DIRECTION OF MOVEMENT OF SALMON IN THE NORTH PACIFIC OCEAN, BERING SEA, AND GULF OF ALASKA AS INDICATED BY SURFACE GILLNET CATCHES, 1962–65

by J. R. Dunn
Biological Laboratory, Bureau of Commercial Fisheries
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ABSTRACT

Directions of movement of sockeye (*Oncorhynchus nerka*), chum (*O. keta*), pink (*O. gorbuscha*), and coho (*O. kisutch*) salmon as indicated by surface gillnet catches in the North Pacific Ocean (north of 45°N), Bering Sea, and Gulf of Alaska are described by season for 1962–1965. Included is an analysis of direction of movement of sockeye and chum salmon by age and stage of maturity.

Mature sockeye salmon in the North Pacific Ocean from 160°W to 167°E, moved westward in May and June; mature sockeye salmon moved eastward in the eastern Bering Sea.

In the central and western North Pacific Ocean movement of immature sockeye salmon was primarily westward to 170°E in July and August, and was easterly west of 170°E. In the fall, movement was quite variable in the central and western North Pacific Ocean. Winter movement of immature and maturing sockeye salmon was primarily eastward in the central and western North Pacific Ocean and in the western Bering Sea. Hypotheses on the oceanic migrations of sockeye salmon were not rejected by the present study.

Near the central Aleutians in July and August of 1963, immature sockeye salmon tended to move west, and mature fish moved east. Among immature sockeye salmon, age .1 and age .2 fish moved in similar directions in the summer and fall of all years studied.

Chum salmon maintained a westward movement in the Gulf of Alaska and in the central and western North Pacific Ocean, and an eastward movement in the eastern Bering Sea. Immature and mature fish were generally moving in a similar direction.

Limited catches of mature pink salmon in the central and western North Pacific Ocean in the summer of 1962 and 1963 and of coho salmon south of Adak Island in the summer of 1963 indicated westward movement.

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INTRODUCTION

The Bureau of Commercial Fisheries, serving as the United States research agency of the International North Pacific Fisheries Commission (INPFC), has gillnetted Pacific salmon (*Oncorhynchus* spp.) in the North Pacific Ocean, Bering Sea, and Gulf of Alaska since 1955. Gillnetting has extended our knowledge of the distribution and relative abundance of salmon on the high seas in all seasons and has given us samples for studies of races, age, and growth. Migration routes of salmon in the ocean—more specifically, directions of movement—have been studied by determining the direction from which salmon entered the gillnets.

This extensive gillnetting, in conjunction with seining and tagging by the Fisheries Research Institute, University of Washington, Seattle, Wash. (under contract to the Bureau of Commercial Fisheries), has enabled various authors to hypothesize the oceanic migration routes of certain species. Royce *et al.* (1968) have hypothesized the total migration model of Bristol Bay sockeye salmon (*O. nerka*) and two populations of pink salmon (*O. gorbuscha*)—the southeastern Alaska-British Columbia stocks and the East Kamchatkan stocks. Favorite and McAlister (1966) have suggested an association of mature sockeye salmon with the strength of the Alaskan Stream. Additional inferences on pink salmon have been made by Ishida (MS1960), Miyake (in Kondo *et al.*, 1965), and others. Hirano (in Kondo *et al.*, 1965), primarily on the basis

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of Japanese tagging experiments, has hypothesized the migration routes of maturing Asian chum salmon (*O. keta*).

Previous studies on the direction of movement of salmon in which surface gillnets and purse seines were used have provided background information for the present study. Johnsen (1964) analyzed direction data for surface gillnet catches in the central and western North Pacific Ocean and in the Bering Sea for 1959 and 1960. He concluded that mature sockeye and chum salmon during May and June in the central and western North Pacific Ocean moved predominantly westward south of the Aleutian Islands and northward through the western passes. Sockeye salmon in the central Bering Sea moved east, whereas chum salmon in the central and western Bering Sea moved northwest. Catches of immature sockeye and chum salmon generally showed westward movement in the central and western North Pacific Ocean in July and August, except in the central Aleutians where movement was variable. Catches of mature pink salmon in the central and western North Pacific Ocean indicated a westward migration from May through August, whereas in the central Bering Sea, movement was more northward.

Larkins (1964b) studied the surface gillnet catch data for the spring and summer of 1961 in the Gulf of Alaska and the central North Pacific Ocean. In the latter area he found that the movement of chum and sockeye salmon was similar to that described by Johnsen (1964). In the Gulf of Alaska in the summer he observed westward movement of sockeye salmon and variable movement of chum salmon. Limited catches of pink salmon showed north and west movement in the central North Pacific Ocean and a general westward movement in the central and western Bering Sea.

Larkins (1964b) also compared data on directions of movement from purse seine sampling during 1956–58 (Hartt, 1962) with his gillnet observations. He concluded that the spring and summer movement of sockeye, chum, and pink salmon in 1961 was similar to that observed in 1956–60.

Analyzed herein are data on the directions of movement of sockeye, chum, pink, and coho (*O. kisutch*) salmon as determined from surface gillnet catches in 1962 through 1965; included are observations from areas and seasons not reported previously. The various directions of movement also are analyzed by species, maturity, and age. Examination is made of the hypotheses of Royce *et al.* (1968) and Favorite and McAlister (1966) for sockeye salmon in the light of these more recent data on direction of movement.

PROCEDURES

Direction of movement was recorded for each fish when gillnets were hauled. Because of weather, direction of set, fishing time, and other variables, some of the catch data could not be used. Discussed here are: (1) sampling areas and gear, (2) methods of determining direction of movement, (3) criteria for usable catches, and (4) criteria for determining maturity of salmon.

Sampling Areas and Gear

The Bureau of Commercial Fisheries conducted 15 research cruises in 1962 through 1965 in the North Pacific Ocean, Bering Sea, and Gulf of Alaska[1], during which 324 gillnet sets were made. The fishing stations and salmon catches for each cruise are listed in the INPFC annual reports for those years (INPFC, 1964–1967). The 165 sets (51% of the total) that yielded usable direction data for one or more species are listed in Appendix Tables 1 through 4.

The sampling area varied yearly according to the purpose of each cruise. Major coverage was in the central and western North Pacific Ocean; secondary coverage was in the western Gulf of Alaska and in the Bering Sea. The amount of fishing varied seasonally and tended to be least during the fall and winter cruises when unfavorable weather prevented fishing for extended periods and limited the number of sets.

Vessels used were the Bureau-owned *George B. Kelez* (overall length 176 feet) and the chartered *Bertha Ann* (a vessel similar to the *Kelez*) in 1962 and 1963; the *Kelez* in 1964; and the *Kelez* and a chartered trawler, the *Paragon*, in 1965.

The number of surface gillnets fished varied. Where immature and maturing salmon were caught, 24 to 40 gillnets (50 fathoms long; i.e., 91.4 meters) of different mesh size ($2\frac{1}{2}$-, $3\frac{1}{4}$-, $4\frac{1}{2}$-, and $5\frac{1}{4}$-inch stretched measure; i.e., 63.5 mm, 82.6 mm, 114.3 mm, and 133.4 mm) were fished. Six nets were arranged in a sequence of $4\frac{1}{2}$-, $5\frac{1}{4}$-, $4\frac{1}{2}$-, $3\frac{1}{4}$-, $4\frac{1}{2}$-, and $2\frac{1}{2}$-inch mesh sizes; the sequence was repeated four times. To increase sample sizes, additional nets of 2- (50.8 mm), $2\frac{1}{2}$-, $3\frac{1}{4}$-, or $4\frac{1}{2}$-inch mesh sometimes were added to the distal end of the net string.

Mesh sizes were limited to $4\frac{1}{2}$ and $5\frac{1}{4}$ inches during those spring cruises concerned exclusively with mature salmon on their spawning migration; the net string

[1] For the purposes of this report, the following areas of the North Pacific Ocean north of 45°N are defined arbitrarily: (1) Gulf of Alaska: east of 155°W; central North Pacific Ocean: 155°W to 180°; western North Pacific Ocean: 180°–165°E. Similarly, the Bering Sea north of the Aleutian Chain has been divided into three areas: eastern Bering Sea: east of 165°W; central Bering Sea: 165°W–180°; western Bering Sea: 180°–165°E.

consisted of 28 to 36 nets.

Gillnets were generally braided nylon. On certain cruises monofilament nylon nets were added to the string for experimental purposes (Larkins, 1963; 1964a). Details on net construction and fishing methods were given by Hanavan and Tanonaka (1959) and Johnsen (1964).

The normal procedure was to set the nets at dusk and lift them in the morning. Fishing time varied by season, but usually the nets were fished 10 to 14 hours per night.

Determination of Direction of Movement

Direction of movement was determined by recording the direction of lay of each net as it was hauled; a mean direction of lay was obtained from the individual headings. The direction of lay was recorded as the net was set and again when hauled. Lay was considered to be the two compass points the net followed; e.g., north-south or east-west. It was necessary to obtain the lay of each individual net when the net was hauled, because the net string did not always stay in a straight line as set. The direction of entry of salmon, either from the left or the right, looking away from the vessel toward the far end of the string of nets, was recorded and later corrected to a compass reading at 90° to the mean lay of the net. Ninety degrees were added to the net direction for fish entering from the left, and subtracted for fish entering from the right. Thus, the direction of movement of salmon was considered perpendicular to the mean lay of the net even though the true direction of entry could conceivably approach 180°.

Most gillnet sets were made perpendicular to the suspected east-to-west or west-to-east flow of fish. Because of the necessity of setting gear downwind, north-to-south or south-to-north sets were not always possible. Sets made in directions other than north-south or south-north provided information on the various directions of movement of salmon.

The data, then, are somewhat biased toward east or west. Because of the wide angle from which fish could enter the nets, the direction indicated for individual fish must be considered as an estimate with a possible error of plus or minus 90°.

That gillnet catches provide evidence of directional movement of salmon as opposed to mere random movement was shown by Larkins and French (1964) and Saito and Nakane (1967). The former authors showed that gillnet fishing by two vessels in the same area indicated similar direction of movement and that salmon moved primarily in one direction over a period of one night. Comparisons of data on gillnet and purse seine catches (Fisheries Research Institute, 1962; 1963) for the same areas and times also show similarity in direction of movement.

Criteria for Usable Catches

A general direction of fish movement could not always be determined from a particular set because of irregularities in the lay of the net string caused by wind and currents. This was especially true during fall and winter when inclement weather prevailed. Usable sets satisfied the following conditions (criteria modified from Johnsen, 1964): (1) nets fished the entire night; (2) no net within the string varied more than 90° from the principal direction of the string; (3) at least 60% of the catch had entered from one side of the net; and (4) a minimum of 10 fish had entered from this "dominant" side of the net. It was assumed that these criteria provided comparable data among sets. Catches with equal numbers of fish on both sides of the net could indicate movement parallel to the net, random movement in the vicinity of the set, opposite movement of different stocks or age groups, or errors in identifying direction of entry. Johnsen (1964) estimated that, under conditions of large catches or severe weather, human error approached 10% in observation and recording of direction of entry; he did not assign a direction of movement to a sample unless 60% of the catch had entered from the same side of the net.

Maturity Criteria

In this paper, mature (or maturing) fish are defined as those individuals which would have spawned in the year of capture; all others were recorded as immature. Maturity determinations were made for all sockeye and chum salmon caught in spring and summer, except for mutilated fish that lacked gonads or for samples so large as to require subsampling. In any case, maturity was based on gonad weight as defined by Ishida and Miyaguchi (1958); i.e., for fish taken in May or later, testis weight of more than 2 g or ovary weight of more than 20 g indicated that the fish would have matured in the year of capture. Fish captured in the fall were considered immature except for those with obviously large gonads of maturing fish. These criteria are not applicable to winter caught sockeye or chum salmon. Sockeye salmon rarely spawn after only one year of ocean life; however, most sockeye salmon which have spent three or more years at sea are maturing fish. Therefore in the winter all age .1[2] sockeye salmon were considered immature and all age .3 or older fish were considered maturing.

[2] Age designation follows that of Koo (1962); the number of ocean annuli on the scale is preceded by a decimal point (age .1 is equivalent to one winter at sea, etc.).

Maturity of some female sockeye salmon captured during winter cruises was determined serologically (Ridgway, 1961 ; Ridgway *et al.*, 1962) from samples taken at sea and returned to the laboratory. Because this method is not valid for male sockeye salmon, maturity of age .2 fish was judged from gonad weight (French *et al.*, 1967) beginning in 1965. Because chum salmon may spawn from June to January there are no adequate criteria to determine the maturity of these fish caught in the winter.

Primarily, catches were composed of maturing sockeye and chum salmon during May and June and immature fish during July and August. Johnsen (1964) and Cleaver (1964) also found this separation of mature and immature fish by time of year. In the fall, immature fish also dominated the catches. The maturity (based primarily on age composition prior to 1965) of winter caught sockeye salmon varied with the location of capture.

DIRECTION OF MOVEMENT

Following is a discussion and analysis of the directions of movement of sockeye, chum, pink, and coho salmon. Because direction of movement of salmon may differ for fish of different stages of maturity or length of ocean residence, the effects of these factors on movement were examined for sockeye and chum salmon.

Fishing locations varied each year ; therefore few areas were covered more than once during the 4-year period of study. The data are presented by season and year first, and then summarized for the four years to indicate general trends of directional movement.

Sockeye Salmon

Direction of Movement by Stage of Maturity

Table 1. Direction of movement of sockeye salmon by stage of maturity.

