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INVESTIGATIONS ON THE CONTINENT OF ORIGIN OF SOCKEYE AND  
COHO SALMON IN THE AREA OF THE JAPANESE LANDBASED  
DRIFTNET FISHERY

by

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FINAL REPORT  
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## INTRODUCTION

The Japanese conduct a high seas landbased driftnet fishery for salmon in the western North Pacific Ocean (Figure 1). The fishery began to develop in 1952 and since 1962 has on the average ranked second among world fisheries in catches of all species of salmon combined. In the 1970's catches of sockeye (Oncorhynchus nerka) and coho (O. kisutch) salmon increased as the fleet's effort shifted to the eastern portion of the fishing area. While it was clear that Asian sockeye and coho salmon were present in the eastern area, no conclusion could be made regarding the presence or absence of North American stocks of these species. The United States unilaterally assumed management authority for her stocks of Pacific salmon throughout their migratory range in 1976 by passing Public Law 94-26 (The Fishery Management and Conservation Act) and there was then a need to initiate a study of the origin of sockeye and coho salmon intercepted by this fishery.

Five specific tasks were identified as elements of this study; they were: 1) to gather, summarize and report information on the fishery and on salmon stocks immediately around and within the fishery, 2) to assess the feasibility of using scale characteristics in a polynomial discriminant function to identify the origin(s) of sockeye salmon, 3) to explore the availability of coastal and high seas coho scale samples for use in a polynomial discriminant function analysis, 4) to gather raw age data from Japanese research vessels for future analysis and to critique Osako's (1975-1976)<sup>1</sup> paper on the origin of sockeye in the area of the landbased fishery, and 5) to assess the logistics and feasibility of performing tagging experiments from either foreign or U.S. registered vessels. This report is organized into five sections corresponding to these tasks.

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<sup>1</sup>Osako, M. 1975 and 1976. INPFC Documents.

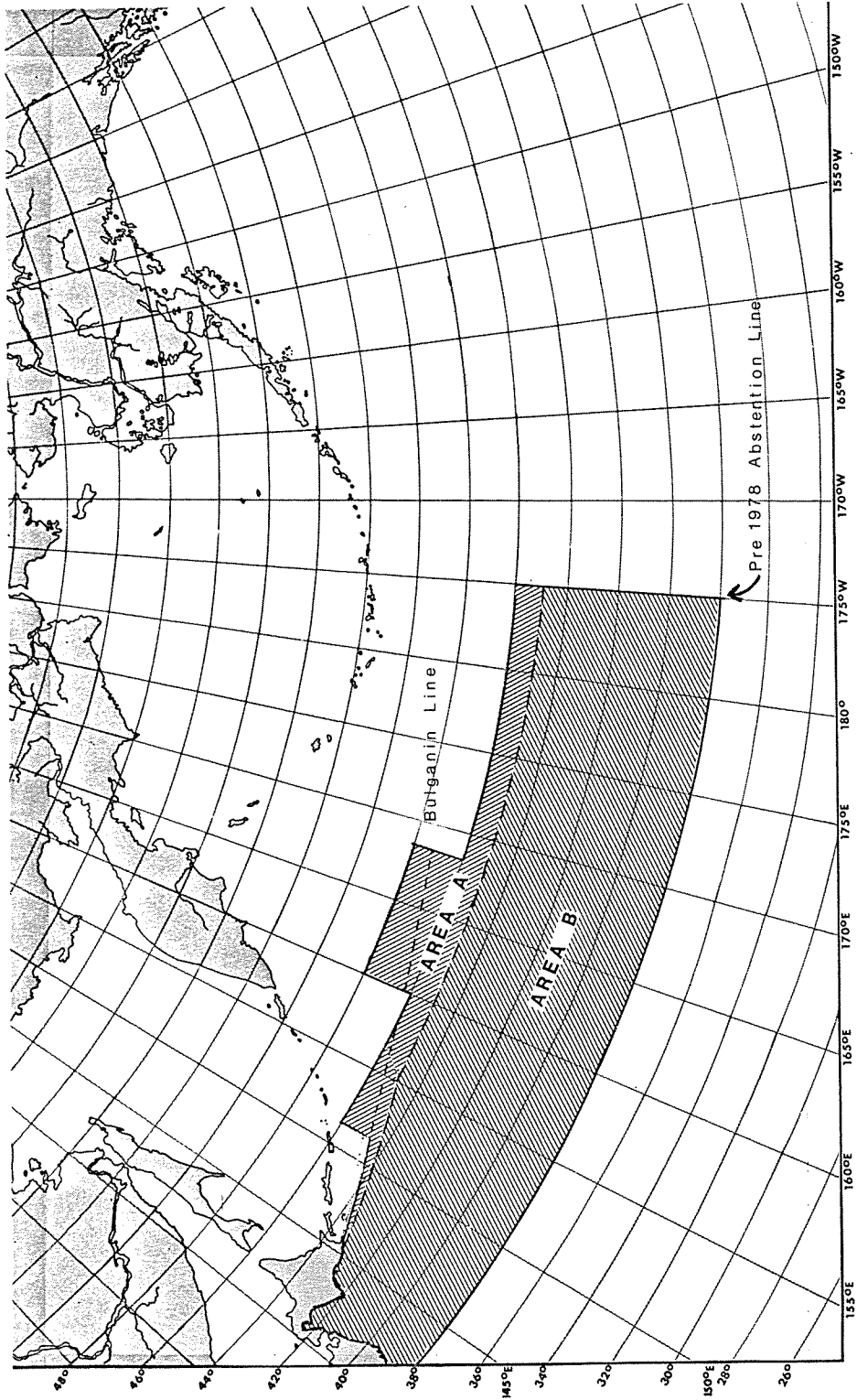


Fig. 1. Map of the North Pacific Ocean showing the area of the Japanese landbased driftnet fishery. The Eastern boundary line was moved to 175°E in 1978.

## COMPREHENSIVE REPORT ON THE FISHERY

The Japanese landbased driftnet fishery underwent rapid development in recent years to become one of the largest fisheries for salmon in the world. Its rank amongst world salmon fisheries in catch of sockeye and coho salmon in particular has steadily increased throughout its development. This section outlines major features and operational characteristics of the landbased fishery and summarizes the current knowledge regarding the continental origin of the sockeye and coho stocks exploited in the landbased area. First, though, we present a brief description of Japan's involvement in high seas exploitation of salmon to put the present landbased fishery in an historical and comparative perspective.

Description of Japan's High Seas Salmon Fisheries

Japan has had several high seas fisheries in the North Pacific Ocean, Okhotsk Sea, and Sea of Japan. These have been of three types: mothership driftnet fisheries, offshore longline fisheries, and landbased driftnet fisheries.

Mothership Fisheries

From 1929 to 1942 Japan maintained a large mothership driftnet salmon fishery in the waters immediately off both coasts of the Kamchatka Peninsula (Kasahara, 1963; Taguchi, 1966). In that period an average of 7,240,000 salmon was caught each year by an average of 9 motherships and 168 catcher boats (Kasahara 1963, Table 34). World War II forced suspension of the mothership fishery from 1943 to 1951. A mothership fishery began again in 1952, but it was restricted to the area around the Aleutian Islands for the first three years because Japan was initially reluctant to fish close to the Soviet coast before resumption of Japanese-Soviet diplomatic relations (Taguchi, 1966).

In 1955 2 motherships supported by 60 catcher boats fished in the Okhotsk Sea near Kamchatka. The threat of new expansion of Japanese high seas fishing prompted the U.S.S.R. to assume authority in restricting catches and areas of operation of the high seas fishery. Hasty negotiations prior to resumption of diplomatic relations resulted in Japan's acceptance of certain restrictions in mid-1956, and set the basic terms of the Japanese-Soviet Fishery Commission which formed later the same year after restoration of diplomatic relations. The treaty permitted only 2 motherships in the Okhotsk Sea through 1958, after which the Okhotsk Sea was permanently closed to high seas fishing.

The post-war mothership fishery, then, began in 1952 and has been limited to North Pacific waters since 1959. The North Pacific mothership fishery (i.e., excluding the small Okhotsk fleet that operated before 1959) consisted of an average of 11 motherships, 345 catcher boats, and deployed an average of 5.75 million tans (1 tan = 50 m) of gill net yearly during the period 1952-1976 (source: Fredin et al., 1977, Table 4.3). Catches of sockeye, coho, and all salmon combined by this fishery in the years 1952-1975 are shown in Table 1. Five-year mean catches and ranks amongst world salmon fisheries shown in Table 2 A-C attest that the mothership fishery has been about the fourth largest salmon fishery, and the second largest fishery for sockeye salmon in particular.

The fishing season extends from about May 20 to August 10 or earlier if the quota is reached. The fishery usually commences operations in the Northwest Pacific and extends east and into the Bering Sea as the season progresses. In recent years motherships have been accompanied by 32-34 catcher boats and all but four catcher boats have fished in the same 220 km

Table 1. World salmon fishery catches, 1952-1975, in millions of fish

Year	Species	LBDN <sup>1</sup>	LBLL <sup>2</sup>	Mothership <sup>3</sup>	Japan coastal <sup>4</sup> and freshwater	USSR coastal <sup>5</sup>	Canada coastal <sup>6</sup>	U.S. coastal <sup>7</sup>
1952	Sockeye	.089	+	.736	+	3.1	4.863	18.239
	Coho	.126	+	.024	+	1.4	2.746	4.768
1953	All species	14.251	.731	2.086	8.149	55.567	22.230	54.333
	Sockeye	.191	+	1.580	+	1.7	5.927	13.883
1954	Coho	.272	+	.340	+	1.9	2.894	3.258
	All species	12.226	.477	7.700	5.982	109.789	25.615	48.889
1955	Sockeye	.344	+	3.816	+	1.4	6.710	14.626
	Coho	.490	+	1.398	+	2.2	2.445	3.604
1956	All species	12.717	.956	20.496	8.136	49.166	21.320	52.874
	Sockeye	.511	+	12.494	+	1.1	2.836	9.846
1957	Coho	.728	.001	3.576	+	1.9	2.968	3.297
	All species	27.630	.915	64.041	9.296	81.236	19.490	49.991
1958	Sockeye	.271	.001	10.290	+	1.9	3.258	15.897
	Coho	.386	.001	3.875	+	1.1	3.050	3.523
1959	All species	24.309	6.011	52.066	13.239	72.812	17.101	56.116
	Sockeye	.488	.005	20.096	+	1.2	3.036	11.696
1960	Coho	.695	.009	.442	+	1.6	3.137	3.410
	All species	35.350	11.735	60.358	13.589	84.092	20.835	42.957
1961	Sockeye	.903	.009	12.026	+	0.3	12.045	11.592
	Coho	.803	.015	3.393	+	0.8	2.990	2.811
1962	All species	35.739	6.991	49.798	22.257	34.571	26.202	49.570
	Sockeye	.845	.009	9.125	+	1.4	3.260	10.105
1963	Coho	1.204	.016	1.423	+	1.2	2.897	2.643
	All species	46.293	11.861	42.331	15.372	45.300	15.896	32.820
1964	Sockeye	1.627	.049	12.879	+	1.4	2.858	19.187
	Coho	1.376	.113	.962	+	0.6	2.030	1.889
1965	All species	31.927	7.665	26.423	19.676	27.171	11.565	45.681
	Sockeye	1.192	.026	12.998	+	2.7	4.565	17.536
1966	Coho	1.486	.003	.284	+	1.3	3.297	2.783
	All species	43.418	12.633	22.704	11.297	34.766	18.070	50.317
1967	Sockeye	.154	.006	10.590	+	1.4	3.499	10.087
	Coho	1.289	.005	1.532	+	1.3	3.626	3.572
1968	All species	23.165	13.360	19.755	11.852	22.800	32.769	66.515

Table 1. cont'd

Year	Species	LBDN <sup>1</sup>	LBL <sup>2</sup>	Mothership <sup>3</sup>	Japan coastal <sup>4</sup> and freshwater	USSR coastal <sup>5</sup>	Canada coastal <sup>6</sup>	U.S. coastal <sup>7</sup>
1963	Sockeye	.018	.002	8.903	+	1.2	2.086	7.637
	Coho	1.492	.008	1.895	+	2.2	3.421	3.576
	All species	40.405	19.470	23.475	14.220	37.524	19.975	58.469
1964	Sockeye	.108	.006	7.097	+	1.0	3.619	10.522
	Coho	1.624	.004	3.535	+	0.3	4.148	4.656
	All species	28.130	9.517	21.964	11.041	18.560	20.616	70.075
1965	Sockeye	.159	.001	12.038	+	1.5	3.020	30.821
	Coho	1.913	.001	1.177	+	1.0	4.443	4.570
	All species	39.637	19.328	23.865	16.313	45.807	14.178	62.279
1966	Sockeye	.703	.001	7.254	+	1.2	4.020	16.477
	Coho	1.458	.001	.469	+	0.9	5.412	5.038
	All species	30.153	13.764	19.046	15.365	24.093	29.169	70.172
1967	Sockeye	2.566	.001	8.087	+	1.0	6.743	10.770
	Coho	1.329	.001	.226	+	1.0	3.302	4.422
	All species	38.134	19.513	23.059	21.396	40.291	22.120	31.650
1968	Sockeye	2.769	.001	6.373	+	0.8	6.266	9.135
	Coho	1.421	.003	.898	+	1.0	5.257	5.314
	All species	28.634	7.833	19.563	15.081	16.383	35.324	67.472
1969	Sockeye	2.495	.001	5.935	+	0.6	4.267	13.103
	Coho	3.328	.002	1.306	+	1.0	2.414	2.957
	All species	34.424	17.964	22.488	22.559	46.022	11.563	48.031
1970	Sockeye	2.966	.051	6.944	+	1.6	4.078	29.021
	Coho	2.259	.001	.180	+	1.6	3.945	4.992
	All species	25.314	8.580	18.925	16.277	17.541	26.518	75.049
1971	Sockeye	3.026	.002	3.554	+	0.8	6.306	17.352
	Coho	2.373	.002	.454	+	1.3	4.788	5.586
	All species	28.760	15.113	22.384	22.452	44.583	22.406	58.807
1972	Sockeye	3.718		3.184	+	0.3	3.574	7.859
	Coho	2.423		.614	+	0.5	3.359	4.167
	All species	32.807		21.227	15.718	15.997	28.779	37.766
1973	Sockeye	3.316		2.613	+	0.7	7.601	7.171
	Coho	3.796		.989	+	0.7	3.531	4.413
	All species	39.341		23.596	21.708	52.91	25.317	33.163

Table 1. cont'd

Year	Species	LEDN <sup>1</sup>	LBLL <sup>2</sup>	Mothership <sup>3</sup>	Japan coastal <sup>4</sup> and freshwater	USSR coastal <sup>5</sup>	Canada coastal <sup>6</sup>	U.S. coastal <sup>7</sup>
1974	Sockeye	3,158		2,282	+	.437	7,225	7,381
	Coho	3,560		1,085	+	1,164	3,724	5,936
	All species	33,861		20,567	20,532	26,970	21,993	30,405
1975	Sockeye	2,982		2,171	+	.5	2,272	9,146
	Coho	3,556		.356	+	1.2	2,332	3,827
	All species	37,483		24,710	30,734	51.38	11,796	34,012

Footnotes for Table 1:

Data sources:

- <sup>1</sup>Landbased driftnet fishery statistics taken from Table 4.5 of Fredin et al. (1977). Includes catches by large vessels only.
- <sup>2</sup>Data calculated from Table 54 of INPFC (1974, MS) for 1958 - 1971, and from estimates in Appendix Tables 1.5, 1.6, and 1.7 in Fredin et al. (1977) for 1952-1957. Catches in weight were converted to numbers by conversions given in Appendix Table 1.8 of Fredin et al. (1977).
- <sup>3</sup>Table 52, INPFC (1974, MS). Figures include catches in the Okhotsk Sea, 1955-1958.
- <sup>4</sup>Coastal catches include catches by the landbased coastal driftnetters (< 7 g.t.), coastal longline vessels, Japan Sea fisheries, traps, angling, and miscellaneous gear. Coastal catches in weight from Fredin, et al. (1977), Appendix Table 1.9, were used for 1952-1957, and data in Table 55 of INPFC (1974, MS) were used for 1958-1975. Freshwater catches are from Table 56 of INPFC (1974, MS). For both coastal and freshwater catches, masu salmon are grouped with pink, and sockeye, coho, and chinook salmon are grouped with chum. Weights were converted to numbers using conversions for coastal catches presented in Table 90 of INPFC (1974, MS) since chum and pink salmon constitute the great majority of the two species-groups reported. The mean weights for the years 1962-1970 and 1972-1975 were used to convert values outside these years.
- <sup>5</sup>Data for 1952-1973 from Tables 3-II, 4-II, 5-II, 6-II, and 7-II of INPFC (1974, MS). 1974 data from 1974 INPFC Statistical Yearbook, Table 28. 1975 data from Appendix C, Tables 17-21, Department of State, 1978. Draft environmental impact statement for the renegotiation of the International Convention for the High Seas Fisheries of the North Pacific Ocean.
- <sup>6</sup>Data for 1952-1971 from Table 62, INPFC (1974, MS). 1972-1975 data from INPFC Statistical Yearbooks.
- <sup>7</sup>Data for 1952-1971 from Table 66, INPFC (1974, MS). 1972-1975 data from INPFC Statistical Yearbooks.

Table 2. Mean catch (in millions of fish) and rank of major world salmon fisheries, by 5-year periods, 1952-1975.

A. SOCKEYE

Period	LBDN	LBLL	Mothership	Japan coastal	USSR coastal	Canada coastal	USA coastal
1952-1956	0.281	+	5.783	+	1.840	4.719	14.498
Rank =	5		2		4	3	1
1957-1961	1.011	0.020	13.425	+	1.400	5.153	14.023
Rank =	5	6	2		4	3	1
1962-1966	0.228	0.003	9.176	+	1.260	3.249	15.109
Rank =	5	6	2		4	3	1
1967-1971	2.764	0.011	6.179	+	0.960	5.532	15.976
Rank =	4	6	2		5	3	1
1972-1975	3.294	-	2.563	+	0.484	5.168	7.889
Rank =	3		4		5	2	1
All years	1.442	0.011	7.573	+	1.218	4.747	13.712
Rank =	4	6	2		5	3	1

B. COHO

Period	LBDN	LBLL	Mothership	Japan coastal	USSR coastal	Canada coastal	USA coastal
1952-1956	0.400	0.001	1.843	+	1.700	2.821	3.690
Rank =	5	6	3		4	2	1
1957-1961	1.113	0.031	1.301	+	1.100	2.870	2.707
Rank =	4	6	3		5	1	2
1962-1966	1.555	0.004	1.722	+	1.140	4.210	4.282
Rank =	4	6	3		5	2	1
1967-1971	2.142	0.002	0.613	+	1.180	3.941	4.654
Rank =	3	6	5		4	2	1
1972-1975	3.334	-	0.761	+	0.891	3.237	4.586
Rank =	2		5		4	3	1
All years	1.641	0.011	1.240	+	1.215	3.423	3.959
Rank =	3	6	4		5	2	1

Table 2. Mean catch (in millions of fish) and rank of major world salmon fisheries, by 5-year periods, 1952-1975, continued.

C. ALL SPECIES

Period	LBDN	LBLL	Mothership	Japan coastal	USSR coastal	Canada coastal	USA coastal
1952-1956	18.227	1.818	29.278	8.960	73.714	21.151	52.441
Rank =	5	7	3	6	1	4	2
1957-1961	38.545	10.177	40.323	16.438	45.180	18.514	44.269
Rank =	4	7	3	6	1	5	2
1962-1966	32.298	15.088	21.621	13.758	29.757	23.341	65.502
Rank =	2	6	5	7	3	4	1
1967-1971	31.053	13.801	21.284	19.553	32.964	23.606	56.202
Rank =	3	7	5	6	2	4	1
1972-1975	35.873	-	22.525	22.173	36.814	21.971	33.837
Rank =	2		4	5	1	6	3
All years	31.005	10.221	25.657	15.927	43.972	21.706	51.142
Rank =	3	7	4	6	2	5	1

- No fishing.

+ Trace catches.

<sup>1</sup> Landbased driftnet fishery.

<sup>2</sup> Landbased longline fishery.

x 260 km area where their motherships were positioned. Four catcher boats serve as scouts and can range far from their mothership in search of future fishing grounds.

The gill nets vary in length and mesh size with respect to position relative to the Soviet-established Bulganin line, but in the majority of the mothership areas gill nets are limited to 15 km (+ 10% allowance) of net per catcher boat per day, with 121 mm mesh permitted in 60% of the length and 130 mm mesh in the remainder. Monofilament nets were first used in 1961 and became standard by 1969. Nets are generally set around 1800 hr in a direction so as to intersect the predominant migratory path of the fish, and are retrieved in the early morning (Neo, 1964).

Fairly complete statistics are provided on the mothership fishery. Each mothership hosts two inspectors from the Japan Fishery Agency (JFA) who record daily catch of each species in weight by each catcher boat and effort. The inspectors sample thirty fish of each species from five catcher boats daily, for age, sex, maturity, and weight. Total daily catches by each mothership's fleet are converted to numbers, and the accumulated catch and effort statistics for the fishery are reported to the International North Pacific Fisheries Commission, by  $2 \times 5^1$  statistical areas and 10-day periods.

More detailed descriptions of the mothership fishery are provided in Fredin et al. (1977), Fredin and Worlund (1974), and Fukuhara (1971).

#### Longline Fisheries

There have been two Japanese offshore longline fisheries for salmon. A small fishery consisting mainly of vessels less than 10 gross tons operates mostly in the Sea of Japan and to a lesser extent off the Pacific coast of

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<sup>1</sup>INPFC  $2^\circ \times 5^\circ$  statistical areas are coded such that the first two digits give the west-bounding longitude and the last two digits give the south bounding latitude. Hence, area E 7544 is the area between  $175^\circ$  E and  $180^\circ$  and between  $44^\circ$  N and  $46^\circ$  N.

Hokkaido and Honshu. A much larger fishery operated from 1952 to 1971 south of 45° N and west of 160° E (165° E in 1971). The smaller fishery operates quite close to the coasts of Japan, albeit mostly outside territorial limits, and its catch statistics are included in the coastal category in the INPFC Historical Catch Statistics Bulletin (INPFC 1974 MS) and in Tables 1 and 2 of the present report. Catches of sockeye and coho salmon by this coastal longline fishery have been negligible in comparison with other world salmon fisheries.

The larger longline fishery consisted of about 369 vessels. Each vessel fished 100-130 hachi (a skate of longline about 135 m long consisting of 49 hooks) of surface drifting longline. Fishing commenced in early May and ceased whenever the catch quota allocation for this fishery had been attained, typically in mid- to late June (INPFC 1974 MS). Estimates of historical catches by this fishery shown in Table 1 were taken from Fredin et al. (1977). Catches of sockeye and of coho salmon by this fishery consistently ranked sixth amongst major world salmon fisheries (Tables 2A and 2B). This longline fishery was discontinued in 1972.

#### Landbased Driftnet Fisheries

Japan has at various times maintained three major landbased driftnet salmon fisheries. Before 1946 there was a significant fishery based around the two northernmost islands of the Kuril chain (Kasahara, 1963). The fishery employed traps as well as driftnets. Most fishing occurred within 50 miles of these islands. Catches by the driftnet faction during the years 1933-1945 averaged 2.17 million sockeye, 0.53 million coho, and 14.96 million salmon of all species combined (data from Kasahara, 1963, Table 35 I). Trap catches were typically higher. Most of the salmon intercepted by these North Kuril

fisheries were bound for the Sea of Okhotsk via Kuril passes.

Two quite different landbased driftnet fisheries have developed since W.W. II. The larger of the two is the landbased offshore driftnet fishery, which is described in detail in the following section. The smaller, coastal driftnet fishery consists of vessels less than 7 gross tons. This fishery operates off the east coasts of Hokkaido and northern Honshu, the smaller vessels (< 5 g. t.) fish east to 147° E while the larger vessels (5-7 g. t. ) fish east to 149° E. A smaller fleet of vessels, mostly under 30 g. t., operates in the Sea of Japan.

The Pacific fleet of the coastal driftnet fishery has consisted of 1200-1500 vessels throughout much of its history, but has shown a marked reduction in the 1970's (Fredin et al., 1977):

<u>Year</u>	<u>No. of vessels less than 7 g. t.</u>
1970	1,388
1971	1,382
1972	1,232
1973	1,110
1974	1,120
1975	1,120
1976	1,120
1977	832

These vessels are licensed by their respective prefectural governments.

Fishing is generally done quite close to shore. Trips last 1 or 2 days, and catches are generally landed fresh.

Catches by the coastal driftnet fishery are provided in Table 5.5 of the INPFC Historical Catch Statistics Bulletin after 1957; only combined catches by the offshore and coastal driftnet fisheries are available for the first six years of operation, 1952-1957. Fredin et al. (1977) estimated the coastal and offshore fractions of the combined catches reported for those early years,

and their estimates were used to compile Tables 1 and 2 of this report.

#### The Landbased Offshore Driftnet Fishery

This large high seas fishery began to develop in 1952 and, as shown in Table 2C, was from its inception one of the world's largest salmon fisheries. In the period after 1961 it has on the average ranked second among world fisheries in catches of all species of salmon combined. Its annual total salmon catches have been larger than those of the more closely monitored mothership fishery since 1958 (Table 1). Its respective rank among world fisheries for sockeye and coho salmon in particular has steadily increased throughout its history (Table 2A and C); in recent years it has been the third largest fishery for sockeye salmon and the second largest for coho salmon, in terms of numbers of fish.

#### Vessels and Gear

Vessels range from 40 to 90 gross tons (Fredin et al., 1977) and, at least in early years, have had crews of 18-20 men (Nakatsu, 1960). The size of the fleet was about 325 through the 1960's and until 1971, 374 in 1972-1974, 371 in 1975, 368 in 1976, and 297 in 1977. These vessels fish as far east as the INPFC Abstention Line and therefore usually stay at sea for up to four weeks. Catches are gutted and salted or frozen for transport back to the home ports in Hokkaido.

Unlike the mothership catcher boats, which belong to the same large companies that operate the mothership factories, the landbased driftnet vessels are generally independent. According to Taguchi (1966), the fast development of the North Pacific driftnet fishery helped absorb many fishermen (and presumably equipment) idled by the termination of the landbased fishery in the Kuril Islands.

The maximum length of gillnet permitted each boat is determined by the Soviet-Japanese Fisheries Commission, and varies with position relative to the Bulganin Line (Fig. 1). North of the line 12 km + 10% allowance of net is allowed, and mesh size is usually 115 mm but can be as small as 110 mm. South of the Bulganin Line 15 km + 10% allowance of gear is allowed, also having 110-115 mm mesh. These mesh sizes are significantly less than the 121-130 mm mesh used in the mothership fishery. Monofilament gillnets appeared later in the landbased fishery than in the mothership fishery but had become standard by the early 1970's.

#### Areas and Times of Operation

The landbased driftnet fishery operates south of 46° N except for an extension to 48° N between 160° E and 170° E. The INPFC treaty of 1978 moved the eastern boundary from 175° W to 175° E (Fig. 1). The landbased area intersects two management areas established by the Japanese-Soviet Fisheries Commission, designated Areas A and B. In its first three years of existence the Commission established regulations for the high seas Area A, north of 45° N and/or north of the Bulganin Line (Taguchi, 1966). Alarmed by the increase in catches by the fisheries in areas south of Area A and by the continuing decline of Soviet coastal catches, the Soviets in 1959 achieved Commission regulation of the remainder of the landbased driftnet area, Area B.

Before the Japanese-Soviet Fisheries Commission regulated fishing in Area B the landbased driftnet fishery season extended from early- or mid-April to the end of July. Concomitant with inclusion of Area B into Commission Authority, the season was delayed until late April or early May. In 1962 a fairly regular season was established, which extends from early May (vessels often departed on 30 April) to 10 August, or whenever the catch quotas are achieved. Vessels are permitted to fish first in Area B only, until the quota

for that area is attained or until June 30, whichever comes first, and then are allowed into the landbased fishery portion of Area A for the remainder of the season.

#### Licensing, Catch Quotas, and Catch Reporting

Vessels in the landbased offshore driftnet fishery are licensed by the Japan Fisheries Agency, Ministry of Agriculture and Forestry, whereas the small vessels in the coastal gillnet fishery are licensed by the Governor of Hokkaido via the prefectural governments. The number of licenses issued is closely controlled, and in recent years has decreased as the size of replacement vessels has increased (Fredin et al., 1977).

Catch quotas for regulatory Area A (north of 45° N) have been imposed since 1957 by the Japanese-Soviet Fisheries Commission. Quotas were first established for Area B in 1962. The quotas are in terms of metric tons of all species, combined, and there has been no attempt to apportion these quotas by species. The quotas for each major area have been allocated to the various fisheries by the Ministry of Agriculture and Forestry of Japan. The catch quota allocations for the combined landbased coastal and offshore driftnet fisheries are shown in Table 3. The allocations for the Area B fraction increased slightly in the early 1970's as the driftnet fishery assumed that part of the total quota for Area B left by the landbased longline fishery, which ceased to operate after 1971.

The reporting of fishery statistics for the landbased driftnet fishery is succinctly described by Fredin et al. (1977):

"In the landbased offshore driftnet fishery, each vessel keeps a logbook in which the location, number of tons of gear set, and the number of each species of salmon caught is recorded for each day's fishing. The logbook information is reported to Fisheries Agency inspectors when the vessels land at their home ports. In the case of the smaller vessels (under 7 gt), the time lag between actual catches and reporting of logbook information

Table 3. Allocations of catch quota to the landbased coastal and offshore driftnet fisheries in the North Pacific Ocean, 1957-1977, in metric tons of all salmon species<sup>1</sup>.

Year	Area A (north of 45°N)	Area B (south of 45°N)	Total
1957	20,000	No quota	
1958	18,333	"	
1959	14,166	"	
1960	13,500	"	
1961	11,400	"	
1962	10,335	Not allocated <sup>2</sup>	
1963	10,710	"	
1964	10,335	37,240	47,575
1965	10,522	39,800	50,322
1966	9,019	32,390	41,409
1967	9,865	37,400	47,265
1968	8,737	31,370	40,107
1969	9,350	35,450	44,800
1970	8,455	28,750	37,205
1971	8,643	31,400	40,043
1972	8,174	38,600	46,774
1973	8,268	41,800	50,068
1974	7,798	36,700	44,498
1975	7,892	40,000	47,892
1976	7,516	35,400	42,916
1977	5,543	28,900	34,443

<sup>1</sup>Source: Fredin et al. (1977).

<sup>2</sup>Quotas of 60,000 and 63,000 m.t. were imposed for area B for 1962 and 1963, but these were not apportioned to the various fisheries operating in the region.

is only 1 or 2 days. For the larger vessels, however, the time lag might be more than a month. Because of the delay, the Agency uses patrol vessels to make daily estimates of total catches by the larger vessels. The estimates are obtained by counting the number of vessels fishing in an area and applying catch rates for a sample of them to the total. By combining the logbook data for the smaller vessels with the estimates of catches by the larger vessels, the Fisheries Agency obtains daily estimates of cumulative numbers of salmon caught. However, since the catch quotas are set in tons of fish (rough weight), not numbers of fish, it is necessary to convert the catches from numbers of fish to tons. Two sources of information are used to make the conversion: data on average weights obtained by JFA research vessels operating in the area fished by the larger vessels and fish tickets. The latter are made out by buyers at the time of purchase from the vessels and indicate the kilograms of fish involved in the transactions. Agency inspectors compare the tickets with the numbers of fish recorded in vessel logbooks to obtain estimates of average weights."

#### Restrictions, Time-area Closures, Surveillance, and Recent Violations of Abstention

There have been few restrictions or special time-area closures for the landbased, offshore driftnet fishery besides those already discussed. However, not all the information on closures and restrictions resulting from Japan-U.S.S.R. negotiations has been made available (Fredin et al., 1977). There was a series of seven specific regulatory measures imposed in 1963-76, designed to reduce Japanese high seas interceptions of salmon originating in the U.S.S.R., and two of these pertained to the landbased fishery. One measure was to limit to 100 the number of vessels operating in an area bordered roughly by the Bulganin Line, 150° E, 40° N, and 154° E, from April 30 through May 30. The other was a limit of 150 vessels allowed to operate in an area roughly bordered by 45° N, 160° E, 42° N, and 164° E, in the same period.

Little is known about surveillance of the landbased fishery. In 1976, at least, surveillance was done by four Japanese enforcement vessels with Soviet inspectors aboard from time to time (Fredin et al., 1977). The agency enforcement officers check licenses, fishing location, length of net, mesh sizes, and obtain catch and effort data from a sample of the boats inspected

which are used to monitor the progress of the fishery.

There have been a number of violations of INPFC abstention by landbased fishery vessels in recent years. These have prompted U.S. concern about interceptions of North American salmon and about the validity of catch statistics reported by statistical area. In July 1972 four boats belonging to this fishery were seen south of Kodiak Island, about 10° north and 22° east of this authorized area. In May 1973 three landbased boats were spotted, again far to the northeast of their authorized area. In July 1974 twenty-two boats were seen between 176° W and 180° at about 49° N. One vessel was fishing. In May 1976 thirty-seven landbased vessels were seen between 173° E and 180°, and 49° N to 50° N.

#### Summary of Landbased Driftnet Fishery Statistics

##### Types of data available

Catch statistics for the landbased driftnet fishery have, until very recently, lacked sufficient detail to permit even a cursory time/area analysis of operation. Table 4 provides all data on this fishery available through the INPFC Statistical Yearbooks, 1952-1975. In the years 1952-1957 combined catches of the small coastal vessels operating in the Pacific Ocean and Japan Sea and of the larger offshore vessels were reported. The catches by the larger vessels, however, constituted the great majority of the combined catches. Fredin et al. (1977) calculated the fraction of total landbased driftnet catches contributed by the large offshore vessels in 1958-1969 to be 97.2% for sockeye, chum, coho, and chinook (combined), 74.8% for pink in even-numbered years, and 83.8% for pink in odd-numbered years. There was no breakdown by time period or by area in the early data, although monthly catches by all landbased fisheries combined (large and small driftnetters, longlines, traps,

Table 4. Catch statistics of the Japanese landbased driftnet fishery for salmon, as presented in the INPFC Statistical Yearbooks.

Part A: Data for 1952-1957<sup>1,2</sup>

Year	Pink and masu <sup>3</sup>	Chum, sockeye, coho, and chinook	All species
1952	47,984	4,043	52,027
1953	32,962	8,722	41,684
1954	33,053	15,708	48,761
1955	71,880	23,330	95,210
1956	77,430	12,370	89,800
1957	97,420	22,270	119,690

<sup>1</sup>Catches by small coastal vessels and large offshore vessels are combined under the gill net heading in early statistical yearbook tables. Includes catches in the Sea of Japan, Okhotsk Sea, and off Honshu.

<sup>2</sup>Catches are reported in thousands of pounds.

<sup>3</sup>Almost entirely pink salmon.

Table 4. Catch statistics of the Japanese landbased driftnet fishery for salmon, as presented in the INPFC Statistical Yearbooks--continued.

