some smolt groups released at a larger size may also have had 2% or better survivals, but all age-classes were not accounted for. Between 1974 and 1981, chinook salmon smolts (greater than 17 g) were released into Halibut Cove Lagoon between 13 May and 3 August. Except for one lot, those released between 1 and 15 June have had survival rates exceeding 2.0% (Figure 4). These data imply that chinook salmon smolts stocked into Halibut Cove Lagoon survive best (1) after they are reared in the lagoon for 14 days, (2) if they are released between 1 and 15 June, and (3) when they weigh at least 17 g. It appears, however, that fish health may have also affected survival rates.

All lots of smolts in poor condition at release (those released in 1977, 1978 [2 lots], and 1980) survived poorly. Even though they averaged 28.3 g in weight, smolts released on 9 June 1977 survived to adult at only a 0.6% rate. The two lots released in 1978 averaged 15.9 g and 33.6 g, but they survived at less than 0.5%. The 16-g smolts (approximate weight) released on 13 May 1980 survived at only 0.4%.

Because of this apparent effect on smolt survival, it is difficult to definitively state the sizes and times at release that will result in the best survivals. However, the data accumulated from the releases of the "healthiest" smolts appear correlated to time and size at release, and we have suggested certain ranges or boundaries for these parameters.

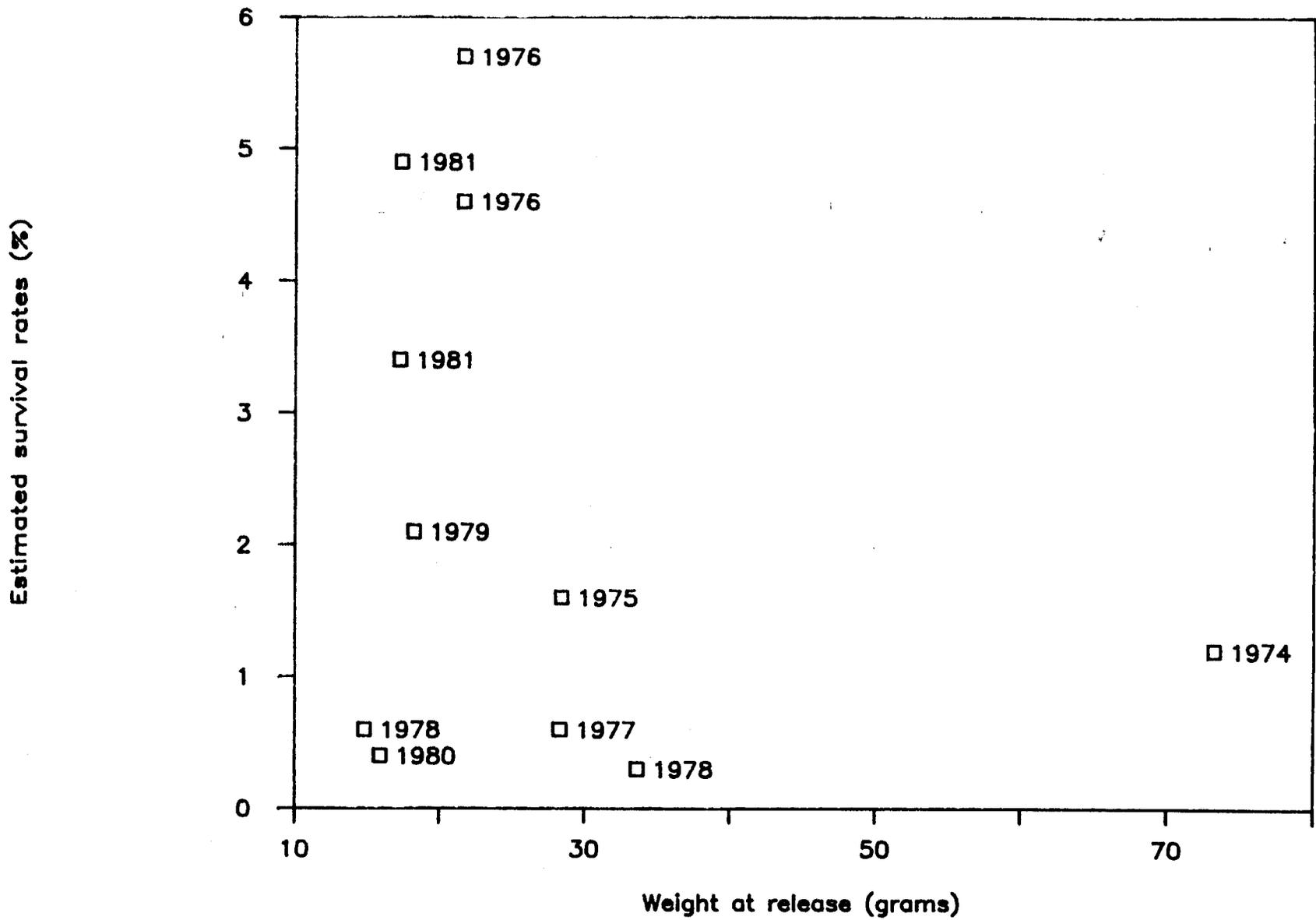


Figure 3. Survival rates of chinook salmon smolts of different sizes released into Halibut Cove Lagoon between 1974 and 1981 (age-classes 0.1 and 0.2 are missing for 1974 release year; age-class 0.1 is missing for 1975 release year; age-class 0.4 is missing for the 1981 release year).