Season, year, and vessel	Set no.	Haul date	Position		Immature				Mature			
			Lat.	Long.	Number caught	Number of fish by direction		Dominant direction (%)	Number caught	Number of fish by direction		Dominant direction (%)
Spring—1962												
(*Bertha Ann*)	8	6/10	50-56N	178-08W	10	6 S W	4 N E	60 S W	28	20 S W	8 N E	71 S W
	9	6/11	50-57N	176-00W	35	26 S W	9 N E	74 S W	45	32 S W	13 N E	71 S W
	Subtotal				45	32W	13 E	71W	73	52W	21 E	71W
	14	6/25	51-10N	170-41 E	33	23 S W	10 N E	70 S W	39	31 S W	8 N E	80 S W
	15	6/26	50-58N	170-05 E	25	16 S W	9 N E	64 S W	12	8 S W	4 N E	67 S W
	16	6/27	51-01N	168-00 E	11	5 S W	6 N E	55 N E	18	17 S W	1 N E	94 S W
	17	6/28	50-53N	171-11 E	54	46 N W	8 S E	85 N W	37	25 N W	12 S E	68 N W
	Subtotal				123	90W	33 E	73W	106	81W	25 E	76W
	Total				168	122W	46 E	73W	179	133W	46 E	74W
Summer—1962												
(*Bertha Ann*)	20	7/ 2	51-00N	177-00W	122	97 S W	25 N E	80 S W	41	26 S W	15 N E	63 S W
	31	7/25	51-33N	174-04W	217	164 N W	53 S E	76 N W	18	6 N W	12 S E	67 S E
	Total				339	261W	78 E	77W	59	32W	27 E	54W
Summer—1963												
(*Kelez*)	11	7/ 4	51-10N	176-15W	19	14 S W	5 N E	74 S W	15	1 S W	14 N E	93 N E
	14	7/ 8	50-49N	176-19W	39	23 S W	16 N E	59 S W	11	2 S W	9 N E	82 N E
	19	7/17	51-14N	176-17W	131	95 S W	36 N E	73 S W	30	5 S W	25 N E	83 N E
	20	7/18	51-22N	176-24W	330	282 S W	48 N E	85 S W	16	7 S W	9 N E	56 N E
	22	7/20	50-55N	176-22W	211	183 N W	28 S E	87 N W	8	2 N W	6 S E	75 S E
	27	7/31	50-54N	176-19W	178	145 S W	33 N E	82 S W	11	1 S W	10 N E	91 N E
	32	8/11	51-28N	176-19W	312	290 S W	22 N E	93 S W	20	1 S W	19 N E	95 N E
	33	8/12	51-09N	176-19W	100	47 N W	53 S E	53 S E	15	11 N W	4 S E	73 N W
	47	8/31	51-16N	176-22W	44	25 S W	19 N E	57 S W	29	3 S W	26 N E	90 N E
	Total				1364	1104W	260 E	81W	155	33W	122 E	79 E
Summer—1963												
(*Bertha Ann*)	27	7/31	53-30N	162-00W	31	24 N W	7 S E	77 N W	11	8 N W	3 S E	73 N W
	39	8/12	54-00N	162-00W	20	19 S W	1 N E	95 S W	63	13 S W	50 N E	79 N E
	46	8/21	50-20N	162-00W	23	0	23 N E	100 N E	50	50 S W	0	100 S W
	Total				74	43W	31 E	58W	124	71W	53 E	57W

Only a few catches contained sizable numbers of mature and immature sockeye salmon (Table 1). Included in Table 1 are catches which did not meet the criterion of dominance (60%) in direction of movement, and which are therefore excluded from Appendix Table 1. They are discussed here, however, to determine if the lack of dominance in direction of movement was due to opposed movement of mature and immature fish by area.

The catches did not differ consistently by maturity or by area except south of Adak Island during the summer of 1963. Nine sets in July and August which contained mature and immature fish were compared; all demonstrated opposed direction of movement. Eight of the nine sets showed westward movement for immature and eastward movement for mature sockeye salmon (Table 1). Eighty-one percent of the immature fish were moving west, but 79% of the mature ones were moving east. Others (Johnsen, 1964; Hartt, 1966) have presented limited data which suggested that direction of movement of sockeye salmon in the Adak area differed by stage of maturity. Although sample sizes are small, it appeared that near Adak in July and August, mature sockeye salmon moved primarily eastward and immature ones generally moved westward. In 1962, two sets in July near 174°W also suggested that immature fish moved west in greater proportion than mature ones (77% of the matures moved west; 54% of the immatures).

The mature sockeye salmon caught south of Adak Island in July and August probably are not all of Bristol Bay origin. Royce (1965) indicates that maturing Bristol Bay sockeye salmon follow a migration schedule that varies remarkably little from year to year and that the end of the migration of mature sockeye salmon through the central Aleutian passes en route to Bristol Bay is approximately June 20. Tagging studies (Hartt, 1966) also support this rigid time schedule of Bristol Bay sockeye salmon. Thus, we may infer that these catches of mature sockeye in July and August were predominantly of other than Bristol Bay origin.

Direction of Movement by Ocean Age

Catches of immature sockeye salmon were examined to determine if direction of movement differed by ocean age (number of winters at sea) and area. Catches of mature salmon were not analyzed because these catches generally were dominated by a single age group—fish that had spent either two or three winters at sea.

Catches of immature sockeye salmon generally were composed of .1, .2, and .3 age fish. The direction of movement of the more abundant .1 and .2 immature fish was similar for most areas and seasons (Table 2). Where percentage differences occurred in the number of each group moving in a certain direction, the differences did not appear to be consistent. We may conclude then, that age .1 and .2 immatures in the summer and fall apparently maintained similar directions of movement.

Direction of Movement by Season

Spring. Sampling was conducted in May and June 1962, from 176°W to 168°E in the North Pacific Ocean and near 176°W in the central Bering Sea (Fig. 1). Southwest movement was evident south of Adak Island, and westward movement (southwest and northwest) predominated west of 180°. Northeast movement was suggested by a single set south of Attu Island. Opposed movement was indicated by two sets in the central Bering Sea, north of Adak Island. In May and early June, mature fish dominated the catches at all stations, but in late June, immature ones made up over half of the catches near 170°E.

Movement south of the Alaska Peninsula from 175°W to 170°E in 1962 was similar to that reported by Johnsen (1964) for 1959 and 1960. Johnsen's more extensive data showed movement to be primarily westward in the central Aleutians, northward between 175°E and 170°E, and eastward in the western Bering Sea south of 55°N.

Sampling in June 1965 was concentrated on maturing sockeye salmon south of Unalaska Island in the central North Pacific Ocean and in the eastern Bering Sea (Fig. 1). South of Unalaska, seven of nine sets indicated a pronounced southwest movement; a single set along 160°W also indicated southwest movement. A predominantly northeast movement occurred in the eastern Bering Sea, although some sets suggested considerable variation. Similar observations were made by Larkins (1964) who reported westward movement along 160°W south of the Alaska Peninsula, and eastward movement near 165°W in the eastern Bering Sea in 1961.

Summer. In July and August 1962, movement of immature sockeye salmon had a marked westward trend between 154°W and 157°W (Fig. 2). Movement varied between primarily southwest and northwest between 165°W and 173°E and was eastward from 169°E to 166°E (two sets between 53° and 54°N). Studies on the continental origin of high seas sockeye salmon (Margolis *et al.*, 1966) indicated that the western limit of distribution of immature Bristol Bay sockeye salmon in the North Pacific Ocean was approximately 172°E. Assuming such limits were representative of immature Bristol Bay sockeye salmon distribution in 1962, we may infer that the fish near

TABLE 2. Direction of movement of immature sockeye salmon by ocean age and area.

Season, year, and vessel	Set no.	Haul date	Position		Age .1				Age .2				Age .3			
			Lat.	Long.	Number caught	Number of fish by direction		Dominant direction (%)	Number caught	Number of fish by direction		Dominant direction (%)	Number caught	Number of fish by direction		Dominant direction (%)
Summer—1962																
(*Bertha Ann*)	33	8/ 4	50–50N	179–00E	98	85SW	13NE	87SW	175	146SW	29NE	83SW	3	3SW	0	100SW
	20	7/ 2	51–00N	177–00W	10	8SW	2NE	80SW	102	80SW	22NE	78SW	7	7SW	0	100SW
	Subtotal				108	93W	15E	86W	277	226W	51E	82W	10	10W	0	100W
	27	7/21	51–30N	173–55W	95	67SW	28NE	71SW	60	44SW	16NE	73SW	1	0	1NE	100NE
	28	7/22	51–00N	173–54W	64	19SW	45NE	70NE	31	15SW	16NE	52NE	0	0	0	—
	29	7/23	50–29N	173–56W	44	22SW	22NE	—	65	26NW	39SE	60SE	3	0	3SE	100SE
	30	7/24	51–04N	174–02W	135	99NW	36SE	73NW	207	132NW	75SE	64NW	2	1NW	1SE	—
	31	7/25	51–33N	174–04W	127	97NW	30SE	76NW	84	64NW	20SE	76NW	1	1NW	0	100NW
	Subtotal				465	304W	161E	65W	447	281W	166E	63W	7	2W	5E	71E
	21	7/12	52–52N	167–07W	26	2NW	24SE	92SE	7	0	7SE	100SE	1	0	1SE	100SE
	22	7/14	51–50N	167–00W	170	149SW	21NE	88SW	185	155SW	30NE	84SW	2	2SW	0	100SW
	23	7/15	52–20N	166–58W	55	44NW	11SE	80NW	36	26NW	10SE	72NW	0	0	0	—
	Subtotal				251	195W	56E	78W	228	181W	47E	79W	3	2W	1E	67W
	44	8/27	52–14N	157–00W	26	19NW	7SE	73NW	60	42NW	18SE	70NW	0	0	0	—
	45	8/28	52–45N	157–00W	20	14NW	6SE	70NW	33	29NW	4SE	88NW	0	0	0	—
	46	8/29	53–30N	157–00W	17	13NW	4SE	77NW	19	16NW	3SE	84NW	0	0	0	—
	47	8/30	54–00N	157–00W	17	12SW	5NE	71SW	7	3SW	4NE	57SW	0	0	0	—
	Subtotal				80	58W	22E	73W	119	90W	29E	76W	0	0	0	—
	34	8/ 8	50–19N	178–59E	74	69NW	5SE	93NW	122	110NW	12SE	90NW	1	1NW	0	100NW
	36	8/10	50–41N	175–54E	22	19NW	3SE	86NW	96	72NW	24SE	75NW	0	0	0	—
	37	8/11	51–57N	172–50E	84	79NW	5SE	94NW	172	152NW	20SE	88NW	0	0	0	—
	38	8/13	51–23N	172–53E	111	105NW	6SE	95NW	173	169NW	4SE	98NW	2	2NW	0	100NW
	39	8/14	50–53N	173–00E	87	83NW	4SE	95NW	79	61NW	18SE	77NW	2	2NW	0	100NW
	Subtotal				378	355W	23E	94W	642	564W	78E	88W	5	5W	0	100W
	42	8/19	53–50N	169–45E	5	0	5SE	100SE	18	7NW	11SE	61SE	0	0	0	—
	Subtotal				5	0	5E	100E	18	7W	11E	61E	0	0	0	—
	Total				1287	1005W	282E	78W	1731	1349W	382E	78W	25	19W	6E	76W
Summer—1963																
(*Kelez*)	11	7/ 4	51–10N	176–15W	1	1SW	0	100SW	14	11SW	3NE	79SW	0	0	0	—
	13	7/ 7	51–17N	176–25W	4	1NW	3SE	75SE	25	2NW	23SE	92SE	0	0	0	—
	14	7/ 8	50–49N	176–19W	2	1SW	1NE	—	35	21SW	14NE	60SW	0	0	0	—
	19	7/17	51–14N	176–17W	32	24SW	8NE	75SW	98	70SW	28NE	71SW	0	0	0	—
	20	7/18	51–22N	176–24W	81	65SW	16NE	80SW	241	209SW	32NE	87SW	2	2SW	0	100SW
	21	7/19	50–30N	176–20W	29	21NW	8SE	72NW	8	8NW	0	100NW	0	0	0	—
	22	7/20	50–55N	176–22W	115	104NW	11SE	90NW	84	68NW	16SE	81NW	1	1SW	0	100SW