Part B: Data for 1958-1969<sup>1,2</sup>

Year/month	SPECIES					
	Sockeye	Chum	Pink <sup>3</sup>	Coho	Chinook	All species
1958	3,000	43,190	79,930	4,325	461	130,906
April	*	73	104	-	*	176
May	1,230	7,385	7,105	*	119	15,840
June	1,609	21,920	27,983	2	113	51,627
July	119	10,785	33,433	1,301	101	45,739
August	42	3,027	11,305	3,022	128	17,524
1959	2,811	42,837	107,070	6,521	725	159,969
April	-	668	112	-	7	789
May	802	9,524	8,962	-	66	19,356
June	1,625	17,740	51,398	11	126	70,906
July	289	10,218	39,072	3,587	348	53,519
August	93	4,683	7,520	2,921	174	15,395
1960	5,410	42,042	61,905	7,412	1,144	117,913
April	-	324	459	-	2	785
May	2,337	9,608	9,074	*	106	21,125
June	1,404	11,671	31,561	7	168	44,811
July	582	14,242	17,429	4,788	553	37,594
August	1,087	6,197	3,382	2,617	315	13,598
1961	3,963	28,920	108,722	8,007	798	150,410
April	-	159	7	-	-	166
May	2,526	7,619	12,218	-	128	22,491
June	930	9,528	46,803	7	212	57,480
July	441	7,002	45,642	4,711	370	58,166
August	66	4,612	4,052	3,289	88	12,107
1962	456	30,285	37,711	8,732	1,241	78,425
May	134	6,303	10,075	15	170	16,697
June	313	15,536	23,428	216	379	39,872
July	9	7,207	3,893	7,291	613	19,013
August	-	1,239	315	1,210	79	2,843
1963	37	30,866	67,361	9,312	913	108,490
May	-	9,843	9,949	-	97	19,890
June	33	12,149	33,245	13	157	45,598
July	4	7,623	21,521	6,281	562	35,992
August	-	1,250	2,646	3,018	97	7,011
1964	362	35,390	44,038	9,376	1,808	90,974
May	57	12,366	6,403	-	243	19,069
June	260	13,364	24,469	9	434	38,537
July	40	4,990	11,018	752	443	17,243
August	4	4,670	2,148	8,615	688	16,125

Table 4. Catch statistics of the Japanese landbased driftnet fishery for salmon, as presented in the INPPC Statistical Yearbooks--continued.

Part B cont'd

Year/month	SPECIES					
	Sockeye	Chum	Pink	Coho	Chinook	All species
1965	664	33,549	71,358	10,174	1,054	116,799
May	71	9,775	5,498	-	187	15,531
June	564	14,696	43,406	11	295	58,973
July	26	7,385	20,730	6,563	399	35,104
August	2	1,693	1,724	3,600	172	7,191
1966	2,063	47,319	44,103	8,047	1,263	102,793
March	-	-	35	-	-	35
April	-	-	49	-	-	49
May	130	12,489	3,620	-	134	16,376
June	1,766	25,029	32,939	284	443	60,459
July	168	9,742	7,436	7,734	683	25,765
August	-	60	24	29	2	115
1967	8,477	41,612	57,560	7,218	1,254	116,122
March	-	-	57	-	-	57
April	-	0	317	-	-	317
May	4,753	18,510	6,526	0	306	30,097
June	3,702	16,739	41,695	417	478	63,029
July	20	6,294	8,682	6,735	465	22,196
August	2	68	285	66	4	425
1968	8,787	35,514	48,225	7,586	988	101,100
April	-	-	20	-	-	20
May	3,444	10,708	7,989	18	287	22,447
June	5,284	17,291	33,942	2,110	419	59,046
July	51	7,447	6,173	5,443	278	19,389
August	9	68	97	18	2	194
1969	8,450	20,697	64,134	15,403	750	109,434
May	2,937	4,910	6,173	-	108	14,127
June	5,068	14,004	55,229	88	381	74,771
July	445	1,772	2,729	15,196	258	20,401
August	-	11	2	119	2	134

<sup>1</sup>Includes only catches made by the large (>7 g.t.) vessels in the Pacific Ocean.

<sup>2</sup>Catches reported in thousands of pounds.

<sup>3</sup>Includes small amounts of masu salmon.

\*Less than one metric ton (2,205 lbs.).

Table 4. Catch statistics of the Japanese landbased driftnet fishery for salmon, as presented in the INPFC Statistical Yearbooks--continued.

Part C: Data for 1970-1975<sup>1,2</sup>

Year/month area	SPECIES					
	Sockeye	Chum	Pink	Coho	Chinook	All species
1970	4,787	11,687	13,596	4,961	398	35,427
May	3,490	4,188	3,296	3	129	11,106
W	887	1,258	2,359	<0.5	74	4,578
E	2,603	2,930	936	2	54	6,528
June	1,054	6,141	9,270	922	145	17,532
W	337	3,505	7,611	1	91	11,545
E	717	2,636	1,659	921	54	5,987
July	243	1,357	1,030	4,036	123	6,789
W	43	706	979	287	36	2,052
E	200	651	51	3,749	87	4,737
1971	4,550	10,804	16,703	5,613	530	38,200
May	3,369	5,671	2,816	<0.5	184	12,040
W	659	2,143	2,248	<0.5	102	5,152
E	2,710	3,528	568	<0.5	82	6,888
June	1,041	4,140	13,205	798	144	19,328
W	585	2,801	11,973	54	97	15,510
E	456	1,339	1,232	744	47	3,818
July	140	993	682	4,815	202	6,832
W	34	214	610	104	3	965
E	106	779	72	4,711	199	5,867
1972	5,614	16,043	17,893	6,115	536	46,201
May	3,951	8,021	3,578	36	203	15,789
W	671	3,705	2,464	2	96	6,938
E	3,280	4,316	1,114	34	107	8,851
June	1,161	6,898	13,237	1,004	235	22,535
W	725	4,677	11,629	63	151	17,245
E	436	2,221	1,608	941	84	5,290
July	502	1,124	1,078	5,075	98	7,877
W	29	192	890	65	5	1,181
E	473	932	188	5,010	93	6,696
1973	4,690	14,072	21,757	8,562	773	49,854
May	3,681	7,441	2,467	3	215	13,807
W	1,074	3,145	1,668	0	89	5,976
E	2,607	4,296	799	3	126	7,831
June	902	5,814	18,538	2,334	265	27,853
W	443	4,246	15,769	43	127	20,628
E	459	1,586	2,769	2,291	138	7,225
July	107	817	752	6,225	293	8,194
W	13	217	631	543	42	1,446
E	94	600	121	5,682	251	6,748

Table 4. Catch statistics of the Japanese landbased driftnet fishery for salmon, as presented in the INPFC Statistical Yearbooks--continued.

Part C: cont'd

Year/month area	SPECIES					
	Sockeye	Chum	Pink	Coho	Chinook	All species
1974	4,217	19,710	12,052	7,152	926	44,057
May	3,632	11,426	3,191	637	344	19,231
W	313	4,319	2,125	2	76	6,835
E	3,319	7,107	1,066	636	269	12,397
June	433	7,910	7,620	1,297	176	17,437
W	65	7,004	6,978	243	116	14,407
E	368	906	642	1,054	59	3,030
July	151	373	1,240	5,218	406	7,389
W	7	191	1,166	586	47	1,998
E	144	182	74	4,632	359	5,391
1975	3,994	20,500	14,946	7,412	665	47,517
May	3,742	8,053	5,220	261	207	17,483
W	648	2,093	3,245	1	45	6,033
E	3,094	5,960	1,975	260	162	11,450
June	147	10,794	9,168	2,014	192	22,315
W	103	9,345	8,491	98	100	18,137
E	44	1,449	677	1,916	92	4,178
July	105	1,653	557	5,137	266	7,719
W	15	266	421	274	13	988
E	90	1,387	136	4,863	253	6,731

<sup>1</sup>Catches are reported separately for the areas west of 165°E (W) and east of 165°E (E). Catches are in metric tons.

<sup>2</sup>Includes only catches made by large (>7 g.t.) vessels in the Pacific Ocean.

unknown, and other miscellaneous gear) were given. Catches of the six salmon species were lumped into two groups: pink and masu, and all others. From 1958 to 1969 data for the large offshore driftnetters were reported separately, by month and by species (although pink and masu salmon were still reported as one category, only negligible numbers of masu salmon are caught by the offshore driftnetters). From 1970 to present catches have been additionally broken down according to two areas: east and west of 165° E longitude. The most detailed Statistical Yearbooks are in terms of weight, and can be converted to numbers by conversions presented in the INPFC Historical Salmon Catch Statistics Bulletin (INPFC, 1974 MS).

On several occasions Japan has honored requests made by the other member nations of INPFC for a greater degree of detail in data from the land-based driftnet fishery. In 1963, Japan presented catch and effort data for the 1962 fishing season, broken down by month and by INPFC 2° x 5° statistical area. These data included catch in weight and numbers of fish, and effort in tans of gear. Similar breakdowns have since been provided through the INPFC for the years 1972-1976.<sup>1</sup> These detailed data, for sockeye and coho salmon only, are presented graphically in Appendix 1. The charts show catch in thousands of fish, effort in thousands of tans, and catch per tan for each statistical area and month of fishing. The United States and Canada have repeatedly requested landbased fishery data in the same level of detail as provided for the mothership fishery (by 10-day period). The United States has also requested the monthly and statistical areal breakdown of catch and effort for the years 1968-1971. Japan has not honored these requests, claiming that the requested data are not available.

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The effort value in the original data for area E 4542 for June, 1973 is suspiciously high and does not justify the given totals for month and year. In this analysis we used the data as provided in the original document.

Fredin et al. (1977) have used data from the INPFC Statistical Yearbooks for 1958-1969 and data from the INPFC Historical Salmon Catch Statistics Bulletin (INPFC, 1974 MS) to calculate the average contributions of the coastal and offshore driftnet fisheries to the combined catches. They applied these mean values to the combined catches reported for 1952-1957 to obtain estimates of the catches made by only the large, offshore vessels in those years. Species compositions of catches in 1952-1957 were, similarly, estimates. They converted these estimates, in terms of weight, into the estimates of catch in numbers of fish presented in Table 5 and illustrated in Fig. 2.

#### Trends in Catches

As shown in Fig. 2, pink and chum salmon have always constituted the great majority of salmon catches by the landbased driftnet fishery. Combined catches (in numbers) of pink and chum salmon made up 90% or more of the total salmon catch in each year until 1966, after which they made up 76% to 89% of the total catch. Catches of sockeye salmon increased substantially after the mid-1960's to average about 3.3 million in the 1970's. Coho catches have increased gradually throughout the history of the fishery, averaging 3.1 million in the 1970's.

#### Trends in Distribution of Fishing Effort

Fishing strategy can often be inferred by correlating spatial and temporal distributions of fishing effort with some measure of the abundance of fish in various periods and areas of the fishery. As mentioned, landbased driftnet fishery catch and effort data sufficiently detailed to permit this type of analysis are available only for the years 1962 and 1972-1976. In the

Table 5. Catch of salmon by the Japanese landbased offshore driftnet fishery, in thousands of fish, 1952-1976<sup>1</sup>.

Year	Sockeye	Pink	Chum	Coho	Chinook	Total
1952	89	13,344	684	126	8	14,251
1953	191	10,270	1,476	272	17	12,226
1954	344	9,193	2,659	490	31	12,717
1955	511	22,396	3,949	728	46	27,630
1956	271	21,534	2,094	386	24	24,309
1957	488	30,353	3,770	695	44	35,350
1958	903	24,833	9,155	803	45	35,739
1959	845	35,129	9,045	1,204	70	46,293
1960	1,627	20,129	8,684	1,376	111	31,927
1961	1,192	34,559	6,104	1,486	77	43,418
1962	154	14,021	7,577	1,289	124	23,165
1963	18	31,255	7,538	1,492	102	40,405
1964	108	17,247	8,956	1,624	195	28,130
1965	159	29,142	8,330	1,913	93	39,637
1966	703	16,032	11,848	1,458	112	30,153
1967	2,566	23,051	11,078	1,329	110	38,134
1968	2,769	15,899	8,457	1,421	88	28,634
1969	2,495	23,610	4,908	3,328	83	34,424
1970	2,966	13,403	6,585	2,259	101	25,314
1971	3,026	16,977	6,250	2,373	134	28,760
1972	3,718	17,578	8,981	2,423	107	32,807
1973	3,316	24,227	7,837	3,796	165	39,341
1974	3,158	14,424	12,531	3,560	188	33,861
1975	2,982	19,049	11,759	3,556	137	37,483
1976	3,504	9,235	11,432	2,751	198	27,120

<sup>1</sup> Source: 1952-1975 from Table 4.5, Fredin et al. (1977).  
1976 from Japan Fishery Agency.

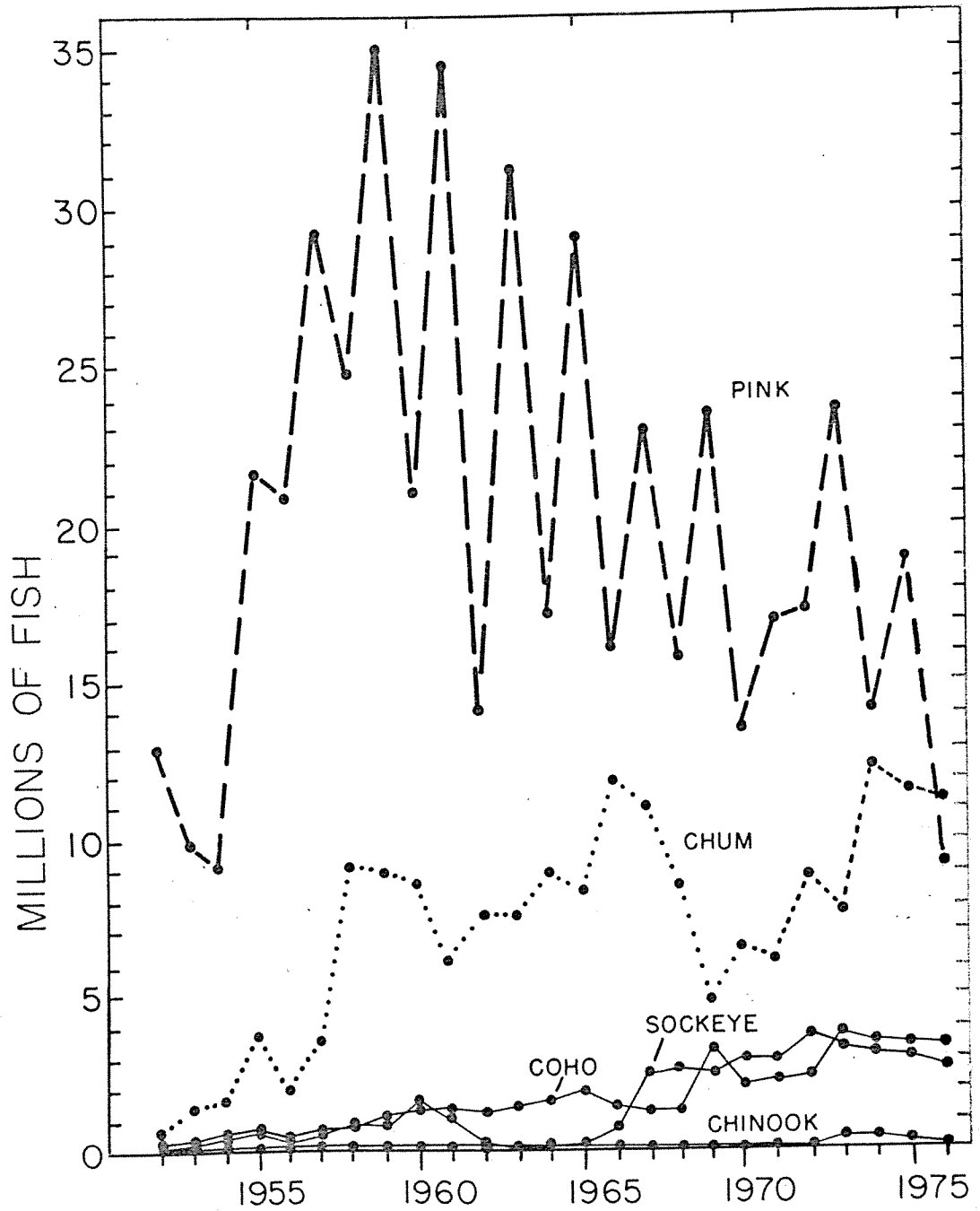


Fig. 2. Annual catch of salmon by the Japanese landbased offshore driftnet fishery, 1952-76. After Fredin, et al. (1977).

subsequent discussion distribution of fishing effort is considered to be the apportionment of tons of gill net to various statistical areas by month, and abundance of each species is measured by catch (in numbers of fish) per ton of net. Enough gear was fished in each area/month combination in most cases that catch per unit of effort (CPUE) probably provides a reliable measure of at least relative abundances of a species across various areas and time periods.

Major changes in spatial and temporal distribution of fishing effort occurred in the years between 1962 and 1972. Figure 3 shows the longitudinal distribution of effort each year by 5° section, and illustrates a major shift of fishing effort to the east before 1972. The reason for this shift is not clear, but an inference is possible from some fragments of economic data provided by Taguchi (1966). He tabulated the profit rates (earnings less expenses/expenses) of driftnet vessels of various sizes for an unspecified year or period between 1952 and 1956, as follows:

<u>Tonnage</u>	<u>Profit rate</u>
< 5	- 76.3%
5	- 60.6
10	- 41.9
15	- 22.9
20	- 20.1
25	- 8.5
30	+ 15.6

Equally striking are his data on the mean profits of driftnet vessels of various sizes in the 1962 calendar year:

<u>Tonnage</u>	<u>Profit</u>
< 10	- 921,000 yen
10-20	- 57,000 "
39-50	+3,151,000 "
50-100	+5,777,000 "

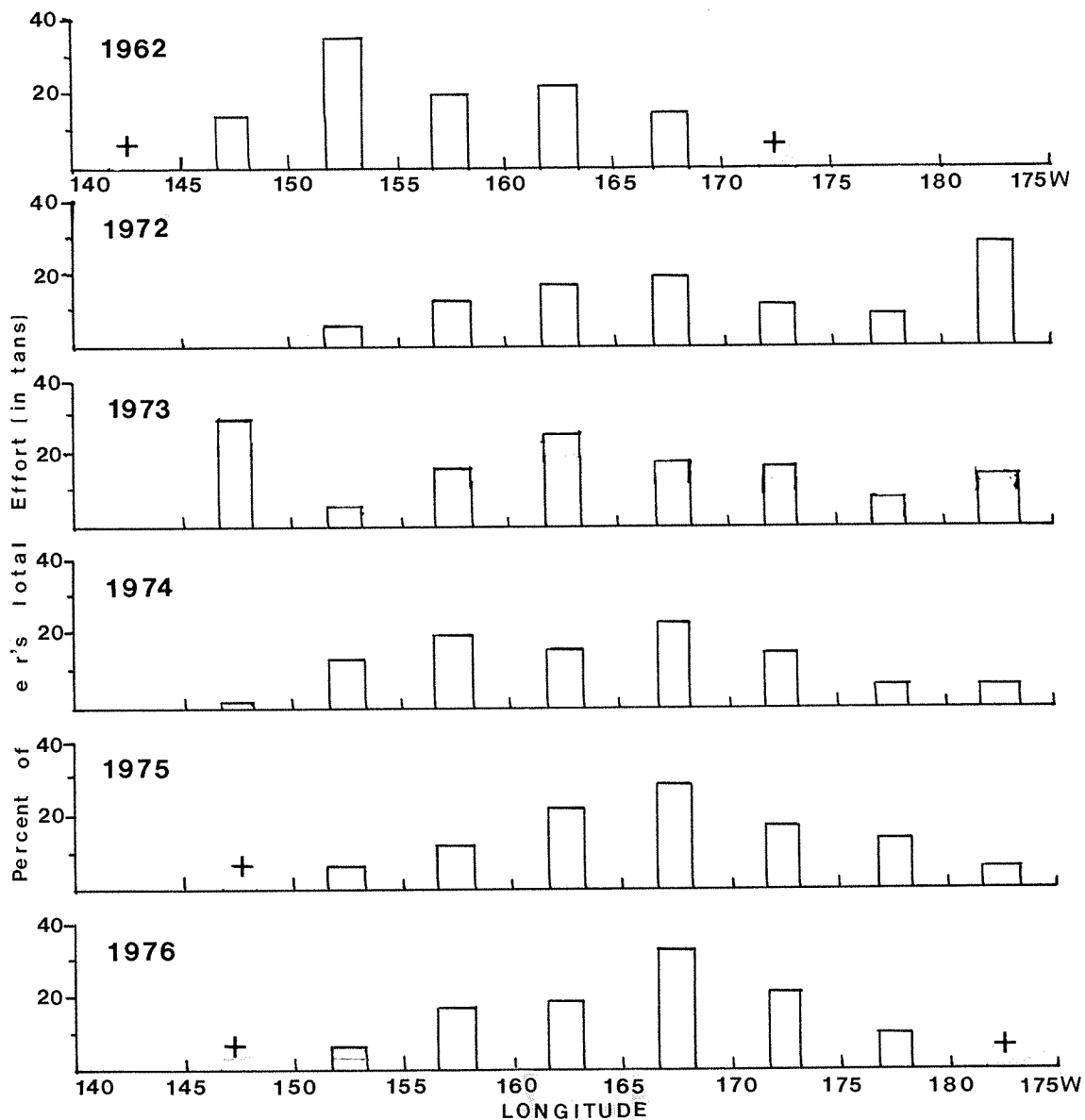


Fig. 3: Longitudinal distribution of landbased offshore (large boats only) driftnet fishing effort, 1962 and 1972-1976. Bars represent the percentage of the year's total effort (in tans of gill net) apportioned to each 5°-longitude section of the fishery region. Plus (+) indicates < 1%.

Clearly the larger vessels, which not only employ more tons of gear but also can stay at sea longer than the smaller boats, had economic advantage in at least the early years of the fishery. There are no data available on changes in size of the large driftnet vessels in the mid- to late-1960's (when the easterly shift in effort probably occurred), but at least in the 1970's replacement vessels were generally larger than their predecessors (Fredin et al., 1977). If this trend extended back into the 1960's, it might have been the newer, larger vessels especially that began to fish farther to the east where abundant offshore stocks could be exploited under conditions of reduced competition from smaller boats.

Figure 4 shows the latitudinal distribution of effort in 1962 and 1972-1976. Fishing has been heavily concentrated in the northern regions of the fishery area, and in the period 1972-1976 it has been almost entirely in the region between  $44^{\circ}$  and  $46^{\circ}$  N.

Another significant change in distribution of landbased driftnet effort that occurred between 1962 and the later years is an increase in the proportion of fishing effort expended in the early part of the fishing season (Table 6). In 1962 about one-third of the year's total effort was expended in each of May, June, and July, whereas in the 1970's almost half (47%) of the total effort occurred in May alone, 34% in June, and only 19% in July.

Because the general longitudinal and temporal distributions of effort varied little in the period 1972-1976 (Fig. 3 and Table 6), we believe that there was one general fishing strategy in this recent five-year period. We have attempted to describe this general strategy by comparing the spatial distribution of fishing effort with the relative abundances of each salmon species across various statistical areas. This analysis only

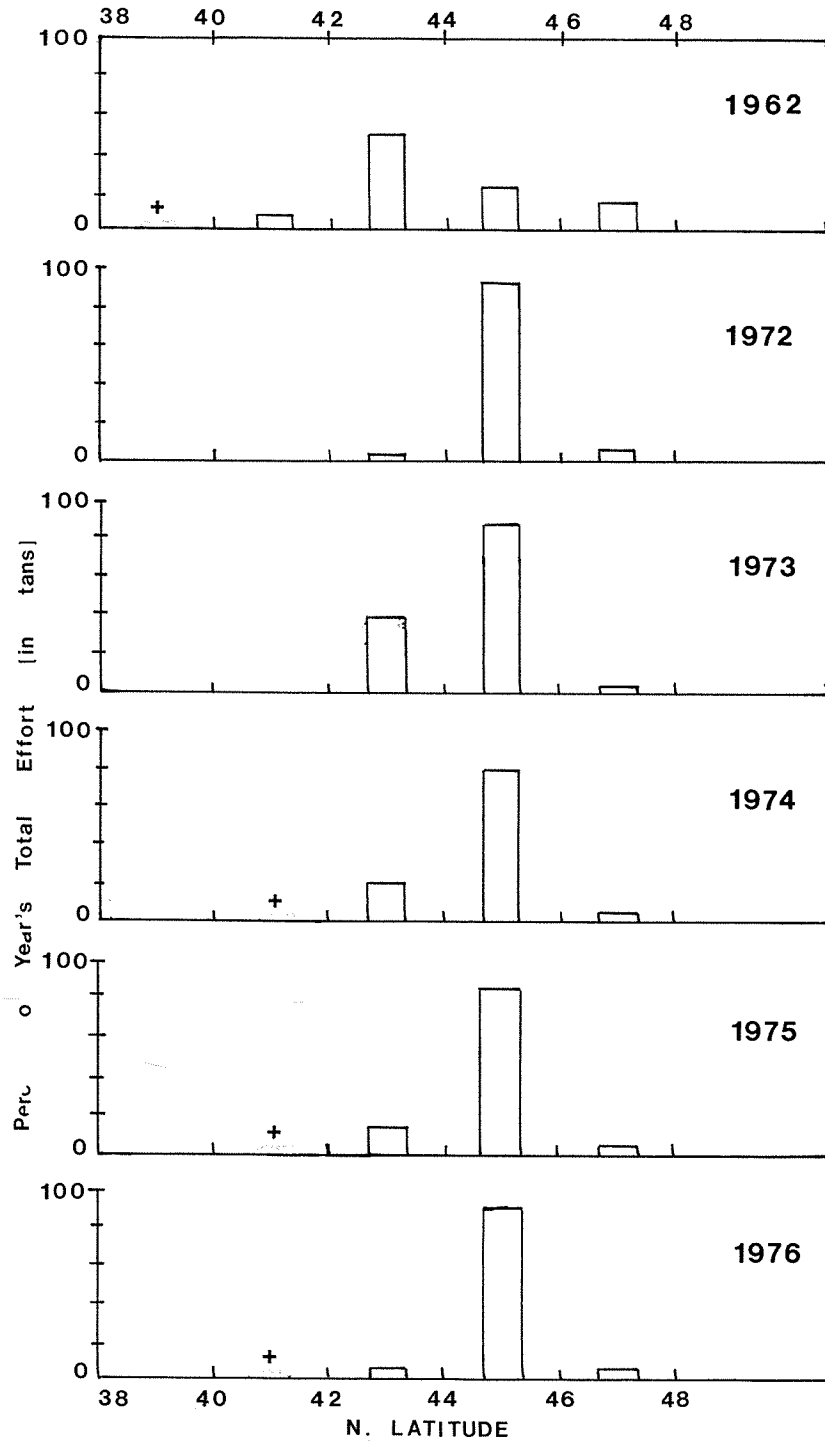


Fig. 4. Latitudinal distribution of landbased offshore (large boats only) driftnet fishing effort, 1962 and 1972-1976. Bars represent the percent of the year's total effort (in tans of gill net) apportioned to each 2°-latitude section of the fishery region. Plus (+) indicates < 1%.

Table 6. Monthly distribution of fishing effort by the Japanese landbased driftnet fishery, 1962 and 1972-1976.<sup>1,2</sup> Units are tons of driftnet, and figures in parentheses are percentages of the year's total effort.

Year	Total tans	MONTH			AUGUST
		MAY	JUNE	JULY	
1962	6,867,075	2,249,877 (32.76)	2,428,869 (35.37)	2,183,270 (31.79)	5,059 (0.07)
1972	5,154,891	2,458,623 (47.70)	1,640,204 (31.82)	1,056,064 (20.49)	-
1973	5,753,803	2,585,078 (44.93)	2,156,279 (37.48)	1,012,446 (17.60)	-
1974	6,019,806	2,835,414 (47.10)	2,148,504 (35.69)	1,035,888 (17.21)	-
1975	5,991,072	2,749,993 (45.90)	1,909,399 (31.87)	1,331,680 (22.23)	-
1976	5,945,590	2,935,124 (49.37)	1,943,432 (32.69)	1,067,034 (17.95)	-

<sup>1</sup> Data source: Japan Fishery Agency.

<sup>2</sup> Data is for large vessels (> 7 g.t.) only.

makes sense after the relative magnitudes of catches of each species in various months are determined. As shown in Fig. 5, almost the entire season's catch of sockeye salmon has been made in May (72-94% in the five-year period). The majority of combined salmon catches in May, however, has consisted of chum and pink salmon. Catches of coho and chinook salmon are incidental in May. By June, pink salmon constitute the majority of total salmon catch. Many fewer sockeye are caught in June than in May, and chum catches are roughly the same as in May. Significantly larger numbers of coho salmon are caught in June than in May, and in the last four years the June coho catches have exceeded the sockeye catch. In July comparatively few sockeye, chum, or pink salmon are caught, leaving coho as the predominant species in the catches.

The May fishing strategy can be deduced from a comparison of Figs. 6-10. Figure 6 shows that the areas of heaviest fishing in May closely coincide with the areas of greatest abundance of sockeye salmon. The concentration of effort in statistical areas E 6044, E 6544, E 7044, E 7544, and 8044 is even more striking than shown in Fig. 6, because fishing in May is restricted to Area B, south of 45° N. Chum salmon are fairly evenly distributed across the entire fishery area, although perhaps somewhat more abundant west of 160° E (Fig. 7). Pink salmon are clearly more abundant in the western half of the fishery area (Fig. 8). The fishing fleet obviously seeks sockeye in May, no doubt because the spring northerly migration of both maturing and immature sockeye (French et al., 1976) makes the species much less abundant later in the season. Although sockeye salmon appears to be a target species in May, chum and pink salmon nevertheless make up the bulk of May catches by virtue of their overall greater abundance.

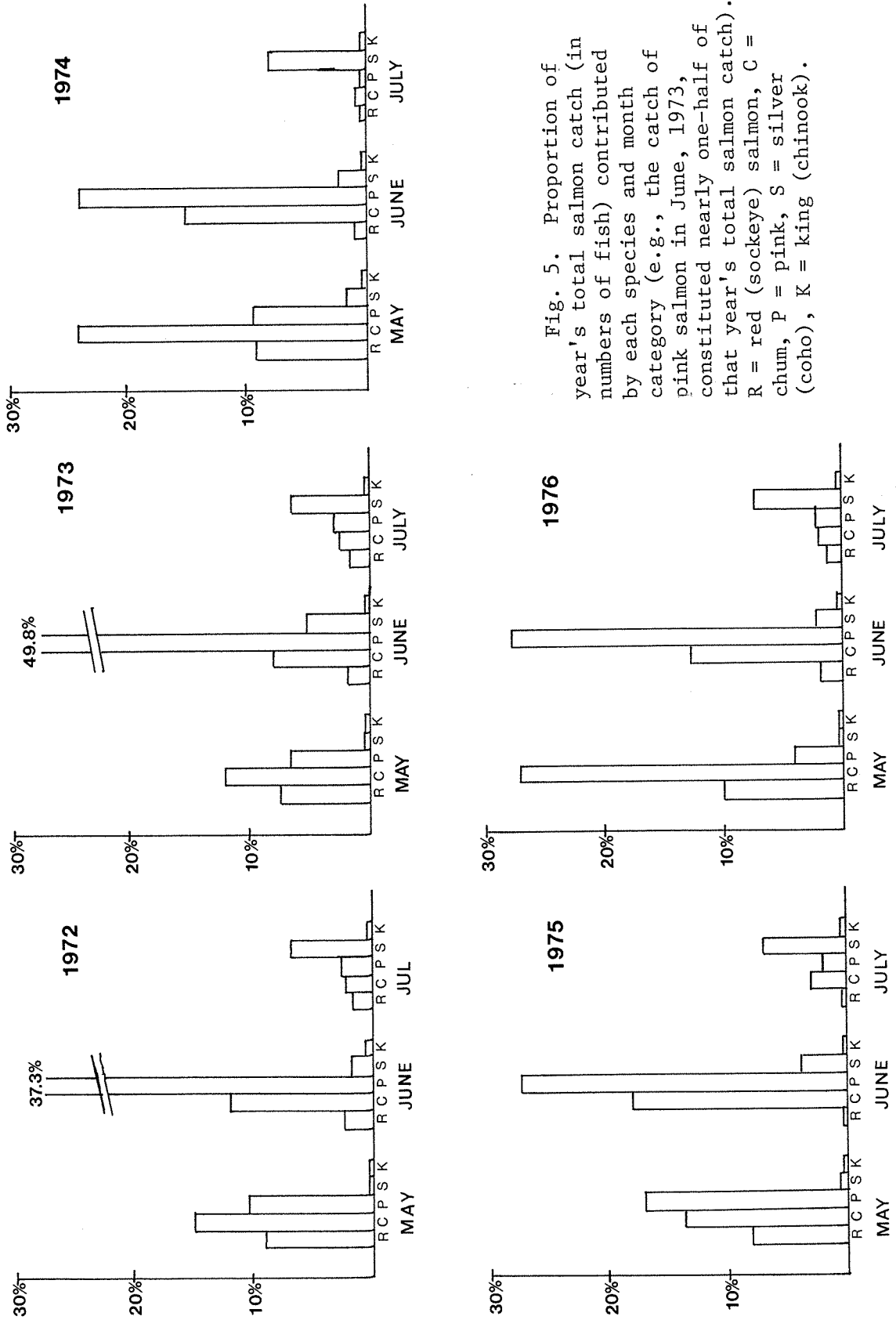


Fig. 5. Proportion of year's total salmon catch (in numbers of fish) contributed by each species and month category (e.g., the catch of pink salmon in June, 1973, constituted nearly one-half of that year's total salmon catch). R = red (sockeye) salmon, C = chum, P = pink, S = silver (coho), K = king (chinook).

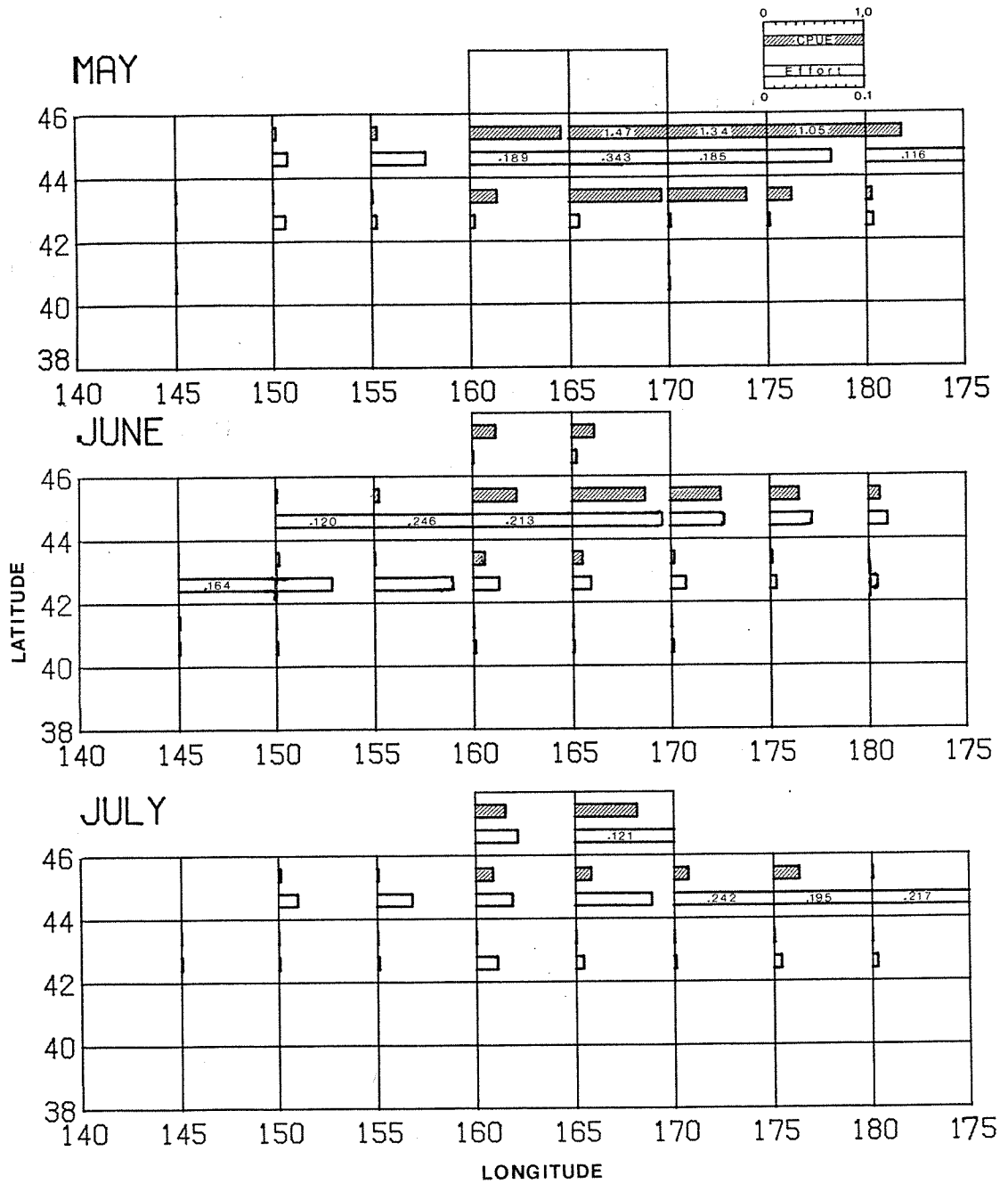


Fig. 6. Comparison of spatial distribution of effort in each month and relative abundance (CPUE) of sockeye salmon in the landbased driftnet fishery region. Top bars are the unweighted mean CPUEs of sockeye, and the bottom bars are the mean proportions of the indicated month's total effort, 1972-1976. Each 2°x5° statistical area is scaled to 0.1 for effort and to 1.0 for CPUE.