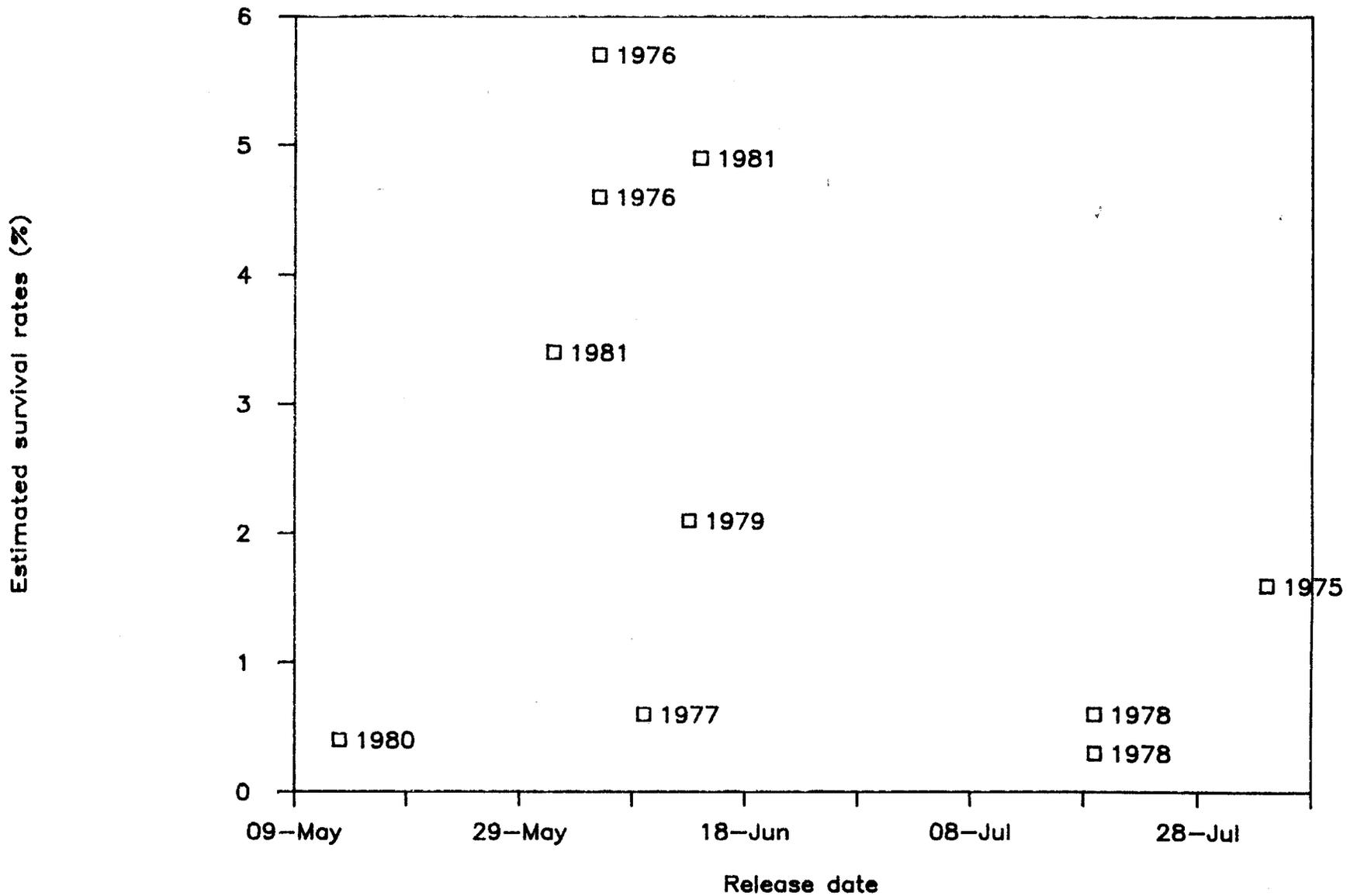


Figure 4. Survival rates of chinook salmon smolts released into Halibut Cove Lagoon at different times of the year between 1975 and 1981 (age-class 0.1 is missing for 1975 release year; age-class 0.4 is missing for 1981 release year).

### Age-Class Composition

Waite (1983) reported that chinook salmon smolts from Crooked Creek return in 1 to 4 years after their release and that most return in 3 years. The average age-class distribution of chinook salmon returning to Halibut Cove Lagoon appears to be similar to that reported by Waite (1983), but the differences in the distributions among the years are much greater in Halibut Cove Lagoon (Figure 5) than in Crooked Creek. Reasons for this variability are not apparent. Smolts released in 1976, 1977, and 1978, however, were reared for 25, 14, and 30 days, respectively; while those released in 1979 and 1980 were not reared at all. Possibly, rearing induces a greater proportion of age-0.1 returnees. Smolts released during 1977, 1978, and 1980 had a history of diseases, and all had poor survivals. We don't know if the disease condition of smolts at the time of release will affect their age-class composition as adults.

### Average Size of Adults

The average lengths of adult chinook salmon caught in Halibut Cove Lagoon between 1975 and 1981 are generally similar to those reported for Crooked Creek (Waite 1983). The average size of the age-0.4 chinook salmon caught in Halibut Cove Lagoon in 1974 may be misleading, since the sample size was not reported and the total run consisted of only 15 fish (Figures 6 and 7). The average lengths of each age-class of chinook salmon caught in Halibut Cove Lagoon are quite consistent from year to year, but the average weights of age-0.2, 0.3, and 0.4 chinook salmon are less consistent. There is no apparent explanation for this observation. There is, however, no evidence that the average size of chinook salmon returning to Halibut Cove Lagoon has declined since the 1974 release.