	25	7/29	51-35N	176-22W	37	31NW	6S E	84NW	20	10NW	10S E	—	1	1S W	0	100S W
	27	7/31	50-54N	176-19W	51	49S W	2N E	96S W	123	93S W	30N E	76S W	2	2S W	0	100S W
	29	8/ 3	50-28N	176-20W	108	95NW	13S E	88NW	136	114NW	22S E	84NW	1	1NW	0	100NW
	30	8/ 4	51-04N	176-20W	176	145NW	31S E	82NW	139	112NW	27S E	81NW	2	1NW	1S E	—
	32	8/11	51-28N	176-19W	293	278S W	15N E	95S W	19	12S W	7N E	62S W	0	0	0	—
	33	8/12	51-09N	176-19W	46	30NW	16S E	65NW	50	14NW	36S E	72S E	0	0	0	—
	34	8/13	50-34N	176-19W	44	28NW	16S E	64NW	57	39NW	18S E	68NW	0	0	0	—
	42	8/26	51-20N	176-19W	28	24NW	4S E	86NW	6	3NW	3S E	—	0	0	0	—
	43	8/27	51-19N	176-17W	30	20NW	10S E	67NW	13	4NW	9S E	69S E	0	0	0	—
	46	8/30	51-22N	176-22W	38	29NW	9S E	76NW	1	0	1S E	100S E	0	0	0	—
	47	8/31	51-16N	176-22W	30	18S W	12N E	60S W	14	7S W	7N E	—	0	0	0	—
	49	9/ 2	50-01N	176-19W	26	16S W	10N E	61S W	14	8S W	6N E	57S W	0	0	0	—
	Total				1171	980W	191E	84W	1097	805W	292E	73W	9	8W	1E	89W
Summer—1963																
(*Bertha Ann*)	19	7/23	53-00N	162-00W	152	121NW	31S E	80NW	15	12NW	3S E	80NW	0	0	0	—
	20	7/24	51-59N	162-04W	43	30S W	13N E	70S W	27	14S W	13N E	52S W	0	0	0	—
	21	7/25	51-00N	162-00W	40	22NW	18S E	55NW	86	44NW	42S E	51NW	0	0	0	—
	24	7/28	50-30N	162-00W	3	3S W	0	100S W	38	29S W	9N E	76S W	0	0	0	—
	25	7/29	51-31N	162-02W	168	148NW	20S E	88NW	106	95NW	11S E	90NW	0	0	0	—
	26	7/30	52-30N	162-00W	18	13NW	5S E	72NW	4	4NW	0	100NW	0	0	0	—
	27	7/31	53-30N	162-00W	30	23NW	7S E	77NW	1	1NW	0	100NW	0	0	0	—
	32*	8/ 5	51-30N	162-00W	106	12N	94S	89S	47	33S	14N	70S	0	0	0	—
	33	8/ 6	52-00N	162-00W	114	72NW	42S E	63NW	57	29NW	28S E	51NW	0	0	0	—
	34	8/ 7	52-20N	162-00W	69	62S W	7N E	90S W	20	11S W	9N E	55S W	0	0	0	—
	35	8/ 8	52-40N	162-00W	36	23NW	13S E	64NW	6	4NW	2S E	67NW	0	0	0	—
	36	8/ 9	53-00N	162-00W	29	17NW	12S E	59NW	1	0	1S E	100S E	0	0	0	—
	37	8/10	53-20N	162-00W	42	29S W	13N E	69S W	5	3S W	2N E	60S W	0	0	0	—
	39	8/12	54-00N	162-00W	20	19S W	1N E	95S W	0	0	0	—	0	0	0	—
	41	8/16	53-40N	162-00W	19	13S W	6N E	68S W	0	0	0	—	0	0	0	—
	42	8/17	53-00N	161-59W	16	10NW	6S E	63NW	3	2NW	1S E	67NW	0	0	0	—
	44	8/19	51-40N	162-00W	36	31NW	5S E	86NW	30	20NW	10S E	67NW	0	0	0	—
	45	8/20	51-00N	162-00W	86	69NW	17S E	80NW	109	73NW	36S E	67NW	2	1NW	1S E	—
	46	8/21	50-20N	162-00W	33	25S W	8N E	76S W	37	24S W	13N E	65S W	0	0	0	—
	47	8/22	49-40N	162-00W	3	2S W	1N E	67S W	48	41S W	7N E	85S W	0	0	0	—
	49	8/25	50-40N	162-00W	64	37NW	27S E	58NW	71	49NW	22S E	69NW	0	0	0	—
	Subtotal*				1021	769W	252E	75W	664	455W	209E	69W	2	1W	1E	—

Continued . . .

TABLE 2. Continued.

Season, year, and vessel	Set no.	Haul date	Position		Age .1				Age .2				Age .3			
			Lat.	Long.	Number caught	Number of fish by direction		Dominant direction (%)	Number caught	Number of fish by direction		Dominant direction (%)	Number caught	Number of fish by direction		Dominant direction (%)
Summer/Fall—1963																
(*Bertha Ann*)	50	8/26	51–20N	162–00W	56	25NW	31S E	55S E	37	7NW	30S E	81S E	2	0	2S E	100S E
	51	8/27	52–00N	162–00W	24	7NW	17S E	71S E	11	3NW	8S E	73S E	0	0	0	—
	52	8/28	52–40N	162–00W	17	5NW	12S E	71S E	3	2NW	1S E	67NW	0	0	0	—
	58	9/ 5	51–00N	162–00W	117	97NW	20S E	83NW	73	49NW	24S E	67NW	0	0	0	—
	59	9/ 6	50–00N	162–00W	27	6S W	21N E	78N E	3	3S W	0	100S W	0	0	0	—
	61	9/ 8	50–30N	162–00W	37	11S W	26N E	70N E	7	3S W	4N E	57N E	0	0	0	—
	62	9/ 9	51–30N	162–00W	148	30S W	118N E	80N E	326	65S W	261N E	80N E	0	0	0	—
	Subtotal				426	181W	245E	58E	460	132W	328E	71E	2	0	2E	100E
	Total*				1447	950W	497E	66W	1124	587W	537E	52W	4	1W	3E	75E
Fall—1964																
(*Kelez*)	1	9/ 2	51–33N	176–18W	34	26S W	8N E	77S W	22	14S W	8N E	64S W	0	0	0	—
	2	9/ 5	51–33N	176–18W	49	37S W	12N E	76S W	10	1S W	9N E	90N E	0	0	0	—
	Subtotal				83	63W	20E	76W	32	15W	17E	53E	0	0	0	—
	4	9/27	51–10N	173–00E	26	8NW	18S E	69S E	18	3NW	15S E	83S E	1	1NW	0	100NW
	5	9/29	50–10N	173–00E	97	2NW	95S E	98S E	41	4NW	37S E	90S E	0	0	0	—
	6	9/30	50–10N	173–00E	113	101S W	12N E	84S W	13	10S W	3N E	77S W	0	0	0	—
	7	10/ 2	50–10N	173–00E	171	143S W	28N E	84S W	9	9S W	0	100S W	0	0	0	—
	Subtotal				407	254W	153E	62W	81	26W	55E	68E	1	1W	0	100W
	Total				490	317W	173E	65W	113	41W	72E	64E	1	1W	0	100W
Fall—1965																
(*Kelez*)	2	10/ 4	51–16N	172–58E	23	10NW	13S E	57S E	55	17NW	38S E	69S E	0	0	0	—
	3	10/ 5	50–19N	173–00E	46	9S W	37N E	80N E	46	7S W	39N E	85N E	0	0	0	—
	4	10/ 6	49–15N	172–58E	27	4S W	23N E	85N E	105	19S W	86N E	82N E	0	0	0	—
	16	11/ 5	49–57N	175–03E	32	4NW	28S E	88S E	45	8NW	37S E	82S E	0	0	0	—
	Total				128	27W	101E	79E	251	51W	200E	80E	0	0	0	—

* Set indicating southern movement eliminated from totals.

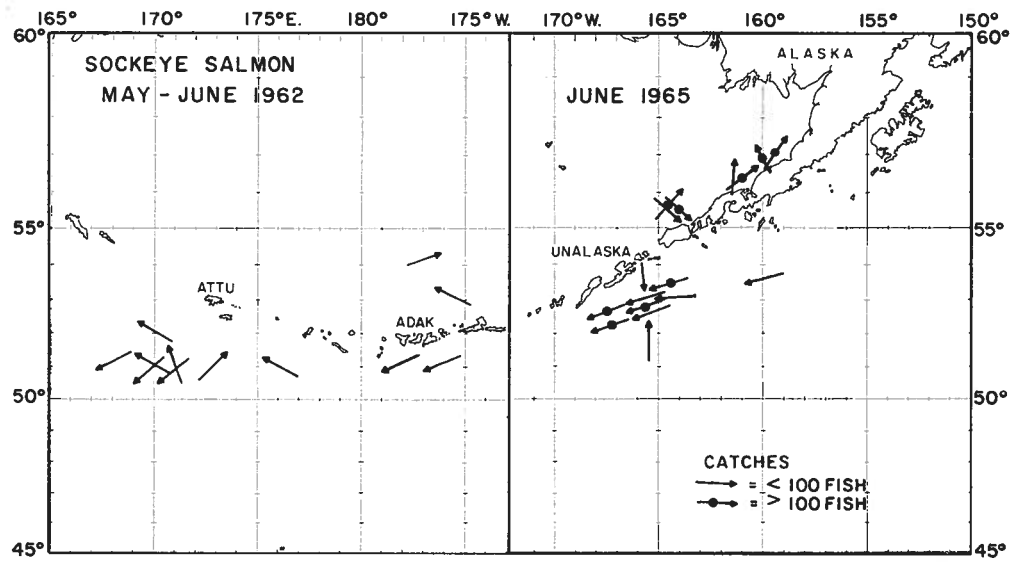

FIGURE 1. Dominant direction of movement of sockeye salmon during May and June 1962 and June 1965.

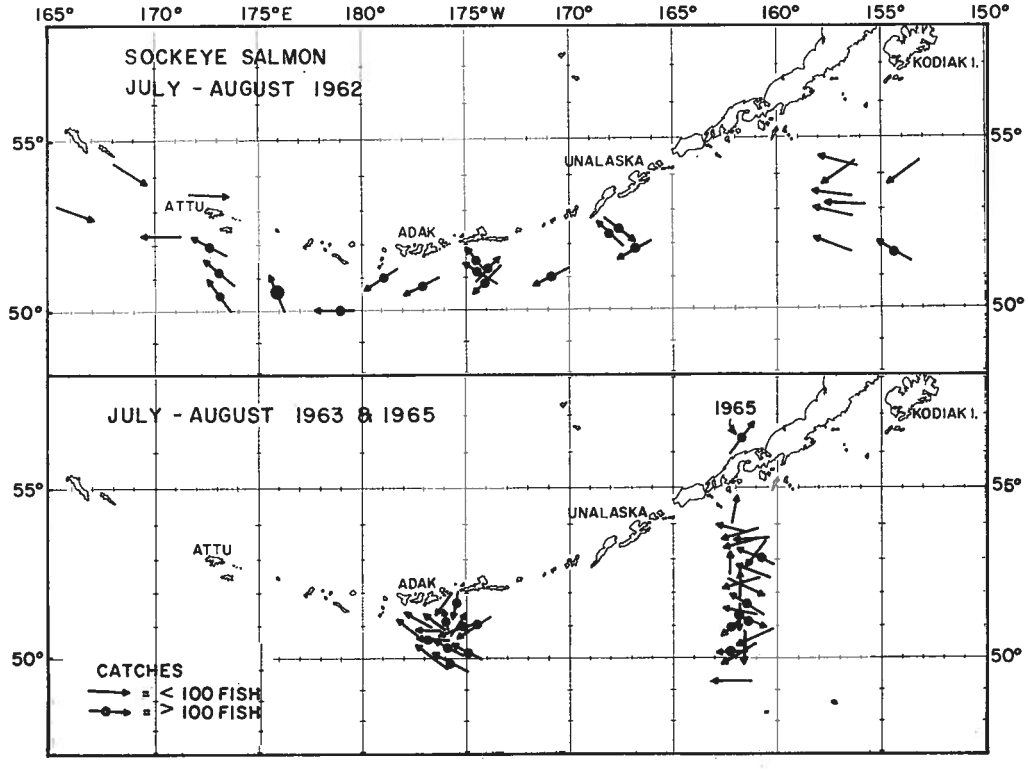

FIGURE 2. Dominant direction of movement of sockeye salmon during July and August 1962, 1963, and 1965.

166°E were probably of Asian origin.

In 1963, movement was westward in 15 of 22 sets near 162°W (between 49°N and 54°N) and westward with some north and south variation in 13 of 15 sets south of Adak Island (Fig. 2). As in 1962, catches were composed primarily of immature fish.

A single catch of mature sockeye salmon in 1965 in the eastern Bering Sea suggested northeast movement (Fig. 2).

Generally, directions of movement in 1962–65 were similar to those reported by Johnsen (1964) for 1959–60. Both analyses showed westward movement from

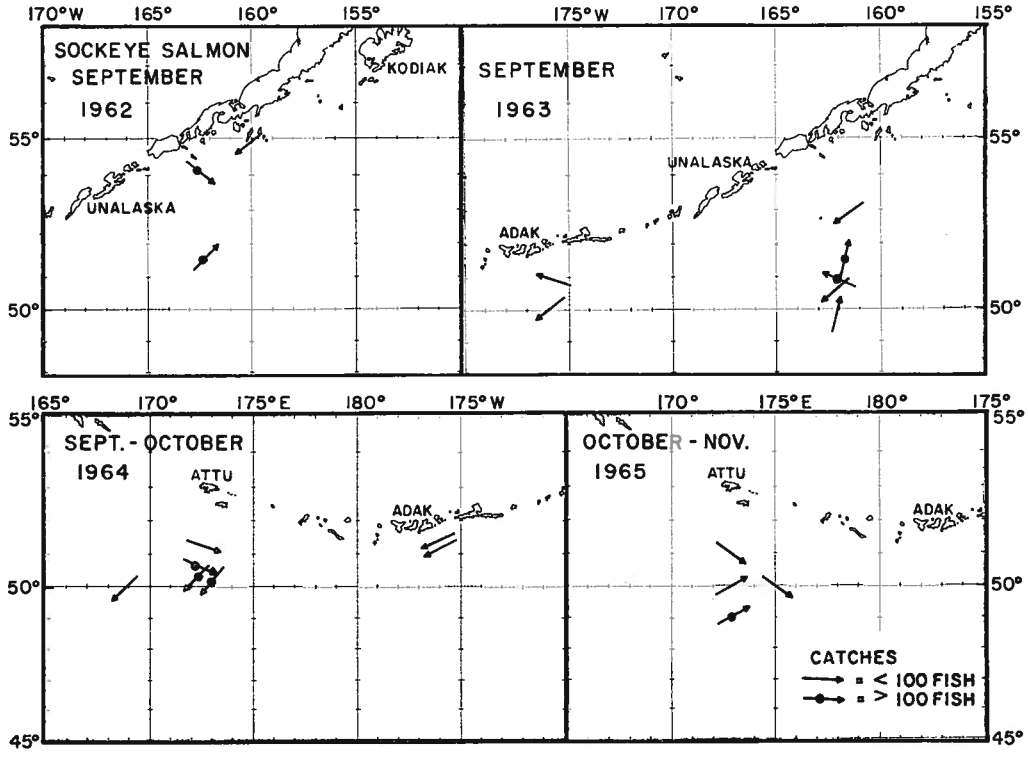

FIGURE 3. Dominant direction of movement of sockeye salmon during September 1962 and 1963; September and October 1964; and October and November 1965.

