EFFECT OF DIRECTION OF SET AND DISTANCE BETWEEN NETS ON THE SALMON CATCH OF TWO GILLNETS

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ABSTRACT

As part of the Bureau of Commercial Fisheries continuing high seas salmon research, a series of five paired surface gillnet sets was fished in the eastern North Pacific Ocean during September 1962. At two of the stations, the nets were set at right angles to each other to determine the effect of direction of net lay on salmon catch. At the remaining three stations, the nets were set parallel but with distances of two, four and eight miles between them to measure changes in abundance over these distances.

Statistical comparisons of salmon and incidental species catches indicated that (1) the lay of the net can influence the salmon and pomfret catch and (2) salmon distribution is quite even with no noticeable change in abundance over the observed distances, although pomfret and Pacific mackerel abundance was very irregular.

CONTENTS

INTRODUCTION

Under the auspices of the United States Section of the International North Pacific Fisheries Commission, research vessels of the Bureau of Commercial Fisheries have conducted a high seas salmon (*Oncorhynchus* spp.) sampling program in the North Pacific Ocean, Bering Sea and Gulf of Alaska since 1955. These vessels, fishing surface drift gillnets, provide data on salmon distribution, abundance and migration routes and collect whole fish samples for racial analysis in the laboratory.

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Use of these catch data assumes that the gillnet catches generally reflect the relative abundance of salmon in the areas sampled. This raises several questions regarding sources of variation in gillnet catches. These may include the efficiency of gillnets relative to the size of the salmon, behavioral characteristics of salmon, direction of set, variations between vessels and other sources. Fukuhara (MS 1961), in comparing salmon catches of two vessels fishing during a comparable time period in the Bering Sea, concluded there was no difference in the relative efficiency of the two vessels. His results in testing the effects of variation due to direction of set indicated significant differences in one year, 1959, but not in 1960.

This report presents the analysis of catch data obtained by two research vessels fishing (1) two parallel gillnet strings, two, four and eight miles apart, and (2) two adjacent gillnet strings set at right angles.

EXPERIMENTAL PROCEDURE

During the summer of 1962, the nearly identical, 176-foot research vessels MV *Bertha Ann* and MV *George B. Kelez* fished together in the eastern North Pacific Ocean at five stations along 157° W. (Fig. 1). The nets of the *Kelez* were set at right angles to the nets of the *Bertha Ann* during the first two sets. In the last three sets, the nets of the two vessels were set in

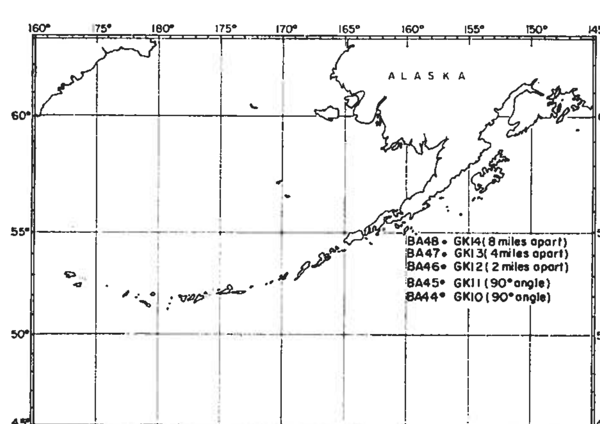

FIGURE 1. Location of paired set gillnet stations, 1962.