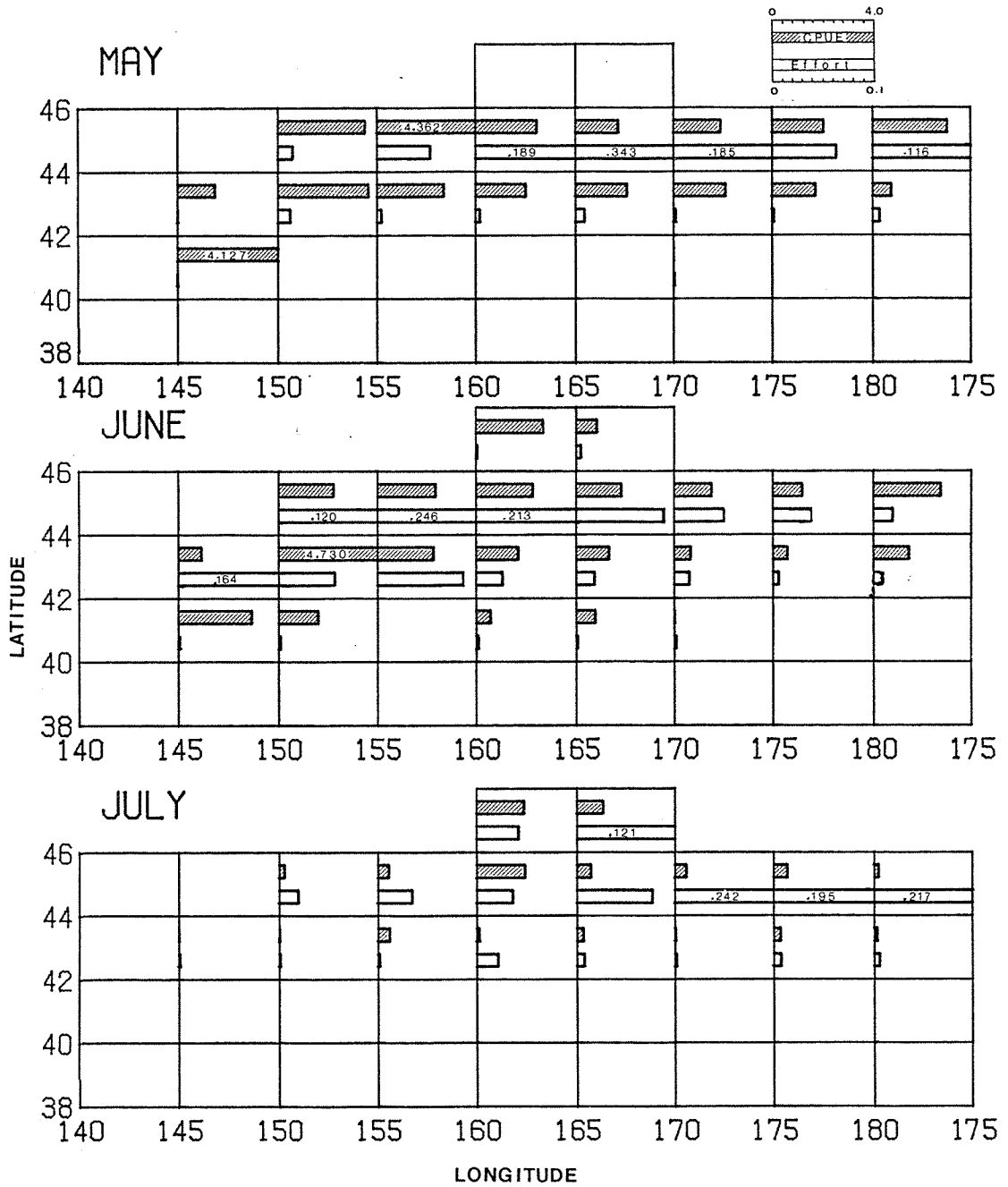


Fig. 7. Comparison of spatial distribution of effort in each month and relative abundance (CPUE) of chum salmon in the landbased driftnet fishery region. Top bars are the unweighted mean CPUE's of chum, and the bottom bars are the mean proportions of the indicated month's total effort, 1972-76. Each 2°x5° statistical area is scaled to 0.1 for effort and to 4.0 for CPUE.

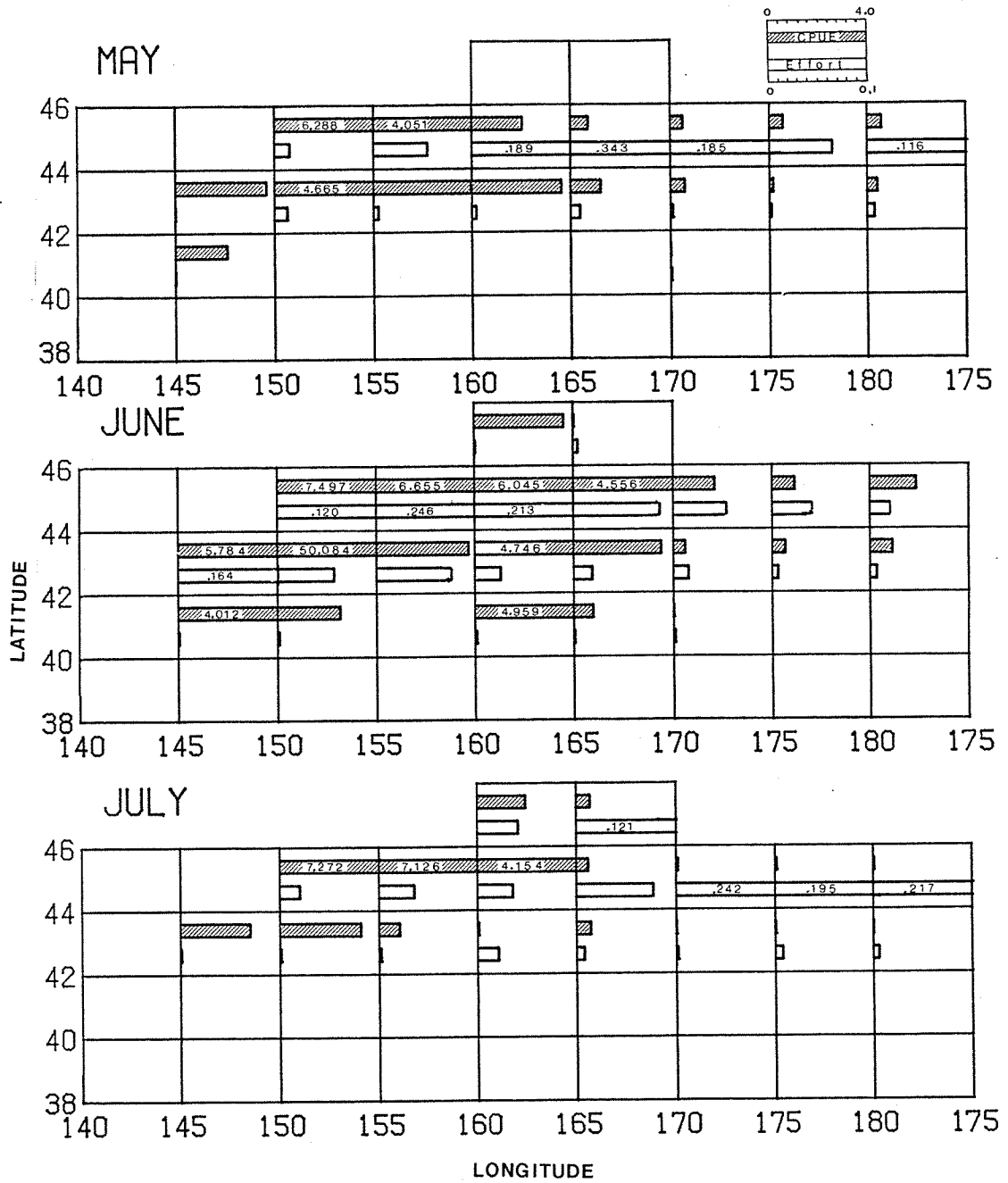


Fig. 8. Comparison of spatial distribution of effort in each month and relative abundance (CPUE) of pink salmon in the landbased driftnet fishery region. Top bars are the unweighted mean CPUE's of pink, and the bottom bars are the mean proportions of the indicated month's total effort, 1972-76. Each 2°x5° statistical area is scaled to 0.1 for effort and to 4.0 for CPUE.

In June the fishing effort is shifted to the west, away from the areas of highest abundance of sockeye salmon (Fig. 6) but toward the large concentrations of pink (Fig. 8) and, to a lesser extent, chum salmon (Fig. 7). The CPUE values of sockeye in June are much lower than in May, while those of pink are higher than in May. We interpret the westward shift in fishing effort as a shift of target species from sockeye, which become less abundant as maturing and immature fish move north, to pink and chum salmon which are most abundant in the western part of the fishery area. Coho salmon are considerably more abundant in the fishery area in June than in May, but mainly in the far eastern areas where fishing effort is least (Fig. 9). Figure 9 shows that fishing effort in July is again concentrated far to the east, where coho are most abundant. There is little doubt that coho salmon is the target species in July.

Figure 10 presents the same comparison of effort distribution and abundance for chinook salmon. Compared to the other four species, very few chinook salmon are caught in any month or region of the fishery. The species is probably not given much consideration by fishermen in deciding fishing strategies.

#### Sockeye and Coho Salmon Stocks in the Landbased Fishery Area

##### Japanese High Seas Salmon Research

Whereas the catches by the mothership salmon fishery are regularly sampled by on-board fishery agents for determination of important biological attributes such as size of fish, weights, and age and maturity composition, very little biological data are taken from the catches of the landbased drift-netters. Virtually all information on the distributions, migrations, age and

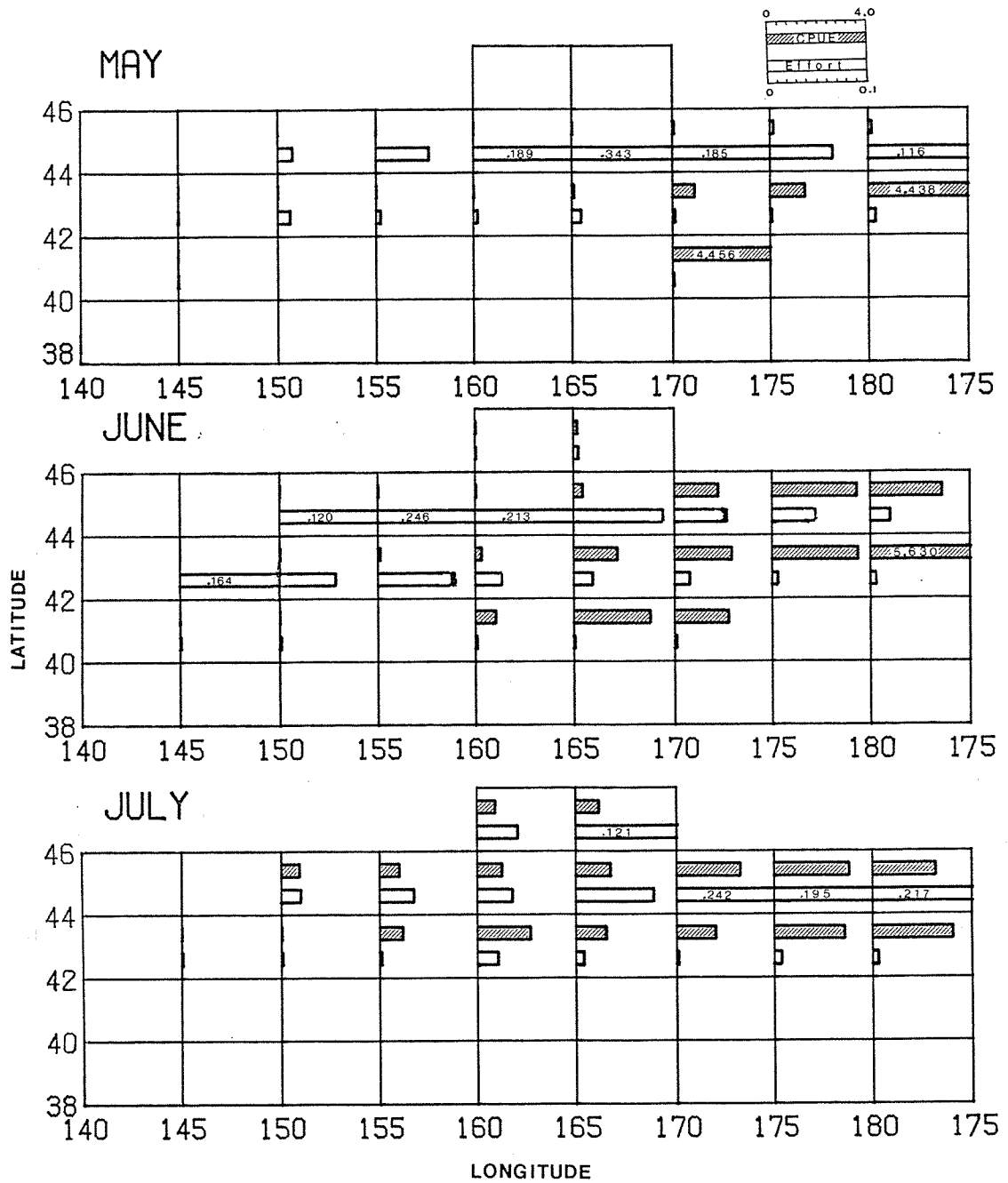


Fig. 9. Comparison of spatial distribution of effort in each month and relative abundance (CPUE) of coho salmon in the landbased driftnet fishery region. Top bars are the unweighted mean CPUE's of coho, and the bottom bars are the mean proportions of the indicated month's total effort, 1972-76. Each 2°x5° statistical area is scaled to 0.1 for effort and to 4.0 for CPUE.

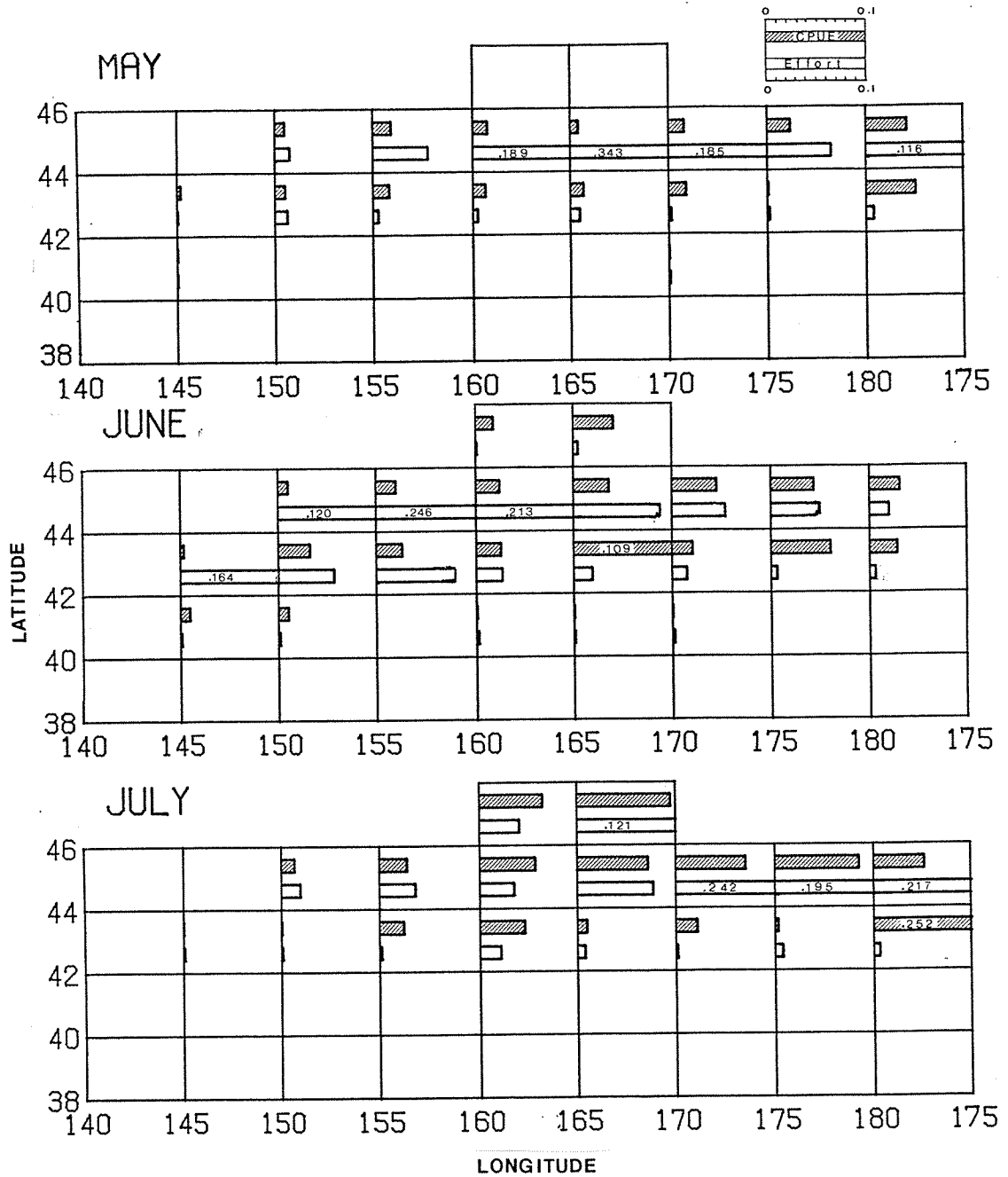


Fig. 10. Comparison of spatial distribution of effort in each month and relative abundance (CPUE) of chinook salmon in the landbased driftnet fishery region. Top bars are the unweighted mean CPUE's of chinook, and the bottom bars are the mean proportions of the indicated month's total effort, 1972-76. Each 2°x5° statistical area is scaled to 0.1 for effort and CPUE.

maturity compositions, and on other biological characteristics comes from the salmon research program carried out by Japan. It is necessary to compare the characteristics and operations of the research and commercial vessels as we must use results of the research operations to infer attributes of the commercial catches.

Japan has regularly monitored the abundance and migrations of salmon stocks in large areas of the western and central North Pacific Ocean, Sea of Okhotsk, and Bering Sea since the mid-1950's as part of its research commitment to the INPFC and to provide information useful to her high seas fisheries. The predominant sampling gear has been gillnets, comparable to those used by the commercial fleets. Abundance and migrations are measured by catch per unit of effort in synoptic sampling across various times and areas. Data routinely recorded prior to each set of gear include date, location, time of set, duration of set, direction of set, surface temperature, bathythermograph readings, water color, wind speed and direction, sea state, and air pressure. Biological information recorded for samples or subsamples of catch of each species include length, body weight, sex, gonad weight, and age (determined from scale samples). A couple of boats engage in tagging experiments, and use longlines (in addition to gillnets) to catch viable fish for tagging.

In the period 1972-1976, 15-16 research vessels sampled large areas of the North Pacific, including the area of the landbased fishery. Pre-determined sampling transects were sampled, but research vessels typically wander over large areas and sample in a non-systematic fashion before or after the sampling legs at the preassigned transects. A little over one

half of the total research effort is according to transect sampling. The vessels are typically much larger than the landbased driftnetters, the largest being over 400 tons. Two types of monofilament gillnet are fished in each set: commercial gear, which consists of mesh sizes (stretch measure) of 111, 115, and/or 121 mm, and the so-called nonselective gear which consists of (usually) equal lengths of the following meshes: 48, 55, 63, 72, 82, 93, 106, 121, 138, and 157 mm. Catches by the two types of net and by the various meshes are tallied separately for determining CPUE indices. A typical set would consist of 264 tans of commercial net (gear A) and 30 tans of the variable-mesh nonselective gear (gear C). In the landbased fishery area, virtually all sets of gear A employ the smaller mesh sizes, 111 or 115 mm, because a comparable size of mesh is used by the commercial fleet (110-115 mm) and because research catches are used to determine average weights of fish which are used as conversion factors applied to the commercial catches (K. Takagi, personal communication).

One notable difference between the operating characteristics of the research vessels (at least of one such vessel visited by a U.S. observer) and the commercial vessels is that the research net is set in a direction with respect to wind and current that facilitates rapid and easy retrieval the following morning.<sup>1</sup> The commercial boats in both the mothership and landbased fishery set their nets so as to intersect the predominant migratory direction of the fish. This difference in operation might well account for the generally lower CPUE indices obtained by the research vessels as compared to the commercial boats.<sup>2</sup> Another factor which would explain the lower CPUE

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<sup>1</sup>Iwaoka, Wayne. Second observer's report on the Japanese salmon research vessel, Riasu Maru No. 2 (Unpublished manuscript prepared 1976), 17 pp and figs. and tables.

<sup>2</sup>Of 59 statistical area/year combinations for which research (gear A) and landbased driftnet CPUE indices were available for sockeye in May, 1972-1976, 43 (73%) cases showed the commercial CPUE higher than the research CPUE. Similarly, of 51 combinations for which research and commercial CPUE was available for coho in July, 43 (84%) cases showed higher CPUE values for the commercial operations.

of research operations is that over half of the total research effort is placed at predetermined sampling stations, while the commercial units are presumably seeking out and fishing in areas of high concentrations of fish.

The distribution of fishing effort by the research fleet has differed somewhat from that of the commercial operations, in part because extensive, area-wide sampling is one goal of the research program. Table 7 shows the monthly allocation of research effort by gear A (approximately the same percentage figures would apply to the nonselective nets as well) in the landbased fishery area during the period May-July. Generally a greater amount of sampling is done in May than the other months, but the research sampling is spread a lot more evenly over the period than is commercial fishing by the driftnetters (Table 6).

The spatial distribution of research effort has also differed from that of the commercial effort. Figure 11 illustrates the average within-month distribution of effort of the research vessels (gear A only) and, for comparison, that of the driftnet vessels. In May the predominant research effort is in the north central landbased area, whereas the driftnetters fish mainly in the northeastern sectors. In June both research and commercial operations have tended to be concentrated in the northern sectors between  $150^{\circ}$  E and  $170^{\circ}$  E. By July the respective effort distributions of research and commercial boats have diverged considerably; the research effort has tended to become even more concentrated in the northwestern sectors, while the commercial operations have shifted far to the northeastern areas, presumably to fish coho stocks.

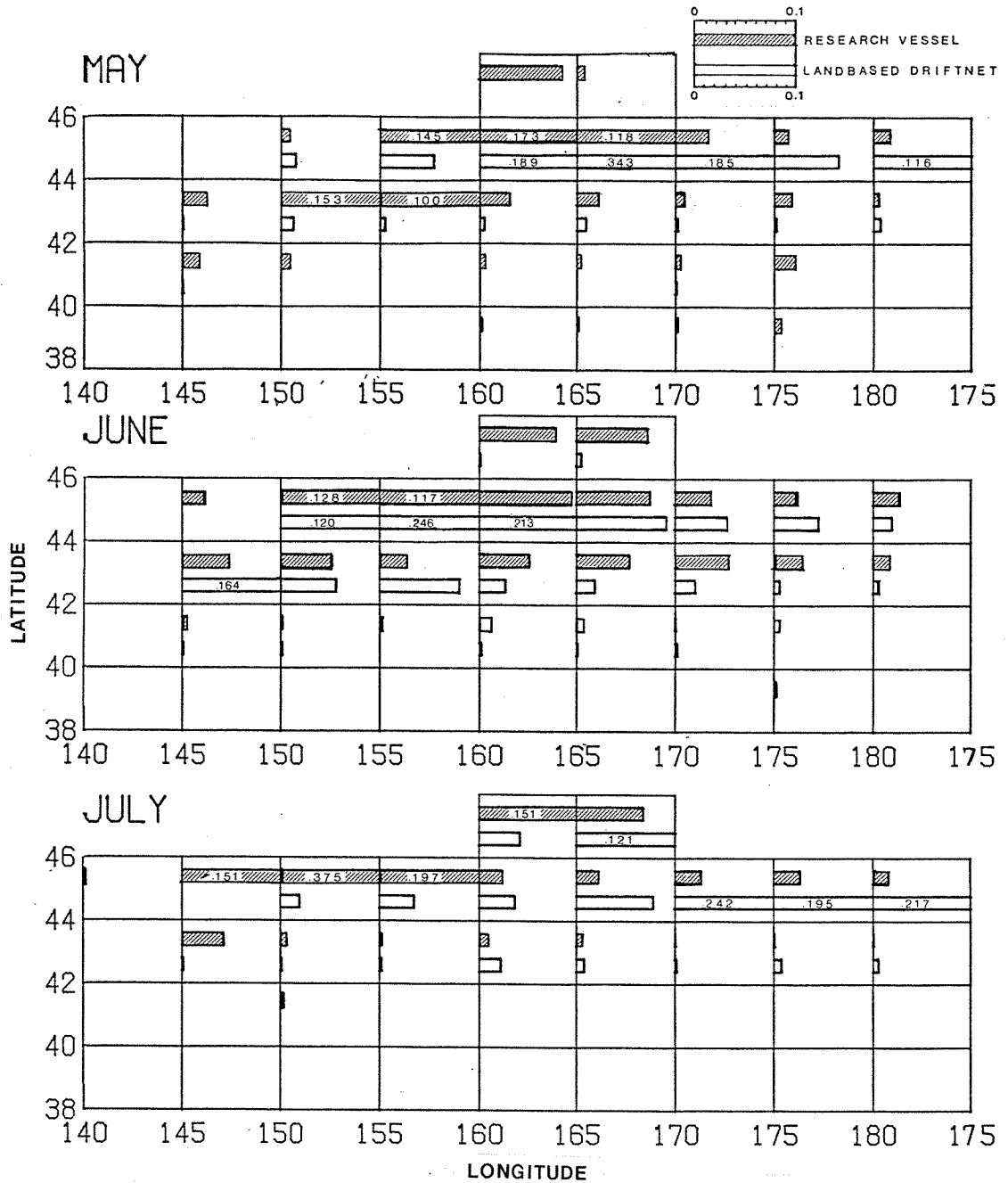


Fig. 11. The mean (unweighted) proportions of the indicated month's total fishing effort by the Japanese salmon research vessels (top bars, gear A only) and by the landbased driftnetters (bottom bars), 1972-1976. Data source is Japan Fishery Agency.

Table 7. Monthly distribution of fishing effort by Japanese salmon research vessels, commercial gear A only, in the landbased fishery region, 1972-1976. Sampling occurred in other months, but the totals are only for the three months indicated.

Year	Total tans	MAY		JUNE		JULY	
		tans	%	tans	%	tans	%
1972	77,827	32,434	41.67	27,078	34.79	18,315	23.53
1973	83,995	41,218	49.07	22,308	26.56	20,469	24.37
1974	83,938	31,577	37.62	25,469	30.34	26,892	32.04
1975	67,251	25,315	37.64	22,961	34.14	18,975	28.22
1976	69,587	25,434	36.55	25,243	36.28	18,910	27.18

### Maturity and Age Composition of Sockeye Salmon in the Landbased Fishery Area

The maturity and age composition and other biological features of the sockeye salmon stocks in the landbased fishery region as known before 1972 are summarized by French et al. (1976). The Fishery Agency of Japan recently provided detailed information on the maturity and age composition of sockeye sampled in 1972-1976 by research vessels (commercial gear A only) in the landbased area. We have used these recent data to infer characteristics of the catches of the landbased driftnetters. Figures 12-14 show the unweighted average percent of mature and immature sockeye sampled by the research vessels in 1972-1976, by INPFC statistical area and by month. Yearly percentages were included in calculation of the means only if based on a sample size of at least 30 fish.

During May catches in the western portion of the fishery area are mainly of maturing fish whereas catches in the eastern portion are mainly of immatures (Fig. 12). The few samples available indicate no north-south deviations in this apparent longitudinal maturity gradient. By June (Fig. 13) the dominance of immatures in the catches has shifted to the west 5-10° longitude. There is also a clear trend in June for the proportions of maturing fish to be larger toward the north. Data for July are very scant (Fig. 14). No change in maturity composition in the far western portion of the fishery is evident. Area E 6546 in the northcentral part of the area shows a predominance of immature fish whereas matures were more abundant in June, suggesting that a further shift to the west in the predominance of immatures may occur in July. This temporal and spatial change in the maturity composition of the samples collected surely reflects the movement of maturing fish from high seas areas towards the parent streams.

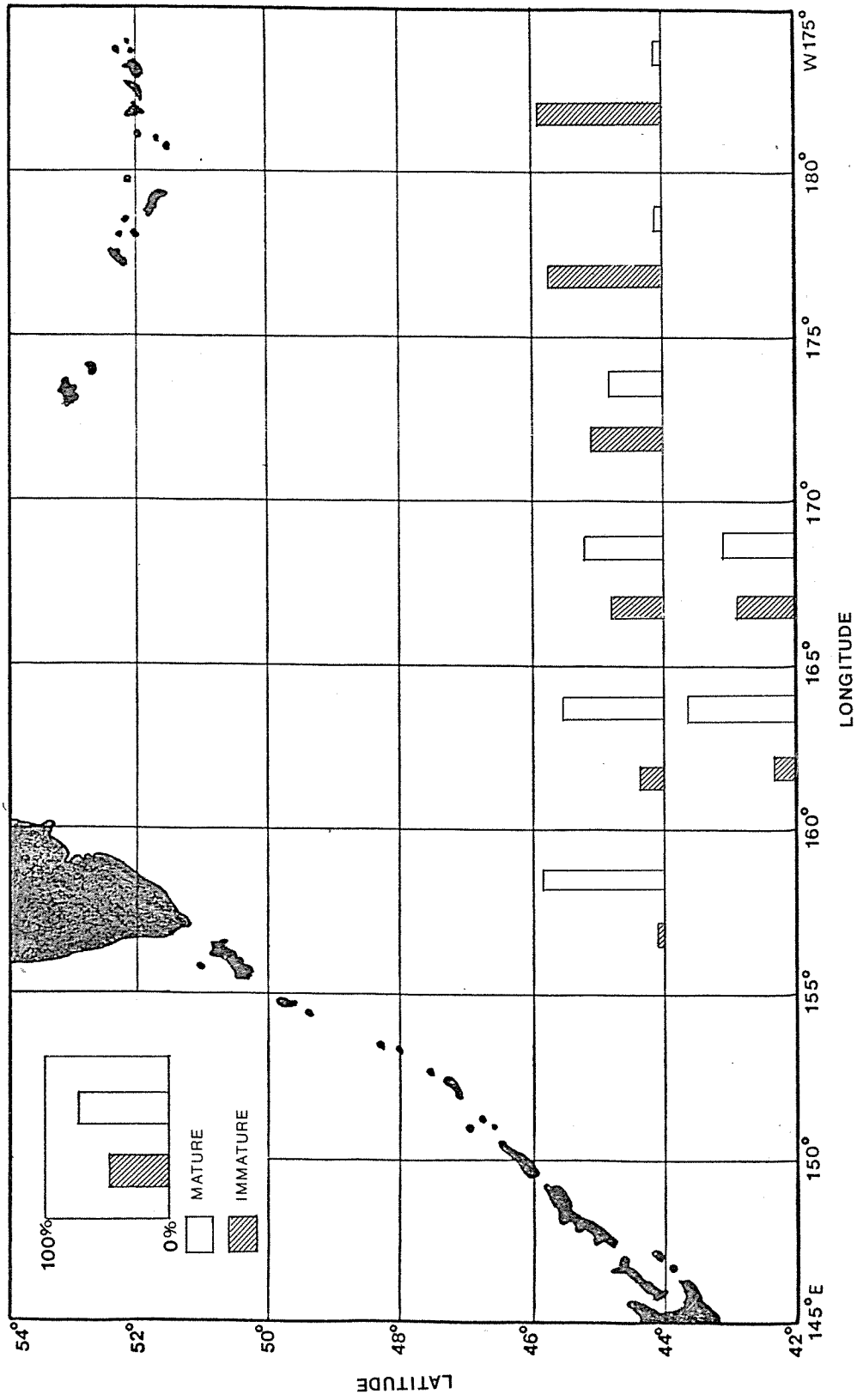


Fig. 12. Unweighted average percent of mature and immature sockeye salmon sampled by JFA research vessels in 1972-1976 by INPFC statistical area for the month of May.

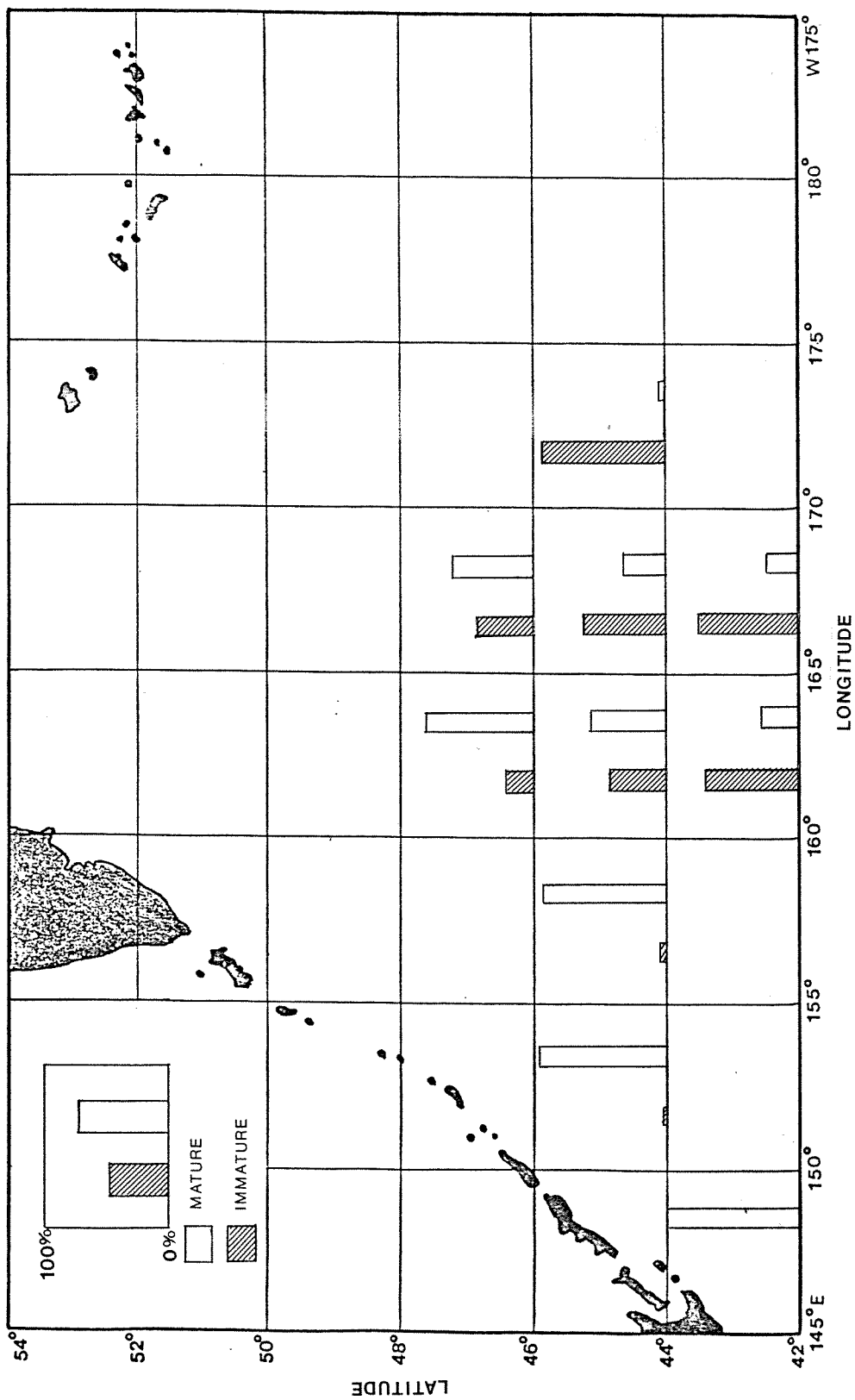


Fig. 13. Unweighted average percent of mature and immature sockeye salmon sampled by JFA research vessels in 1972-1976 by INPFC statistical area for the month of June.