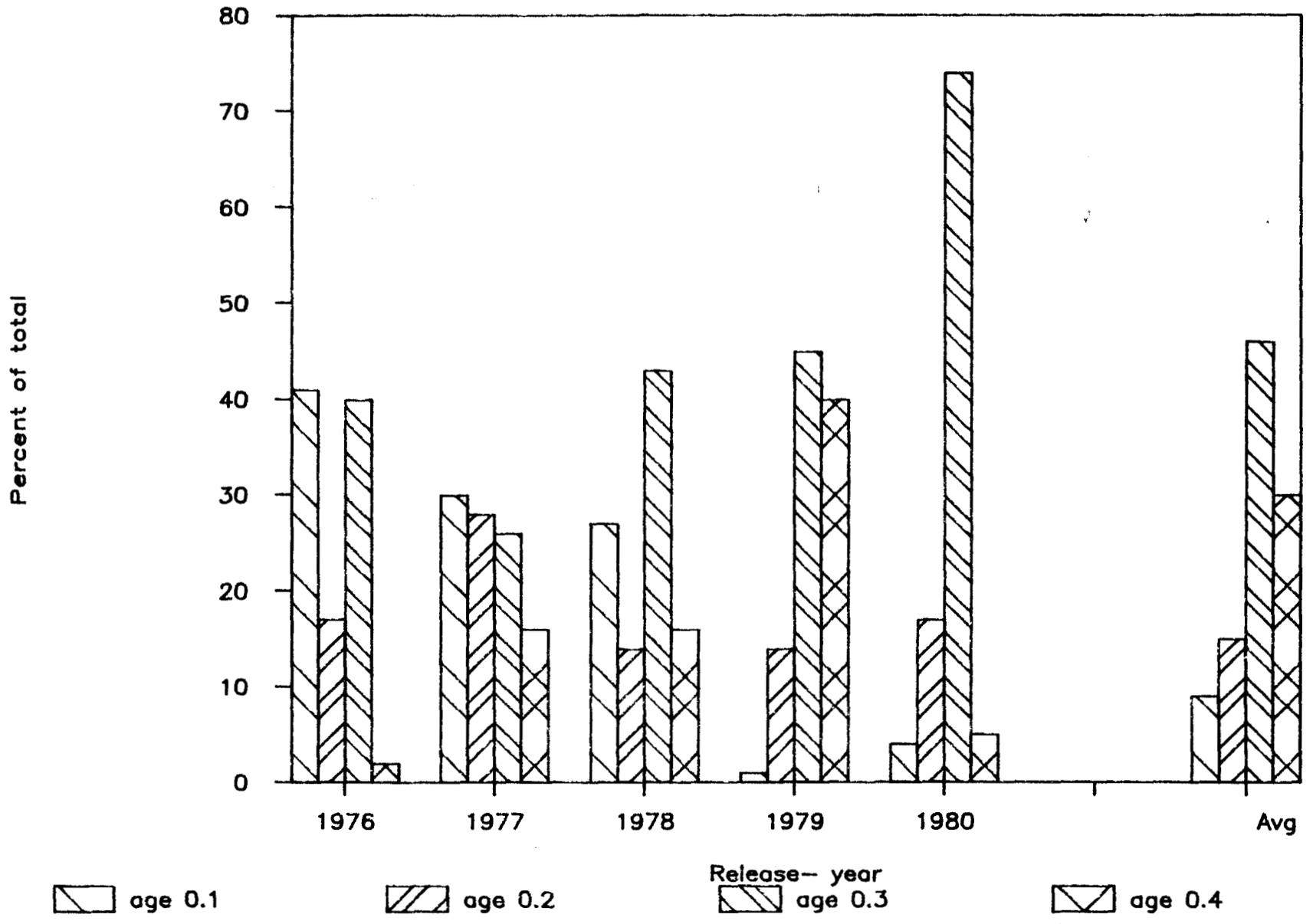


Figure 5. Age-class composition of adult chinook salmon in Halibut Cove Lagoon from smolts released between 1976 and 1980.