160°W to 175°E in the North Pacific Ocean. Johnsen's report, however, suggested more northward movement of sockeye salmon in the area south of Attu Island than indicated by the present data. Summer movement of immature sockeye salmon in the North Pacific Ocean between 160°W and 175°E appears to have been reasonably consistent over the past seven years.

Fall. Cruises in the fall were initiated in 1962 (Fig. 3). In September 1962, the catches of immature sockeye salmon between 160°W and 163°W in the North Pacific Ocean evidenced eastward movement in two of three sets; in September 1963 the catches along 162°W showed westward movement in three sets and northeast movement in two, and south of Adak Island movement was westward in two sets.

In September and October 1964, two sets south of Adak Island showed westward movement; four sets along 173°E, between 50°N and 52°N, indicated opposed movement (two southeast, two southwest); and one set at 50°N, 169°E suggested southwest movement.

In October-November 1965, four sets south of Attu Island indicated eastward movement of immature sockeye salmon.

Movement appeared to be more variable in the fall than in the spring and summer. (Fishing was not conducted in the Bering Sea in the fall.)

Winter. In 1962, catches along 155°W in the Gulf of Alaska in February and March showed a pronounced eastward movement (Fig. 4). The catches were composed of immature and maturing (based on age composition) sockeye salmon, but maturing age .3 fish constituted 46% of the total. A single set near Adak Island indicated eastward movement.

In 1963, three sets along 175°E in the western Bering Sea showed southwest movement (Fig. 4); of three sets along 180° in the Bering Sea, two indicated southeast and one southwest movement. Of the three sets in the central North Pacific Ocean, south of 51°N, two showed westward and one southeast movement. Only two sets in the central North Pacific Ocean, along 165°W, contained usable data; these sets suggested opposed movement. Seventy-one percent of the sockeye salmon in the 1963 catches were age .3, which were considered maturing fish.

In 1965, of the six sets in the area from 167°E to 178°W, south of the Alaska Peninsula, five demonstrated eastward movement—four southeast and one northeast—and one showed northwest movement. Maturing fish dominated all sets except one at 46°04'N, 179°E, where the catch was composed pri-

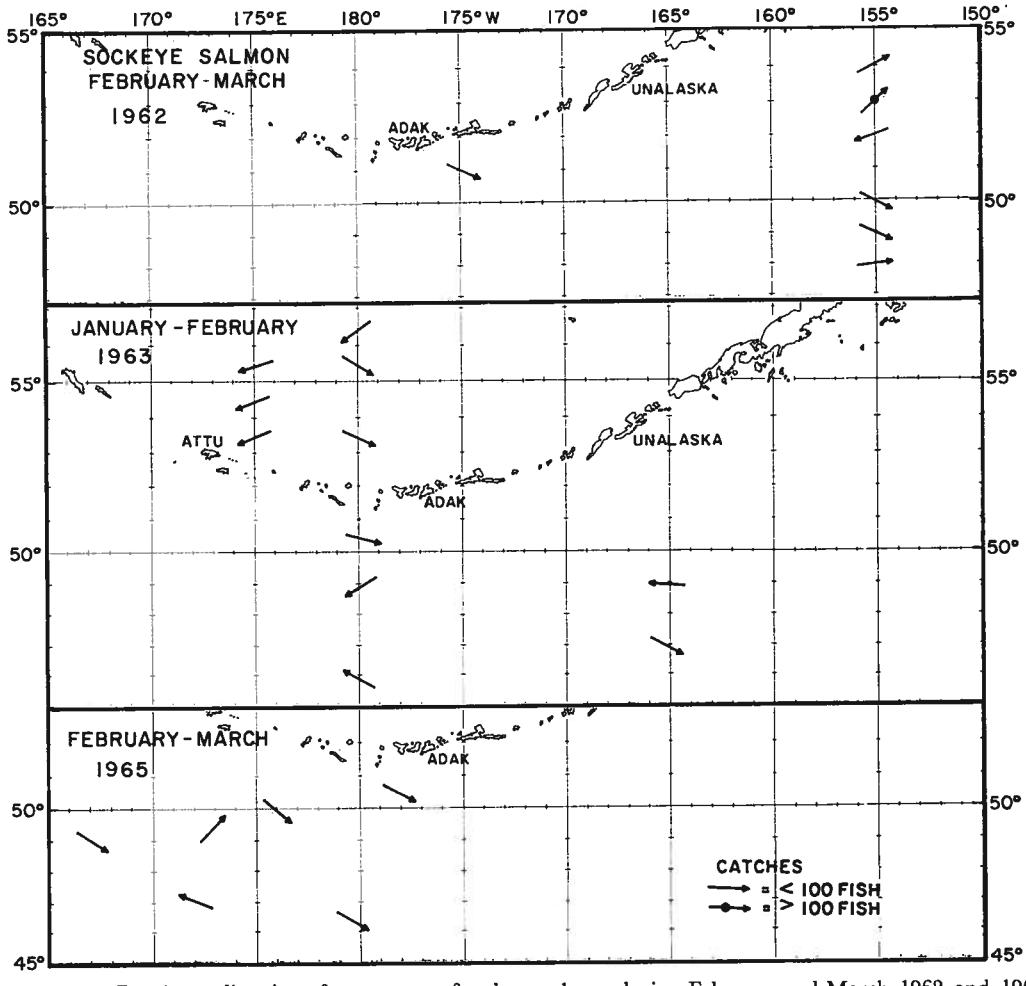

FIGURE 4. Dominant direction of movement of sockeye salmon during February and March 1962 and 1965, and January and February 1963.

marily of immature age .1 fish.

Directions of movement of immature and maturing sockeye salmon in the winter were more consistent than during the fall. South of the Alaska Peninsula, movement tended to be primarily eastward.

Summary of Sockeye Salmon Movement

Although our knowledge of the oceanic migrations of sockeye salmon is far from complete, it is pertinent to summarize what we know of the directions of movement of this species as indicated by surface gillnet catches in 1962–65. Comments on the interpretation of these data and reviews of the recent hypotheses on ocean migrations of this species also are appropriate.

Maturing sockeye salmon in the central and western North Pacific Ocean consistently migrated westward between 160°W and 175°E and possibly as far west as 167°E in May and June (Fig. 1). The eastern boundary of this westward movement is not known. In years of large Bristol Bay returns, such as 1965, however, tagging (Fisheries Research Board of Canada, 1967) has indicated that maturing Bristol Bay sockeye salmon dominate the western Gulf of Alaska in April and May and occur as far east as 140°W. Hence, in some years we may infer that the westward migration from at least 160°W in May and June is composed primarily of maturing Bristol Bay fish. Near 170°E, northward movement suggests entry into the western Bering Sea. In the central Bering Sea, between 180° and 175°W, movement was variable. East of 165°W in the Bering Sea, movement was generally to the northeast, the migrants apparently consisting of maturing sockeye salmon bound for Bristol Bay.

Immature sockeye salmon appeared in catches in the North Pacific Ocean in late June, July, and August. Like the mature ones, these fish evidenced westward movement between 154°W and 170°E ; south of Adak Island (and in 1963 near 162°W), however, movement

was more variable (Fig. 2). West of 170°E, movement of sockeye salmon presumably originating in Asia was to the east. Data on direction of movement in the Bering Sea in the summer were sparse.

Limited data on the direction of movement of immature sockeye salmon in the fall (September-November) indicated that movement in the North Pacific Ocean was variable near 162°W, west near 176°W, and primarily eastward in the area near 173°E (Fig. 3). Winter (January-March) movement of immature and maturing sockeye salmon in the North Pacific Ocean indicated eastward movement between 155°W and 167°E (Fig. 4). In the Bering Sea, movement was west near 175°E and apparently east near 180°.

These data suggest that sockeye salmon in the central and western North Pacific Ocean move primarily west in the spring and summer ; variably in the fall (with a tendency to move eastward at least near 173°E) ; and generally eastward in the winter.

Royce *et al.* (1968) postulated that Bristol Bay sockeye salmon swim downstream actively in the major currents of the North Pacific Ocean and undertake an elongated counterclockwise migration extending from about 165°E to 140°W. They inferred that immature sockeye salmon complete two or three circuits of this migration route before their maturation and subsequent northeastward migration to Bristol Bay to spawn. In general, our data (Figs. 1–4) do not conflict with this hypothesis.

Further hypotheses concerning the relationships between sockeye salmon and their environment have been given by Favorite and McAlister (1966). These authors suggested that mature sockeye salmon are associated with the Alaskan Stream. In particular, they inferred that the ocean distribution of this species is limited by the southern limit of a temperature-minimum stratum at depth and that fluctuations in current systems could cause displacement of stocks, particularly near the terminus of the Alaskan Stream. In a later work, McAlister *et al.* (1969) suggested that in August some immature sockeye salmon may follow the path of recirculating water in the central North Pacific Ocean near 167°W. If true, this theory may help explain the variable direction of movement in certain years and seasons between 160°W and 167°W

TABLE 3. Direction of movement of chum salmon by stage of maturity.

Season, year, and vessel	Set no.	Haul date	Position		Immature				Mature			
			Lat.	Long.	Number caught	Number of fish by direction		Dominant direction (%)	Number caught	Number of fish by direction		Dominant direction (%)
Spring—1962												
(*Bertha Ann*)	4	6/ 3	51–00N	170–00E	15	14NW	1S E	93NW	46	39NW	7S E	85NW
	14	6/25	51–10N	170–41E	21	13S W	8N E	62S W	11	9S W	2N E	82S W
	16	6/27	51–01N	168–00E	10	6S W	4N E	60S W	10	9S W	1N E	90S W
	Subtotal				46	33W	13E	72W	67	57W	10E	85W
	5*	6/ 4	51–28N	173–01E	29	1S W	28N E	97N E	19	2S W	17N E	90N E
	6*	6/ 5	51–00N	176–00E	38	5S	33N	87N	20	8S	12N	60N
	Subtotal				67	6S	61N	91N	39	10S	29N	74N
	8	6/10	50–56N	178–08W	22	10S W	12N E	54N E	10	6S W	4N E	60S W
	9	6/11	50–57N	176–00W	33	22S W	11N E	67S W	32	26S W	6N E	81S W
	Subtotal				55	32W	23E	58W	42	32W	10E	76W
	Total*				101	65W	36E	64W	109	89W	20E	82W
Summer—1962												
(*Kelez*)	1	8/16	55–30N	154–03W	95	67S W	28N E	71S W	20	12S W	8N E	60S W
	2	8/17	54–45N	153–59W	142	91NW	51S E	64NW	11	3NW	8S E	73S E
	Total				237	158W	79E	67W	31	15W	16E	52E
Summer—1963												
(*Bertha Ann*)	33	8/ 6	52–00N	162–00W	84	58NW	26S E	69NW	11	6NW	5S E	55NW
	39	8/12	54–00N	162–00W	230	176S W	54N E	77S W	15	9S W	6N E	60S W
	Subtotal				314	234W	80E	75W	26	15W	11E	58W
	54	8/30	54–00N	162–00W	46	9S W	37N E	80N E	35	2S W	33N E	94N E
	Subtotal				46	9W	37E	80E	35	2W	33E	94E
	Total				360	243W	117E	68W	61	17W	44E	72E

* Sets not included in total.

(Figs. 2 and 3).

It is evident that the causes, timing, and location of the changes in migration behavior of sockeye salmon are, at present, imperfectly understood. Our data, however, do not provide sufficient reason at this stage to reject the hypotheses of either Royce *et al.* (1968) or Favorite and McAlister (1966).

Chum Salmon

Direction of Movement by Stage of Maturity

Catches of chum salmon which contained immature and maturing fish are listed in Table 3. These sets include catches that did not meet the criterion for dominance.

Of the 12 sets that contained immature and maturing fish, only two showed opposed movement. Despite the limited data, the patterns of movement seemed not to differ by stage of maturity or by area and maturity.

Direction of Movement by Age

Catches of immature chum salmon are generally composed of .1, .2, and .3 age fish and occasionally age .4 and .5. Table 4 lists the gillnet catches of .1, .2, and .3 immature chum salmon for 1962–65. Again, this table includes catches of less than 60% dominance to determine if this lack of dominance is due to opposed movement of different age groups.

Comparisons of directions of movement can be made only between .1 and .2 age fish because of the small catches of older fish. Few of these catches indicated opposed movement.

For most of the areas and times sampled, then, .1 and .2 age chum salmon apparently maintained similar movements.

Direction of Movement by Season

Discussed here are movements of chum salmon by season and year. Comparisons are made of spring and summer movements with those reported for previous years.

Spring. Chum salmon catches in May and June of 1962, west of 175°W in the North Pacific Ocean, demonstrated westward movement (Fig. 5). Seven of 10 sets indicated westward movement, with northerly movement suggested near 173°E. A single set in the central Bering Sea suggested southwest travel. Mature fish dominated catches until mid-June when immature ones became more abundant.