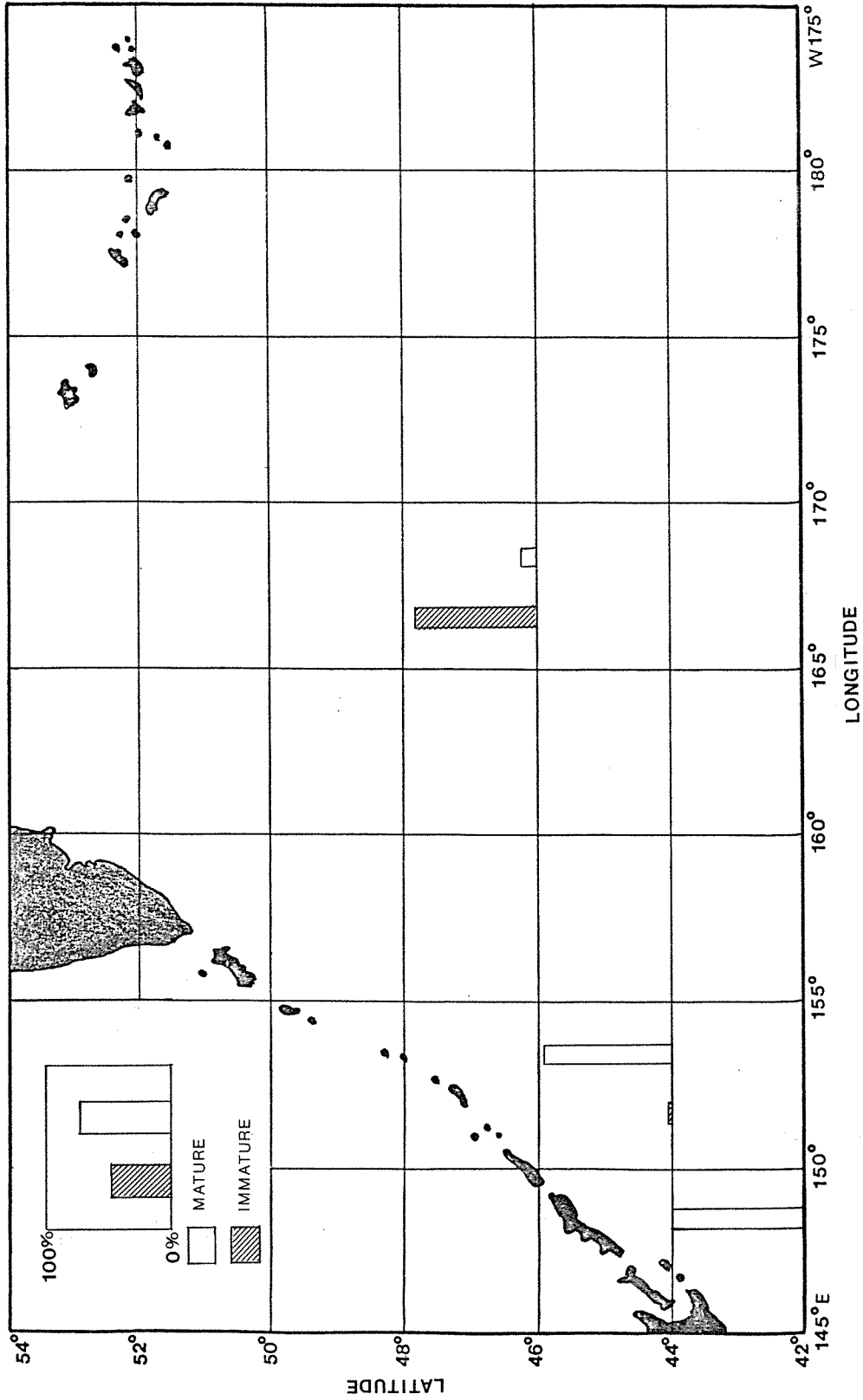


Fig. 14. Unweighted average percent of mature and immature sockeye salmon sampled by JFA research vessels in 1972-1976 by INPFC statistical area for the month of July.

The average ocean age composition of samples collected from maturing and immature sockeye is similarly shown in Figures 15-20. Immature sockeye are almost entirely 2-ocean age regardless of time or location of sampling. Maturing fish are also mainly 2-ocean age, although the proportion of age .3 fish is markedly higher in areas west of about 160° E in May-July.

Current Status of Knowledge Regarding the Origin of Sockeye and Coho Salmon in the Landbased Fishery Area

Most of what is known about the continent of origin of sockeye salmon in various areas of the North Pacific has come from four types of studies: tagging experiments, parasitological studies, age composition analyses, and scale pattern recognition analyses. Racial analysis of sockeye in the landbased area by means of scale pattern analysis has not been attempted before the present study. The origins of coho salmon in the North Pacific are poorly known, and are based solely on tagging studies (Godfrey et al., 1975).

Extensive tagging experiments have provided much information about the oceanic distributions of various major stocks of sockeye, and, to a lesser extent, coho salmon (Godfrey et al., 1975; French et al., 1976; French, et al., 1975). It is difficult to establish the farthest extents of various stocks' oceanic distributions by tagging because of the relatively low probability of catching fish of a certain stock near the extremity of its range, coupled with the overall low probability of recapture. To assess the effectiveness of tagging experiments in determining the distribution of a given stock, the number of and spatial and temporal distributions of tag releases must be examined in light of the most likely times and locations of that stock in the area of interest.

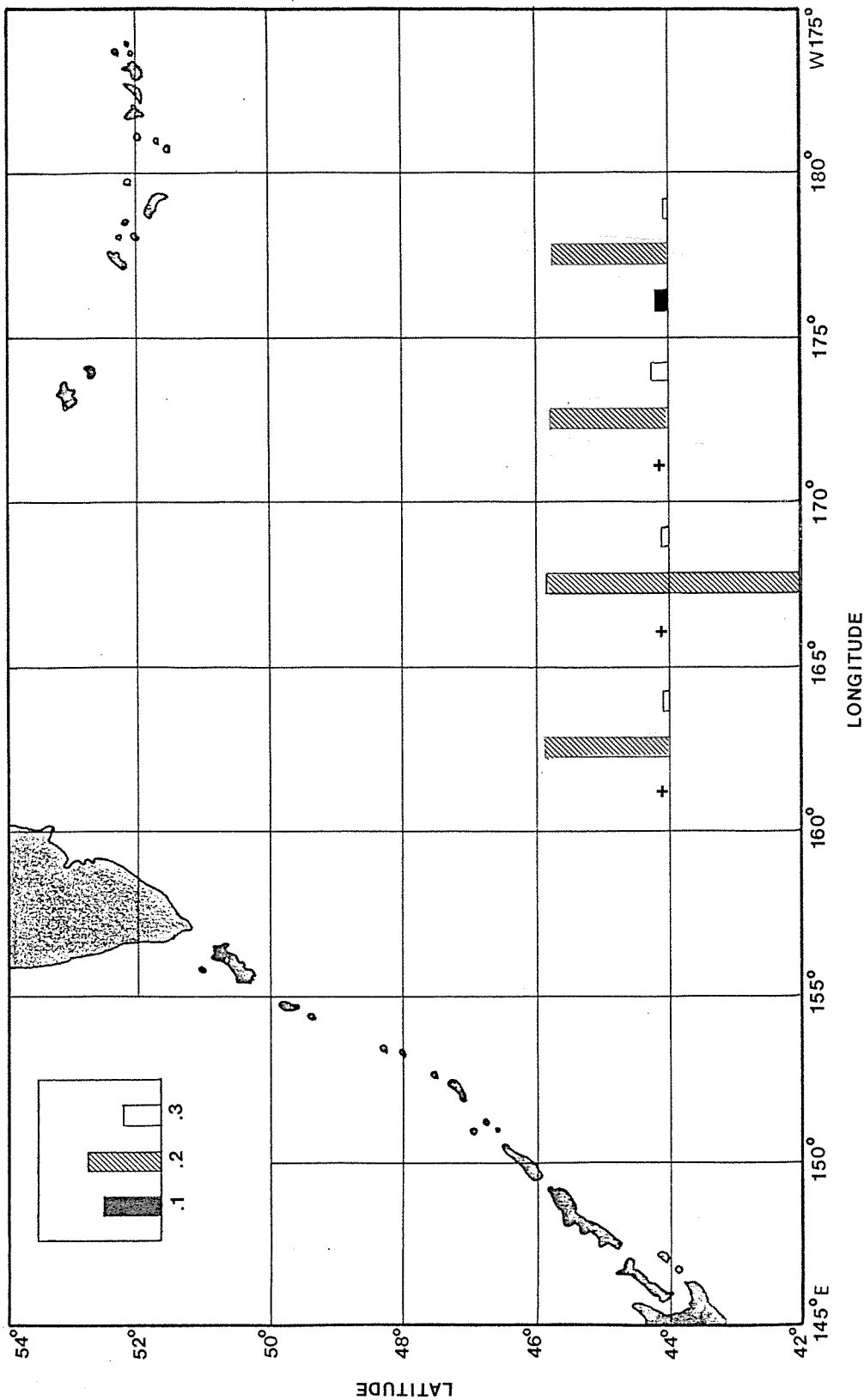


Fig. 15. Ocean age composition of immature sockeye salmon sampled by JFA research vessels for the month of May in the years 1972-1976, by INPFC statistical area. Data for a year were included in the calculation of the mean unweighted percent only if based on a sample of at least 30 fish. Plus (+) indicates < 1%.

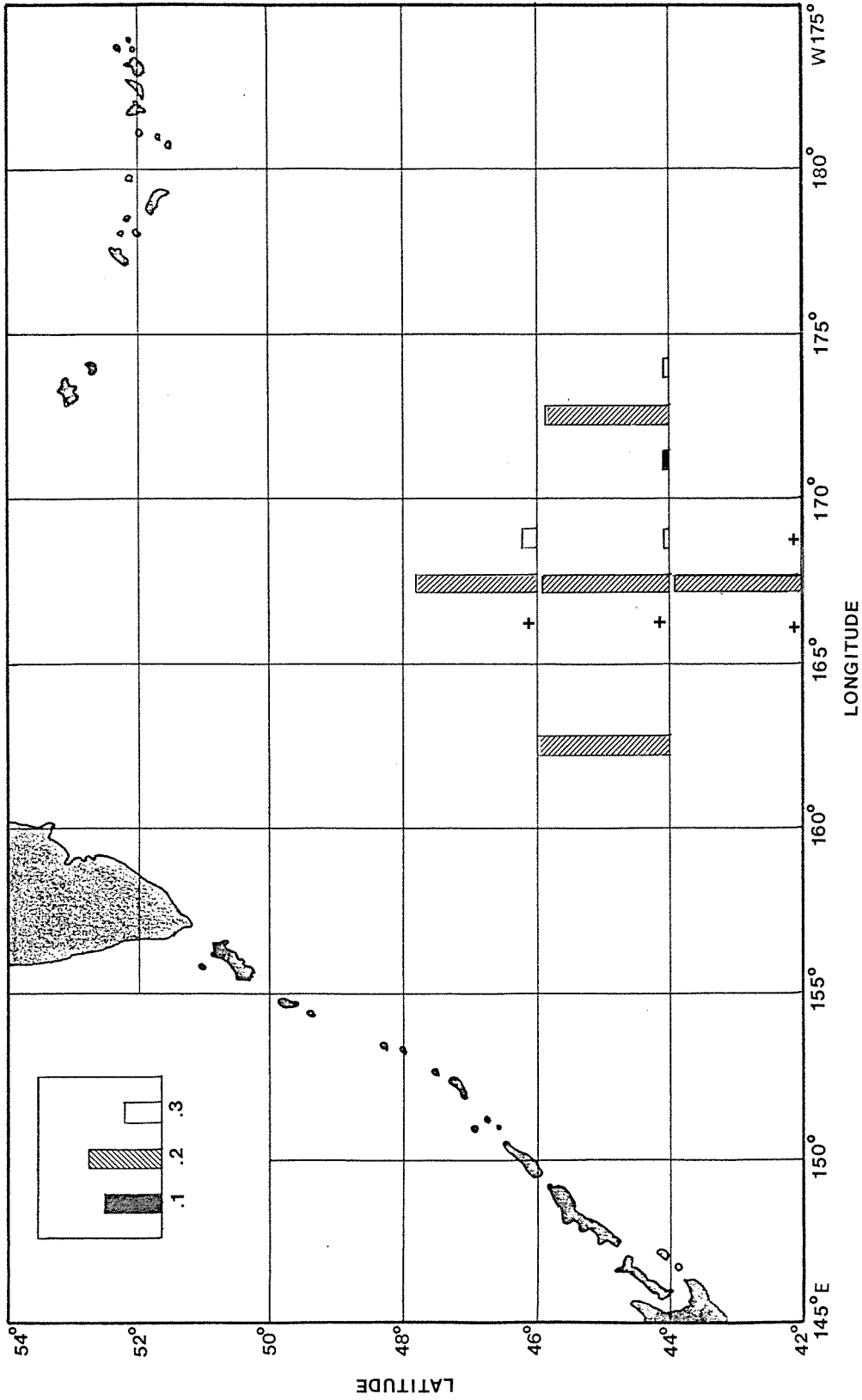


Fig. 16. Ocean age composition of immature sockeye salmon sampled by JFA research vessels for the month of June in the years 1972-1976, by INPFC statistical area. Data for a year were included in the calculation of the mean unweighted percent only if based on a sample of at least 30 fish. Plus (+) indicates < 1%.

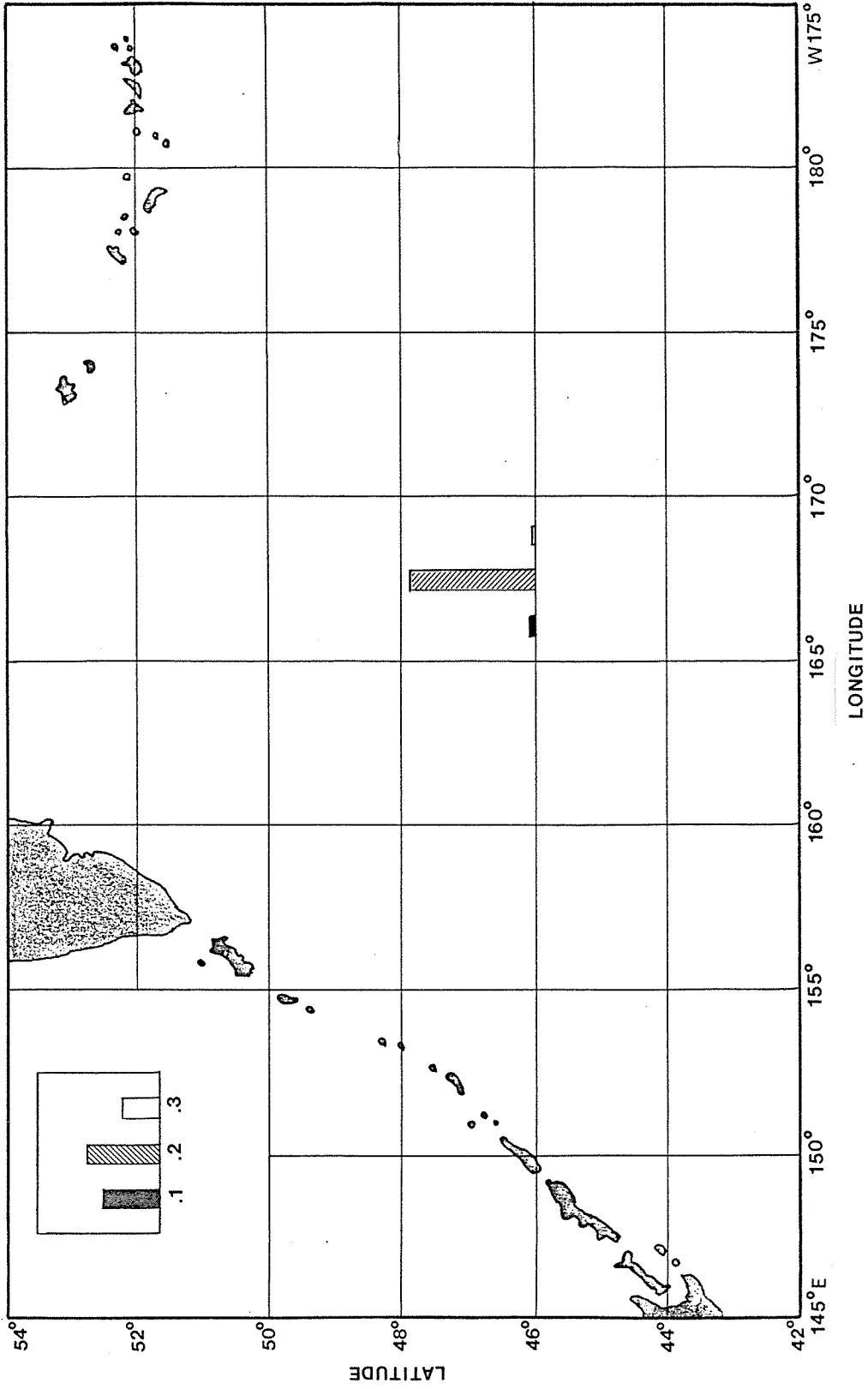


Fig. 17. Ocean age composition of immature sockeye salmon sampled by JFA research vessels for the month of July in the years 1972-1976, by INPPC statistical area. Data for a year were included in the calculation of the mean unweighted percent only if based on a sample of at least 30 fish.

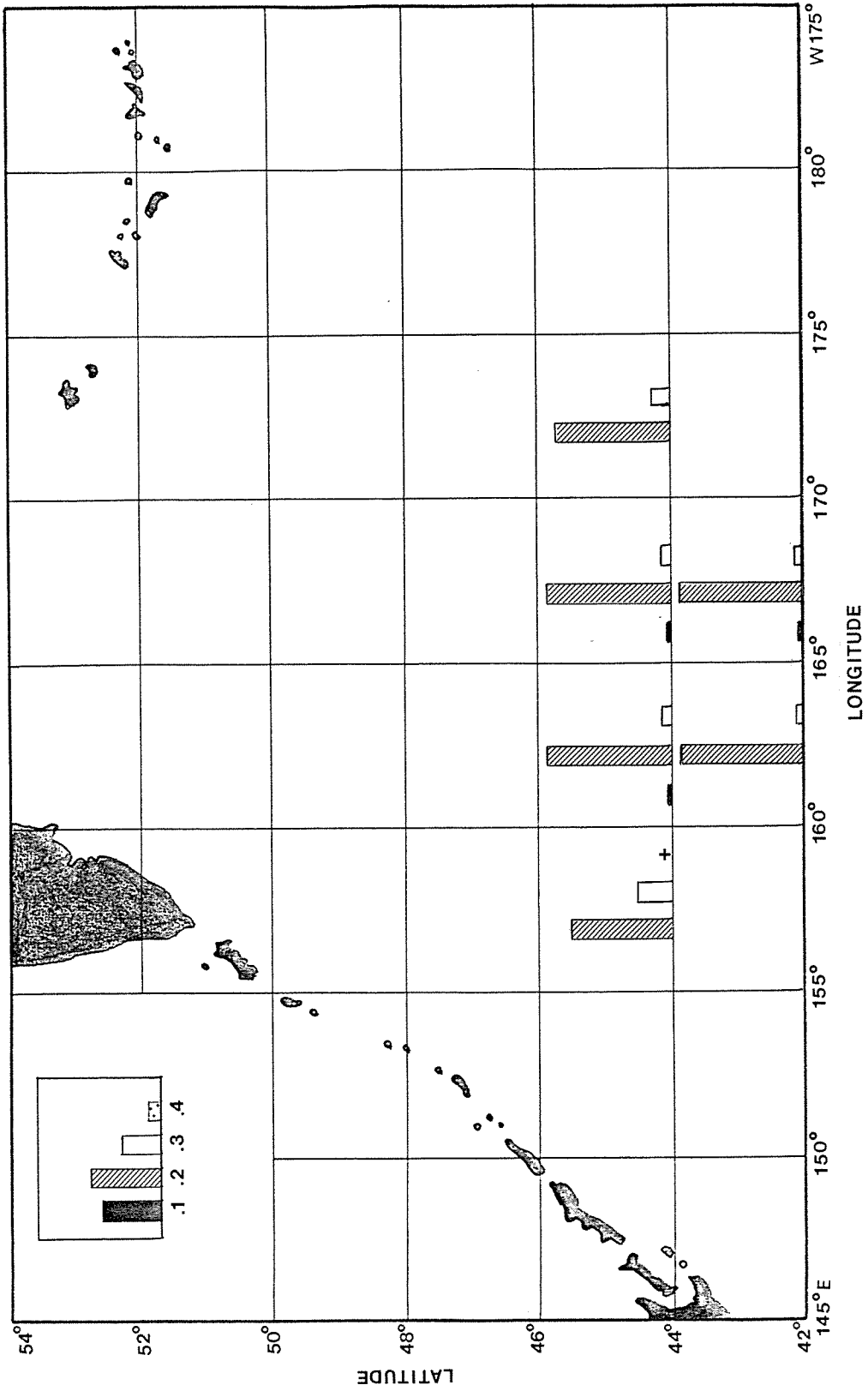


Fig. 18. Ocean age composition of maturing sockeye salmon sampled by JFA research vessels for the month of May in the years 1972-1976, by INPFC statistical area. Data for a year were included in the calculation of the mean unweighted percent only if based on a sample of at least 30 fish. Plus (+) indicates < 1%.

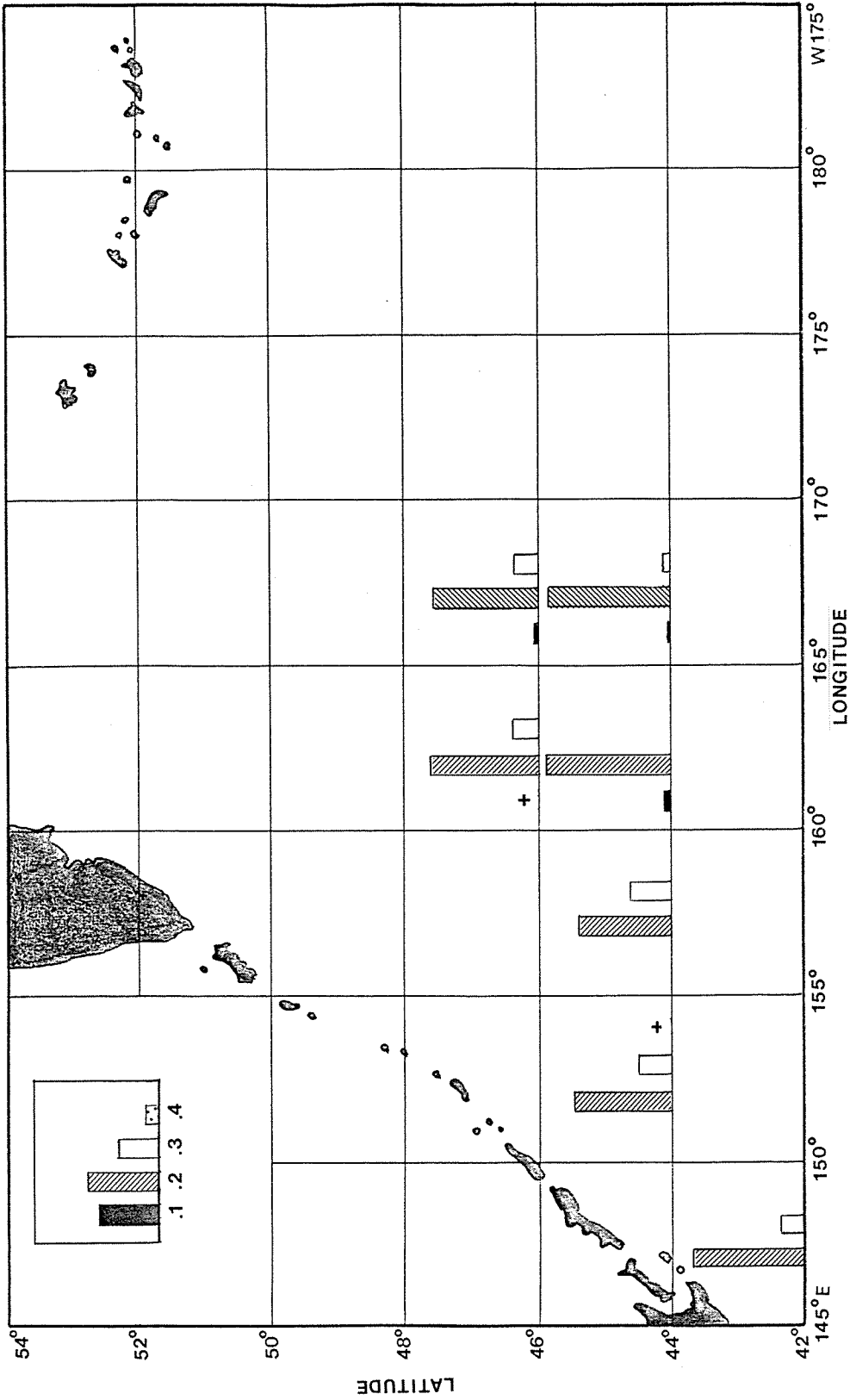


Fig. 19. Ocean age composition of maturing sockeye salmon sampled by JFA research vessels for the month of June in the years 1972-1976, by INPFC statistical area. Data for a year were included in the calculation of the mean unweighted percent only if based on a sample of at least 30 fish. Plus (+) indicates  $> 1\%$ .

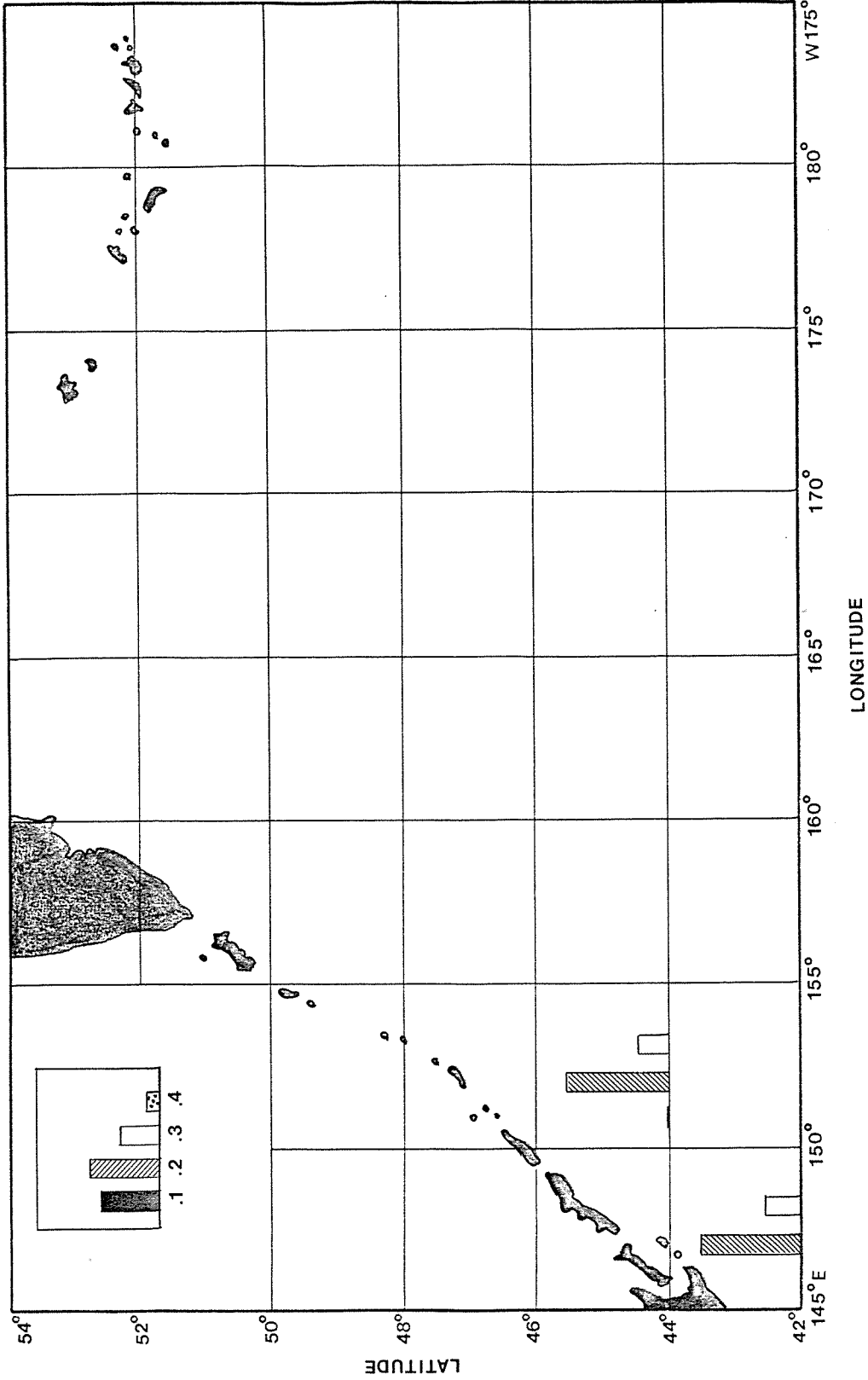


Fig. 20. Ocean age composition of maturing sockeye salmon sampled by JFA research vessels for the month of July in the years 1972-1976, by INPFC statistical area. Data for a year were included in the calculation of the mean unweighted percent only if based on a sample of at least 30 fish.

The extent of tagging in the landbased fishery area from 1956 to 1977 is summarized by Figs. 21-23. All tag releases in the area have been made by the Japanese research vessels. A total of 1,520 sockeye has been tagged, over half of them in the two statistical areas E 6544 and E 6546 (Fig. 21). Although most of the sockeye were tagged in the areas where the largest commercial catches are made, they were tagged largely before the start of the fishing season in both areas A and B. The overall numbers of sockeye releases are very small compared to those in statistical areas immediately to the north of the landbased area, and in areas around the central and western Aleutian chain. Even fewer coho have been tagged and released in the landbased fishery area (Fig. 22); only 566 coho salmon were tagged from 1956 through 1977. Very few coho were released from the areas and times in which the largest driftnet coho catches have occurred.

A recent analysis of tag recoveries of sockeye salmon in the landbased area (Hartt, 1975 MS) was broken down by the maturity stage of the fish. He mentioned that most of the sockeye which had been coded as unknown maturity were probably maturing fish, on the basis of lengths at recovery. In the present analysis all sockeye coded unknown maturity but which were longer than 54 cm at recovery were considered maturing. This length has been quite reliable as a criterion for categorizing sockeye sampled by purse seine south of Adak Island in the central Aleutians (FRI, unpublished data).

Through September 1977 there have been 104 recoveries of sockeye salmon from releases in the landbased area; 79 were maturing fish, 8 were immature fish, and 17 were of unknown maturity. The release and recovery locations of the sockeye recovered as maturing fish are shown in Fig. 24. All fish recovered as matures except one were recovered in the year of tagging. High seas recoveries of matures were generally about a month after release. One

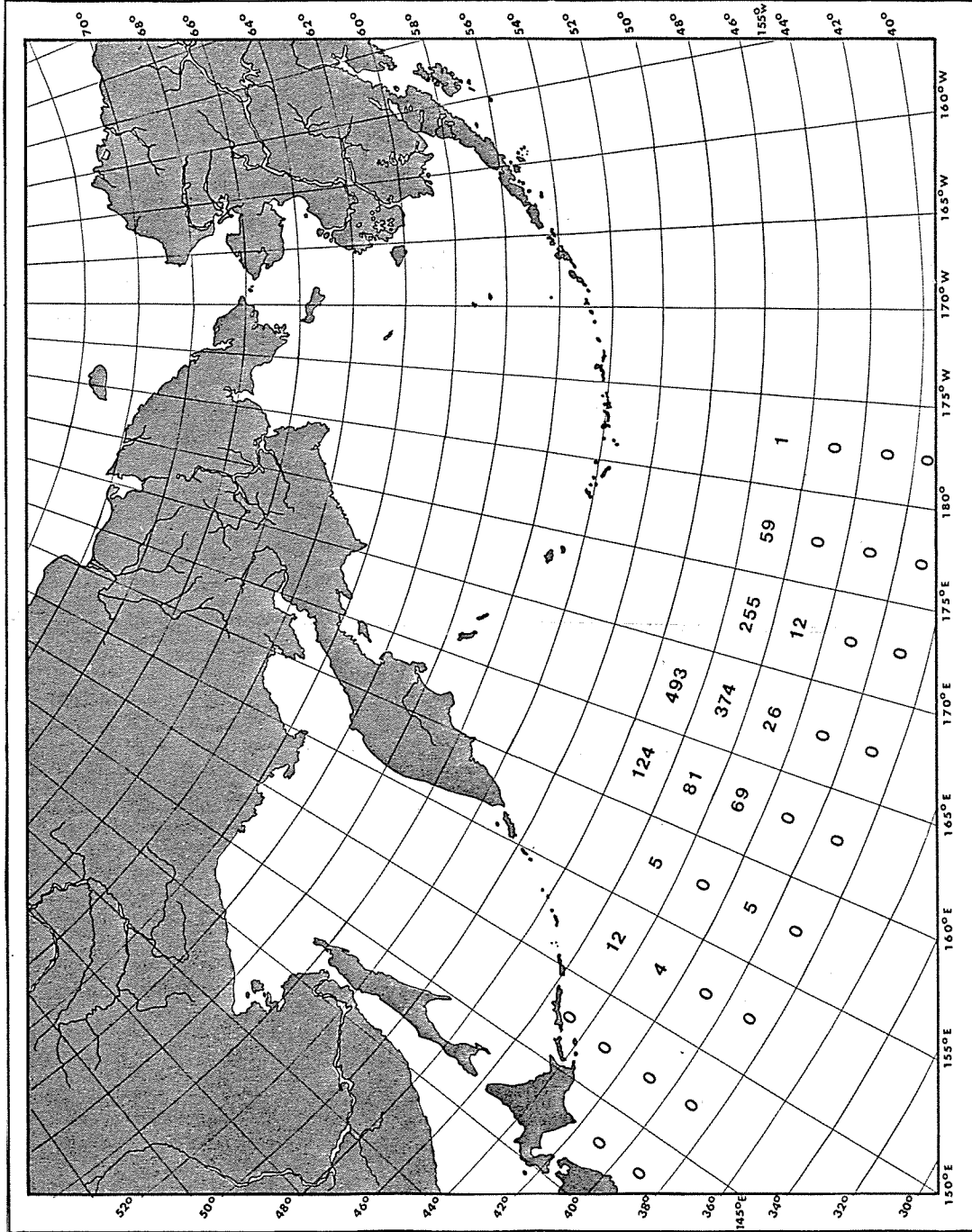


Fig. 21. Number of tagged sockeye salmon released in the landbased driftnet fishery area, by statistical area, 1956-1977. Data source is Japan Fishery Agency.