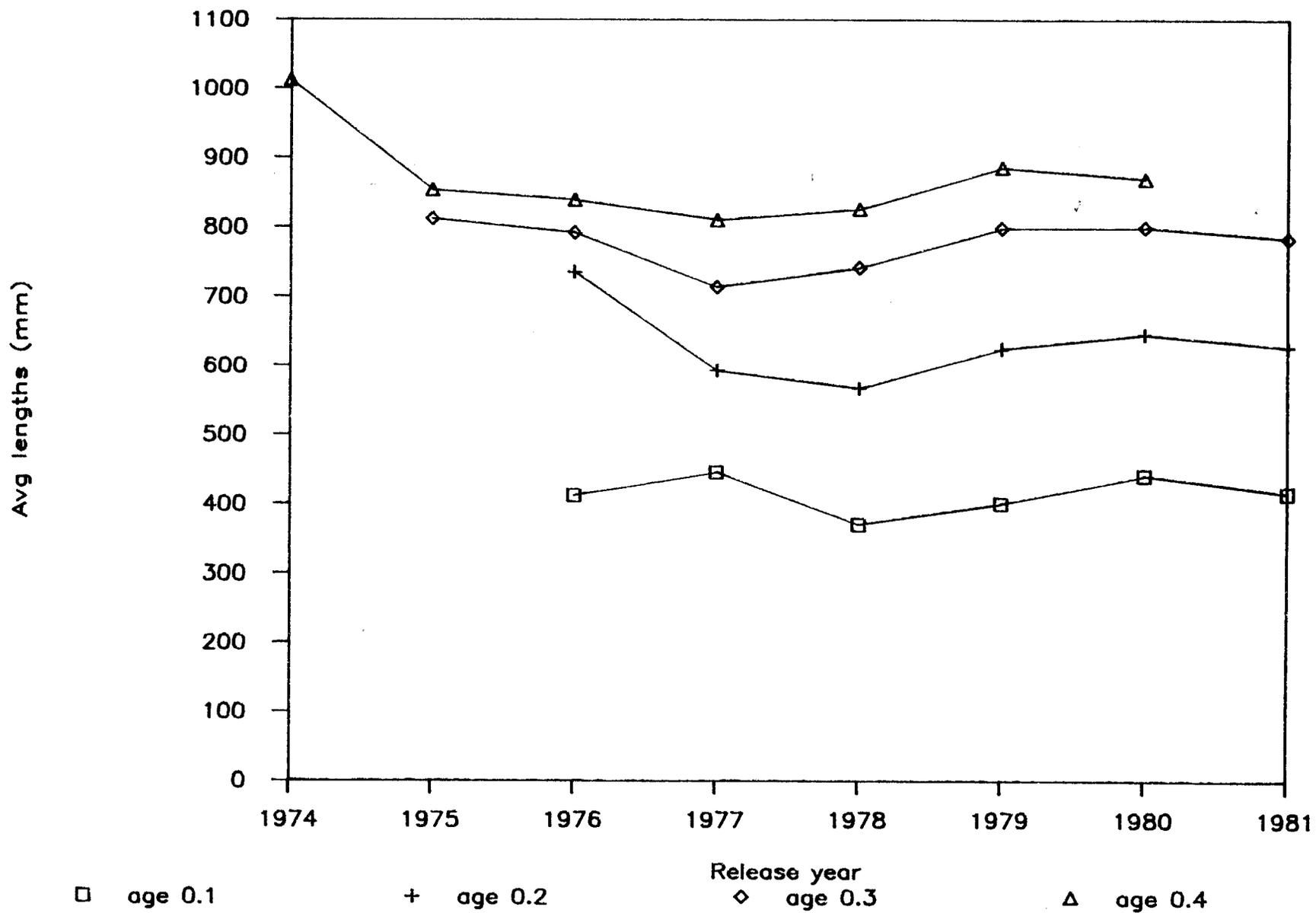


Figure 6 . Average lengths (mm) of adult chinook salmon harvested in Halibut Cove Lagoon from smolts released between 1974 and 1981.