In June 1965, sampling south of the Alaska Peninsula between 160°W and 167°W (Fig. 5) suggested that chum salmon were generally moving west. Three of the four sets indicated southwest movement; one set showed a southward direction of travel. In the eastern Bering Sea, movement was north to northeast in two sets, northwest in one and southeastward in one. All fish caught were mature.

Johnsen's (1964) data for the spring of 1959 and 1960, primarily for mature chum salmon, indicated the following directions of movement: westward between 165°W and 175°E, south of the Alaska Peninsula; northward at 175°E, between 47°N and 55°N; north and west (with evidence of limited south and east movement), west of 175°E; and westward in the Bering Sea, west of 175°W. Tagging (Hartt, 1966) indicated that mature Asian chum salmon dominated

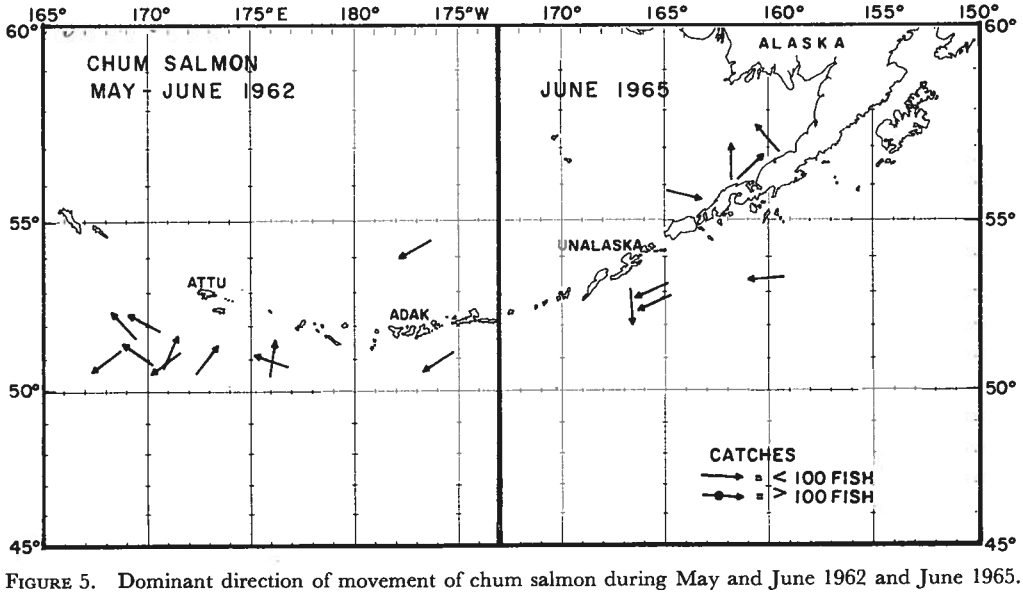

FIGURE 5. Dominant direction of movement of chum salmon during May and June 1962 and June 1965.

TABLE 4. Direction of movement of immature chum salmon by age and area.

Season, year, and vessel	Set no.	Haul date	Position		Age .1				Age .2				Age .3			
			Lat.	Long.	Number caught	Number of fish by direction		Dominant direction (%)	Number caught	Number of fish by direction		Dominant direction (%)	Number caught	Number of fish by direction		Dominant direction (%)
Summer/Fall—1962																
(*Bertha Ann*)	22	7/14	51-50N	167-00W	5	4S W	1N E	80S W	58	45S W	13N E	78S W	18	16S W	2N E	89S W
	23	7/15	52-20N	166-58W	12	8NW	4S E	67NW	44	33NW	11S E	75NW	16	10NW	6S E	63NW
	44	8/27	52-14N	157-00W	27	21NW	6S E	78NW	34	26NW	8S E	77NW	2	1NW	1S E	—
	47	8/30	54-00N	157-00W	19	14S W	5N E	74S W	11	10S W	1N E	91S W	0	0	0	—
	49	9/ 2	55-32N	152-00W	101	86NW	15S E	85NW	53	44NW	9S E	83NW	2	1NW	1S E	—
	Total				164	133W	31 E	81W	200	158W	42 E	79W	38	28W	10 E	74W
Summer/Fall—1962																
(*Kelez*)	2	8/17	54-45N	153-59W	88	25NW	63S E	72S E	54	26NW	28S E	52S E	0	0	0	—
	3	8/18	54-00N	154-00W	111	93S W	18N E	84S W	109	43S W	66N E	61N E	2	0	2N E	100N E
	5	8/20	52-30N	154-00W	31	18NW	13S E	58NW	19	11NW	8S E	58NW	0	0	0	—
	6	8/22	51-45N	154-00W	29	23NW	6S E	79NW	42	36NW	6S E	86NW	1	1NW	0	100NW
	Subtotal				259	159W	100 E	61W	224	116W	108 E	52W	3	1W	2E	67 E
	15	9/ 7	54-00N	160-00W	46	28S W	18N E	61S W	56	18S W	38N E	68N E	7	0	7N E	100N E
	Subtotal				46	28W	18 E	61W	56	18W	38 E	68 E	7	0	7 E	100 E
	21	9/16	51-45N	162-59W	20	4S W	16N E	80N E	119	9S W	110N E	92N E	11	1S W	10N E	91N E
	22	9/17	52-30N	162-59W	31	10S W	21N E	68S E	121	51NW	70S E	58S E	13	5NW	8S E	62S E
	Subtotal				51	14W	37E	73E	240	60W	180E	75E	24	6W	18E	75E
	Total				356	201W	155E	57W	520	194W	326E	63E	34	7W	27E	79E
Summer—1963																
(*Kelez*)	20	7/18	51-22N	176-24W	18	7S W	11N E	61N E	17	13S W	4N E	77S W	6	5S W	1N E	83S W
	32	8/11	51-28N	176-19W	41	40S W	1N E	98S W	30	27S W	3N E	90S W	0	0	0	—
	37	8/18	51-25N	176-24W	72	14NW	58S E	81S E	62	14NW	48S E	77S E	2	0	2S E	100S E
	41	8/23	51-28N	176-23W	16	12NW	4S E	75NW	45	36NW	9S E	80NW	2	2NW	0	100NW
	46	8/30	51-22N	176-22W	22	14NW	8S E	64NW	56	30NW	26S E	54NW	9	5NW	4S E	56NW
	Total				169	87W	82E	52W	210	120W	90E	57W	19	12W	7E	63W
Summer/Fall—1963																
(*Bertha Ann*)	19	7/23	53-00N	162-00W	11	10S W	1N E	91S W	11	8S W	3N E	73S W	3	1S W	2N E	67N E
	24	7/28	50-30N	162-00W	15	12S W	3N E	80S W	24	22S W	2N E	92S W	3	3S W	0	100S W
	25	7/29	51-31N	162-02W	15	12NW	3S E	80NW	74	66NW	8S E	89NW	3	2NW	1S E	67NW
	26	7/30	52-30N	162-00W	16	15NW	1S E	94NW	24	19NW	5S E	79NW	0	0	0	—
	31	8/ 4	52-30N	160-00W	28	3NW	25S E	89S E	26	8NW	18S E	69S E	2	1NW	1S E	—
	32*	8/ 5	51-30N	162-00W	10	6N	4S	60N	29	11N	18S	62S	1	1N	0	100N
	33	8/ 6	52-00N	162-00W	17	4NW	13S E	77S E	65	21NW	44S E	68S E	2	1NW	1S E	—
	34	8/ 7	52-20N	162-00W	30	23S W	7N E	77S W	91	72S W	19N E	79S W	5	5S W	0	100S W
	35*	8/ 8	52-40N	162-00W	14	9N	5S	64N	20	13N	7S	65N	1	1N	0	100N

	36	8/ 9	53–00N	162–00W	21	18NW	3 S E	86NW	61	45NW	16 S E	74NW	2	1NW	1 S E	100NW
	37	8/10	53–20N	162–00W	25	12 S W	13N E	52N E	73	49 S W	24N E	67 S W	1	1 S W	0	100 S W
	38	8/11	53–40N	162–00W	11	7 S W	4N E	64 S W	38	18 S W	20N E	53N E	2	2 S W	0	100 S W
	39	8/12	54–00N	162–00W	103	81 S W	22N E	79 S W	112	87 S W	25N E	78 S W	8	4 S W	4N E	—
	41	8/16	53–40N	162–00W	19	10 S W	9N E	53 S W	37	19 S W	18N E	51 S W	0	0	0	—
	42	8/17	53–00N	161–59W	13	9NW	4 S E	69NW	32	15NW	17 S E	53 S E	4	2NW	2 S E	—
	45	8/20	51–00N	162–00W	10	8 S W	2N E	80 S W	37	22 S W	15N E	60 S W	7	5 S W	2N E	71 S W
	49	8/25	50–40N	162–00W	29	22NW	7 S E	76NW	55	30NW	25 S E	55NW	5	3NW	2 S E	60NW
	52	8/28	52–40N	162–00W	25	19NW	6 S E	76NW	21	19NW	2 S E	91NW	2	2NW	0	100NW
	59	9/ 6	50–00N	162–00W	39	24 S W	15N E	62 S W	19	1 S W	18N E	95N E	2	0	2N E	100N E
	61	9/ 8	50–30N	162–00W	10	7 S W	3N E	70 S W	29	6 S W	23N E	79N E	3	2 S W	1N E	67 S W
	62	9/ 9	51–30N	162–00W	12	8 S W	4N E	67 S W	32	25 S W	7N E	78 S W	4	2 S W	2N E	—
	Total*				449	304W	145 E	68W	861	552W	309 E	64W	60	39W	21 E	65W
Fall—1964																
(*Kelez*)	6	9/30	50–10N	173–00 E	23	22 S W	1N E	96 S W	94	85 S W	9N E	90 S W	4	4 S W	0	100 S W
	7	10/ 2	50–10N	173–00 E	11	8 S W	3N E	73 S W	37	25 S W	12N E	68 S W	1	1 S W	0	100 S W
	9	10/ 8	49–56N	168–52 E	21	1 S W	20N E	95N E	107	22 S W	85N E	79N E	12	2 S W	10N E	83N E
	Total				55	31W	24 E	56W	238	132W	106 E	56W	17	7W	10 E	59 E
Fall—1965																
(*Kelez*)	2	10/ 4	51–16N	172–58 E	3	1NW	2 S E	67 S E	18	3NW	15 S E	83 S E	16	3NW	13 S E	81 S E
	3	10/ 5	50–19N	173–00 E	0	0	0	—	12	6 S W	6N E	—	20	15 S W	5N E	75 S W
	4	10/ 6	49–15N	172–58 E	0	0	0	—	21	15 S W	6N E	71 S W	7	5 S W	2N E	71 S W
	Total				3	1W	2 E	67 E	51	24W	27 E	53 E	43	23W	20 E	53W

* Sets not included in total.

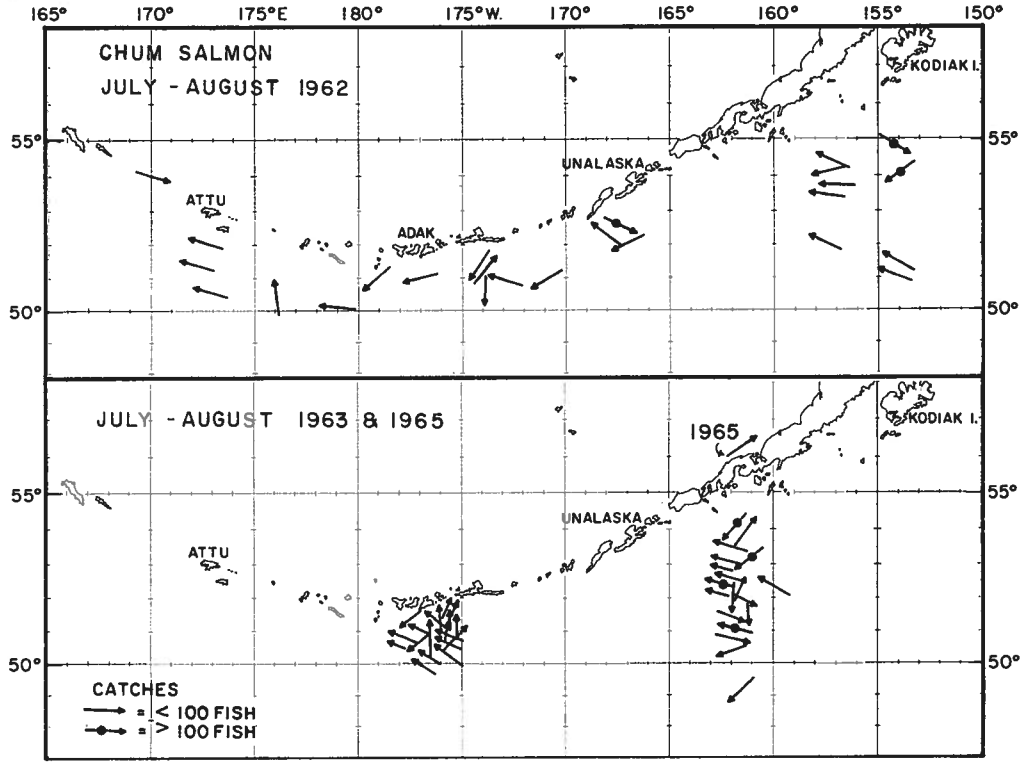

FIGURE 6. Dominant direction of movement of chum salmon during July and August 1962, 1963, and 1965.