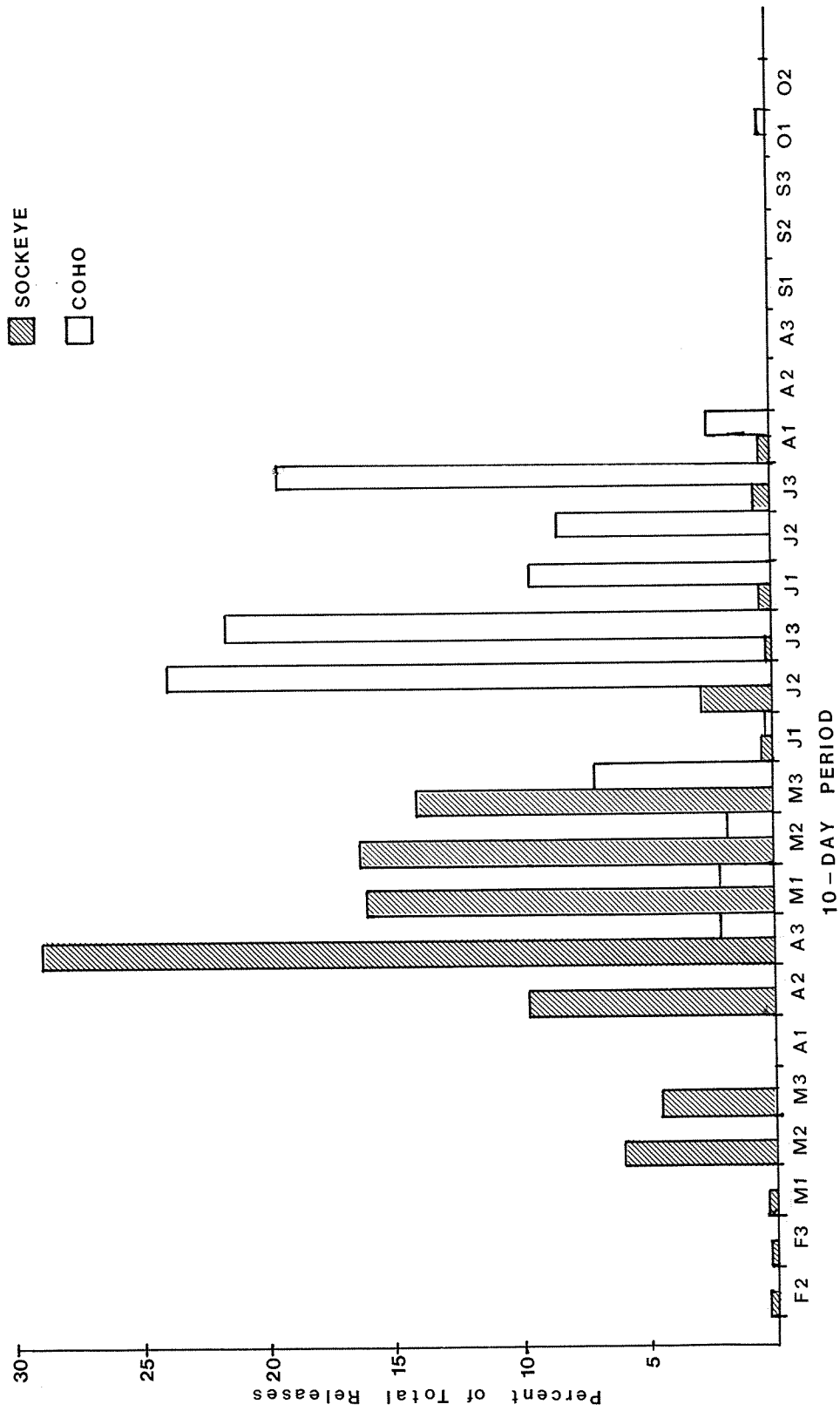


Fig. 23. Timing of releases of tagged sockeye and coho salmon in the Japanese landbased driftnet fishery area, by 10-day period, 1956-1977. Data source is Japan Fishery Agency.

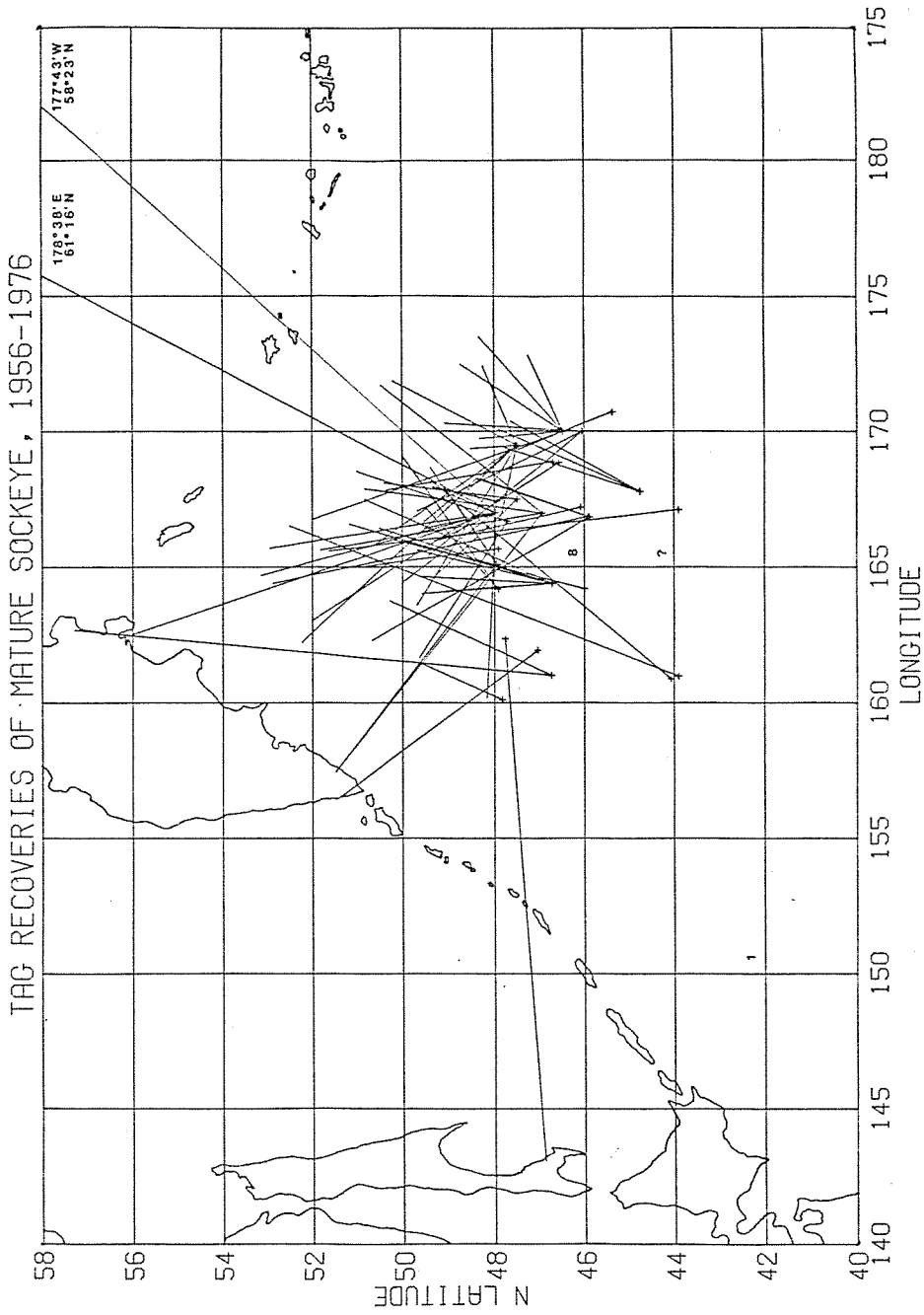


Fig. 24. Release and recovery locations of 79 sockeye salmon released in the landbased fishery area and recovered in the same year (78) or in the year after tagging (1). Numbers in lower left are the number of high seas recoveries in the same statistical area of release. Question mark (?) denotes unknown recovery area.

fish was released in area E 6542 and recovered the following year when mature in area E 6550. There have been 6 coastal recoveries of sockeye from the releases in the landbased area, all to Asia and primarily to east and west Kamchatka. High seas recoveries have all been made northwest, north, or northeast of the release locations, which, as mentioned by Hartt (1975 MS), reflects the general northward movement of maturing sockeye that occurs in the late spring and early summer. Two fish released from area E 6546 were recovered on 27 June and 14 July in 1965 in the central Bering Sea. French et al. (1976) mentioned that maturing sockeye of western Alaskan origin are abundant in the central Bering Sea, so that the sockeye recovered there could have been of either continental origin. The fairly scattered high seas recoveries south of the Aleutian chain were probably fish of mainly Asian origin, although some recoveries significantly northeast of the release positions (Fig. 24) give cause to suspect that North American stocks are present in the landbased area. The recoveries of immature sockeye and sockeye of unknown maturity (Figs. 25 and 26) are equally inconclusive, although the migratory vectors indicated are in line with the general migratory model of Asian sockeye proposed by French et al. (1976). Hartt (1975 MS) said that tagging recoveries of sockeye released in the landbased area have been too few to permit any firm conclusions about the existence of North American stocks in the landbased fishery area, and subsequent tagging data have not changed this situation.

Recoveries of 21 coho salmon released in the landbased area (Fig. 27) definitely suggest that all of the fish were of Asian origin (see also Godfrey et al., 1975 and Machidori, 1972). A single recovery made in 1977 in Bristol Bay, however, would suggest that the occurrence of some North American coho

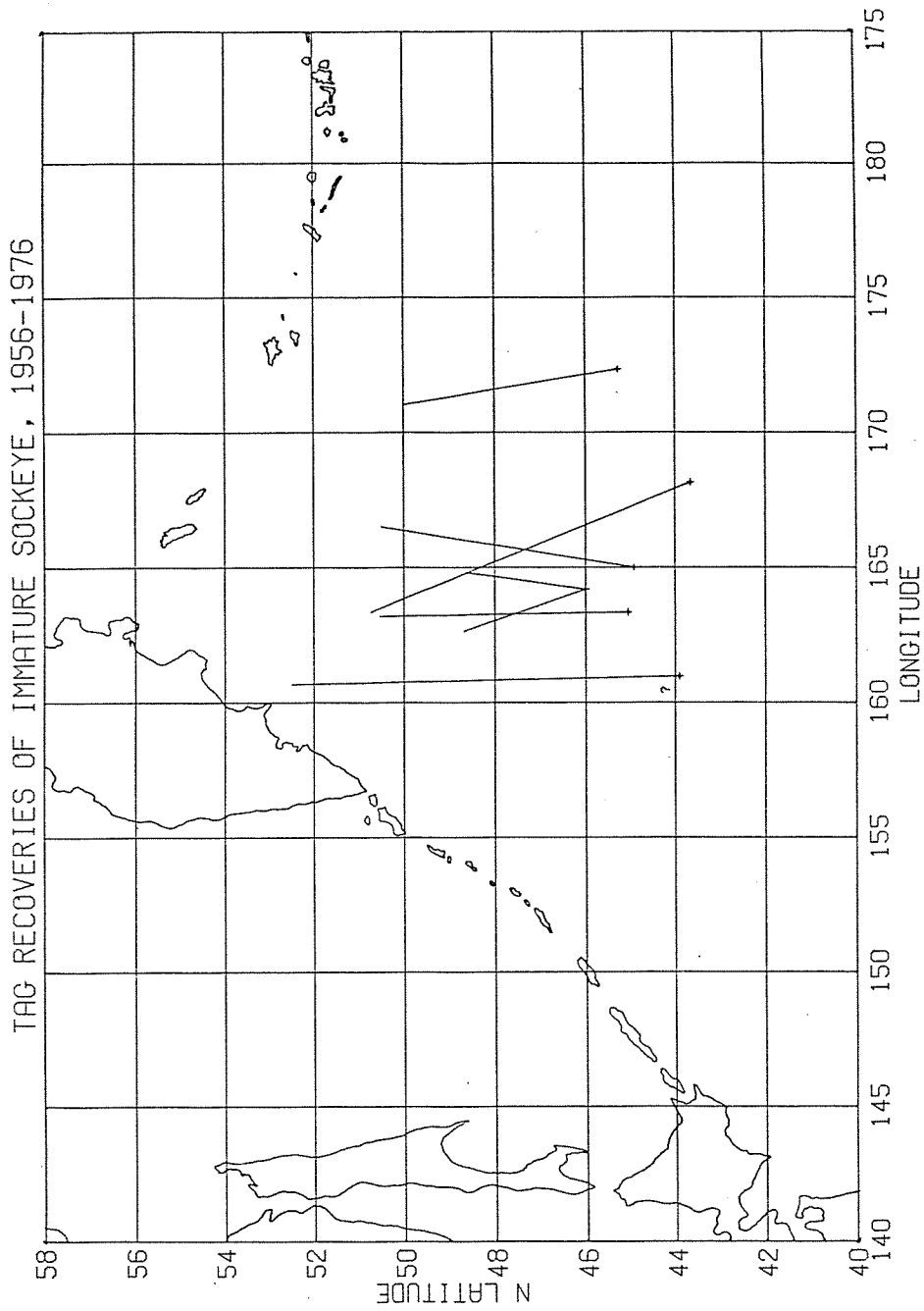


Fig. 25. Release and recovery locations of 8 sockeye salmon released in the landbased fishery area and recovered in the same year as immatures. Question mark (?) denotes unknown recovery area.

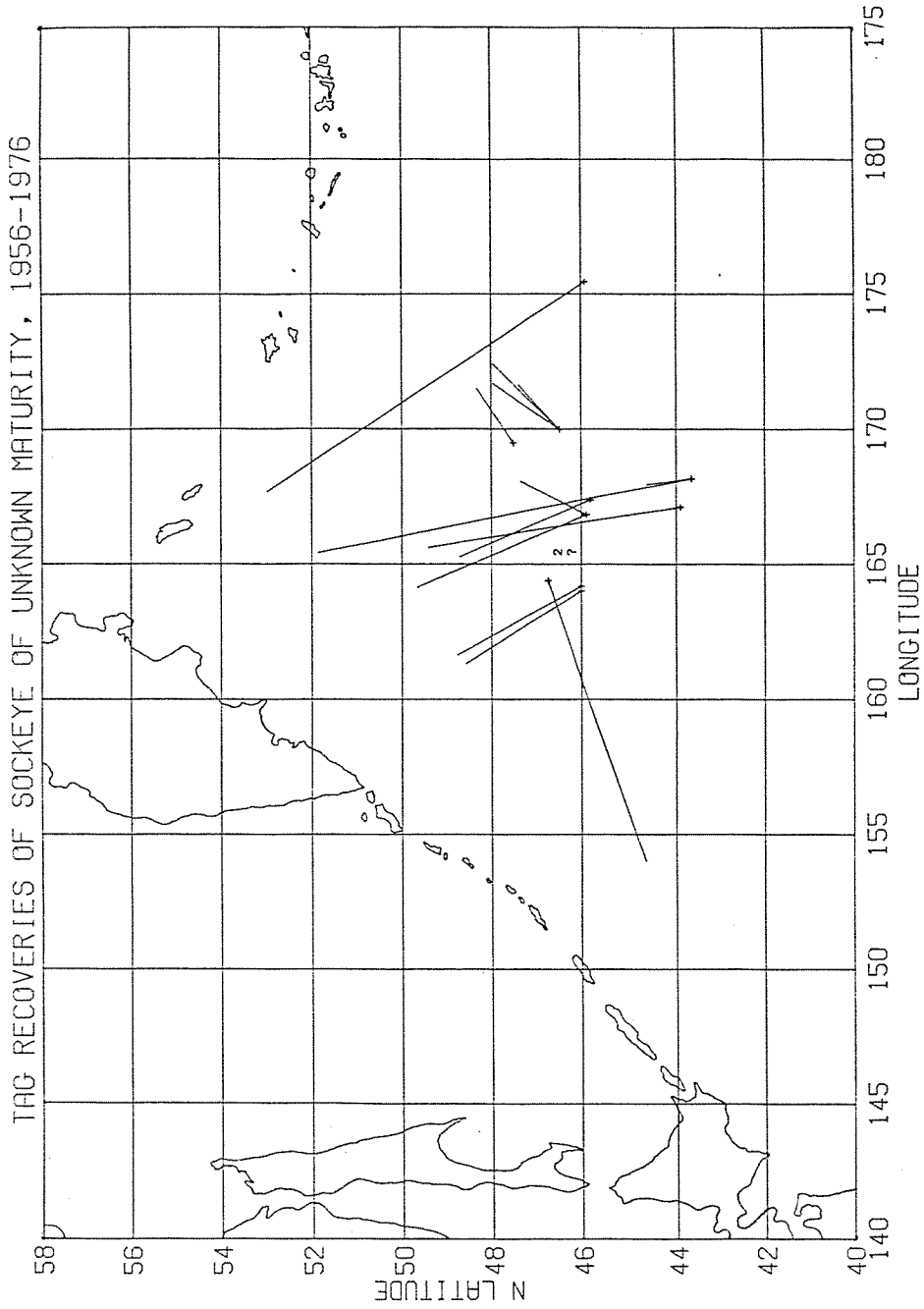


Fig. 26. Release and recovery locations of 17 sockeye salmon released in the landbased fishery area and recovered in the same year (maturity uncertain at recovery). Number in lower left corner of statistical area E6546 is the number of fish recovered in the same area. Question mark (?) denotes unknown recovery area.

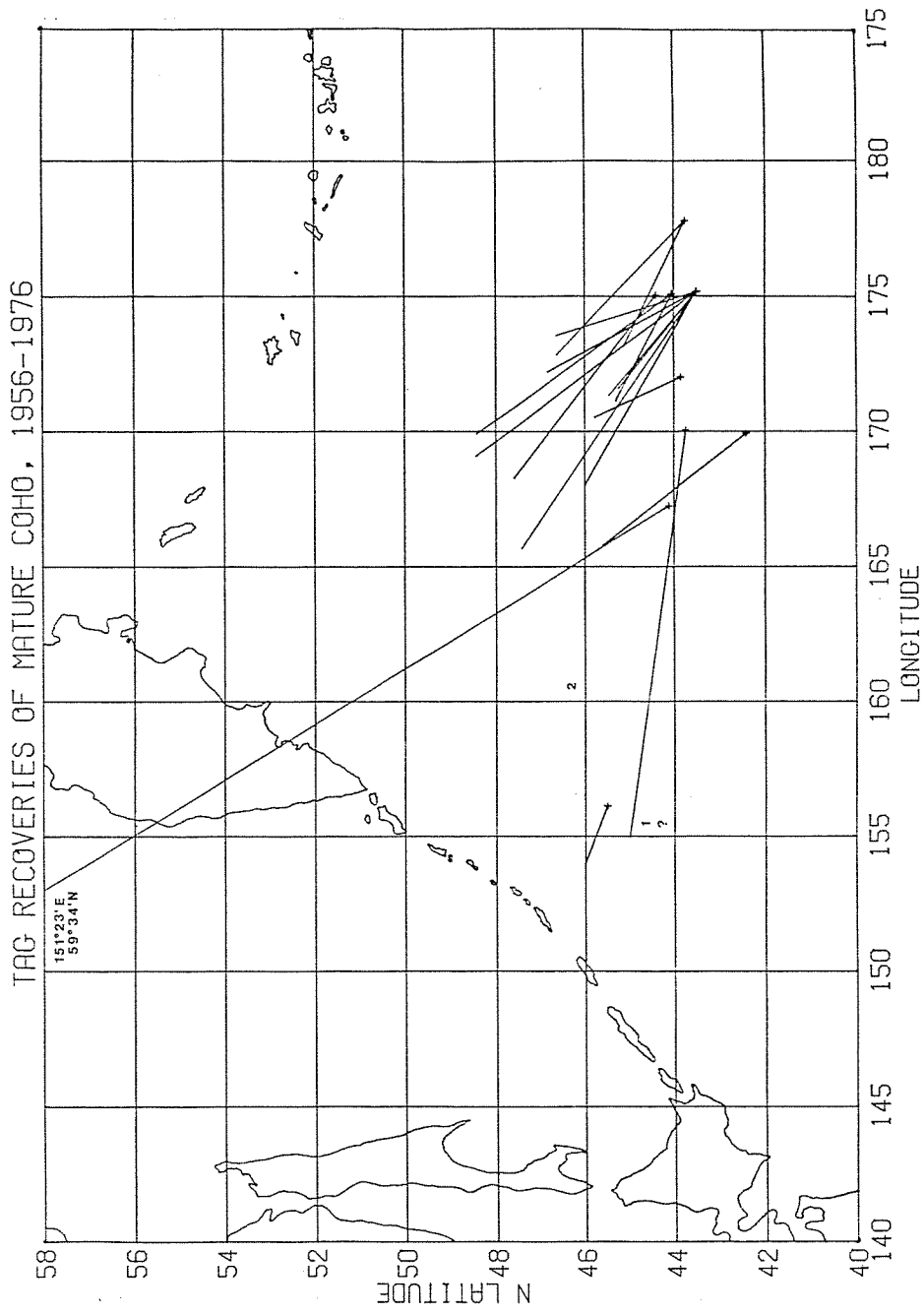


Fig. 27. Release and recovery locations of 21 coho salmon released in the landbased driftnet fishery area, 1956-1976. Numbers in lower left corner of statistical areas are the numbers of fish recovered in the same area. Question mark (?) denotes unknown recovery areas.

in at least the far eastern portion of the landbased fishery area is very likely (Harris, 1977 MS). That recovery was made in the Nushagak River in September 1977; the fish was tagged on 28 June 1977 at 173°31'W x 44°28'N, just east of the INPFC Abstention Line and near the areas where the largest driftnet catches of coho are made in late June and July. Before that recovery the southernmost release location west of the tip of the Alaska Peninsula of coho recovered in North American coastal areas was in area 8050 (Godfrey et al., 1975). The 1977 recovery, then, extends the known distribution of North American coho over 350 miles to the south where intersection with the landbased fishery seems certain.

The extent of our knowledge of the origin of sockeye salmon in the land-based area as provided by analyses of the incidence of parasite "tags" was recently summarized by Margolis (1975 MS). Only three fish in a total of nearly 10,000 sockeye examined in two major parasitological studies (Konovalov, 1971; Margolis, 1963) were sampled in the landbased fishery area. These were identified by Konovalov as follows:

<u>Locality of capture</u>	<u>Origin</u>	<u>Maturity stage</u>
45°58'N, 175°29'W	Naknek R., Bristol Bay	Immature
45°57'N, 179°35'E	Kamchatka R., USSR	Mature
45°19'N, 174°00'E	Naknek R., Bristol Bay	Immature

Margolis (1975 MS) noted, however, that the specific characteristics on which the above identifications were made were not given, and that the identification key (which employed scale characters as well as parasite indicators) used by Konovalov is of questionable validity for several reasons. Margolis concluded:

"In summary, parasitological data pertaining to the question of the continent of origin of sockeye occurring in the Japanese landbased fishery area is meager and what is available is of doubtful reliability."

# USE OF SCALE CHARACTERS AND A POLYNOMIAL DISCRIMINANT FUNCTION TO IDENTIFY THE ORIGIN OF SOCKEYE SALMON IN THE AREA OF THE LANDBASED FISHERY

## Introduction

In this section we present an assessment of the use of scale characters and a polynomial discriminant function to identify the origin of sockeye salmon in the area of the landbased fishery. We first present our rationale for use of the method chosen and describe it in summary form. In the next section we report on the results of classifying scales of maturing sockeye salmon collected by the JFA in and contiguous to the area of landbased fishery during 1975. We conclude that the method provides good separation of Asian and North American sockeye in the final section and discuss the need to assess available scale samples prior to implementing the method.

## Methods and Materials

Scales of sockeye salmon record their growth and Mosher (1968) summarized typical patterns. One to three freshwater growth zones and one to four oceanic growth zones are common and each zone represents a year's growth (Fig. 28). In addition, a zone of plus or intermediate growth may be present between the freshwater and oceanic zones on some scales; this zone corresponds to growth realized in the year of seaward migration. The use of scales for identifying the racial origins of sockeye salmon depends upon the genetic similarity of a local (or regional) stock of fish acting in conjunction with local (or regional) environmental conditions to produce differences in scale patterns on a local (or regional) basis. Generally, multivariate statistical analyses are used to identify these patterns.

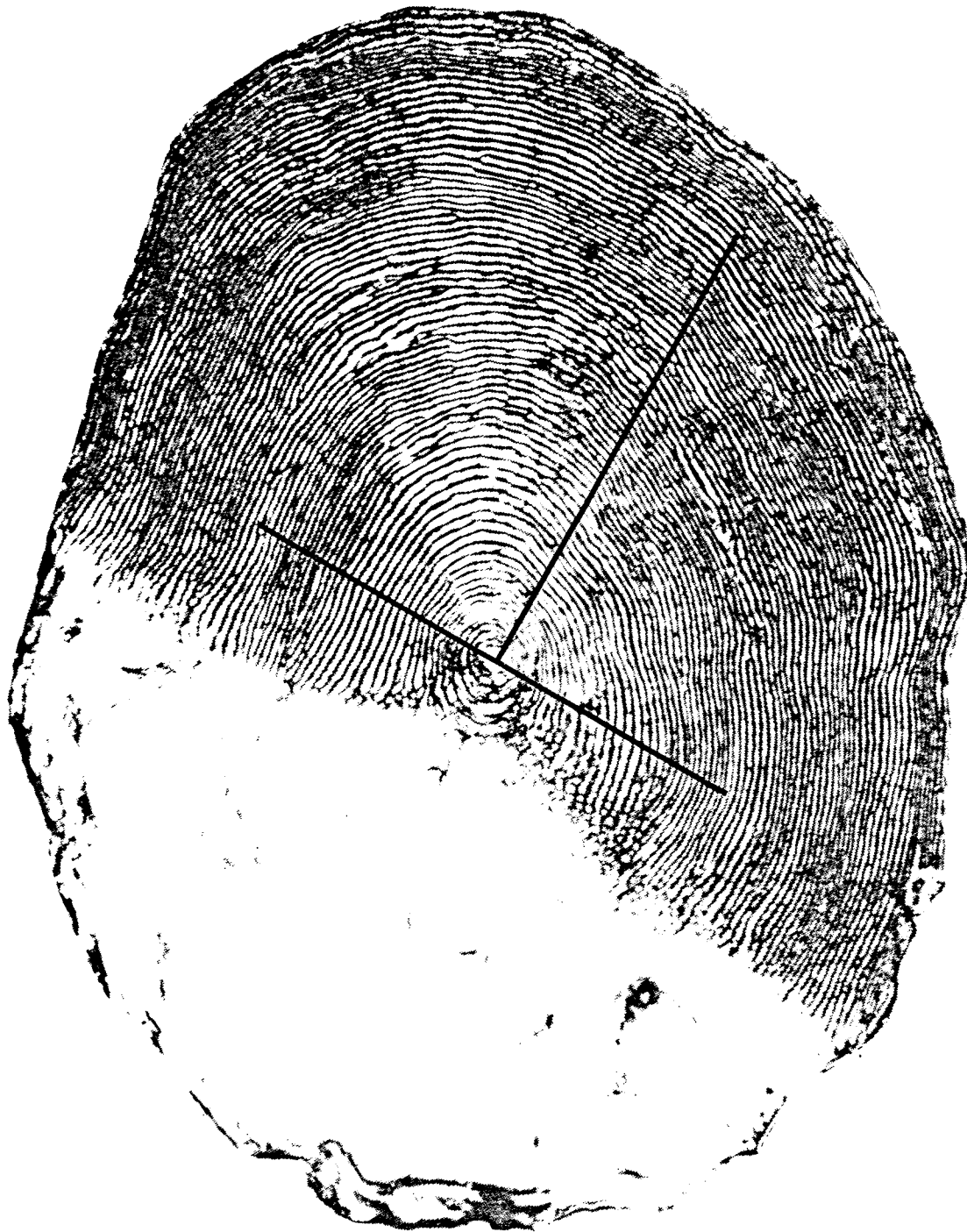


Fig. 28. Photograph of a scale from an age 1.3 sockeye salmon. Line perpendicular to sculptured field indicates radius along which measurements and counts were made.

### Analytical Procedures

Discriminant function analysis depends upon recognition of patterns differing among classes of objects. In our case a measurement of p-scale characters from an individual sockeye salmon provides a description of that fish. A set of p-scale characters for a number of sockeye from a specific geographic area estimates the region in p-space (i.e., the multivariate distribution) characteristic of that group of fish. Samples from sockeye of different and known origins, which are herein called learning samples, estimate regions in p-space for the stocks to be differentiated. Discriminant functions define decision surfaces between such regions. A sockeye of unknown origin may then be classified depending upon which region its set of scale measurement data occupies.

Three types of decision surfaces have been used to describe the boundaries between regions; linear, quadratic and polynomial. Equations for describing linear surfaces were developed by Fisher (1936) and require that the data be multivariate normal with common variance-covariance matrices and that each individual to be classified is a member of one of the groups to which individuals are being assigned. Quadratic decision surfaces were developed by Smith (1947) and do not require common variance-covariance matrices. The polynomial discriminant function of Specht (1966) is nonparametric. Linear models have enjoyed great popularity among biologists attempting to identify the origins of salmon in mixed populations (Fukuhara et al., 1962; Amos et al., 1963; Dark and Landrum, 1964; Mason, 1966; Anas and Murai, 1969; Krasnowski and Bethe, 1978) and this is probably related to the robustness of the model to violations of the assumption of a common variance-covariance matrix when large sample sizes are used (Issacson, 1954; Anas and Murai, 1969). A quadratic model was used by Anas and Murai (1969) and

they found it performed only slightly better than the linear model. Cook and Lord (1978) used the polynomial model. They believe the polynomial method to be preferable to Gaussian-based functions because no assumptions of underlying distributions need be made. Specht (1966) showed that the polynomial method performs better than linear models even when the data are multivariate normal. We chose to use the polynomial method for these reasons.

The polynomial method of Specht (1966) is based upon estimating the underlying multivariate density distribution of each class. Each class distribution is modeled by a sum of multivariate Gaussian functions; one such function is computed for each fish in the learning sample. A polynomial term in the density function is derived from a power series expansion of the sum of the individuals' multivariate Gaussian functions. The coefficients are a function of the scale characters measured in the learning sample and define the decision surfaces between the classes. Each multivariate Gaussian function contains an artificial standard deviation or smoothing parameter ( $\sigma$ ) that is incorporated into the estimate of the polynomial coefficients. This smoothing parameter must be supplied by the user. In general, as  $\sigma \rightarrow \infty$  the boundaries become linear while as  $\sigma \rightarrow 0$  the boundaries become nonlinear. A trade-off then exists between generating a simple linear model with a large smoothing parameter that would poorly describe nonlinear boundary surfaces, and more precisely describing such surfaces with a small value for  $\sigma$  which yields a high order equation. We choose a value for  $\sigma$  that maximized classification accuracy with an equation of order 4.

The polynomial discriminant function is:

$$\begin{aligned}
 P(x) = & D_0 + D_1 X_1 + D_2 X_2 + \dots + D_p X_p + D_{11} X_1^2 + \dots + D_{k_1 k_2} X_{k_1} X_{k_2} + \dots \\
 & + D_{pp} X_p^2 + D_{111} X_1^3 + \dots + D_{k_1 k_2 k_3} X_{k_1} X_{k_2} X_{k_3} + \dots + D_{ppp} X_p^3 + \dots \\
 & + D_{k_1 \dots k_j \dots k_h} X_{k_1} \dots X_{k_j} \dots X_{k_h} \dots + \dots,
 \end{aligned}$$

where  $p$  = dimension of vector  $X$ , i.e., the set of scale characters  
 $1 \leq k_j \leq p$  ( $k_j$  = an integer)

$j = 1, 2, \dots, h$

$h$  = the degree of the variable portion of the term.

One such function is calculated for each class. The decision of an unknown fish ( $X$ ) is:

choose  $d(X) = \theta_r$  so that  $h_r p^r(X) \geq h_s p^s(X)$   
 for all  $s \neq r$

where  $d(X)$  = the decision of an unknown ( $X$ )

$\theta_i$ 's = the origins or classes

$p^i(X)$  = the polynomial value for  $X$  calculated using the discriminant function for class  $\theta_i$

$h_i$  = the a priori probability

A priori probabilities are used to define more precisely the decision boundaries. For illustrative purposes consider the univariate distributions in Fig. 29.

In this example any fish whose value for the character is greater than  $Z$  will classify as a member of  $\theta_2$  while a value less than  $Z$  will classify as a member of  $\theta_1$ . It can be seen, however, that the area of overlap ( $A_1$ ) of  $\theta_1$ 's distribution into  $\theta_2$ 's is greater than the area of overlap ( $A_2$ ) of  $\theta_2$ 's distribution into  $\theta_1$ 's. A decision boundary at  $Z_1$  would therefore tend to classify more members of  $\theta_1$  as belonging to  $\theta_2$  than vice versa. By changing the values of the a priori probabilities we shift the decision boundary to the right to  $Z_2$  to balance the errors of misclassification. This is accomplished iteratively using an independent set of data also collected from the fish of interest when segregated.

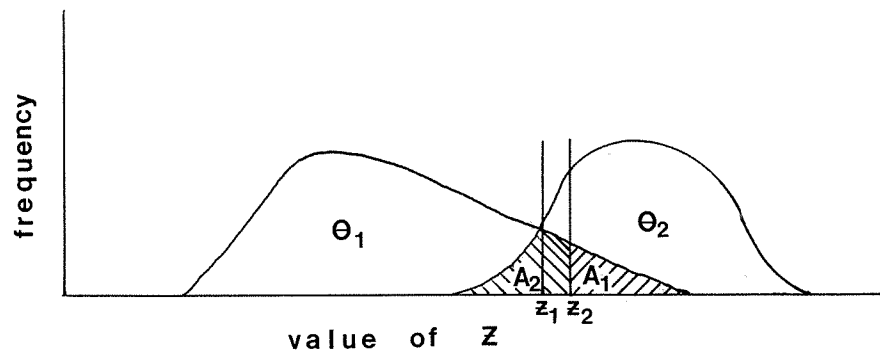


Fig. 29. The effect of changing a priori probabilities on the areas of overlap between two hypothetical univariate distributions.

A complication arises in this procedure, however, because the proportions of the various stocks in the unknowns are rarely the same as were used in the test data to adjust the a priori probabilities. Thus imbalances among the misclassified fish will recur unless the expected accuracy of classification is near 100%. Cook and Lord (1978) identified this problem and devised a correction procedure.

Letting  $\hat{C}$  = the classification matrix where each  $\hat{c}_{ij}$  is the proportion of fish if allocated to class i that belongs to class j

$R_u$  = the classification vector where each element is the portion of fish allocated to the ith class

$U$  = the vector in which the  $u_i$  is the true proportion of fish in unknowns sampled belonging to the ith class.