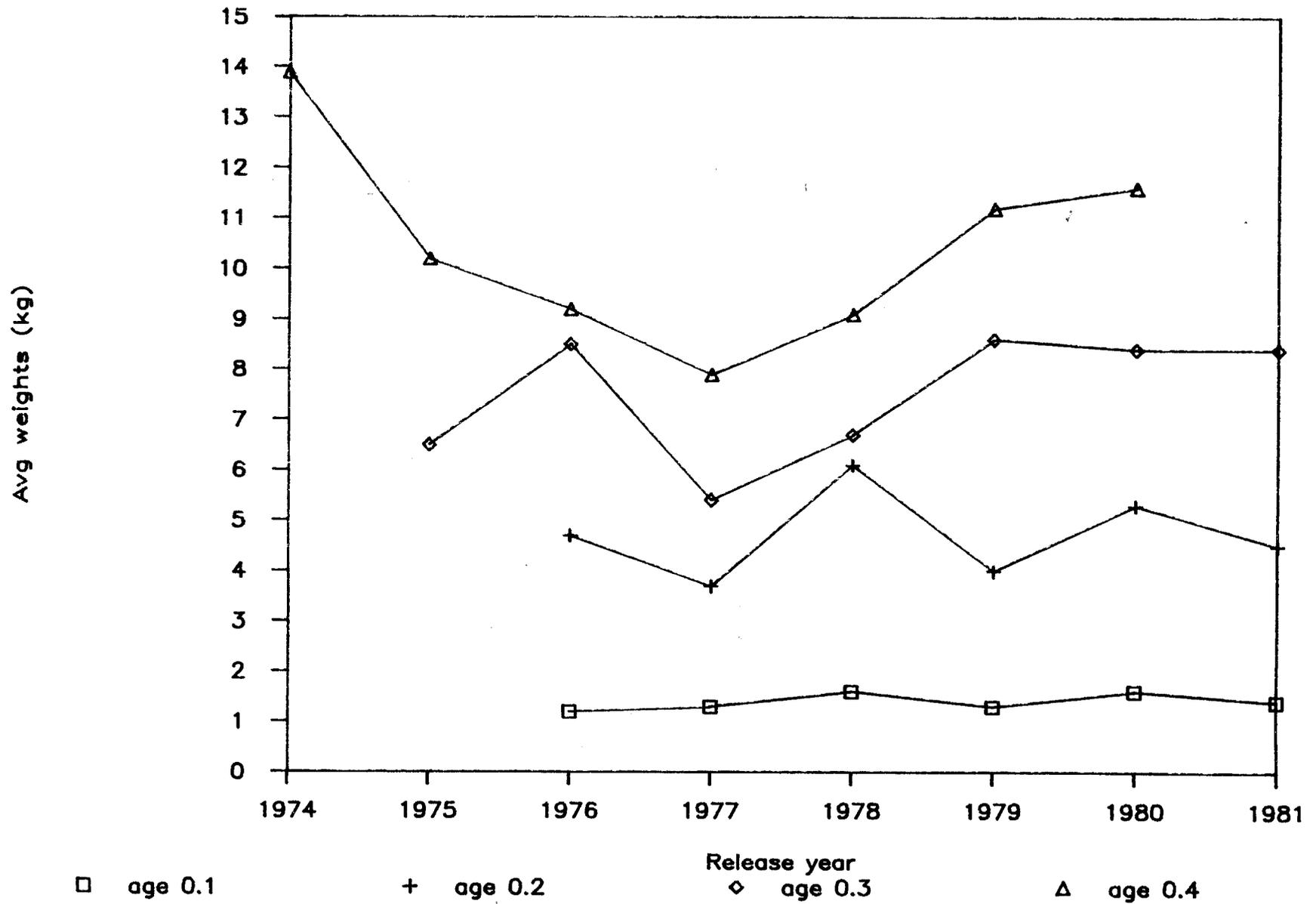


Figure 7. Average weights (kg) of adult chinook harvested in Halibut Cove Lagoon from smolts released between 1974 and 1981.

### Run Timing

The timing of the chinook salmon return run in Halibut Cove Lagoon is difficult to compare with that of the run in Crooked Creek. The data presented by Waite (1983) represent fish counted at the weir, approximately 8 km upstream from Cook Inlet; while our data from Halibut Cove Lagoon represent fish harvested. In Halibut Cove Lagoon, the catches are highly dependent on weather conditions. Since it is a remote area, most angling occurs on weekends. If the weather is inclement, anglers cannot traverse Kachemak Bay. If the weather is warm, glacial water clouds Halibut Cove Lagoon, fish observation is restricted, and the harvest rate declines. Both of these factors greatly affect the numbers of fish caught, so seasonal changes in the catches are not a reflection of fish abundance in the lagoon.