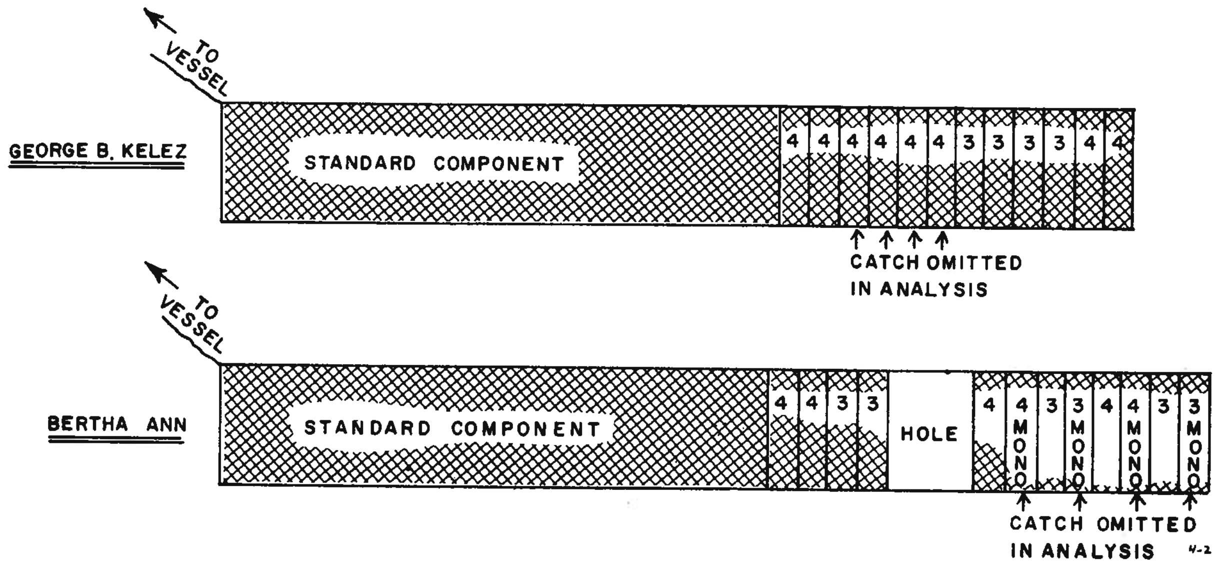

FIGURE 2. Gillnet string make-up used by research vessels during paired set experiment.

the same direction but with distances of two, four and eight miles between them.

The strings of both vessels consisted of an identical 24-net INPFC standard component plus 12 additional nets. The standard component is constructed of different mesh sizes in the following order: 4½-inch, 5¼-inch, 4½-inch, 3¼-inch, 4½-inch, 2½-inch (stretched measure), repeated four times. The additional 12 nets of the *Bertha Ann* string contained four 4½-inch, four 3¼-inch, two 4½-inch monofilament and two 3¼-inch monofilament nets. In the *Kelez* string, this section contained eight 4½-inch and four 3¼-inch nets (Fig. 2).

The monofilament nets in the *Bertha Ann* string have been shown to be much more efficient than multifilament nets of like mesh size (Larkins, 1963); therefore, the catch of these four nets was eliminated from the *Bertha Ann* data for purposes of comparison. In order to present the catch data of the two strings in terms of equal effort, the catch of four 4½-inch nets of the *Kelez* string was also eliminated. These adjustments reduced both strings to a total of 32 multifilament nets, each consisting of the standard component plus four 4½-inch and four 3¼-inch nets.

Larkins also indicated that the presence of monofilament nets can reduce the catch of adjacent 3¼-inch multifilament nets. However, due possibly to the relatively small numbers of salmon taken in the 3¼-inch nets, this effect was not found to be significant in the *Bertha Ann* catches made during this experiment.

Descriptions of individual nets, fishing method and shipboard routine were given by Powell and Peterson (1957) and Hanavan and Tanonaka (1959). Procedures for determining the direction of net lay have been described by Johnsen (1964) and Larkins (1964) and essentially consist of recording the heading of each net during the hauling process. The individual headings, and their average, delineate the shape and direction of the entire string.

As the nets were hauled aboard, the fish were tabulated by species, direction of entry into the net and the mesh size in which caught.

RESULTS

Catches of the two net strings for the five paired sets are shown in Tables 1 and 2. Through length-frequency analysis, it was found that 94 percent of the younger age group of both sockeye (*O. nerka*) and chum (*O. keta*) salmon, 1-winter-at-sea and 2-year-olds, respectively, were taken in the 2½-inch and 3¼-inch nets (small mesh); 97 percent of the older age groups, 2-winter-at-sea sockeye and 3-year-old and older chum, were caught in the 4½-inch and 5¼-inch nets (large mesh). Therefore, in the following analyses, the catch of the small mesh nets is considered to represent only the younger age groups and that of the large mesh nets only the older age groups.

In comparing the catches of the two strings in relation to the direction of set and distance between them, a necessary assumption is that the two strings fished

TABLE 1. Sockeye salmon catches in paired gillnet sets[1].