Now,  $CU = R_u$  and our best estimate ( $\hat{U}$ ) of  $U$  is  $\hat{U} = \hat{C}^{-1} R_u$

The estimates thus obtained have a variance dependent upon 1) the unknown sample size, 2) the test sample sizes, and 3) the classification accuracy (Cook in prep.)

The estimated variance,

$$\widehat{\text{Var}}(\hat{U}_i) = \frac{\hat{u}_i(1-\hat{u}_i)}{N_u} + \frac{2 \hat{u}_i^2 c_{ii}(1-c_{ii})}{N_i (c_{ii}-c_{ij})^2} + \frac{2 \hat{u}_j^2 c_{ij}(1-c_{ij})}{N_j (c_{ii}-c_{ij})^2}$$

where  $\hat{U}_i$  = the estimate of the proportion of class i in the unknown population,

$\hat{u}_i$  = the estimate of the proportion of class i in the unknown sample,

$N_u$  = the size of the unknown sample,

$c_{ii}$  = the fraction of the test sample from class i that classified as class i,

$c_{ij}$  = the fraction of the test sample from class j that classified as class i,

$N_i$  = the size of the ith test sample,

$N_j$  = the size of the jth test sample,

$i$  = the class of concern,

$j$  = all other classes.

### Definition of Continental Standards

In development of continental standards we wished to strike a balance between achieving good classification accuracy by factoring out as many sources of variability as possible and keeping the number of standards that must be developed small. Maximum classification accuracy would be achieved by treating each year class from each brood year by stock separately (Cook and Lord, 1978; Krasnowski and Bethe, 1978; Anas and Murai, 1969). This procedure would, however, result in an overwhelmingly large experimental design. Additionally, scale samples from sockeye when segregated in either terminal fisheries or in the spawning grounds were available from only one Asian stock in 1975. These considerations led us to group stocks within regions and to treat year class within brood years separately; one Asian and two North American standard regions were defined. For the Asian standard samples collected aboard Japanese research vessels operating off the southwest coast of Kamchatka were used to represent the West Kamchatka stocks, i.e., the Ozernaya and Bolshaya rivers. An attempt was made to allocate samples based on the catch per tan (of commercial gear only) by age class by INPFC area by month. A dearth of samples required divergence from this scheme, however. Escapement samples from the Kamchatka River were used to represent the stocks of the east side of Kamchatka. Table 8 summarizes sample sizes used.

Two regions of the North American continent were defined corresponding to the water mass into which the parent streams terminate: Bristol Bay and the south coast of Alaska from about 160° W to 145° W (hereafter called the Gulf of Alaska standard). Standards by age class within these regions were compiled by sampling from the major stocks within the region in proportion to

Table 8. Catch per tan, desired sample size, available scales and final sample sizes for age 2.2, 1.3 and 2.3 sockeye salmon taken by Japanese research vessels operating off the southwest coast of Kamchatka, gear A, mature fish, by month and area in 1975 and sample sizes used to represent the Kamchatka River.

Month	Area	2.2			1.3			2.3					
		Catch/tan	Total scales available	Desired sample size	Final sample sizes	Catch/tan available	Total scales available	Desired sample size	Final sample sizes	Catch/tan available	Total scales available	Desired sample size	Final sample sizes
June	E 5052	0.082	15	10	10	0.034	55	15	21	0.066	106	13	13
	E 5050	0.023	31	3	3	0.066	88	29	38	0.104	140	21	21
	E 5552	0.013	3	2	2	0.017	4	8*	4	0.014	26	23	23
July	E 5550	0.012	5	1	1	0.017	6	8*	6	0.072	30	15	15
	E 5052	0.020	29	2	2	0.057	64	25	62	0.027	40	5	31
	E 5050	0.079	6	9*	6	0.	0	0	0	0.039	3	8*	3
August	E 5552	0.052	21	6	7	0.156	55	69*	55	0.052	21	11	17
	E 5550	0.280	42	33	35	0.047	7	21*	7	0.133	19	27*	19
	E 5052	0.029	12	3*	12	0.	0	0	0	0.017	7	3	7
Sub-total	E 5050	0.437	36	52*	36	0.011	1	5*	1	0.117	10	24*	10
	E 5552	0.082	58	10	35	0.005	2	2*	2	0.042	25	9	22
	E 5550	0.576	51	69*	51	0.040	4	18*	4	0.199	19	41*	19
Sub-total			309	200	200		286	200	200		446	200	200
Kamchatka River escapement			3	3	3		35	35	35		34	34	34
Total					203				235				234

\*Indicates time x area deficiencies in available samples.

the abundance of each age class by stock. Tables 9 and 10 summarize the run size by stock and age class within each region and the resulting sample sizes. This report does not include the southeastern Alaska and British Columbia region due to the extreme unlikelihood of the presence of these fish in the area in question (French et al., 1976).

#### Sample Collection, Preparation and Viewing

Scale samples to serve as standards were provided by the Alaska Department of Fish and Game, the Japan Fishery Agency and TINRO, USSR. Scale samples to serve as unknowns were obtained from the Japan Fishery Agency (JFA). The request was for samples collected aboard research vessels operating in and around the landbased fishery area. Scale samples are not collected aboard commercial vessels within the area. Samples were grouped by age class, INPFC area and 10-day periods for analysis. Impressions of scales were made in cellulose acetate (Koo, 1955). Personal communication with biologists of the providing agency (except for those scales provided by the Soviet Union) indicate that most scale samples were collected from body area A as established by the International North Pacific Fisheries Commission (Anas, 1963). This area includes the first four rows of scales above and below the lateralline. The area is bounded anteriorly by an imaginary line dropping ventrally from the middle of the dorsal fin and posteriorly by an imaginary line dropping ventrally from the anterior edge of the adipose fin. Scale samples within this region from either side of the fish were used.

Scale images were projected at 100 power using a Bausch & Lomb microprojector.<sup>1</sup> Measurement and count data were recorded directly onto a form from this image. A consistent radius along which measurements and counts were recorded was found by aligning the form so that the radius approximated

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<sup>1</sup>Catalog No. 42-63-59

Table 9. Inshore run of the major stocks of sockeye salmon returning to the Bristol Bay region for age classes 2.2, 1.3 and 2.3 and resulting sample sizes.

Stock	Run size (thousands)			Sample size		
	2.2	1.3	2.3	2.2	1.3	2.3
Goodnews & Kwinhok <sup>1</sup>	24.7	3.2	4.1	0	0	0
Togiak	20.2	204.5	4.3	0	18	0
Igushik	90.5	172.7	113.8	1	15	8
Snake	0.3	9.0	<0.1	0	1	0
Wood	193.4	838.6	85.4	2	74	6
Nushagak	3.6	60.8	2.2	0	5	0
Nuyakuk	120.3	567.0	3.9	1	51	0
Kvichak	14,014.5	13.8	520.7	161	1	36
Alagnak	5.7	61.2	20.4	0	5	1
Naknek	1,674.5	275.1	968.8	20	24	66
Egegik	739.5	70.1	961.5	8	6	66
Ugashik	249.0	2.7	21.1	3	0	1
Bear	241.4	<0.1	198.8	3	0	14
Sapsuk	129.0	11.0	25.0	1	0	2
Total	17,506.6	2,289.7	2,930.0	200	200	200

<sup>1</sup> Age composition estimated by using the average age composition for the region because of a lack of samples--run size estimated at 2 times catch because of a lack of data.

Table 10. Inshore run of the major stocks of sockeye salmon returning to the Gulf of Alaska region for age classes 2.2, 1.3 and 2.3 and resulting sample sizes.

Stock	Run size (thousands)			Sample size		
	2.2	1.3	2.3	2.2	1.3	2.3
Chignik	149.2	221.3	540.8	35	41	133
Akalura	12.6	2.6	0.6	3	0	0
Frazer	51.3	1.9	4.5	12	0	1
Upper Station	32.8	6.1	12.1	8	1	3
Red River	49.5	2.9	14.3	11	1	3
Karluk	264.0	7.9	55.2	62	1	14
Cook Inlet	262.9	402.5	93.0	62	74	23
Bering River	no scale samples available					
Copper River	11.4	259.5	80.3	3	48	20
Prince William Sound Management Area	18.6	182.4	13.1	4	34	3
<b>Total</b>	<b>852.3</b>	<b>1,087.1</b>	<b>813.9</b>	<b>200</b>	<b>200</b>	<b>200</b>

a perpendicular angle to the sculpture field (Fig. 28) (Mosher, 1968; Narver, 1963). This axis was chosen over the longest axis because of the tendency for sockeye salmon scales from stocks returning to the south side of Alaska Peninsula, Cook Inlet and some rivers of the Kamchatka Peninsula to show broken and irregular circuli along the longest axis (Mosher, 1968).

#### Aging

Two technicians independently read each scale for age and then compared their readings with that provided by the agency supplying the scale. If all readers agreed, the age was accepted. If a disagreement was found, the scale in question was examined jointly by the two technicians. During these conference readings the pattern in question was identified and an attempt was made to resolve the conflict. If a conflict could not be resolved the biologist in charge read the scale. If after this reading only one in four readings was discrepant, the age determination of the three readers was accepted, if a three-way discrepancy emerged, the scale was rejected. In the case where the agency supplying the scale had not aged the fish a similar procedure was used except that only two rather than three agreements were needed to accept the age reading.

#### Screening of Characters

Some characters selected for screening were identified from previous work. Anas and Murai (1969) reported that: 1) the number of circuli in the first half of the first ocean zone; 2) the measured distance between circuli 1 and 6 of the first ocean zone; and 3) the measured distance between circuli 13 and 18 of the first ocean zone provided good separation of Asian from Bristol Bay sockeye salmon when used in either a linear or quadratic discriminant function. Mosher (1963) used the number of circuli in the total freshwater zone and the first ocean zone for sockeye of age groups 1.- and 2.- and the size of the same two zones for sockeye of age group 3.- in bivariate

frequency tables to classify Asian and North American fish. We screened the following characters (Table 11): characters A1 and A2 are the same as those of Mosher (1963), character B1 is the same as Anas and Murai (1969). A combination of characters B4 and B5 and B8 and B9 are similar to Anas and Murai's character numbers 2 and 3 above, respectively.

Characters were selected from this group for use in classifying unknowns using the method of Cook and Lord (1978). Briefly, the Kruskal-Wallis 'H' statistic (Kruskal and Wallis, 1952) and the difference in average sum of ranks for each pairwise class combination is calculated for each characteristic. Characters were then ranked according to value of the H statistic and by the greatest difference in average sum of ranks. In two category cases these procedures produce the same results. In three or more category problems it is often necessary to make decisions as to whether or not to choose a variable with good overall discriminating power versus one which has a lower H value but which provides good separation for one group from the others. In circumstances where the choice is unclear it is a simple matter to compare classificatory accuracy using each variable in question.

#### Classification of Unknowns

We classified unknowns by one of two methods depending upon location of sampling. Samples collected between 175° E and 170° W were classified using a three-way comparison of Bristol Bay, Gulf of Alaska and Kamchatka Peninsula; those collected west of 175° E were classified in a two-way comparison without the Gulf of Alaska category. This procedure was adapted because: scale patterns of fish from the Gulf of Alaska are very similar to those of Kamchatka (Anas and Murai, 1969) and especially to the Kamchatka

Table 11. Scale characters evaluated.

---

A	Freshwater Zone
	1. Number of circuli
	2. measured width
B	First Ocean Zone
	1. Number of circuli in first half of zone
	2. number of circuli in second half of zone
	3. measured width
	4. distance between outer edge of last freshwater circuli to the third ocean circuli
	5. distance between circuli 3 and 6
	6. " " " 6 and 9
	7. " " " 9 and 12
	8. " " " 12 and 15
	9. " " " 15 and 18
	10. " " " 18 and 21
	11. " " " 21 and 24
	12. " " " 24 and 27
	13. " " " 27 and 30
C	Second Ocean Zone
	1. Number of circuli
	2. measured width

---

River (this report) and because a bias exists in our analysis due to under-representation of Kamchatka River fish. Tests showed us that these two factors tended to result in the classification of Kamchatka River fish as Gulf of Alaska fish. We therefore used a three-way classification procedure only for samples collected in areas where a high probability of the presence of all stocks was indicated from previous studies (French et al., 1976).

### Results

#### Characters Selected and Classification Arrays

Characters selected for use in the polynomial discriminant function (PDF) analysis are summarized for each age class in Table 12. Variability in discriminating power for a character between age classes produced some differences in those selected. The ability of these characters to identify fish to region of origin when used in the PDF analysis is summarized by calculating the percent correctly classified. The percent of samples correctly classified for age groups 2.2, 1.3 and 2.3 in a three-way scheme is 70.5, 59.8 and 64.1, respectively. Table 13 presents the classification arrays for each age class. The classification array shows that most errors occur because of the low separability of Kamchatka Peninsula and Gulf of Alaska fish. In the two-way classification procedure (Table 14) the percent of samples that correctly classified for age classes 2.2, 1.3 and 2.3 are 88.1, 78.2 and 85.7, respectively. Accuracy is slightly better for 2-ocean age fish than for 3-ocean age fish regardless of whether a 2- or 3-way procedure is used. Exclusion of Gulf of Alaska fish produced a large increase in accuracy.

Table 12. Characters selected for use in identifying the origins of mature sockeye intercepted by the Japanese landbased fishery, by age, class, 1975. (A + indicates use of the character within an age class.)

Character	Age Class		
	2.2	1.3	2.3
Number fresh water circuli - - - - -	+		+
Size freshwater zone - - - - -	+	+	
Number circuli in first half of first ocean zone - - - - -	+	+	+
Number circuli in second half of second ocean zone - - - - -	+		
Size of first ocean zone - - - - -		+	+
Distance between circuli $n_1$ and $n_2$ of first ocean zone			
$n_1 = 0^1$ $n_2 = 3$ - - - - -		+	+
$n_1 = 0$ $n_2 = 6$ - - - - -	+		
$n_1 = 3$ $n_2 = 6$ - - - - -			+
$n_1 = 6$ $n_2 = 9$ - - - - -		+	
$n_1 = 12$ $n_2 = 15$ - - - - -		+	
$n_1 = 12$ $n_2 = 18$ - - - - -			+
$n_1 = 15$ $n_2 = 18$ - - - - -	+		

1

0 indicates the distance is measured from the outer edge of the last freshwater circuli.

Table 13. Classification arrays for mature sockeye salmon of Bristol Bay vs. Gulf of Alaska vs. Kamchatka Peninsula origin, by age class, 1975.

Age 2.2

<u>Calculated decision</u>	<u>Correct decision</u>		
	<u>Bristol Bay</u>	<u>Gulf of Alaska</u>	<u>Kamchatka</u>
Bristol Bay	103	17	5
Gulf of Alaska	14	75	35
Kamchatka	8	32	88

Age 1.3

<u>Calculated decision</u>	<u>Correct decision</u>		
	<u>Bristol Bay</u>	<u>Gulf of Alaska</u>	<u>Kamchatka</u>
Bristol Bay	77	27	16
Gulf of Alaska	19	63	39
Kamchatka	24	31	92

Age 2.3

<u>Calculated decision</u>	<u>Correct decision</u>		
	<u>Bristol Bay</u>	<u>Gulf of Alaska</u>	<u>Kamchatka</u>
Bristol Bay	90	22	8
Gulf of Alaska	16	65	43
Kamchatka	14	37	95

Table 14. Classification arrays for mature sockeye salmon of Bristol Bay vs. Kamchatka Peninsula, by age class, 1975.

Age 2.2

---

<u>Calculated decision</u>	<u>Correct decision</u>	
	<u>Bristol Bay</u>	<u>Kamchatka</u>
Bristol Bay	110	15
Kamchatka	15	113

---

Age 1.3

---

<u>Calculated decision</u>	<u>Correct decision</u>	
	<u>Bristol Bay</u>	<u>Kamchatka</u>
Bristol Bay	91	29
Kamchatka	29	118

---

Age 2.3

---

<u>Calculated decision</u>	<u>Correct decision</u>	
	<u>Bristol Bay</u>	<u>Kamchatka</u>
Bristol Bay	101	19
Kamchatka	19	127

---

### Classification of Unknowns

The percent of scales that classified as typical of Bristol Bay, Gulf of Alaska and Kamchatka Peninsula fish in samples stratified by age class, INPFC statistical area and 10-day periods are summarized in Figures 30 to 32 and in Appendix Tables 1-3.

#### Age 2.2

Scale samples from four INPFC areas in the north central portion of the fishery in the period May 1-10 were classified (Fig. 30a). These samples indicate a predominance of Kamchatka Peninsula fish. This dominance is also evident in areas E 6046 and E 7046. Confidence intervals indicate that none of the estimates for North American fish are significantly different from zero. In areas E 7548 and W 7548, well to the north and east of the fishery, significant incidences of North American fish were found. During the period May 11-20 estimates were made in three areas E 6546, E 6544 and E 6542. Results (Fig. 30b) show a preponderance of Kamchatka Peninsula fish. During the last period in May (Fig. 30c) the data show a dominance of Kamchatka Peninsula fish in the north central area of the fishery and to the north of the fishery. Significant incidences of North American fish were found in area E 7548.

#### Age 1.3

Only one sample of age 1.3 maturing sockeye was available from areas within the landbased fishery in 1975. This sample from area E 6544 taken in the period May 1-10 (Fig. 31a) indicates the presence of only Kamchatka Peninsula fish. Two samples were available for the period May 11-20 (Fig. 31b), both well north of the fishery in areas E 6548 and E 7048. Both show a pre-

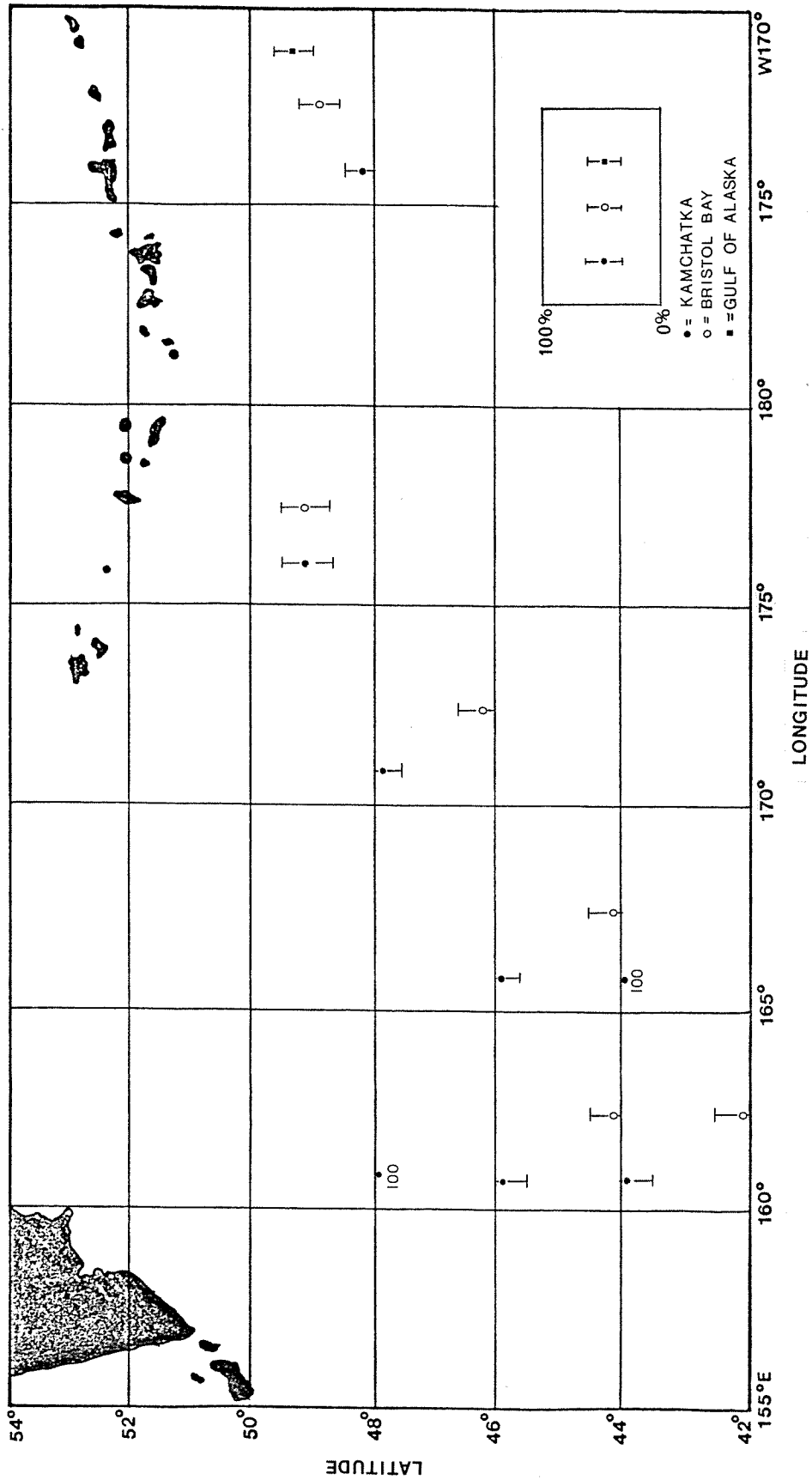


Fig. 30a. Results of classifying scale samples collected from age 2.2 maturing sockeye salmon during the period May 1-10, 1975.



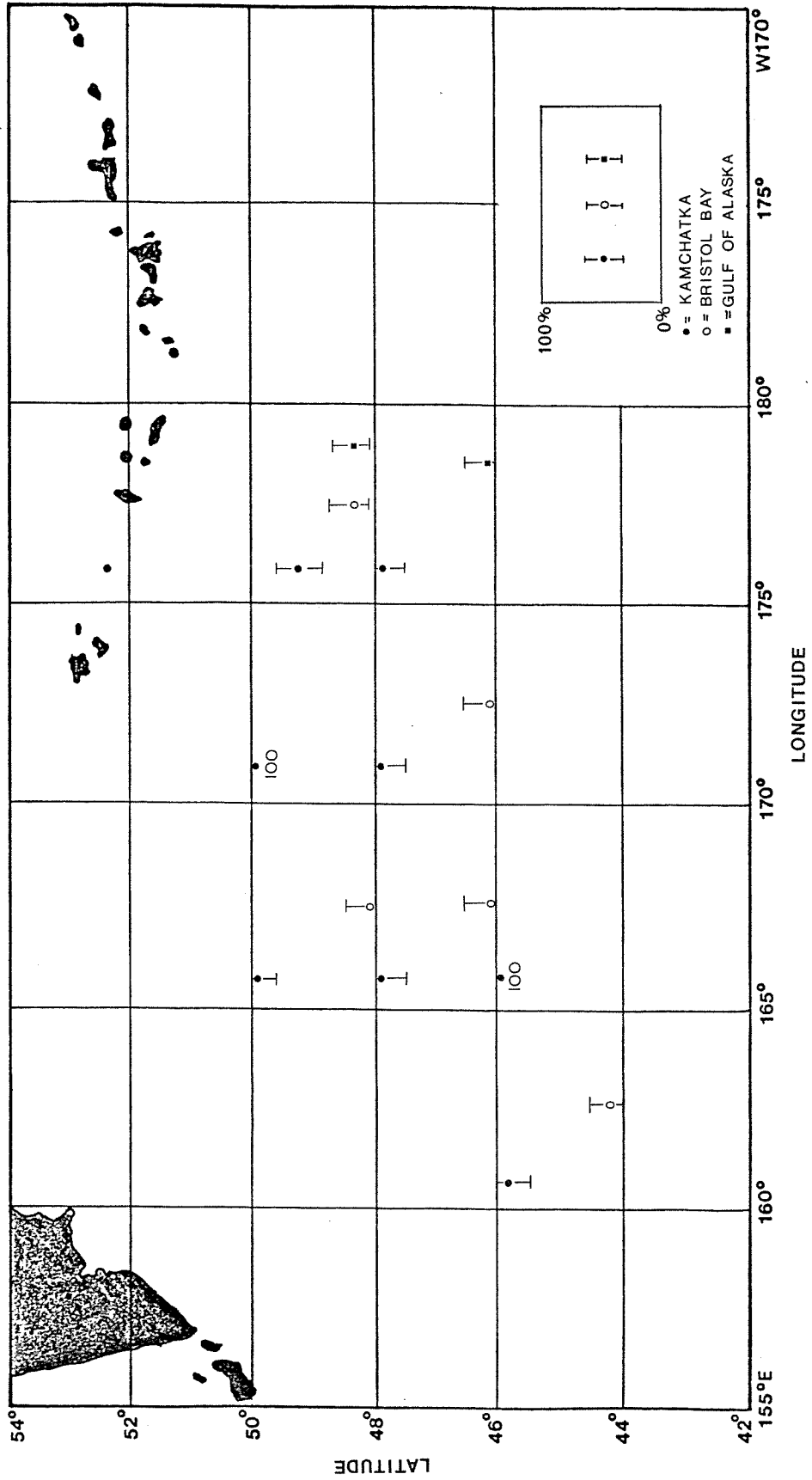


Fig. 30c. Results of classifying scale samples collected from age 2.2 maturing sockeye salmon during the period May 21-31, 1975.

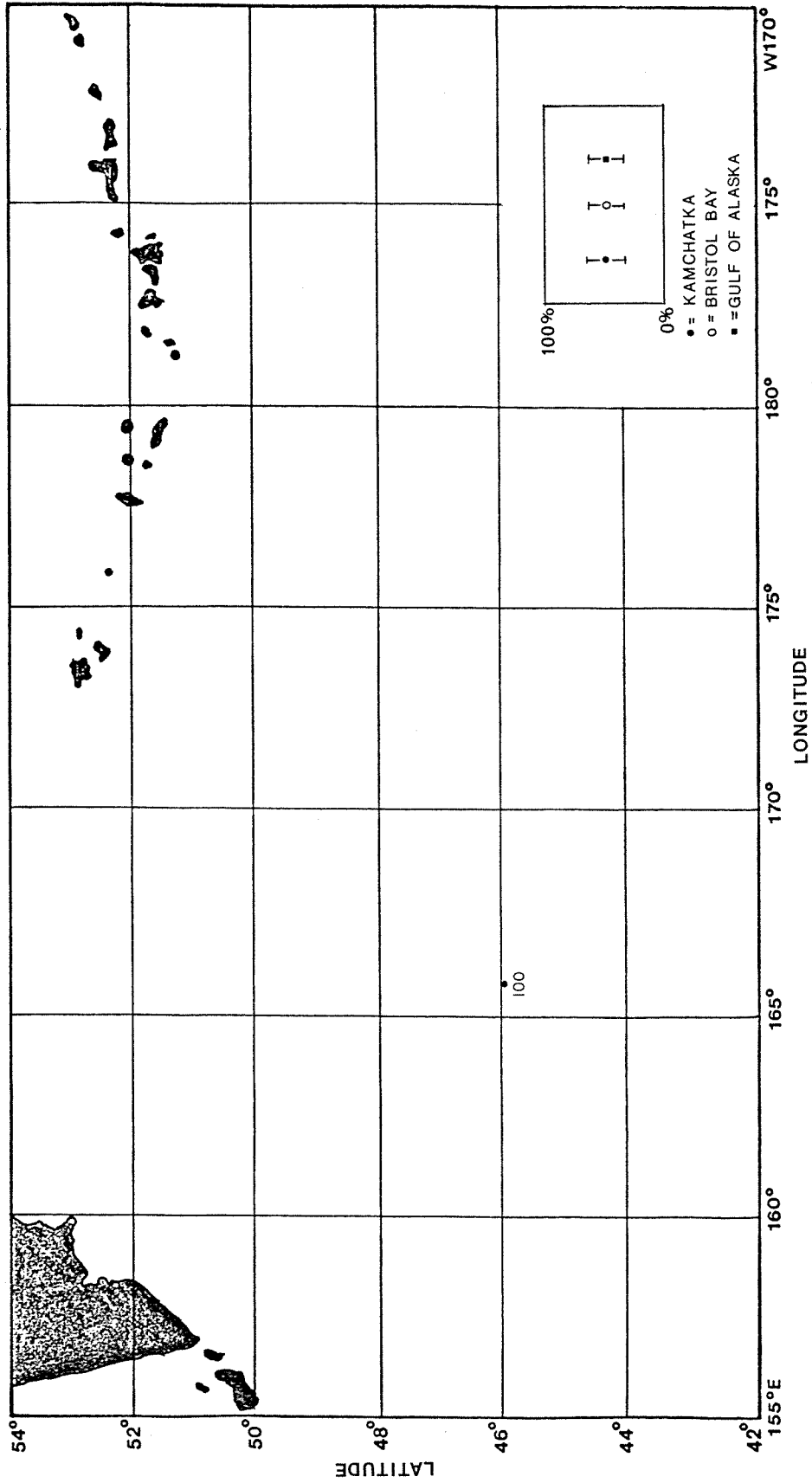


Fig. 31a. Results of classifying scale samples collected from age 1.3 maturing sockeye salmon during the period May 1-10, 1975.

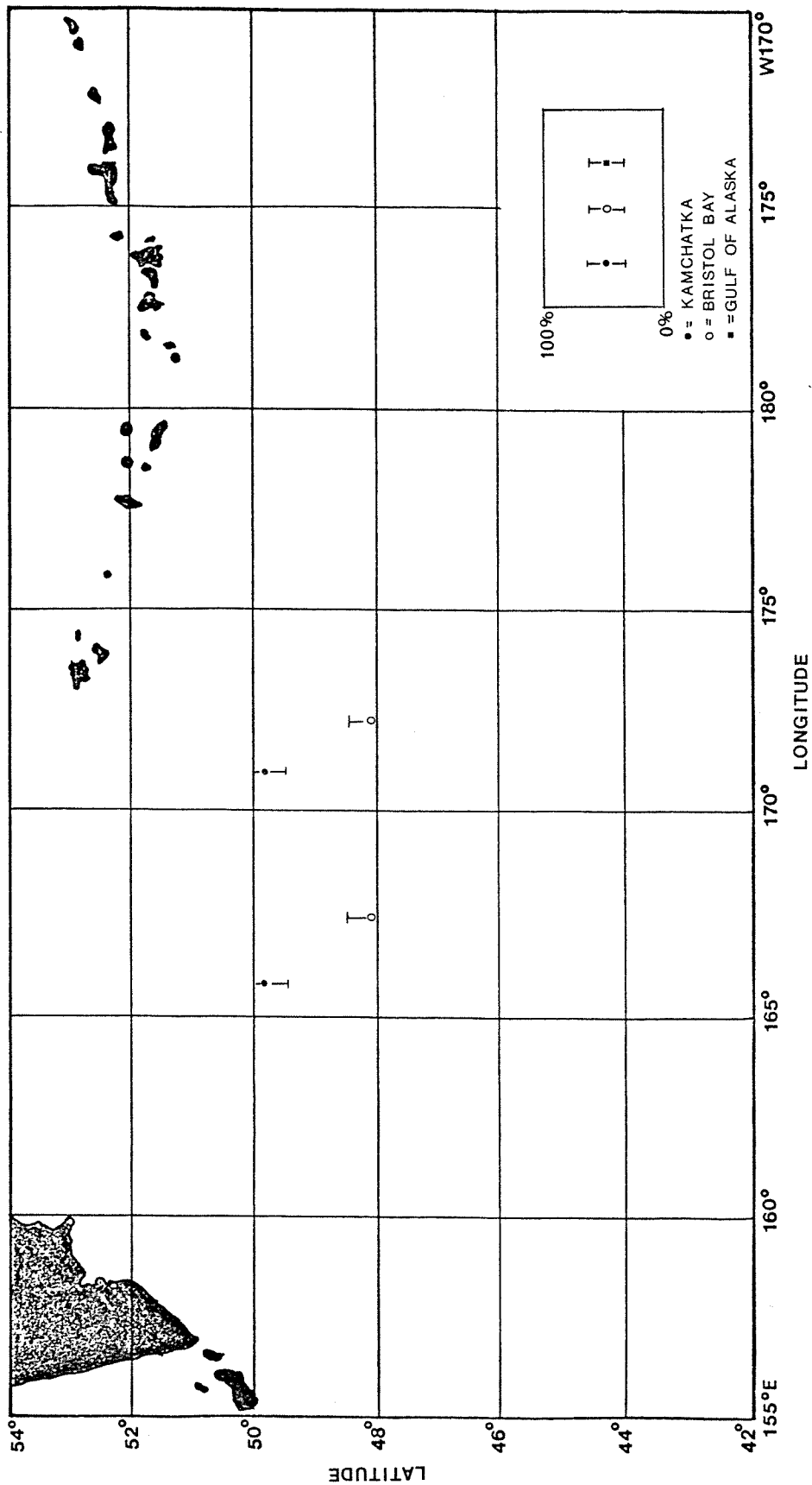


Fig. 31b. Results of classifying scale samples collected from age 1.3 maturing sockeye salmon during the period May 11-20, 1975.

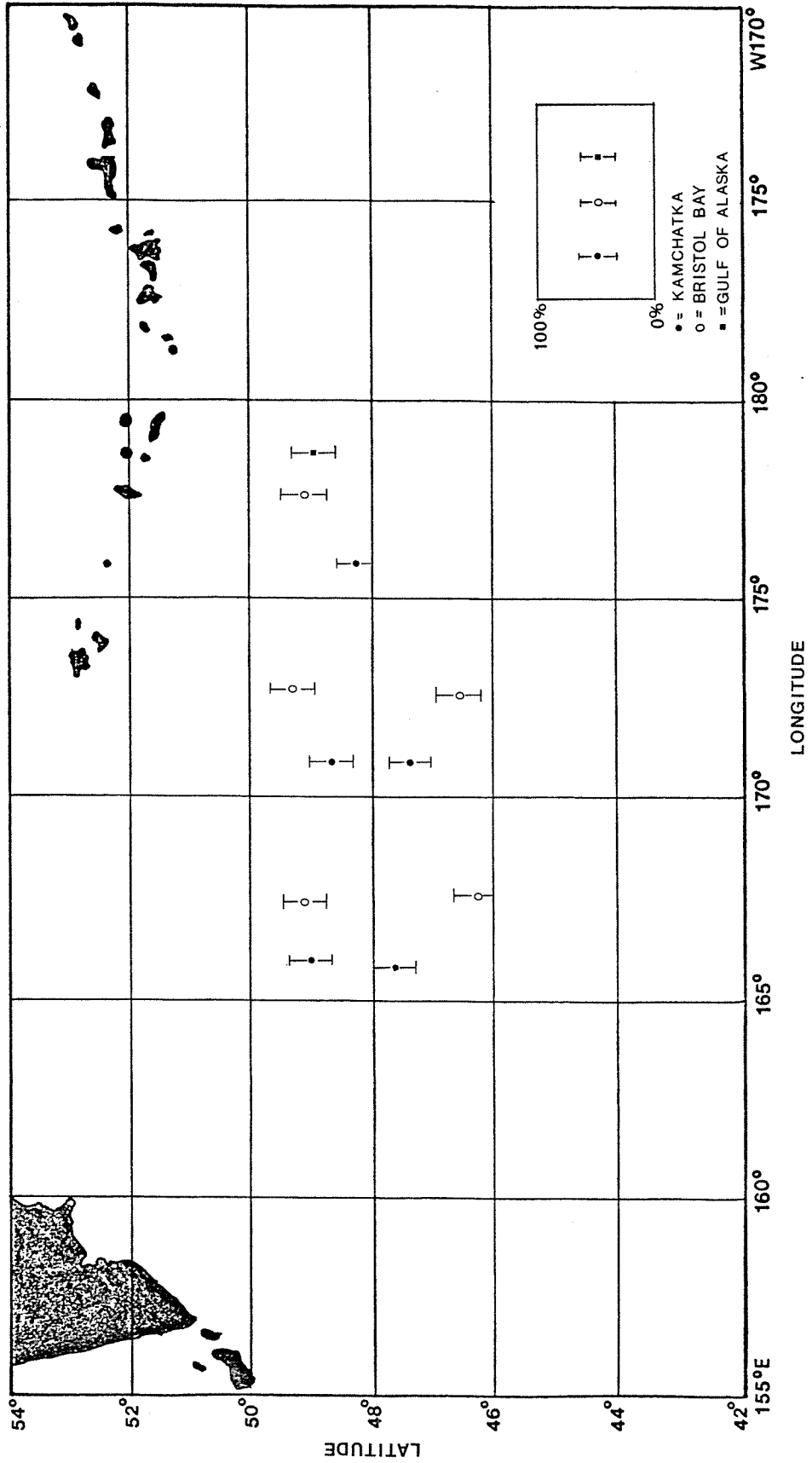


Fig. 31c. Results of classifying scale samples collected from age 1.3 maturing sockeye salmon during the period May 21-31, 1975.

dominance of Kamchatka Peninsula fish. Fairly good coverage of the areas to the north of the fishery was achieved during the last time period in May (Fig. 31c). These data show a high incidence of North American fish between 165° E - 170° E and 48° N-50° N and in area E 7046.