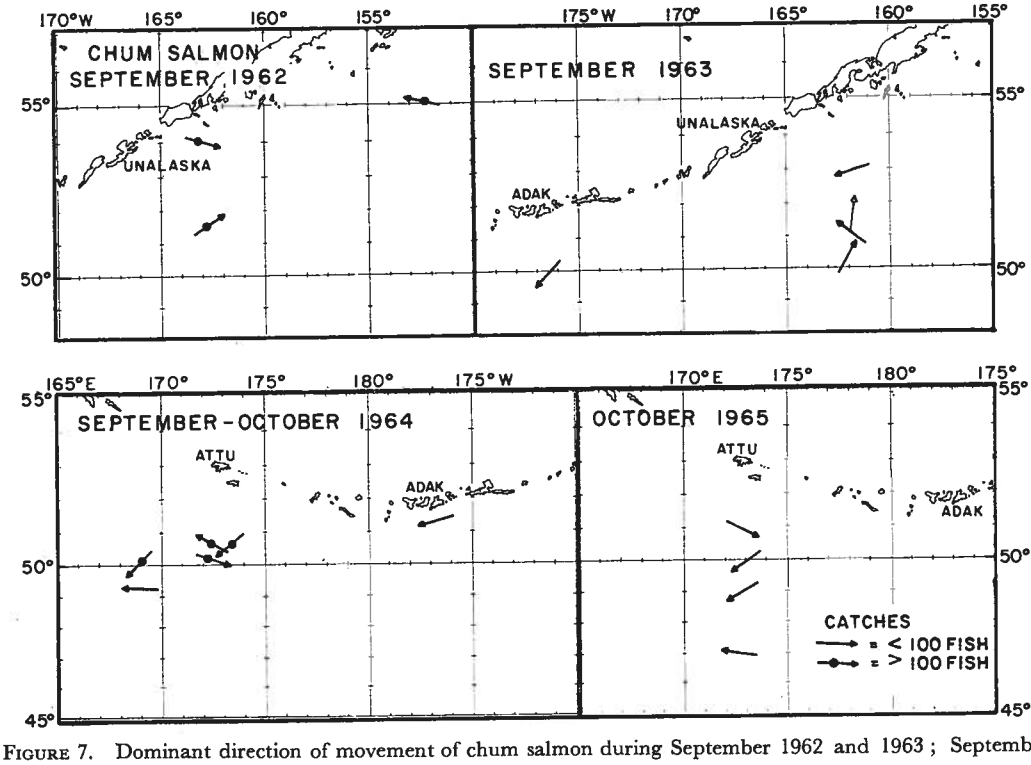

FIGURE 7. Dominant direction of movement of chum salmon during September 1962 and 1963; September and October 1964; and October 1965.

the area west of 175°W in the Bering Sea and in the North Pacific Ocean. We should expect, then, that these westward moving chum salmon west of 175°W were probably of Asian origin.

Summer. Movement of chum salmon in July and August is presented in Figure 6. Sampling extended from 154°W to 170°E in the Gulf of Alaska and North Pacific Ocean.

In 1962 movement of chum salmon was westward in eight of nine sets between 154°W and 157°W and in two of three sets between 165°W and 170°W; primarily southwest (although individual sets showed northeast, south, and west directions) in the central North Pacific Ocean between 170°W and 180°; and variable (primarily westward, but single sets indicated eastward and northward movement) between 180° and 170°E. Over 95% of the chum salmon in these catches were immature.

In 1963 the direction of movement of immature chum salmon varied considerably along 162°W (between 49°N and 54°N) where 12 of 19 sets showed westward movement, and south of Adak Island, where only 11 of 19 sets indicated westward travel. Catches consisted almost entirely of immature fish.

A single set in the eastern Bering Sea in July 1965 suggested northeast movement.

When the data from the summers of 1962–65 are compared with the 1959–61 data from Johnsen (1964) and Larkins (1964b), the same general westward movement is evident between 160°W and 175°W. The variation in direction of movement along 162°W in 1963 was not evident in previous years, but variation was present south of Adak in 1959–61 and in 1963.

Fall. In September 1962, observations on the movement of chum salmon were limited to three sets in the central North Pacific Ocean and Gulf of Alaska (Fig. 7). One set south of Kodiak Island indicated westward movement, whereas two sets south of the Alaska Peninsula along 163°W showed eastward migration. All three catches were of more than 100 fish and were composed primarily of immature chum salmon.

In September 1963, four catches along 162°W indicated variable movement: two west, one north, and one northeast. Again, immature fish were dominant. A single catch at 50°N near Adak Island suggested southwest travel (Fig. 7).

Another single catch south of Adak Island in September 1964, exhibited southwest movement. Farther west, between 169°E and 173°E, four of the five sets in late September and early October indicated westward movement. Immature fish dominated all catches (Fig. 7).

In October 1965, along 173°E, the principal direction of movement shown was southwest for two sets, westward for one, and southeast for one (Fig. 7). These catches were primarily of immature fish.

Winter. In April 1962, two sets in the Gulf of Alaska indicated westward movement of .2 and. 3 age chum salmon. In February 1963 three sets along 180° contained .3 and .4 age fish; two catches indicated movement to the west, whereas one set showed movement to the northeast (Fig. 8).

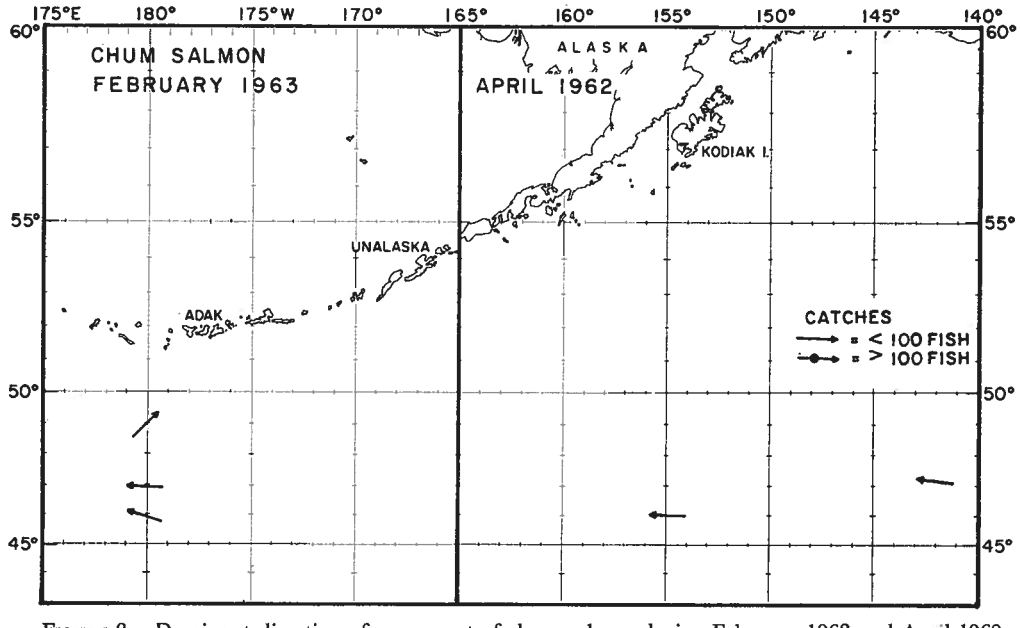

FIGURE 8. Dominant direction of movement of chum salmon during February 1963 and April 1962.

Summary of Chum Salmon Movement

In May and June, maturing chum salmon in the central and western North Pacific Ocean generally moved to the west in an area between 160°W and 168°E, but northward near 173°E (suggesting movement into the western Bering Sea). In the Bering Sea, a single set near 177°W suggested westward movement, whereas east of 165°W, movement tended to be northerly or easterly (Fig. 5).

In the summer, movement of immature chum salmon in the North Pacific Ocean also was generally to the west between 154°W and 173°E, but variable south of Adak Island and near 162°W. A single set in the eastern Bering Sea suggested eastward movement (Fig. 6).

In the fall, movement appeared to be variable near 162°W, but predominantly westward west of 175°W (Fig. 7). Winter movement appeared to be to the west, although the data are limited to five sets south of 50°N, between 142°W and 180° (Fig. 8).

Chum salmon data, then, are inadequate to define the migration pattern of this species throughout the year.

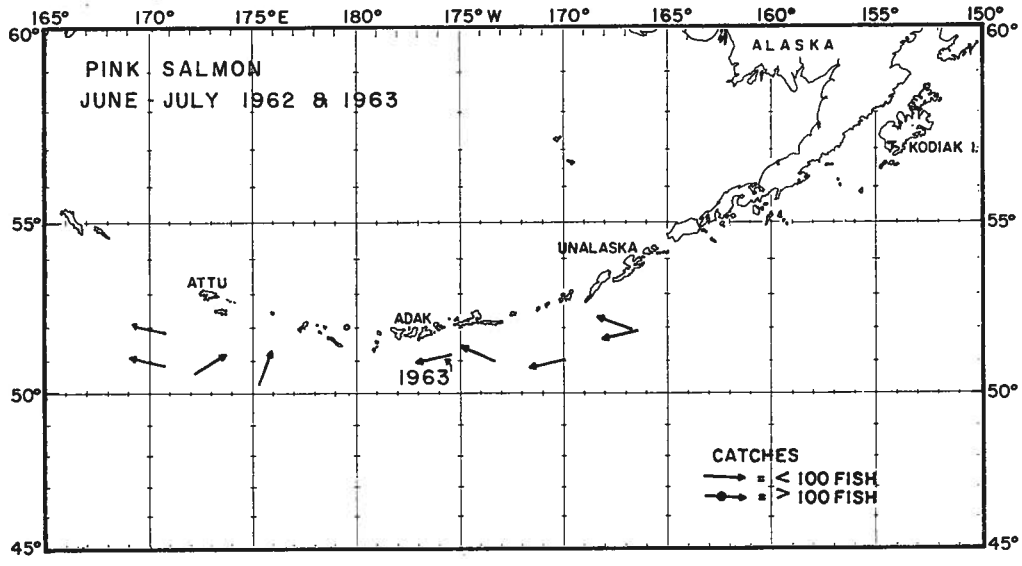

FIGURE 9. Dominant direction of movement of pink salmon during June and July 1962 and 1963.

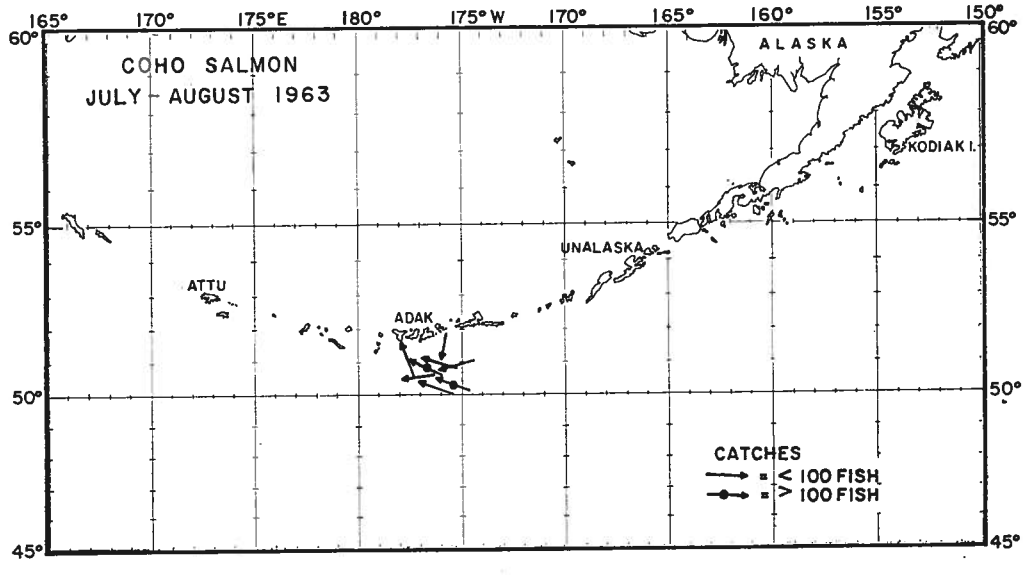

FIGURE 10. Dominant direction of movement of coho salmon during July and August 1963.

Pink Salmon

Few pink salmon were captured by our research vessels in 1962–65; these catches have been mainly of mature fish.

Of eight catches of mature pink salmon in 1962, all were captured in June and July (Fig. 9). Four sets in the central North Pacific Ocean between 167°W and 175°W showed westward movement. Two sets near 175°E showed northeast movement and two sets along 170°E indicated northwest movement.

A single set south of Adak Island in July 1963 suggested westward movement (Fig. 9).

Coho Salmon

Coho salmon generally are not captured in abundance during our research cruises. The only large catches of this species were made in July and August 1963 south of Adak Island (Fig. 10) and were mature fish. Directions of movement were northwest in four sets, southwest in two, north in one, and south in one.