		1-winter-at-sea			2-winters-at-sea			
Vessel	Set	No. of fish	No. 2½″ and 3¼″ mesh nets	Catch/small mesh net	No. of fish	No. 4½″ and 5¼″ mesh nets	Catch/large mesh net	Type of set
Bertha Ann	44	15	12	1.25	47	20	2.35	90° angle
George B. Kelez	10	73	12	6.08	90	24	3.75	
Bertha Ann	45	12	12	1.00	22	20	1.10	90° angle
George B. Kelez	11	9	12	0.75	36	24	1.50	
Bertha Ann	46	14	12	1.17	13	20	0.65	2 miles
George B. Kelez	12	12	12	1.00	32	24	1.33	
Bertha Ann	47	14	12	1.17	3	20	0.15	4 miles
George B. Kelez	13	8	12	0.67	11	24	0.46	
Bertha Ann	48	4	12	0.33	3	20	0.15	8 miles
George B. Kelez	14	9	12	0.75	4	24	0.17	

[1] Excluding catch of *Bertha Ann* monofilament nets.

TABLE 2. Chum salmon catches in paired gillnet sets[1].

		2-year-old			3-year-old and older			
Vessel	Set	No. of fish	No. 2½″ and 3¼″ mesh nets	Catch/small mesh net	No. of fish	No. 4½″ and 5¼″ mesh nets	Catch/large mesh net	Type of set
Bertha Ann	44	19	12	1.58	21	20	1.05	90° angle
George B. Kelez	10	28	12	2.33	36	24	1.50	
Bertha Ann	45	12	12	1.00	4	20	0.20	90° angle
George B. Kelez	11	18	12	1.50	20	24	0.83	
Bertha Ann	46	9	12	0.75	6	20	0.30	2 miles
George B. Kelez	12	5	12	0.42	13	24	0.54	
Bertha Ann	47	13	12	1.08	11	20	0.55	4 miles
George B. Kelez	13	15	12	1.25	7	24	0.29	
Bertha Ann	48	24	12	2.00	7	20	0.35	8 miles
George B. Kelez	14	12	12	1.00	4	24	0.17	

[1] Excluding catch of *Bertha Ann* monofilament nets.

TABLE 3. Determination of relative efficiency of the two net strings[1].

Species and age	*Bertha Ann* set No. 46	*George B. Kelez* set No. 12	Total	Average	Chi-square	*d.f.*	Probability level
Sockeye							*Percent*
1-winter-at-sea	14	12	26	13.0	0.15	1	90–95
2-winters-at-sea	13	25	38	19.0	3.79	1	5–10
Chum							
2-year-old	9	5	14	7.0	1.14	1	20–30
3-year-old and older	6	13	19	9.5	2.58	1	10–20
Total	42	55	97	48.5	1.74	1	10–20
Pooled					7.66	4	10–20

[1] Excluding *Bertha Ann* monofilament nets and four 4½-inch nets of *George B. Kelez*.

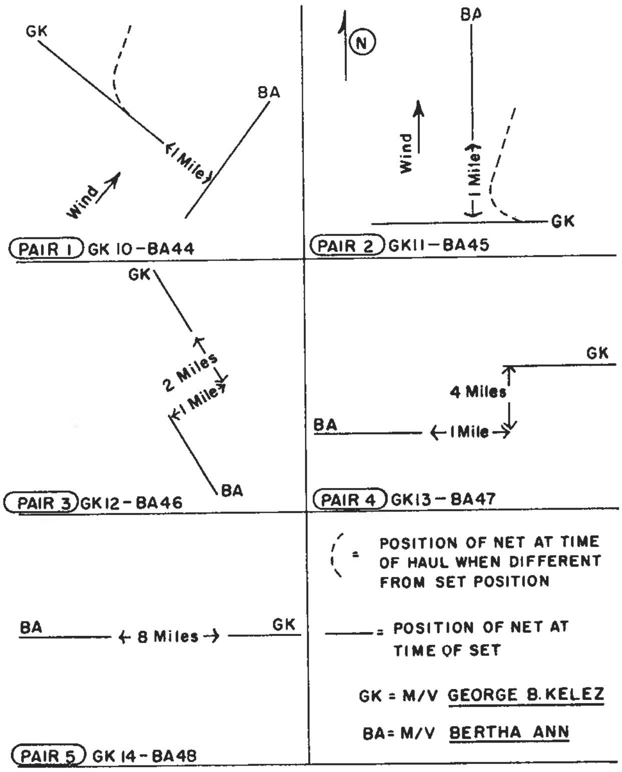

FIGURE 3. Position of net strings of MV *George B. Kelez* and MV *Bertha Ann* during paired set experiment.