#### Age 2.3

No samples were available for the period May 1-10. In the middle of May (Fig. 32a) one sample from area E 6548 showed the presence of Kamchatka Peninsula fish only. Samples from 5 areas were analyzed in the period May 21-31 (Fig. 32b) from areas north of the central and eastern portions of the fishery. A significant incidence of North American fish was detected in areas E 7048, E 7548 and E 7046.

#### Discussion

In this study our primary concern was to assess the feasibility of using scale characteristics and a polynomial discriminant function to identify the origins of sockeye salmon intercepted by the Japanese landbased driftnet fishery. We found, as did Anas and Murai (1969) and Mosher (1963), that stocks of the Kamchatka Peninsula and Bristol Bay are readily separable. Scale characteristics of stocks from the Gulf of Alaska closely resemble those from fish of the Kamchatka Peninsula, however. The reduced accuracy caused by this resemblance in a three-way analysis translates into higher variance for the proportional estimates, but does not preclude such an analysis. We also confirmed the results of Mosher (1963) and Anas and Murai (1969) which showed that characters in the freshwater and first ocean zone provide the best separation of Asian and North American sockeye. Our data do, however, provide evidence that differences in the discriminant power for a character may differ between year classes and

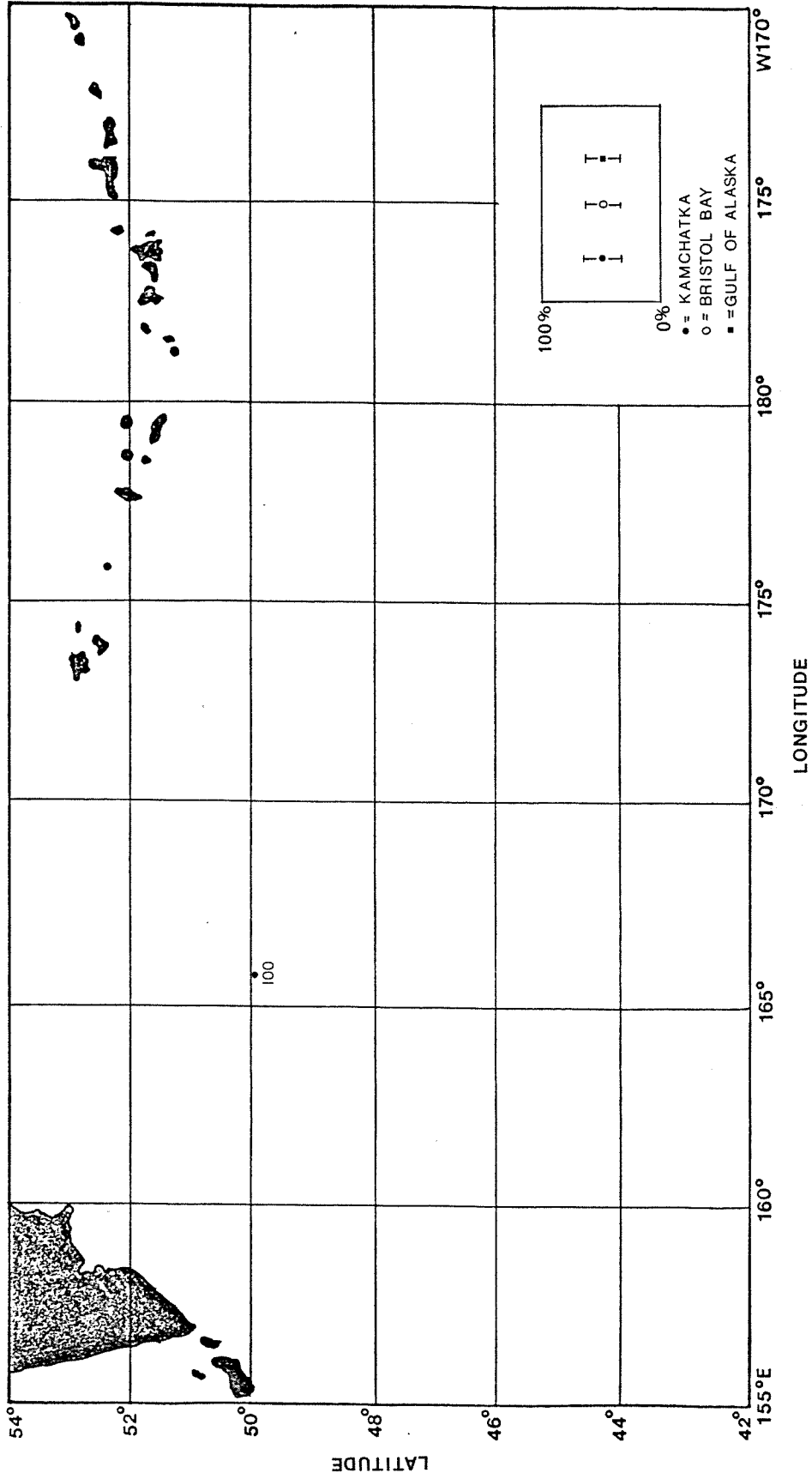


Fig. 32a. Results of classifying scale samples collected from age 2.3 maturing sockeye salmon during the period May 11-20, 1975.

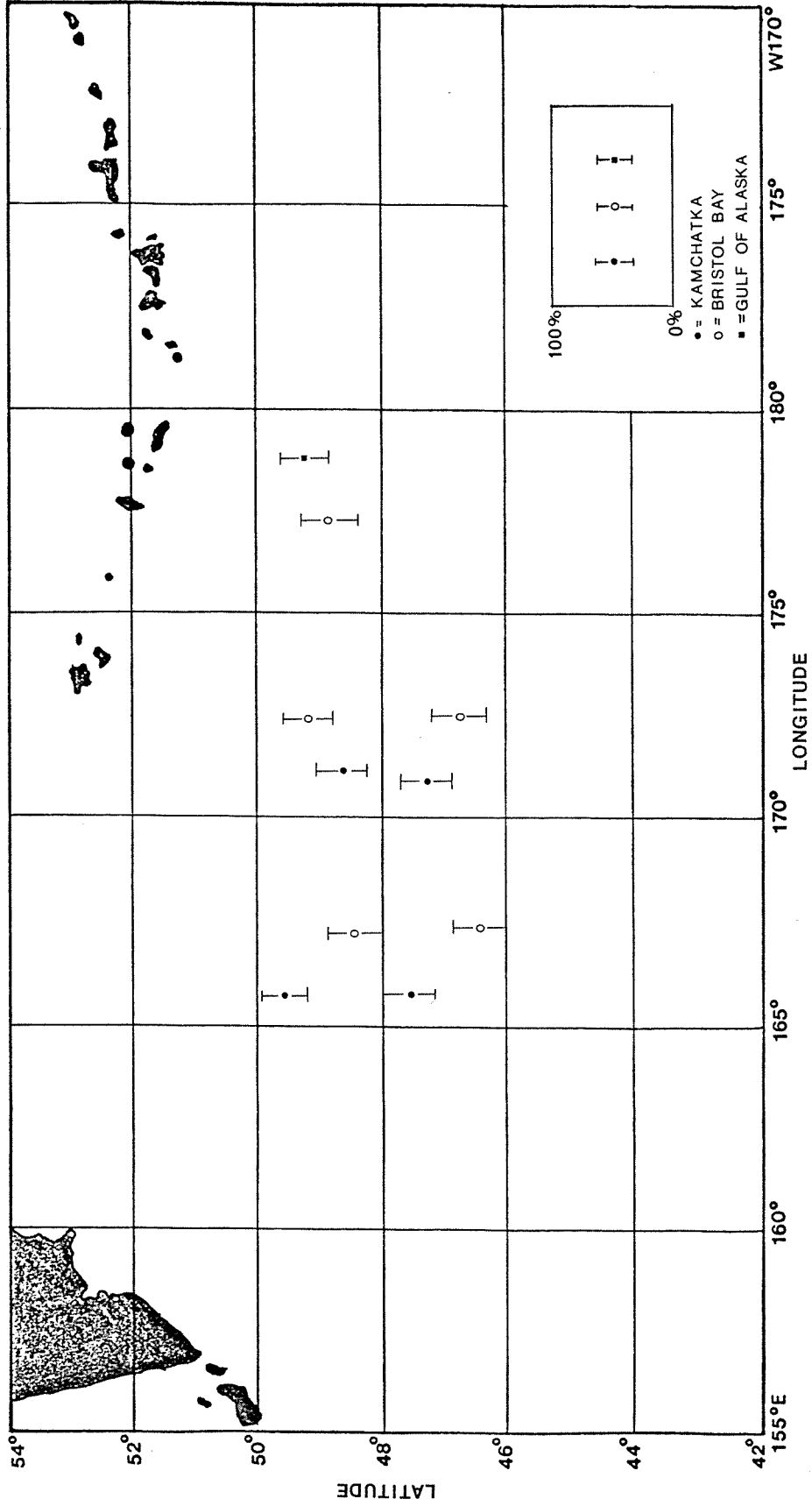


Fig. 32b. Results of classifying scale samples collected from age 2.3 maturing sockeye salmon during the period May 21-31, 1975.

brood years.

During 1977 we classified scale samples collected in 1975 from maturing sockeye of age classes 2.2, 1.3 and 2.3 by the JFA in a broad region of the North Pacific Ocean bounded by 160°E-170°W and 42°N-50°N. We did not detect a significant incidence of North American sockeye in samples collected from within the landbased fishery. Relative to areas further north, few scale samples were available from the landbased area. This precludes our ability to make any definitive statement regarding the interception of maturing North American sockeye.

Results of classifying the available samples provide provisional evidence that the models of oceanic migration for North American sockeye presented by French et al. (1976) are incomplete. Regarding the stocks of the Gulf of Alaska, we found a significant incidence of maturing 2- and 3-ocean age fish of this group in area E 7548 in May. French et al. (1976) do not show these stocks to range south of 50°N at longitudes west of 180°. We also found 3-ocean age fish which identified as Bristol Bay distributed further to the west and south than 2-ocean age fish identified as Bristol Bay. Thus western Alaskan sockeye maturing at age .3 may range further to the southwest from their natal streams during their third year at sea than they do during their second year.

We still need to explore two factors prior to determining the feasibility of implementing the PDF method for the identification of the origin of sockeye salmon in the area of the landbased fishery: 1) the availability of scale samples from the Kamchatka Peninsula to serve as Asian standards; and 2) the adequacy of scale samples in terms of numbers by maturity, age class, time and location of sampling to serve as unknowns. The first matter will be

resolved through personal contact with Soviet scientists, the second through tabulation of records provided by the JFA.

We believe that any further study of the origins of sockeye in the landbased fishery area directed at determining whether fish of North America are intercepted should emphasize an analysis of 2-ocean age immatures. We based this recommendation on the observation that if North American fish are present in the area they would be found in the eastern portion of the fishery and that research catch samples provided by JFA indicate a predominance of immature age .2 fish in the eastern portion of the fishery.

## AVAILABILITY OF COHO SALMON SCALES

The availability of coho salmon scale samples to serve as standards for the Alaska region of North America was assessed by correspondence, telephone conversations, and personal meetings with biologists of the Alaska Department of Fish and Game responsible for salmon management or research in all areas of the state. Scales are available in very limited numbers for only a small proportion of the Alaskan stocks. We have assembled a collection of scales for the years 1972-1975. Only one stock is represented in the Bristol Bay region, ten from the Gulf of Alaska and three from southeastern Alaska. For any one of the years 1972-1975, we have scales from no more than seven stocks. We are in the process of determining the availability of scales for years other than 1972-1975. We are not optimistic that the situation will improve. This dearth of samples is a result of the relatively minor emphasis placed on the management and research of coho salmon stocks. Scale samples are available from JFA research vessels operating in the area of the landbased fishery for the years 1972-1976. The availability of scale samples from Asia to serve as standards is still uncertain.

We recommend that, rather than initiating an analysis with the scant samples available, a comprehensive scale collection program be initiated for 1979. For such a program to succeed, data must be obtained from escapements and/or terminal fisheries in Alaska, and Kamchatka and from JFA research vessels operating within the landbased fishery area. It appears to us that the only feasible means of obtaining such samples would be through a cooperative scale collection program involving the State of Alaska, Japan and the Soviet Union.

CRITIQUE OF THE AGE COMPOSITION METHOD FOR DETERMINING THE  
ORIGIN OF SOCKEYE SALMON IN THE AREA OF THE LANDBASED FISHERY

Comparisons of the age compositions of sockeye salmon from the area of the landbased fishery with the age compositions from Kamchatka and Bristol Bay runs have been used to identify the continental origin of sockeye in the landbased fishery.<sup>1</sup> It was concluded that the fish in the landbased area were predominantly Asian largely because of the relatively high proportion of age 3.2 fish in this area and the higher proportion of this age group in the Asian runs compared to the Bristol Bay runs. Statistics on the abundance and age compositions of the Asian (Kamchatkan) sockeye salmon runs are meager; however, these runs appear to have a consistently higher proportion of ages 2.3 and 3.2 than occurs typically in the Bristol Bay runs.

The age compositions of sockeye salmon runs vary considerably among locations and from year to year. The age composition of the Bristol Bay runs is largely determined by the abundant Kvichak runs and the cyclic behavior of those runs. Sockeye of age 2.2 are usually the most abundant age group in the Bristol Bay runs; however, this age group is seldom abundant in the Nushagak runs, which are primarily fish of ages 1.2 and 1.3.

During the years 1972-1976, mature sockeye salmon of age 2.2 were most abundant in the catches by commercial nets employed by Japan's research vessels during May (Table 15). The bulk of the sockeye catches by the commercial fleet were made in May between 160° E and 175° E longitude, and 40° N and 45° N latitude.

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<sup>1</sup>Osako, M. 1975 and 1976. INPFC Documents.

Table 15. Age compositions of mature sockeye salmon from samples collected in landbased fishing areas during May. Sampling by research vessels using commercial gill nets.

Year	Area	1.1	2.1	3.1	1.2	2.2	3.2	0.3	1.3	2.3	3.3	1.4
1972	6042*				9.1	63.6	27.3					
	6044	.5	1.0	.5	12.8	53.6	25.0	.5		5.6	.5	
	6544*				11.5	61.5	26.9					
1973	6044		1.2	.4	8.3	63.2	14.6		5.1	5.5	1.6	
	6542*				12.5	50.0	6.3	6.3	18.8	6.3		
	6544		.4		5.2	60.8	22.0	1.3	3.9	6.0	.4	
	7044				9.1	60.3	15.3	2.4	8.6	3.8	.5	
	7544*		7.7		30.8	38.5	7.7		7.7	7.7		
1974	6044	1.7			15.5	62.1	17.2	1.7	.9	.9		
	6544		2.5	1.0	8.9	63.1	19.1	1.0	.6	3.8		
1975	6042				2.1	85.1	8.5		2.1	2.1		
	6044		.9		2.3	82.3	8.2		2.7	3.6		
	6542		1.2		2.4	89.4	4.7			2.4		
	6544				3.9	81.4	5.1	.6	3.6	5.1	.3	
	7044*		6.3			62.5	12.5	6.3	6.3		6.3	
1976	6042*				4.2	62.5	29.2	4.2				
	6044				5.4	75.1	17.6		.5	1.4		
	6544		.3		4.4	73.1	14.0	1.0	3.9	3.4		
	7044				9.4	65.9	9.4	2.4	5.9	4.7	1.2	

\* Sample size small (10-30).

Therefore, if the sampling by the research vessels was representative of the commercial fleet then the majority of the catch by the landbased fishery was sockeye of age 2.2 and secondarily fish of age 3.2.

The most abundant age group in the Bristol Bay runs during 1972-1976 was age 2.2 except in 1973 but the run that year was the smallest in history (Table 16). Fish of age 3.2 were relatively scarce, except in 1975 and 1976, and occur primarily in the Egegik district. The percentage of age 2.2 fish was highest during 1972-1976 in 1975 and in that year there was also the highest percentage of age 2.2 fish in the landbased fishery.

We obtained samples of sockeye scales from the 1974 runs to three locations in Kamchatka through JFA and made the age determinations ourselves (Table 17). We do not know the abundance of the runs to the Kamchatka Peninsula but historically the Ozernaya run was the most abundant. The Kamchatkan runs typically contain a high proportion of age .3 sockeye and this was apparently the case in 1974.

In May, 1974, the landbased fishery caught 3.6 million sockeye salmon and they were predominantly age 2.2. Although the estimated age composition of this catch did not closely resemble either the Bristol Bay or Kamchatkan inshore run, the Bristol Bay run contained 62% age 2.2 (Table 18). The percentage of age 3.2 in the landbased fishery is unexplainable since such high percentages did not occur in either inshore run.

Unless the abundances of the inshore runs by age group are known for both Kamchatka and Bristol Bay, it is not possible to make reasonably precise estimates of the origin of the sockeye caught by the landbased fishery solely on the basis of age composition. The data available to us certainly do not suggest that the landbased fishery catches only Asian sockeye, but rather that

Table 16. Bristol Bay sockeye salmon runs by age group (A), number of fish in thousands and (B) age composition (%) excluding ages .1 and .4.

Year	0.2	1.2	2.2	3.2	0.3	1.3	2.3	3.3	Total	1.1	2.1	-.4
<u>A</u>												
1967	2	1145	5675	30	31	1336	2035	52	10306	16	15	11
68	3	3062	1921	46	19	1676	1083	17	7827	35	138	10
69	8	10792	5344	79	18	1171	992	21	18425	36	566	1
70	2	3405	32153	82	60	2667	971	12	39352	13	13	0
71	5	1577	4775	9	50	6811	2557	9	15793	9	11	12
1972	2	1019	1686	6	7	1242	1403	16	5381	0	0	9
73	1	218	214	1	86	1010	859	8	2397	4	12	13
74	4	2014	6805	5	10	1392	621	2	10853	3	60	26
75*	3	1585	17111	293	36	2275	2705	9	24017	19	86	28
1976*	8	1413	5339	449	70	2592	1393	112	11376	0	115	7
77*	2	1587	2809	67	62	1756	3130	29	9442	17	5	10
<u>B</u>												
1967	0.0	11.1	55.1	0.3	0.3	13.0	19.7	0.5				
68	0.0	39.1	24.6	0.6	0.3	21.4	13.8	0.2				
69	0.0	58.6	29.0	0.4	0.1	6.4	5.4	0.1				
70	0.0	8.7	81.7	0.2	0.1	6.8	2.5	0.0				
71	0.0	10.0	30.2	0.1	0.3	43.1	16.2	0.1				
1972	0.0	19.0	31.3	0.1	0.1	23.1	26.1	0.3				
73	0.1	9.1	8.9	0.1	3.6	42.1	35.8	0.3				
74	0.0	18.6	62.7	0.1	0.1	12.8	5.7	0.0				
75*	0.0	6.6	71.2	1.2	0.2	9.5	11.3	0.0				
1976*	0.1	12.4	46.9	4.0	0.6	22.8	12.2	1.0				
77*	0.0	16.8	29.8	0.7	0.7	18.6	33.1	0.3				

\* Preliminary data from the Alaska Department of Fish and Game.

Table 17. Age compositions (%) of sockeye salmon from samples collected in 1974 from the Bolshaya (1), Ozernaya (2), and Kamchatka River (3), and in 1975 from the Kamchatka River (5).\*

Date	Age										
	1.1	2.1	3.1	1.2	2.2	3.2	0.3	1.3	2.3	3.3	1.4
1. 5/27				4.2	2.1			66.0	27.7		
6/4	2.2			41.3	10.9			30.4	13.0		2.2
6/24				4.2			12.5	64.6	14.6		4.1
7/9				29.8	2.1			57.4	4.3		6.4
Means	.5			19.9	3.8		3.1	54.6	14.9		3.2
2. 7/15		30.5	1.7	1.7	25.4	3.4		1.7	32.2	3.4	
8/12		3.1	1.0		37.1			1.0	51.6	6.2	
Means		16.8	1.3	.9	31.3	1.7		1.3	41.9	4.8	
3. 6/18				2.1	2.1		19.2	42.6	34.0		
6/25				6.5	2.2		15.2	54.3	10.9		10.9
7/10		2.2				2.2	15.2	56.5	6.5		17.4
7/?				6.1			14.3	65.3	6.1		8.2
Means		.5		3.7	1.1	.5	16.0	54.7	14.4		9.1
4. 6/30		3.4						38.6	55.7		2.3

\* Scales collected by the USSR and provided by Japan for our reading.

Table 18. Age compositions of sockeye salmon in the inshore runs to Bristol Bay and Kamchatka in 1974 and the age composition of mature sockeye salmon from research vessels (commercial nets) in the landbased fishing areas in May.

Location	Percent by age									Total run (thousands)
	x.1	1.2	2.2	3.2	0.3	1.3	2.3	3.3	x.4	
<u>Bristol Bay</u>										
Naknek-Kvichak	1.0	4.1	80.2	0.0	0.0	9.2	5.4	0.0	0.1	6,428
Egegik	0.0	4.0	73.6	0.2	0.0	6.6	15.4	0.1	0.1	1,448
Ugashik	1.3	6.4	80.9	0.0	0.0	6.6	4.6	0.0	0.2	64
Nushagak	0.0	58.8	18.2	0.0	0.4	20.7	1.2	0.0	0.6	2,778
Togiak	0.0	24.2	12.3	0.0	0.5	56.3	5.3	0.0	1.3	222
B.B. Total Run	0.6	18.4	62.2	0.04	0.1	12.7	5.7	0.02	0.3	10,940
<u>Kamchatka</u>										
Bolshaya	0.5	19.9	3.8	0.0	3.1	54.6	14.9	0.0	3.2	
Ozernaya	18.1	0.9	31.3	1.7	0.0	1.3	41.9	4.8	0.0	
Kamchatka	0.5	3.7	1.1	0.5	16.0	54.7	14.4	0.0	9.1	
<u>Landbased fishery in May</u>										
Area 6044	1.7	15.5	62.1	17.2	1.7	0.9	0.9	0.0	0.0	
Area 6544	3.5	8.9	63.1	19.1	1.0	0.6	3.8	0.0	0.0	

a significant portion of this catch comes from sockeye of Bristol Bay origin or at least non-Asian origin.

## FEASIBILITY OF TAGGING

The possibility of conducting tagging experiments from JFA research vessels operating in and around the area of the landbased fishery was discussed with Mr. K. Takagi, JFA. He indicated that no purse seine vessels were available for charter in Japan, but that U.S. scientists were welcome aboard JFA vessels which employ longlines. Furthermore, he indicated that while JFA wanted to retain the present general pattern of deployment, some adjustment could be made to meet specific research goals.

While this approach to conducting tagging experiments would be quite inexpensive we have serious reservations regarding the success of such an undertaking primarily because of the JFA use of inefficient longlines to capture fish for tagging.

A second possibility would be to conduct tagging experiments from U.S. vessels. We believe that two combination purse seine-longline vessels operating over three summers could tag enough fish to provide an adequate number of recoveries for analysis. This approach would, however, require a major funding commitment, in the range of \$750,000 per year.

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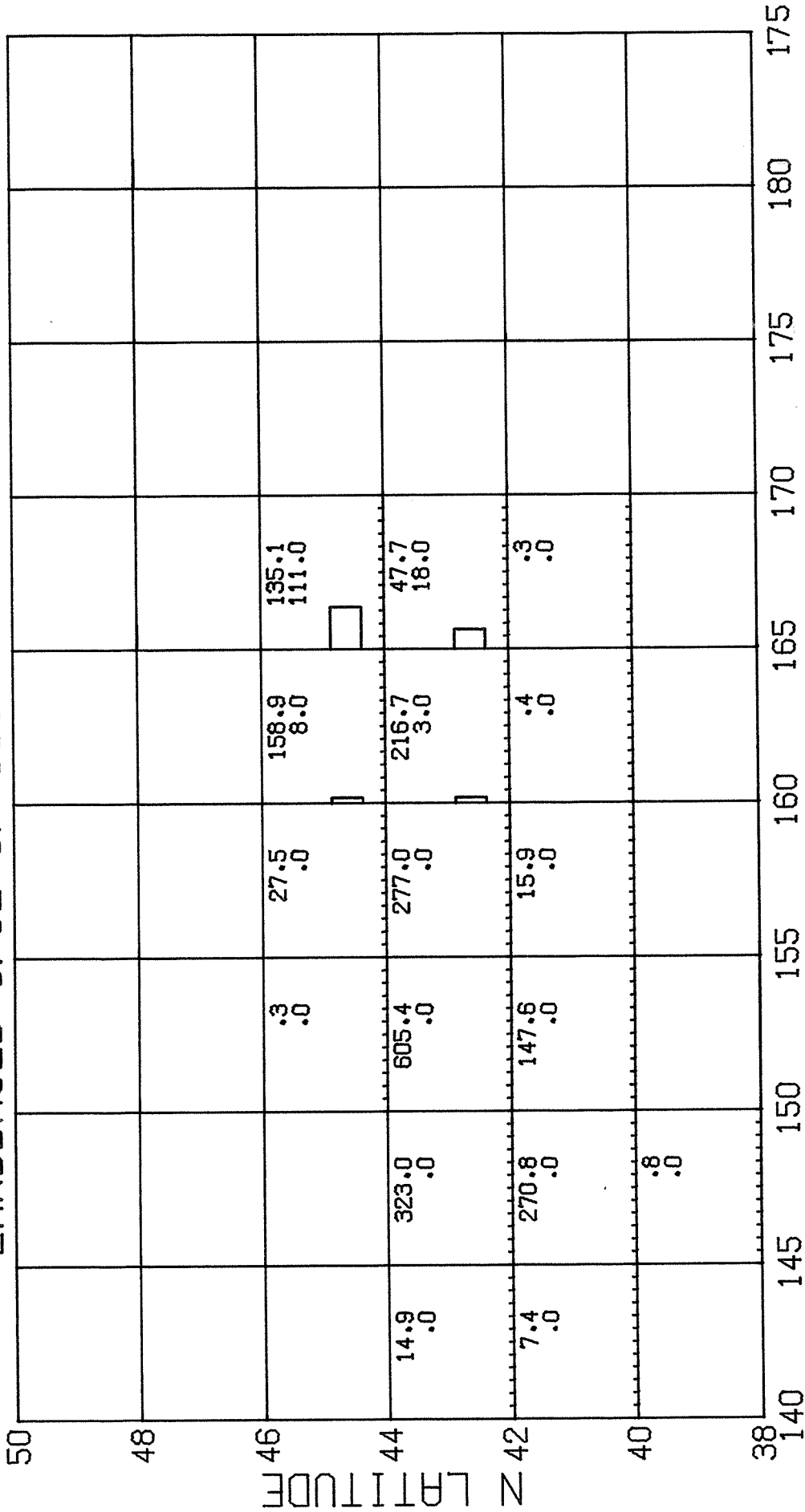
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## Appendix 1

Japanese landbased offshore driftnet catch, effort, and catch per unit of effort (CPUE) atlas for sockeye and coho salmon, 1962 and 1972-1976. Data are for large vessels only (> 30 g.t.), and were provided by the Japan Fishery Agency. CPUE indices are in terms of catch (in numbers of fish) per tan of drift net. Pages are ordered by species, year, and month.

LANDBASED CPUE OF SOCKEYE IN MAY 1962



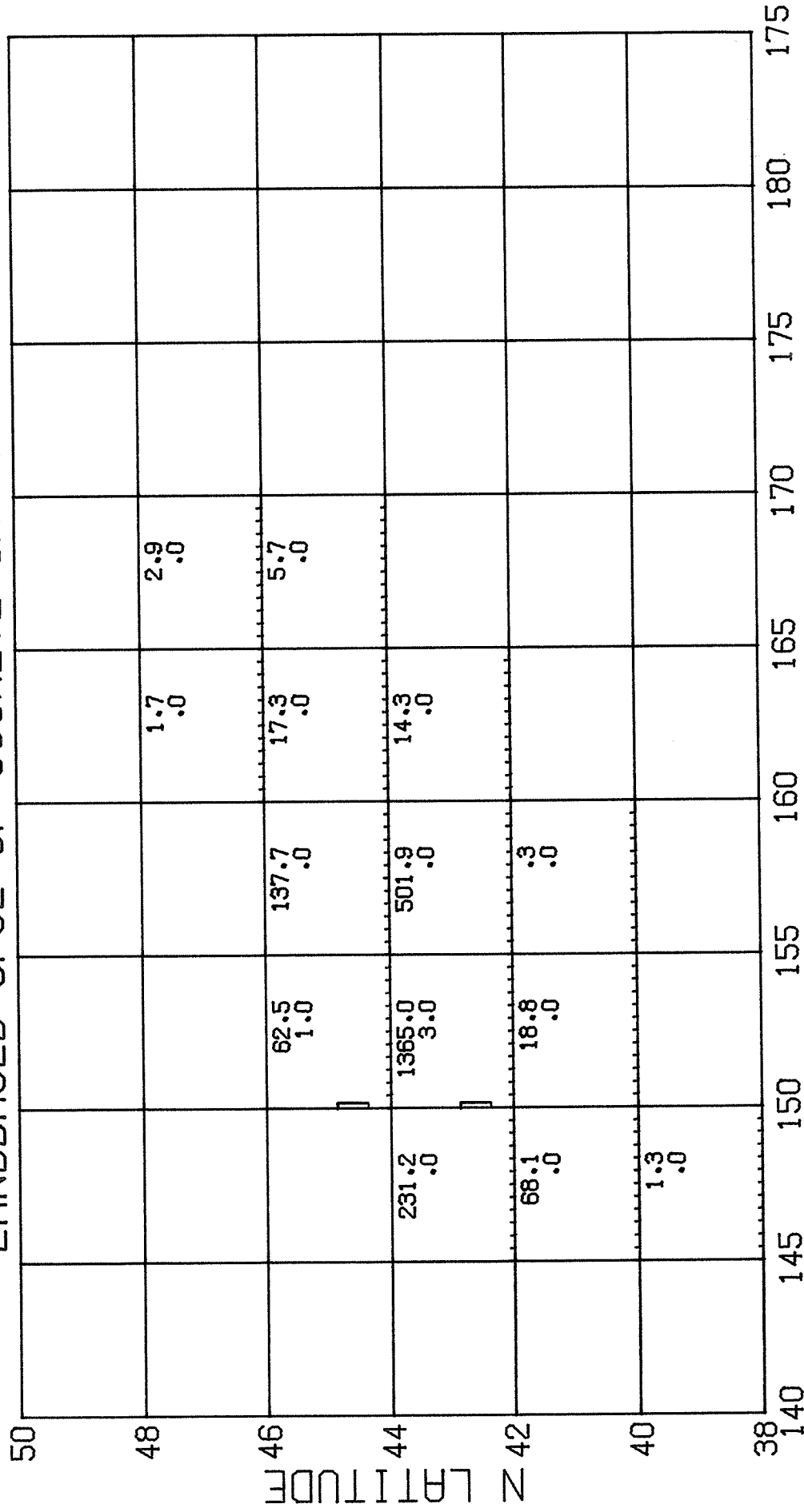
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TANS, 1000'S  
CATCH, 1000'S

CPUE

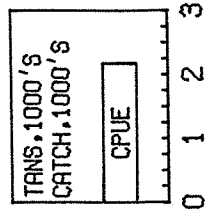
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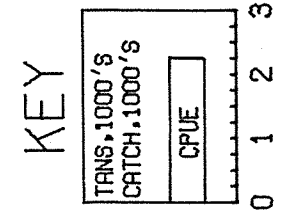
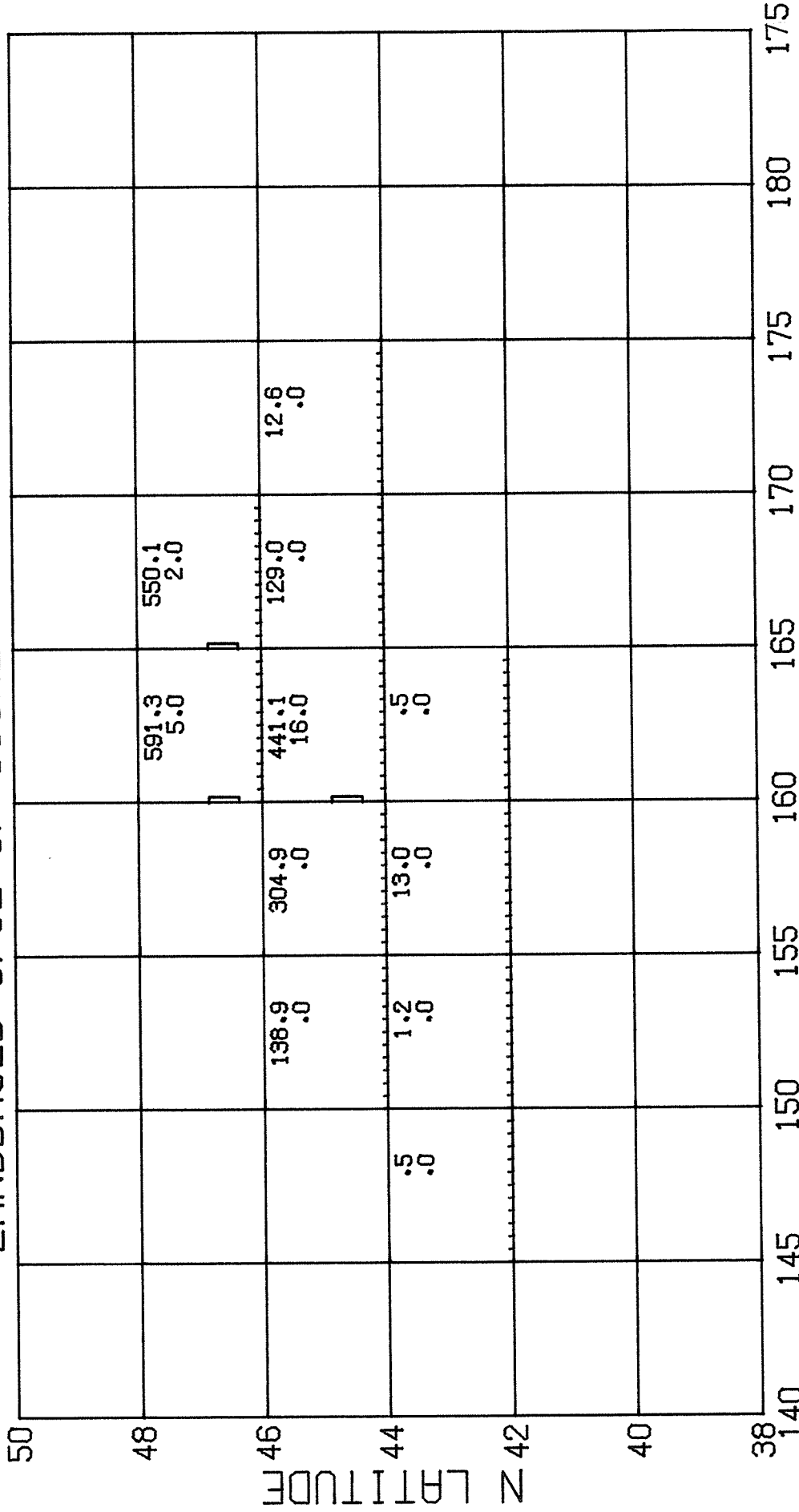