CONCLUSIONS

1. Sockeye salmon
   a. Movement of sockeye salmon differed by stage of maturity south of Adak Island in July and August 1963. Most immature sockeye salmon moved westward and mature ones (of unknown origin) eastward.
   b. For most areas and times sampled, age .1 and age .2 immature sockeye salmon maintained similar directions of movement.
   c. In May and June, mature sockeye salmon moved primarily eastward in the eastern Bering Sea. In the central North Pacific Ocean, movement was predominantly westward between 160°W and 180°; and primarily west and northwest in the western North Pacific Ocean between 180° and 167°E.
   d. In summer, movement of immature sockeye in the North Pacific Ocean was westward from the Gulf of Alaska to 175°W; was variable south of Adak Island and (in 1963) near 162°W; tended to be northwestward between 180° and 170°E; and was southeastward in the area west of 170°E.
   e. In the fall, movement of immature sockeye salmon was more variable than in the summer, particularly near 162°W. South of Adak Island movement was to the west, and between 176°E and 171°E it was primarily to the east. In the winter, immature and maturing sockeye salmon in the central North Pacific Ocean and Gulf of Alaska moved predominantly eastward; along 180° movement was primarily eastward in the Bering Sea and in the North Pacific Ocean; and west of 180°, movement was southwest in the Bering Sea and primarily eastward in the North Pacific Ocean.
   f. Data on direction of movement suggest that sockeye salmon in the North Pacific Ocean move west in the spring and summer, variably in the fall, and primarily eastward in the winter. The hypotheses on migrations of sockeye salmon proposed by Royce *et al.* (1968) and Favorite and McAlister (1966) were not rejected on the basis of these data.
2. Chum salmon
   a. Direction of movement of chum salmon did not differ among fish of different stages of maturity or (for most areas) of different ages.
   b. In the spring, mature chum salmon moved primarily westward in the central and western North Pacific Ocean, except near 173°E where northward movement was suggested. Movement was eastward or northward in the eastern Bering Sea. In the summer, immature chum salmon generally exhibited westward movement between 154°W and 173°E, although in some years movement was variable south of Adak Island and near 162°W.
   c. Fall catches consisted primarily of immature chum salmon; movement in the central North Pacific Ocean was variable and generally was westward in the western North Pacific Ocean. Limited winter catches of older chum salmon in the Gulf of Alaska and central North Pacific Ocean generally showed westward movement.
3. Pink salmon
   Limited catches of mature pink salmon in the central and western North Pacific Ocean in June and July of 1962 and 1963 indicated a general westward movement.
4. Coho salmon
   Catches of mature coho salmon in July and August 1963 displayed westward (although somewhat variable) movement near Adak Island.

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APPENDIX TABLES

APPENDIX TABLE 1. Assignment of direction of movement to sockeye salmon, 1962–65.

Season, year, and vessel	Set no.	Haul date	Position		Catch by side of net		Total catch	Percent direction	Direction of haul	Individual net variation	Net swing	Dominant direction of movement		Immature		Mature		Percent mature
			Lat.	Long.	L	R						Degrees	Compass	N	%	N	%	
Winter—1962																		
(*Bertha Ann*)	1	2/10	51–03N	174–56W	20	2	22	91L	034	070	011	124	S E	Incomplete maturity data				
	12	3/20	54–00N	155–00W	7	12	20	63R	150	0	015	060	N E	"		"	"	
	13	3/22	53–00N	155–00W	151	24	177	86L	290	0	020	020	N N E	"		"	"	
	14	3/24	52–00N	155–00W	3	10	13	77R	310	0	022	220	S W	"		"	"	
	16	3/26	50–00N	155–00W	19	48	74	72R	228	070	025	138	S E	"		"	"	
	17	3/28	49–00N	155–00W	16	45	63	74R	235	050	010	145	S E	"		"	"	
	18	3/29	48–00N	155–00W	12	8	20	60L	352	080	008	082	E	"		"	"	
Spring—1962																		
(*Bertha Ann*)	1	5/30	51–04N	170–59E	13	1	14	93L	197	025	063	287	N W	2	100L	12	92L	86
	2	6/ 1	52–00N	170–12E	38	12	50	76L	215	030	005	305	N W	0	0	50	76L	100
	4	6/ 3	51–00N	170–00E	60	29	89	67L	238	015	002	328	N W	4	75L	80	68L	95
	5	6/ 4	51–28N	173–01E	28	5	33	85L	314	020	004	044	N E	0	0	33	85L	100
	8	6/10	50–56N	178–08W	15	26	41	63R	290	030	020	200	S W	10	60R	28	71R	74
	9	6/11	50–57N	176–00W	26	64	90	71R	316	080	044	226	S W	35	74R	45	71R	56
	10	6/16	54–01N	177–07W	3	65	68	96R	164	010	029	074	E N E	0	0	67	95R	100
	12	6/19	53–28N	175–57W	1	38	39	97R	199	060	089	289	N W	0	0	35	97R	100
	14	6/25	51–10N	170–41E	56	18	74	76L	133	020	027	223	S W	33	70L	39	80L	54
	15	6/26	50–58N	170–05E	25	13	38	66L	113	010	003	203	S W	25	64L	12	67L	32
	16	6/27	51–01N	168–00E	23	7	30	77L	133	030	017	223	S W	11	55R	18	94L	62
	17	6/28	50–53N	171–11E	76	21	97	78L	266	050	041	356	N	54	85L	37	68L	41
Summer—1962																		
(*Bertha Ann*)	20	7/ 2	51–00N	177–00W	41	125	166	75R	327	030	027	237	S W	122	80R	41	63R	25
	21	7/12	52–52N	167–07W	6	46	736	89R	254	060	016	164	S S E	34	91R	9	67R	21
	22	7/14	51–50N	167–00W	57	320	377	85R	330	030	0	240	S W	358	86R	9	56R	2
	23	7/15	52–20N	166–58W	24	84	108	78R	058	020	032	328	N W	93	76R	6	100R	6
	24	7/17	51–00N	170–52W	19	88	107	82R	324	030	006	234	S W	98	84R	3	100L	3
	27	7/21	51–30N	173–55W	54	125	179	70R	284	030	014	194	S W	161	72R	8	50R	5
	28	7/22	51–00N	173–54W	63	40	103	61L	287	020	017	017	N E	98	62L	2	100L	2
	30	7/24	51–04N	174–02W	251	121	372	68L	194	030	014	284	N W	352	67L	6	67L	2
	31	7/25	51–33N	174–04W	171	69	240	71L	227	090	047	317	N W	217	76L	18	67R	8
	33	8/ 4	50–50N	179–00E	255	47	302	84L	152	010	017	242	S W	290	85L	1	100L	<1
	34	8/ 8	50–19N	178–59E	190	17	207	92L	183	090	023	273	W	197	91L	1	100L	<1
	36	8/10	50–41N	175–54E	95	29	124	77L	261	040	041	351	N	121	76L	0	—	0
	37	8/11	51–57N	172–50E	241	26	267	90L	191	050	011	281	N W	258	90L	0	—	0
	38	8/13	51–23N	172–53E	292	12	304	96L	217	030	037	307	N W	300	96L	0	—	0
	39	8/14	50–53N	173–00E	148	24	172	86L	240	030	060	330	N W	169	87L	0	—	0
	40	8/15	52–21N	170–00E	34	6	40	85L	184	010	004	274	W	36	83L	0	—	0

	41	8/18	53-00N	166-00E	45	15	60	75L	011	070	041	101	SE	55	76L	2	100L	3
	42	8/19	53-50N	169-45E	18	7	25	72L	035	010	005	125	SE	24	71L	1	100L	4
	43	8/20	53-25N	173-17E	12	2	14	86L	354	030	040	086	E	13	85L	0	—	0
	44	8/27	52-14N	157-00W	70	27	97	72L	240	020	020	330	NW	88	71L	0	—	0
	45	8/28	52-45N	157-00W	45	10	55	82L	218	050	038	308	NW	53	81L	0	—	0
	46	8/29	53-30N	157-00W	32	7	39	82L	201	030	051	291	NW	36	81L	0	—	0
	47	8/30	54-00N	157-00W	8	16	24	67R	299	090	029	209	SW	24	67R	0	—	0
Summer/Fall—1962																		
(*George B.*	3	8/18	54-00N	154-00W	19	9	31	68L	130	035	045	220	SW	25	76L	2	100R	7
Kelez)	6	8/22	51-45N	154-00W	106	14	127	88L	242	040	082	332	NW	119	88L	0	0	0
	12	8/29	53-35N	156-59W	44	5	49	90L	183	040	023	273	W	47	89L	0	0	0
	13	8/30	54-01N	156-48W	15	7	22	68L	251	090	019	341	NW	21	71L	0	0	0
	15	9/ 7	54-00N	160-00W	22	37	60	63R	278	045	008	188	SW	57	61R	0	0	0
	21	9/16	51-45N	162-59W	136	81	219	63L	347	015	013	077	NE	181	64L	1	100L	<1
	22	9/17	52-30N	162-59W	71	124	200	64R	194	045	031	104	SE	144	63R	1	100L	<1
Winter—1963																		
(*Bertha Ann*)	2	1/29	53-27N	179-53E	21	13	34	62L	053	020	003	143	SE	Incomplete maturity data				
	4	2/ 1	55-30N	179-58E	31	5	36	86L	066	030	014	156	SE	»	»	»		
	6	2/ 4	56-25N	175-28E	53	24	78	69L	102	040	032	192	SW	»	»	»		
	8	2/ 6	55-29N	174-50E	32	5	37	87L	119	020	019	209	SW	»	»	»		
	9	2/ 7	54-26N	174-57E	13	4	17	77L	116	060	009	206	SW	»	»	»		
	10	2/ 8	53-28N	175-14E	21	3	24	88L	119	020	001	209	SW	»	»	»		
	11	2/16	50-52N	179-31W	41	12	53	77L	032	030	032	122	SE	»	»	»		
	13	2/18	48-57N	179-45W	13	21	34	62R	292	030	022	202	SW	»	»	»		
	16	2/21	45-55N	180	1	13	14	93R	031	070	021	301	NW	»	»	»		
Winter—1963																		
(*George B.*	5	2/19	49-00N	165-02W	4	10	14	71R	359	070	060	269	W	Incomplete maturity data				
Kelez)	6	2/20	47-30N	165-00W	12	1	13	92L	045	000	045	135	SE	»	»	»		
Summer/Fall—1963																		
(*George B.*	13	7/ 7	51-17N	176-25W	4	32	38	89R	268	060	020	178	S	30	90R	6	83R	17
Kelez)	19	7/17	51-14N	176-17W	61	100	161	62R	278	070	027	188	S	131	73R	30	83L	19
	20	7/18	51-22N	176-24W	289	57	356	84L	158	070	008	248	SW	330	85L	16	56R	5
	21	7/19	50-30N	176-20W	33	9	42	79L	219	020	019	309	NW	39	80L	3	67L	7
	22	7/20	50-55N	176-22W	185	34	222	85L	223	040	018	313	NW	211	87L	8	75R	4
	25	7/29	51-35N	176-22W	48	23	72	68L	204	040	054	294	NW	64	73L	7	86R	10
	27	7/31	50-54N	176-19W	146	43	189	77L	140	015	040	230	SW	178	82L	11	91R	6
	29	8/ 3	50-28N	176-20W	213	35	250	86L	237	070	017	327	NW	247	86L	1	100L	2
	30	8/ 4	51-04N	176-20W	267	62	330	81L	268	030	043	358	N	321	81L	8	75L	2
	32	8/11	51-28N	176-19W	291	41	333	88L	112	050	028	202	SW	312	93L	20	95R	6
	34	8/13	50-34N	176-19W	68	35	104	66L	251	050	006	341	NW	102	66L	0	—	0
	36	8/15	50-47N	176-18W	10	6	18	63L	180	0	015	270	W	15	60L	0	—	0
	42	8/26	51-20N	176-19W	7	27	35	79R	080	0	035	350	N	34	79R	0	—	0

Continued . . .

APPENDIX TABLE 1. Continued.

Season, year, and vessel	Set no.	Haul date	Position		Catch by side of net		Total catch	Percent direction	Direction of haul	Individual net variation	Net swing	Dominant direction of movement		Immature		Mature		Percent mature
			Lat.	Long.	L	R						Degrees	Compass	N	%	N	%	
	46	8/30	51–22N	176–22W	10	29	39	74R	074	020	034	344	NW	39	74R	0	—	0
	47	8/31	51–16N	176–22W	45	28	73	62L	306	010	024	036	NE	44	57R	29	90L	40
	48	9/ 1	50–52N	176–22W	13	6	23	68L	235	070	025	325	NW	19	68L	0	—	0
	49	9/ 2	50–01N	176–19W	26	16	47	62L	130	060	015	220	SW	40	60L	2	100L	5
Summer/Fall—1963																		
(*Bertha Ann*)	19	7/23	53–00N	162–00W	134	35	169	79L	220	0	0	310	NW	168	79L	1	100L	1
	20	7/24	51–59N	162–04W	30	47	77	61R	275	0	0	185	S	72	63R	5	60L	6
	24	7/28	50–30N	162–00W	35	9	44	80L	157	020	003	247	SW	44	80L	0	—	0
	25	7/29	51–31N	162–02W	254	33	287	89L	200	025	030	290	NW	279	89L	7	86L	2
	26	7/30	52–30N	162–00W	20	9	29	69L	225	075	045	315	NW	22	77L	7	57R	24
	27	7/31	53–30N	162–00W	32	10	42	76L	220	035	020	310	NW	31	77L	11	73L	26
	30	8/ 3	53–30N	160–00W	10	4	14	71L	276	080	026	006	N	8	75L	6	67L	43
	32	8/ 5	51–30N	162–00W	29	130	159	82R	270	025	010	180	S	155	83R	4	50L	2
	34	8/ 7	52–20N	162–00W	19	79	98	81R	321	035	025	231	SW	94	82R	4	50L	4
	35	8/ 8	52–40N	162–00W	32	17	49	65L	269	020	011	359	N	42	60L	7	100L	14
	37	8/10	53–20N	162–00W	35	18	53	66L	130	025	040	220	SW	47	68L	6	50L	11
	38	8/11	53–40N	162–00W	10	4	14	71L	115	030	015	205	SW	13	69L	1	100L	7
	39	8/12	54–00N	162–00W	32	51	83	61R	108	025	007	018	N	20	95L	63	79R	76
	41	8/16	53–40N	162–00W	18	6	24	75L	175	035	010	265	W	19	68L	5	100L	21
	42	8/17	53–00N	161–59W	14	9	23	61L	191	050	006	281	W	19	63L	4	50L	17
	44	8/19	51–40N	162–00W	15	51	66	77R	014	025	034	284	W	66	77R	0	—	0
	45	8/20	51–00N	162–00W	145	55	200	73L	125	070	005	215	SW	199	72L	1	100L	<1
	46	8/21	50–20N	162–00W	50	23	73	69L	164	025	001	254	SW	23	100R	50	100L	69
	47	8/22	49–40N	162–00W	46	8	54	85L	176	089	016	266	W	54	85L	0	—	0
	49	8/25	50–40N	162–00W	52	91	143	64R	002	025	058	272	W	143	64R	0	—	0
	50	8/26	51–20N	162–00W	92	40	132	70L	060	080	060	150	SE	128	71L	1	100L	<1
	51	8/27	52–00N	162–00W	25	12	37	68L	073	080	017	163	SE	36	69L	1	100R	3
	58	9/ 5	51–00N	162–00W	149	44	193	77L	239	030	009	329	NW	193	77L	0	—	0
	59	9/ 6	50–00N	162–00W	21	9	30	70L	278	055	008	008	N	30	70L	0	—	0
	61	9/ 8	50–30N	162–00W	15	29	44	66R	300	070	010	210	SW	44	66R	0	—	0
	62	9/ 9	51–30N	162–00W	387	96	484	80L	288	060	022	018	N	483	80L	0	—	0
	63	9/10	53–02N	162–04W	10	3	13	77L	127	020	007	217	SW	13	77L	0	—	0
Fall—1964																		
(*George B. Kelez*)	1	9/ 2	51–33N	176–18W	42	21	74	67L	119	030	051	209	SW	63	67L	2	50L	3
	2	9/ 5	51–33N	176–18W	50	23	73	68L	135	0	0	225	SW	73	69L	0	—	0
	4	9/27	51–10N	173–00E	11	33	47	75R	210	0	008	120	SE	44	75R	0	—	0
	5	9/29	50–10N	173–00E	7	135	148	90R	240	060	018	150	SE	143	95R	0	—	0
	6	9/30	50–10N	173–00E	15	112	127	88R	302	025	013	212	SW	126	88R	1	100R	<1