with the same efficiency. In order to test this assumption, the pair of sets in which the strings were parallel and only two miles apart was used. Because the two-mile distance is only slightly longer than the net strings themselves, and because there was no noticeable change in the catch along the length of either net string, it is believed that the differences in abundance, species composition and age class composition over that distance are no greater than those within each string. Therefore, the comparison of catches in those two net strings should serve as an adequate measure of whether or not one string is more efficient than the other.

Individual chi-square tests for the catches of 1-winter and 2-winter-at-sea sockeye salmon and 2-year-old and 3-year-old and older chum salmon in the two strings (Table 3) show no significant[1] differences. Furthermore, total and pooled chi-square values indicate no difference between catches, leading to the conclusion that the relative efficiency of the two net strings is equal.

Direction of Set

In two pairs of sets (*Bertha Ann* 44—*George B. Kelez* 10 and *Bertha Ann* 45—*George B. Kelez* 11), the net strings of the two vessels were set at a 90 degree angle to each other to test whether direction of set (or direction of net lay) has any influence on the catch of a gillnet string. One vessel set downwind and moored to the downwind end of its string; the other set crosswind and moored to the end of its string. Because of the wind effects on the vessels during the night, the vessel which set crosswind fell off with the wind, bowing the string. In the morning, the string was "U" shaped, the distal end still in the set direction with the vessel end downwind and parallel to the string of the other vessel (Fig. 3). Therefore,

[1] Throughout this paper, probabilities of 5 percent or less are considered to be significant.

TABLE 4. Comparison of salmon catches of gillnets set in different directions[1].

Species and age	Set number: *Bertha Ann*	Set number: *George B. Kelez*	Catch: *Bertha Ann*	Catch: *George B. Kelez*	Total	Average	Chi-square	*d.f.*	Probability level
Sockeye									*Percent*
1-winter-at-sea	44	10	15	73	88	44.0	38.23	1	<0.1
	45	11	12	9	21	10.5	0.43	1	50-60
2-winters-at-sea	44	10	47	73	120	60.0	5.63	1	1-2.5
	45	11	22	30	52	26.0	1.23	1	20-30
Chum									
2-year-old	44	10	19	28	47	23.5	1.72	1	10-20
	45	11	12	18	30	15.0	1.20	1	20-30
3-year-old and older	44	10	21	23	44	22.0	0.09	1	70-80
	45	11	4	15	19	9.5	6.37	1	1-2.5
Total			152	269	421	210.5	16.26	1	<0.1
Pooled							54.90	8	<0.1

[1] Excluding *Bertha Ann* monofilament nets and four $4\frac{1}{2}$-inch nets of *George B. Kelez*.

differences in catch of the two strings are not necessarily due only to direction of set, but may be due to such factors as leading in the curved string, having one end of the bowed string in the shadow of the other end, etc.

Chi-square tests between the catches of the two vessels by species and age group show significant differences in three of eight comparisons as do total and pooled tests (Table 4), leading to the conclusion that either the shape of the net string (straight, curved) or the direction of net lay can influence the salmon catch of a gillnet.

Distance Between Sets

In three pairs of sets (*Bertha Ann* 46—*George B. Kelez* 12, *Bertha Ann* 47—*George B. Kelez* 13, *Bertha Ann* 48—*George B. Kelez* 14), the net strings of the two vessels were set in the same direction with distances of two, four and eight miles between them (Fig. 3). The catches of each of these pairs of sets (Table 5) were also analyzed with chi-square tests by species and age group. In these tests, there was a significant difference in only one of twelve comparisons and no difference in total or pooled tests. This indicates that there is no measureable change in sockeye and chum salmon abundance over distances of up to eight miles at the observed abundance levels. However, the combined catches of the two vessels did change significantly over the 90 miles between these stations in two of four cases (2-winter-at-sea sockeye and 2-year-old chum) (Table 6).