### Conclusions

1. A highly successful fishery has been established in Halibut Cove Lagoon by releasing chinook salmon smolts.
2. Because some age-classes were not recorded and some fisheries not monitored, a conservative estimate of the survival rate for all lots of chinook salmon smolts released into the lagoon between 1974 and 1981 is 2.3%.
3. Good survival of chinook salmon smolts can be expected if healthy smolts, weighing 17.0 g or more, are reared and released between 1 and 15 June.
4. Between 1977 and 1984, more than 12,000 anglers harvested an estimated 8,266 chinook salmon in Halibut Cove Lagoon.

5. The average age-class composition of chinook salmon harvested from Halibut Cove Lagoon is similar to that of the donor stock. Annual variations in the age-class composition may be related to their rearing regime.
6. The average sizes of chinook salmon harvested in Halibut Cove Lagoon are similar to those from Crooked Creek, and there is no evidence of changes in their average sizes.

#### Recommendations

1. The chinook salmon smolt direct-release stocking program in Halibut Cove Lagoon should be continued.
2. A multiyear study should be performed to determine the appropriate time and size of release for optimal survival.

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Kit Rawson reviewed the manuscript and provided biometric support for most of the analyses. Ken Leon made suggestions for technical changes and Sid Morgan assisted with the final revisions.

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APPENDIX



Estimation of the Hatchery Contribution  
in the  
Halibut Cove Project

by

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Expansion of Mark-recoveries

The contribution (number of fish) from a single release group to a single year's chinook salmon run in Halibut Cove may be estimated by expanding the number of tags recovered to account for the fact that only a fraction of the release was tagged and only a fraction of the fish in the adult run were examined for missing adipose fins. The expansion formula is

$$C = m (N/n) (R/r),$$

where C is the estimated hatchery contribution,  
m is the number of tags recovered from the release group,  
N is the total adult chinook run for the year,  
n is the number of fish examined for missing adipose  
fins,  
R is the number of fish released in this release group,  
r is the number of fish tagged in the group.

For example, consider the contribution of the 1980 release to the 1983 adult run. Given the following information

m = 50 tags from this group recovered in 1983,  
N = 3,080 fish estimated in the 1983 return,  
n = 974 fish examined for missing adipose fins in 1983,  
R = 155,754 smolts released in 1980, and  
r = 49,813 smolts tagged in the 1980 release,

we have  $C = 50 \times (3,080/974) \times (155,754/49,813) = 495.$

The individual estimates in Table 2 were computed in this way. Overall estimates of the contribution of a single release group and the contribution of hatchery fish to a single year's return were computed by summing individual estimates, as is apparent from an examination of Table 2. The estimated survival rates (Table 3) were computed by dividing the estimated number of returning adults for a particular release group (summed over all return years) by the number of fish released for that group.

#### Variance of the Estimates

Under the usual assumptions of equal survival of tagged and untagged fish and random sampling of the fishery, a confidence interval can be computed for the estimates described above. Under these assumptions the number of marks recovered from all the release groups in a single return year follow a multivariate hypergeometric distribution. A discussion of variance and covariance formulas for this distribution may be found in Johnson and Kotz (1969, 300-302).

For computing the variance of the estimated return of adult fish for a single release group, summed over all years in which fish

returned, independence of recoveries between years was assumed. Therefore, the variance of the estimated total return for a single release group was simply the sum of the variances of the estimated returns for each single year. For the variance of the total number of hatchery fish in a single year's Halibut Cove chinook salmon run, the marks recovered from the different release groups were assumed to follow a multivariate hypergeometric distribution, with non-zero covariances between the recoveries of the different tag codes. Therefore, the variance of the total hatchery contribution for a single year was the sum of the individual variance plus the appropriate covariance terms (*see* Mood, Graybill, and Boes [1974] for the general formula for the variance of a sum of random variables).

Confidence intervals were derived from the variances by taking the square root of the variance to get the standard deviation and multiplying by 1.96 to get the half-width of the 95% confidence interval. All quantities other than the number of marks recovered (such as the number of fish released or the number of fish marked) were assumed to be constants and treated appropriately in computing variances and standard deviations.

A computer program, written in Turbo Pascal for the IBM PC and compatibles, was used to compute the estimates, their variances and associated quantities. A copy of this program is available from the FRED Division Anchorage office.

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