	7	10/ 2	50–10N	173–00E	30	154	185	84R	290	0	025	200	SW	182	84R	2	50L	1
	9	10/ 8	50–00N	169–00E	6	14	22	70R	310	0	040	220	SW	20	70R	0	—	0
Winter—1965																		
(*George B.*	6	2/22	49–12N	167–18E	27	15	42	64L	070	070	025	160	SE	0	—	42	64L	100
Kelez)	11	3/ 1	47–12N	172–39E	25	9	34	74L	197	065	040	287	W	11	55R	17	77L	61
	12	3/ 2	49–34N	173–10E	4	11	15	73R	148	090	013	058	NE	0	—	15	80R	100
	13	3/ 3	50–02N	176–15E	1	18	19	95R	243	068	027	153	SE	0	—	19	95R	100
	21	3/16	46–40N	179–30E	46	14	60	77L	029	045	061	119	SE	48	75L	6	67L	11
	23	3/18	50–18N	178–12W	19	54	73	74R	233	068	008	143	SE	0	—	67	72R	100
Spring/Summer—1965																		
(*George B.*	1	6/ 6	53–23N	166–00W	15	8	24	65L	108	NA	NA	198	SW	0	—	24	65L	100
Kelez)	8	6/14	53–07N	166–37W	92	151	268	62R	335	NA	NA	245	SW	0	—	268	62R	100
	9	6/15	52–55N	167–43W	108	220	363	67R	352	NA	NA	262	SW	0	—	363	67R	100
	13	6/22	55–50N	164–00W	16	165	183	91R	246	0	015	156	SE	0	—	183	91R	100
	14	6/23	56–10N	162–31W	62	42	109	60L	270	0	010	360	N	0	—	109	60L	100
	15	6/25	57–01N	159–58W	96	270	367	74R	083	0	006	353	N	0	—	367	74R	100
	17	6/27	57–21N	159–22W	90	360	450	80R	115	NA	0	025	NE	0	—	450	80R	100
	21	7/ 2	56–24N	162–00W	110	72	186	60L	336	0	0	066	NE	0	—	186	60L	100
Spring—1965																		
(*Paragon*)	1	6/ 1	53–43N	160–44W	31	20	51	61L	139	NA	NA	229	SW	0	—	51	61L	100
	2	6/ 4	53–23N	166–01W	26	3	29	90L	090	NA	NA	180	S	0	—	29	90L	100
	4	6/ 8	53–26N	165–57W	130	320	488	71R	309	NA	NA	219	SW	0	—	450	71R	100
	5	6/10	53–18N	166–00W	25	47	79	65R	360	NA	NA	270	W	0	—	72	65R	100
	7	6/12	52–52N	166–12W	15	32	52	68R	315	NA	NA	225	SW	0	—	47	68R	100
	9	6/15	52–57N	167–41W	79	123	374	61R	340	NA	NA	250	SW	0	—	202	61R	100
	10	6/17	53–18N	166–30W	10	0	17	100L	280	0	20	010	N	0	—	10	100L	100
	12	6/21	55–48N	164–31W	107	35	147	75L	290	NA	NA	020	NE	0	—	147	75L	100
	13	6/22	55–55N	164–00W	7	19	27	73R	200	0	015	110	SE	0	—	26	73R	100
	14	6/23	56–06N	162–30W	284	94	395	75L	315	0	010	045	NE	0	—	378	75L	100
Fall—1965																		
(*George B.*	2	10/ 4	51–16N	172–58E	51	27	78	65L	069	025	029	155	SE	77	65L	0	—	0
Kelez)	3	10/ 5	50–19N	173–00E	79	16	98	83L	300	090	060	030	NE	95	83L	0	—	0
	4	10/ 6	49–15N	172–58E	25	114	140	82R	123	067	012	033	NE	139	81R	0	—	0
	16	11/ 5	49–57N	175–03E	77	16	94	83L	051	023	009	141	SE	93	84L	0	—	0

APPENDIX TABLE 2. Continued.

Season, year, and vessel	Set no.	Haul date	Position		Catch by side of net		Total catch	Perce n direc- tion	Direc- tion of haul	Indi- vidual net varia- tion	Net swing	Dominant direc- tion of movement		Immature		Mature		Percent mature
			Lat.	Long.	L	R						De- grees	Com- pass	N	%	N	%	
	34	8/ 7	52–20N	162–00W	31	105	136	77R	321	035	025	231	S W	129	79R	7	57L	5
	35	8/ 8	52–40N	162–00W	27	15	42	64L	269	020	011	359	N	40	65L	2	50L	5
	36	8/ 9	53–00N	162–00W	65	21	86	76L	222	025	013	312	N W	84	76L	2	50L	2
	37	8/10	53–20N	162–00W	69	38	107	65L	130	025	040	220	S W	104	64L	2	50L	1
	39	8/12	54–00N	162–00W	185	60	245	76L	108	025	007	198	S	230	77L	15	60L	6
	49	8/25	50–40N	162–00W	57	35	92	62L	002	025	058	092	E	91	63L	1	100R	1
	50	8/26	51–20N	162–00W	46	15	61	75L	060	080	060	150	S S E	61	75L	0	—	0
	51	8/27	52–00N	162–00W	24	9	33	73L	073	080	017	163	S S E	32	72L	1	100L	3
	52	8/28	52–40N	162–00W	41	8	49	84L	088	045	023	173	S	48	83L	0	—	0
	54	8/30	54–00N	162–00W	70	11	81	86L	335	085	010	065	E N E	46	75L	35	94L	44
	58	9/ 5	51–00N	162–00W	24	11	35	69L	239	030	009	329	N W	35	69L	0	—	0
	61	9/ 8	50–30N	162–00W	27	15	42	64L	300	070	010	030	N N E	42	64L	0	—	0
	62	9/ 9	51–30N	162–00W	36	13	49	74L	288	060	022	018	N	48	73L	1	100L	2
	63	9/10	53–02N	162–04W	6	17	23	74R	127	020	007	217	S W	20	70R	3	100R	13
Fall—1964																		
(*George B.*	2	9/ 5	51–33N	176–18W	25	7	32	78L	119	030	051	209	S W	32	78L	0	—	0
Kelez)	5	9/29	50–10N	173–00E	49	153	218	76R	240	060	018	150	S E	197	75R	3	100R	2
	6	9/30	50–10N	173–00E	10	112	128	92R	302	025	013	212	S W	121	92R	0	—	0
	7	10/ 2	50–10N	173–00E	16	34	54	68R	290	000	025	290	N W	50	68R	1	100R	2
	9	10/ 8	50–00N	169–00E	25	119	160	83R	310	000	040	220	S W	141	82R	1	100R	<1
	10	10/ 9	48–30N	169–00E	72	11	84	87L	181	070	001	271	W	80	86L	3	100L	4
Spring/Summer—1965																		
(*George B.*	13	6/22	55–50N	164–00W	2	20	22	91R	246	0	015	156	S E	0	—	22	91R	100
Kelez)	14	6/23	56–10N	162–31W	20	8	29	71L	270	0	010	360	N	0	—	28	71L	100
	15	6/25	57–01N	159–58W	7	32	39	82R	083	0	006	353	N	0	—	39	82R	100
	21	7/ 2	56–24N	162–00W	14	7	21	67L	336	0	0	066	N E	0	—	21	67L	100
Spring—1965																		
(*Paragon*)	1	6/ 1	53–43N	160–44W	12	3	15	80L	139	0	015	229	S W	0	—	15	80L	100
	2	6/ 4	53–23N	166–01W	14	3	17	82L	090	0	0	180	S	0	—	17	82L	100
	4	6/ 8	53–26N	165–57W	3	10	13	77R	309	0	025	219	S W	0	—	13	77R	100
	8	6/14	53–15N	166–38W	1	11	12	92R	315	0	0	225	S W	0	—	12	92R	100
	14	6/23	56–06N	162–30W	43	11	54	80L	315	0	0	045	N E	0	—	54	80L	100
Fall—1965																		
(*George B.*	2	10/ 4	51–16N	172–58E	37	8	45	82L	069	025	029	155	S E	43	81L	2	50L	4
Kelez)	3	10/ 5	50–19N	173–00E	13	37	50	74R	300	090	060	210	S W	46	72R	4	100R	8
	4	10/ 6	49–15N	172–58E	27	9	36	75R	123	067	012	213	S W	35	74L	0	—	0
	7	10/ 9	47–30N	173–05E	16	9	25	64L	197	045	017	287	W	24	63L	1	100L	4

APPENDIX TABLE 3. Assignment of direction of movement to pink salmon, 1962–63.

Season, year, and vessel	Set no.	Haul date	Position		Catch by side of net		Total catch	Percent direction	Direction of haul	Individual net variation	Net swing	Dominant direction of movement		Immature		Mature		Percent mature
			Lat.	Long.	L	R						Degrees	Compass	N	%	N	%	
Spring—1962																		
(*Bertha Ann*)	2	6/ 1	52-00N	170-12E	10	0	10	100L	215	030	005	305	NW	0	—	10	100L	100
	4	6/ 3	51-00N	170-00E	42	7	49	88R	238	015	002	328	NW	0	—	49	88R	100
	5	6/ 4	51-28N	173-01E	18	1	19	95R	314	020	004	044	NE	0	—	19	95R	100
	6	6/ 5	51-00N	176-00E	14	8	22	64L	276	060	054	006	N	0	—	22	64L	100
Summer—1962																		
(*Bertha Ann*)	22	7/14	51-50N	167-00W	19	7	26	73L	330	030	0	240	WSW	0	—	26	73L	100
	23	7/15	52-20N	166-58W	15	76	91	84R	058	020	032	328	NW	0	—	91	84R	100
	24	7/17	51-00N	170-52W	6	12	18	67R	324	030	006	234	SW	0	—	18	67R	100
	31	7/25	51-33N	174-04W	33	11	44	75L	227	090	047	317	NW	0	—	44	75L	100
Summer—1963																		
(*George B. Kelez*)	14	7/ 8	50-49N	176-19W	1	12	13	92R	154	050	019	244	WSW	0	—	13	92R	100

APPENDIX TABLE 4. Assignment of direction of movement to coho salmon, 1963.

Season, year, and vessel	Set no.	Haul date	Position		Catch by side of net		Total catch	Percent direction	Direction of haul	Individual net variation	Net swing	Dominant direction of movement		Immature		Mature		Percent mature
			Lat.	Long.	L	R						Degrees	Compass	N	%	N	%	
Summer—1963																		
(*George B.*	18	7/15	50-54N	176-19W	15	2	17	88L	239	090	014	329	NW	0	—	17	88L	100
Kelez)	19	7/17	51-14N	176-17W	12	42	54	78R	278	070	027	188	S	0	—	54	78R	100
	20	7/18	51-22N	176-24W	80	18	98	82L	158	070	008	248	SW	0	—	98	82L	100
	21	7/19	50-30N	176-20W	280	10	290	97L	219	020	019	309	NW	0	—	290	97L	100
	22	7/20	50-55N	176-22W	266	9	275	97L	223	040	018	313	NW	0	—	275	97L	100
	27	7/31	50-54W	176-19W	26	3	29	90L	140	015	040	230	SW	0	—	29	90L	100
	29	8/ 3	50-28N	176-20W	12	1	13	92L	237	070	017	327	NW	0	—	13	92L	100
	30	8/ 4	51-04N	176-20W	86	8	94	92L	268	030	043	358	N	0	—	94	92L	100