Table 5. Comparison of salmon catches of gillnets set at two, four and eight miles apart[1].

Species and age	Set number: *Bertha Ann*	Set number: *George B. Kelez*	Catch: *Bertha Ann*	Catch: *George B. Kelez*	Total	Average	Chi-square	*d.f.*	Probability level	Distance apart
Sockeye									*Percent*	
1-winter-at-sea	46	12	14	12	26	13.0	0.15	1	60–70	2 miles
	47	13	14	8	22	11.0	1.64	1	20	4 miles
	48	14	4	9	13	6.5	1.92	1	10–20	8 miles
2-winters-at-sea	46	12	13	25	38	19.0	3.79	1	5–10	2 miles
	47	13	3	10	13	6.5	3.77	1	5–10	4 miles
	48	14	3	3	6	3.0	0	1	—	8 miles
Chum										
2-year-old	46	12	9	5	14	7.0	1.14	1	20–30	2 miles
	47	13	13	15	28	14.0	0.14	1	70–80	4 miles
	48	14	24	12	36	18.0	4.00	1	2.5–5	8 miles
3-year-old and older	46	12	6	13	19	9.5	2.58	1	10–20	2 miles
	47	13	11	7	18	9.0	0.89	1	30–40	4 miles
	48	14	7	3	10	5.0	1.60	1	20–30	8 miles
Total			124	122	246	123.0	0.02	1	80–90	
Pooled							21.64	13	5–10	

[1] Excluding *Bertha Ann* monofilament nets and four 4½-inch nets of *George B. Kelez*.

Table 6. Determination of change in salmon abundance over 90 miles[1].

Species and age	Combined catches in set nos: *Bertha Ann* 46 and *George B. Kelez* 12	*Bertha Ann* 47 and *George B. Kelez* 13	*Bertha Ann* 48 and *George B. Kelez* 14	Total	Average	Chi-square	*d.f.*	Probability level
Sockeye								*Percent*
1-winter-at-sea	26	22	13	61	20.3	4.37	2	10–20
2-winters-at-sea	38	13	6	57	19.0	29.79	2	<0.1
Chum								
2-year-old	14	28	36	78	26.0	9.54	2	<0.1
3-year-old and older	19	18	10	47	15.7	3.10	2	20–30
Total	97	81	65	243	81.0	6.32	2	2.5–5

[1] Excluding *Bertha Ann* monofilament nets and four 4½-inch nets of *George B. Kelez*.

TABLE 7. Catches of pink, coho and chinook salmon and steelhead trout in paired gillnet sets[1].

Vessel	Set no.	Pink	Coho	Chinook	Steelhead
Bertha Ann	44	0	0	0	2
George B. Kelez	10	0	1	0	0
Bertha Ann	45	0	1	0	3
George B. Kelez	11	1	0	0	9
Bertha Ann	46	0	0	0	4
George B. Kelez	12	0	0	0	7
Bertha Ann	47	0	0	0	4
George B. Kelez	13	1	0	0	2
Bertha Ann	48	0	2	0	11
George B. Kelez	14	0	2	0	7
Totals *Bertha Ann*		0	3	0	24
George B. Kelez		2	3	0	25

[1] Includes all nets of both vessels.

Other Salmonids

Pink (*O. gorbuscha*), coho (*O. kisutch*) and chinook (*O. tshawytscha*) salmon and steelhead trout (*Salmo gairdneri*) are also of primary interest in the high seas sampling program. However, the catches of these species (Table 7) were so low that statistical comparisons within pairs of sets were not feasible. There was no apparent difference in the distribution of these fish between catches of the vessels in any of the pairs of sets.

Incidental Catch

The only other species encountered during this study were the Pacific mackerel (*Pneumatophorus japonicus*)[1] and pomfret (*Brama raii*). The catches of these two species, corrected to eliminate the monofilament catch of the *Bertha Ann* and to equate the effort of the two vessels, are shown in Table 8. The results of chi-square tests indicate significant differences in the catches of pomfret in each pair of sets. For this species, it would appear that direction of set or net shape does affect the catch. Also, the distribution of both the pomfret and Pacific mackerel is probably much less even than that of salmon as shown by the differences of catch between net strings set two, four and eight miles apart.

DISCUSSION AND CONCLUSIONS

The direction of lay or shape of the gillnet string can, apparently, affect the catch of sockeye and chum salmon and pomfret. This can be interpreted to mean that the majority of fish of these three species did not move randomly but, instead, over the period of one night, moved primarily in one direction. Therefore, measures of relative abundance obtained through gillnet samples should be used with this variable in mind.

In the station pattern followed during the series of paired sets, the decrease in total salmon catch indicated a decrease in salmon abundance from south to north. However, the paired sets with two, four and eight miles between net strings failed to show any significant difference in catches of sockeye and chum

[1] *Scomber japonicus.*

TABLE 8. Catches of Pacific mackerel and pomfret in paired gillnet sets[1].

Species	Set: *Bertha Ann*	Set: *George B. Kelez*	Catch: *Bertha Ann*	Catch: *George B. Kelez*	Total	Average	Chi-square	*d.f.*	Probability level
									Percent
Pomfret	44	10	43	111	154	77.0	30.03	1	<0.1
	45	11	62	19	81	40.5	22.83	1	<0.1
	46	12	203	129	332	166.0	16.49	1	<0.1
	47[2]	13	60	19	79	39.5	21.28	1	<0.1
	48[2]	14	47	27	74	37.0	5.41	1	1–2.5
Pacific mackerel	44	10	7	15	22	11.0	2.91	1	5–10
	45	11	2	0	2	1.0	—	—	—
	46	12	0	0	0	—	—	—	—
	47[3]	13	8	1	9	4.5	5.44	1	1–2.5
	48[3]	14	6	41	47	23.5	26.06	1	<0.1

[1] Excluding *Bertha Ann* monofilament nets and four $4\frac{1}{2}$-inch nets of *George B. Kelez.*

[2] *Bertha Ann* multifilament catches computed using 84 percent of total pomfret catch to allow for catch of monofilament nets. Individual net catches not available.

[3] *Bertha Ann* multifilament catches computed using 69 percent of total mackerel catch to allow for catch of monofilament nets. Individual net catches not available.

salmon, implying that the populations of these species in the study area are well dispersed and that the abundance gradients are gradual. This is contrasted with the apparently uneven and perhaps clustered distributions of pomfret and Pacific mackerel.

Because of the limited scope of this study and the lack of replicates at the various stations, the above conclusions should be extended to other areas, times, or abundance levels only with caution.

LITERATURE CITED

FUKUHARA, FRANCIS M. MS 1961. Significance of research vessel catches in estimating the oceanic distribution and abundance of salmon. U. S. Fish and Wildlife Service, Bureau of Commercial Fisheries, Biological Laboratory, Seattle, Washington. Unpublished.

HANAVAN, MITCHELL G., and GEORGE K. TANONAKA. 1959. Experimental fishing to determine distribution of salmon in the North Pacific Ocean and Bering Sea, 1956. *U. S. Fish and Wildlife Service, Special Scientific Report—Fisheries*, No. 302, 22 pp.

JOHNSEN, RICHARD C., 1964. Direction of movement of salmon in the North Pacific Ocean and Bering Sea as indicated by surface gillnet catches, 1959–1960. *Int. North Pac. Fish. Comm., Bulletin*, No. 14, pp. 33–48.

LARKINS, HERBERT A. 1963. Comparison of salmon catches in monofilament and multifilament gill nets. *U. S. Fish and Wildlife Service, Commercial Fisheries Review*, 25 (5) : 1–11.

LARKINS, HERBERT A. 1964. Direction of movement of salmon in the North Pacific Ocean, Bering Sea and Gulf of Alaska as indicated by surface gillnet catches, 1961. *Int. North Pac. Fish. Comm., Bulletin*, No. 14, pp. 49–58.

POWELL, DONALD E., and ALVIN E. PETERSON. 1957. Experimental fishing to determine distribution of salmon in the North Pacific Ocean, 1955. *U. S. Fish and Wildlife Service, Special Scientific Report—Fisheries*, No. 205, 30 pp.