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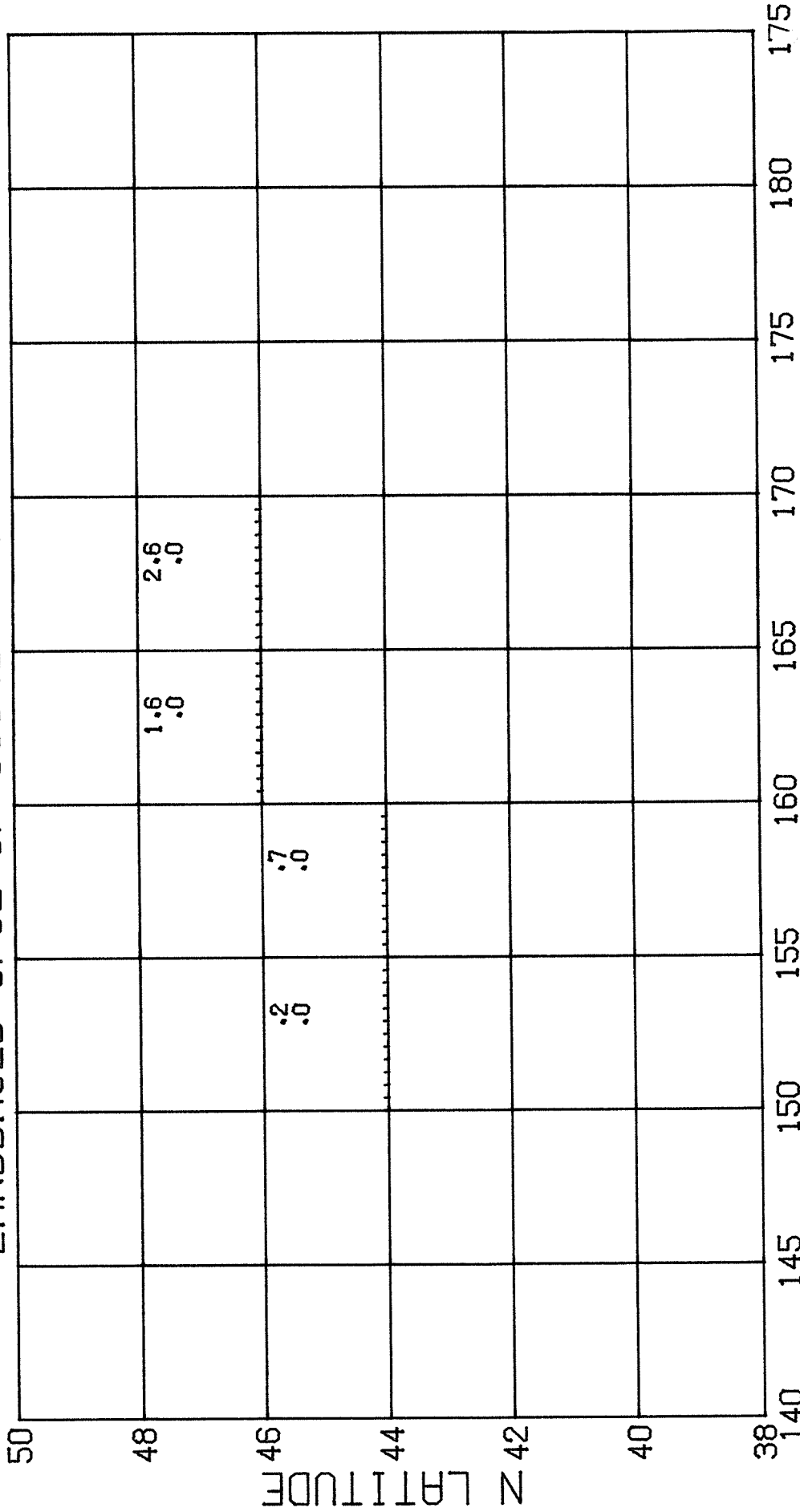
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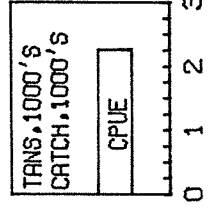


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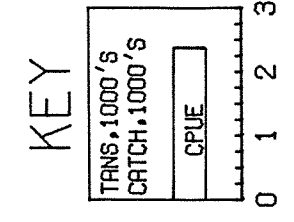
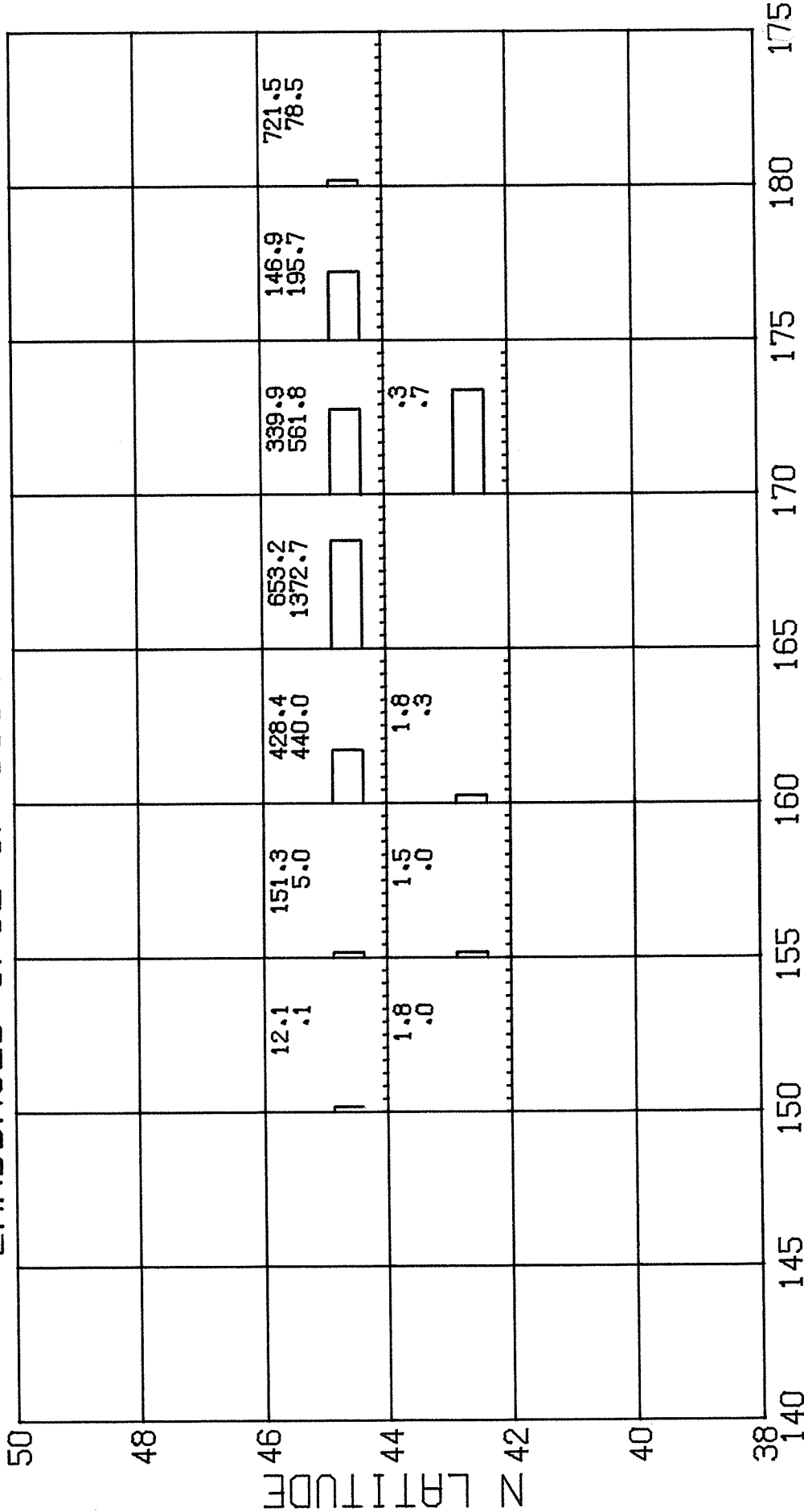
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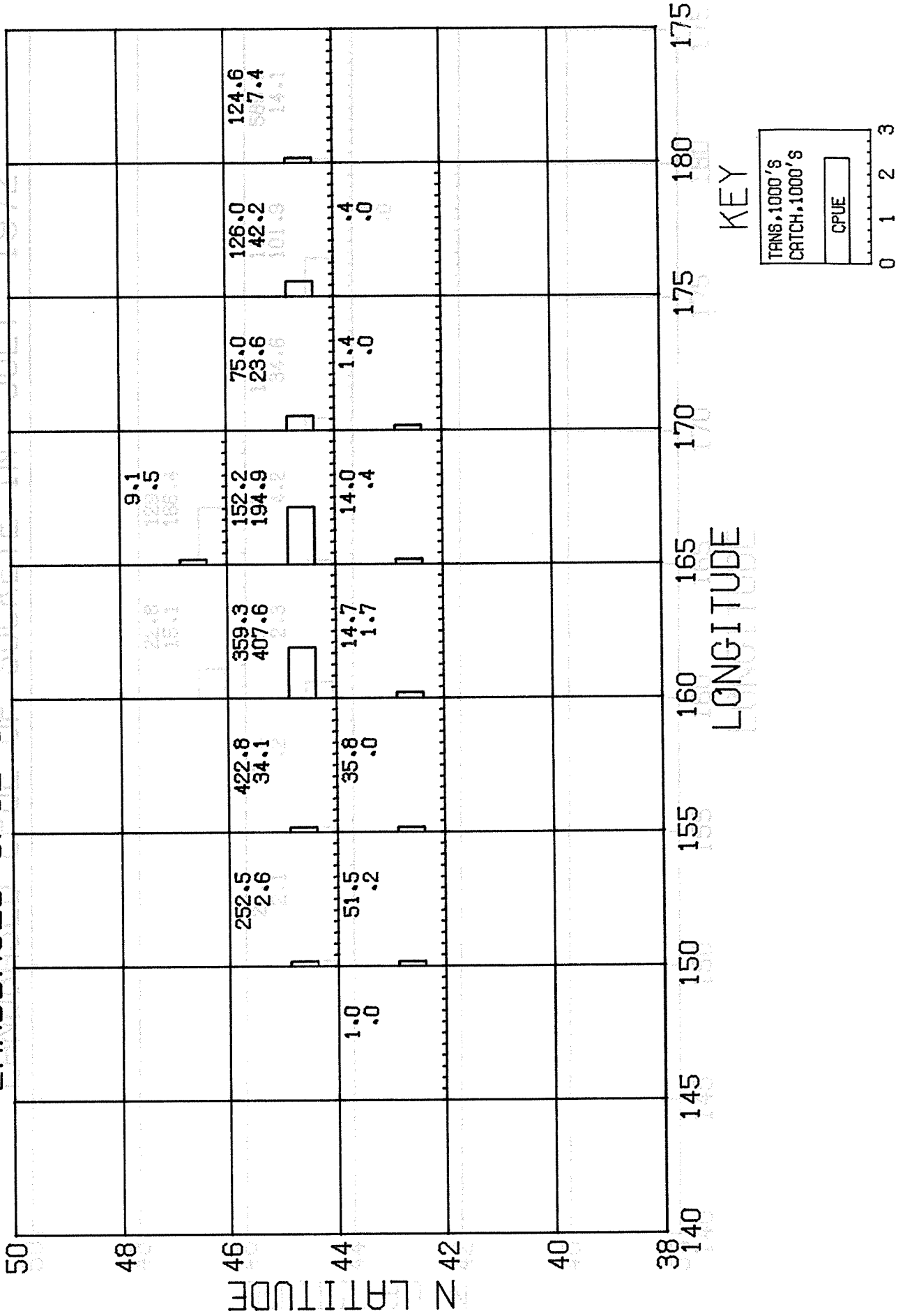


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LANDBASED CPUE OF SOCKEYE IN MAY 1972



# LANDBASED CPUE OF SOCKEYE IN JUNE 1972



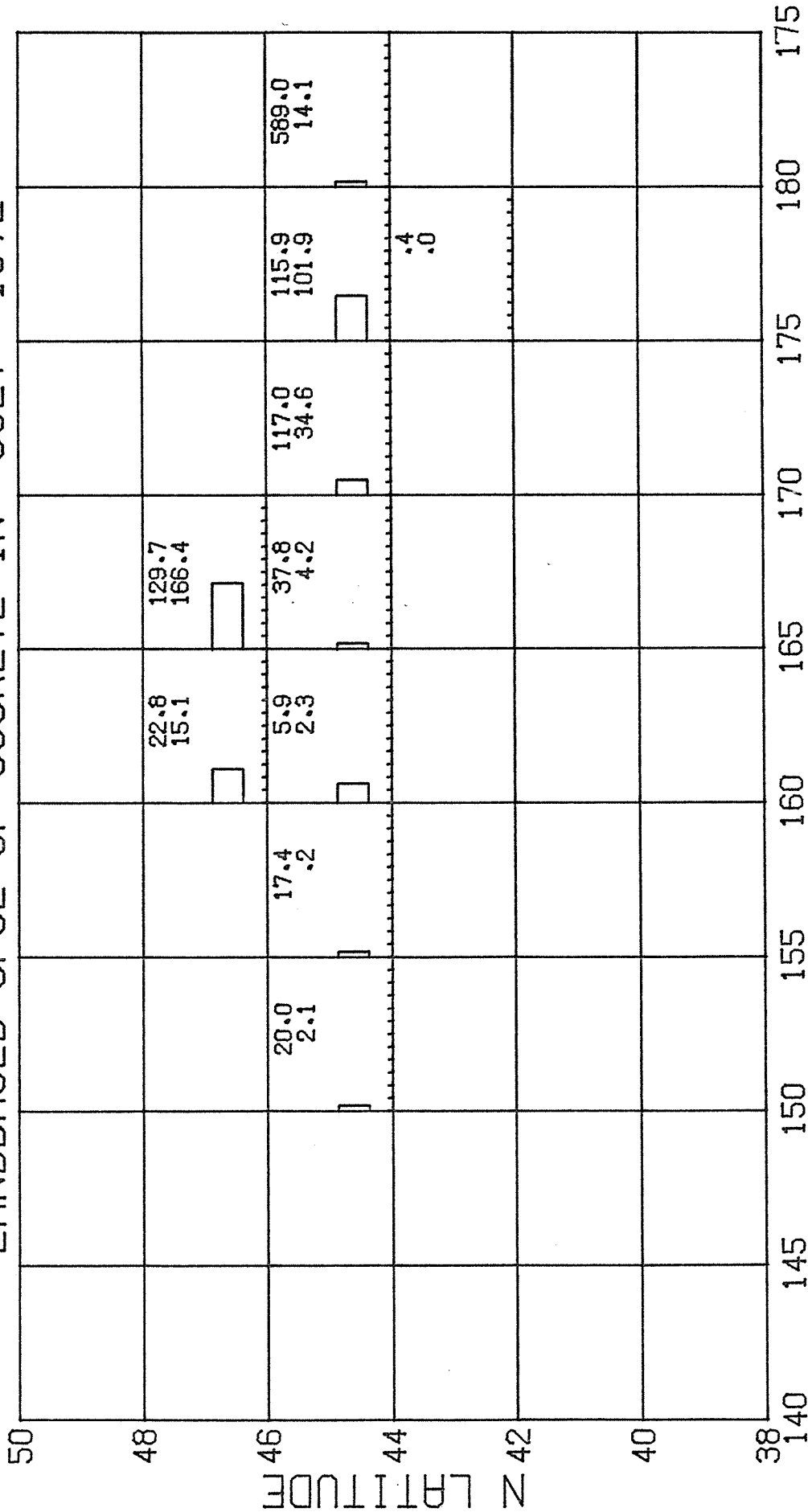
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TANS, 1000'S  
CATCH, 1000'S

CPUE

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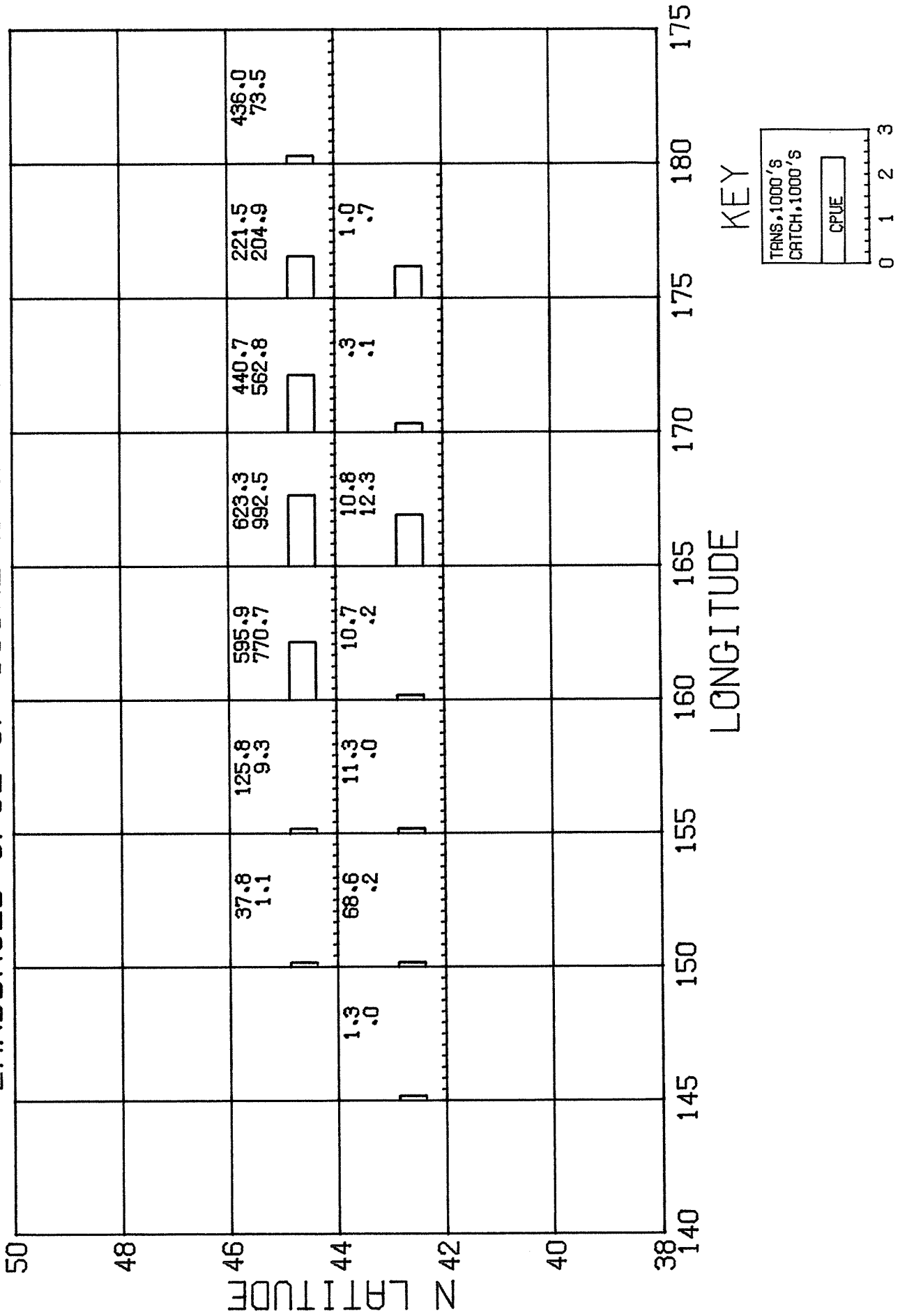


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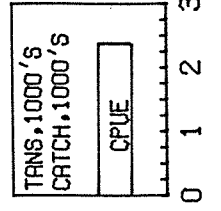
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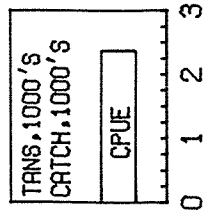
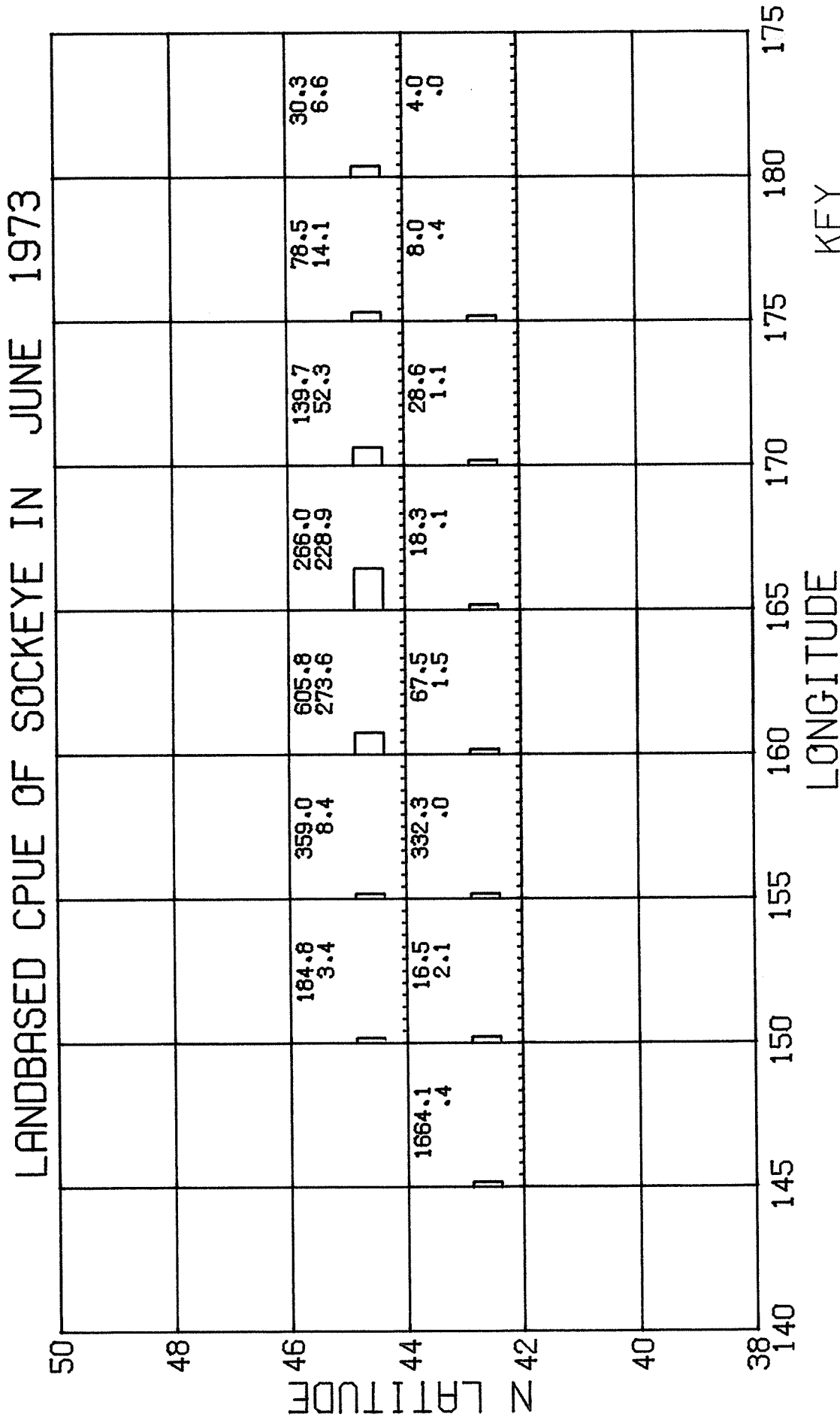
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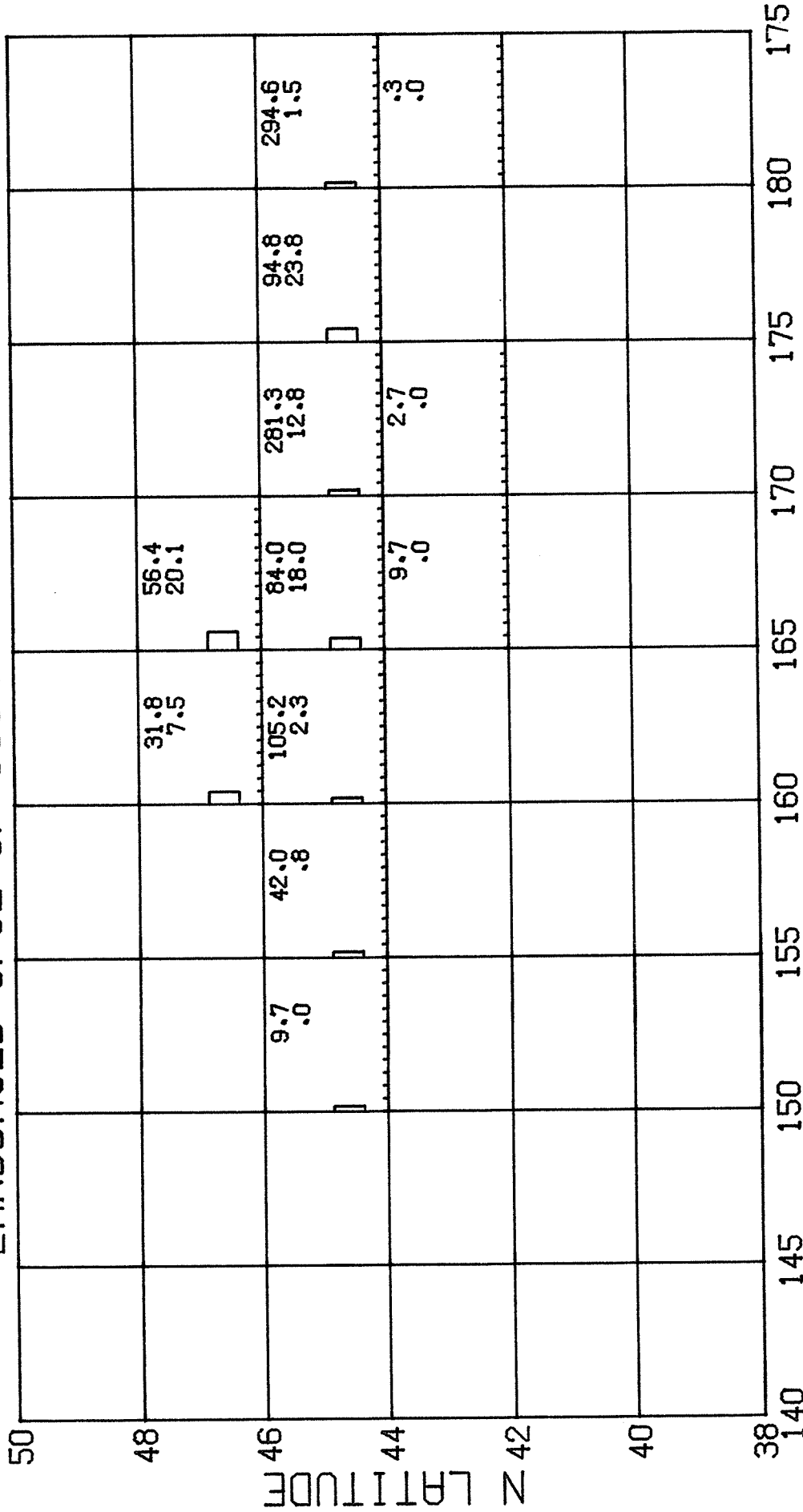


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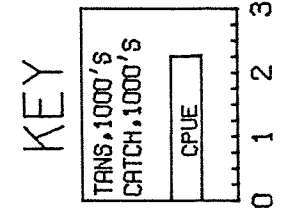
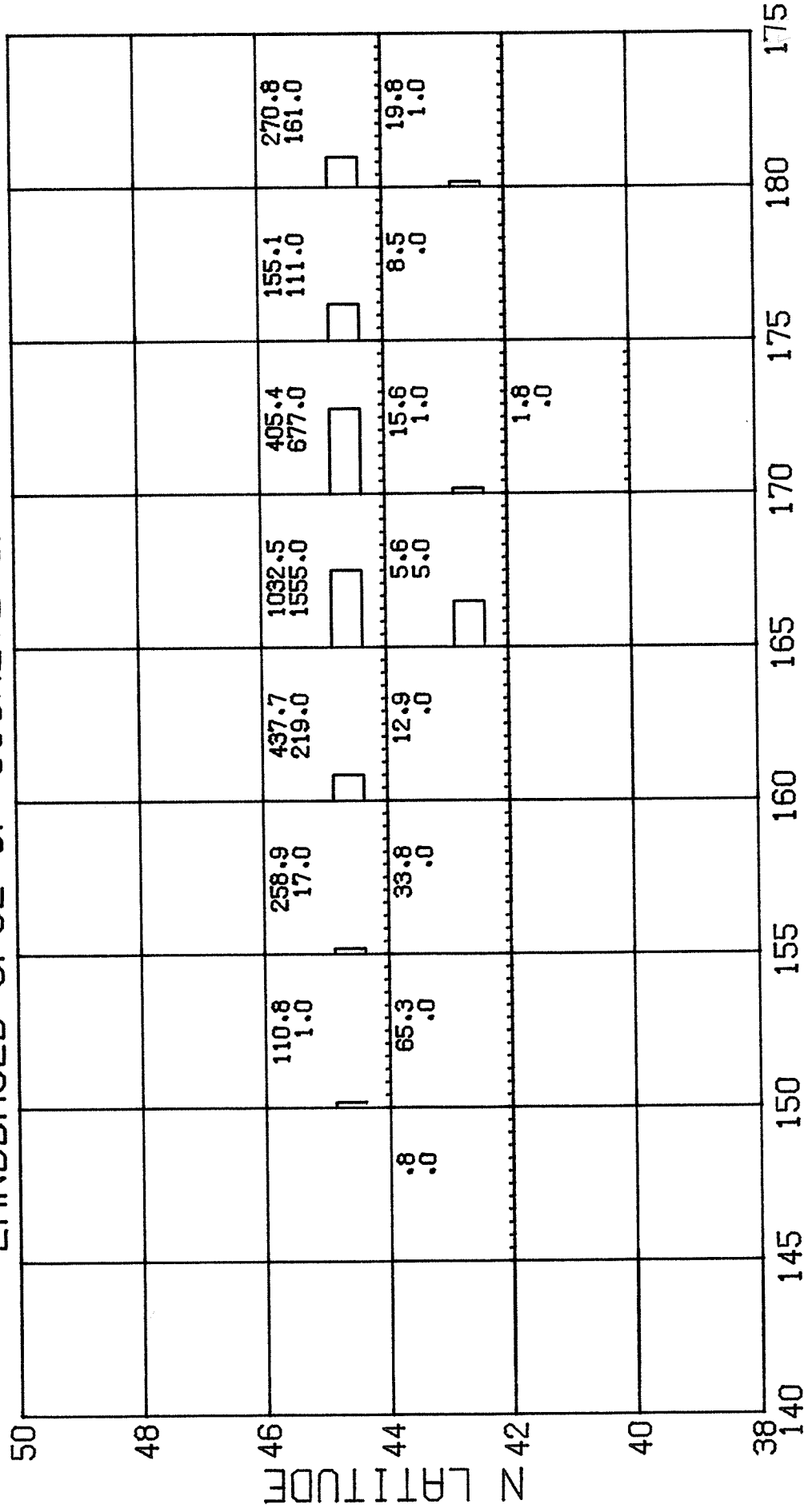




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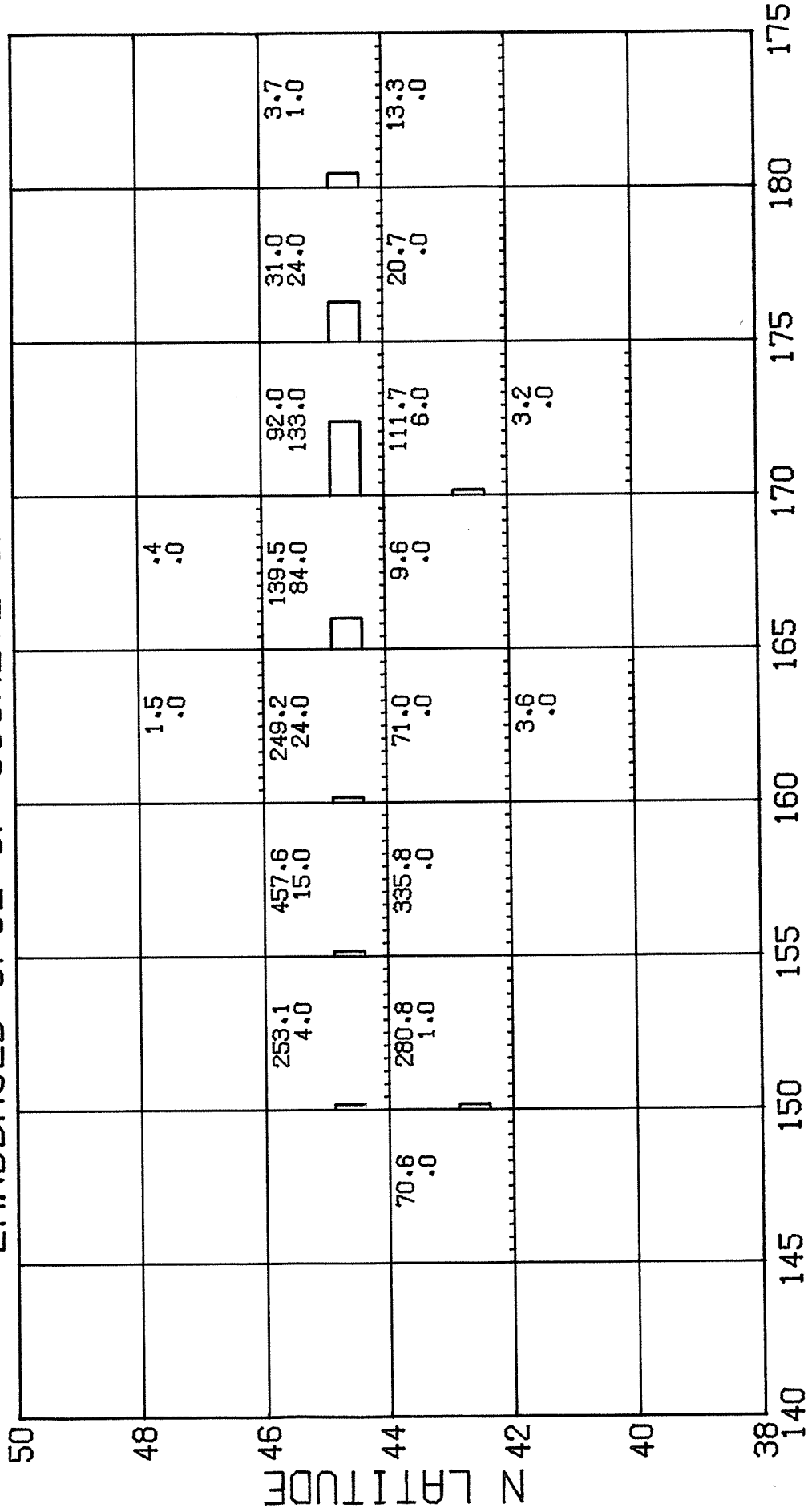
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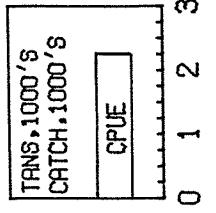
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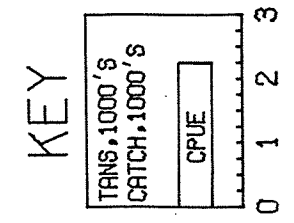
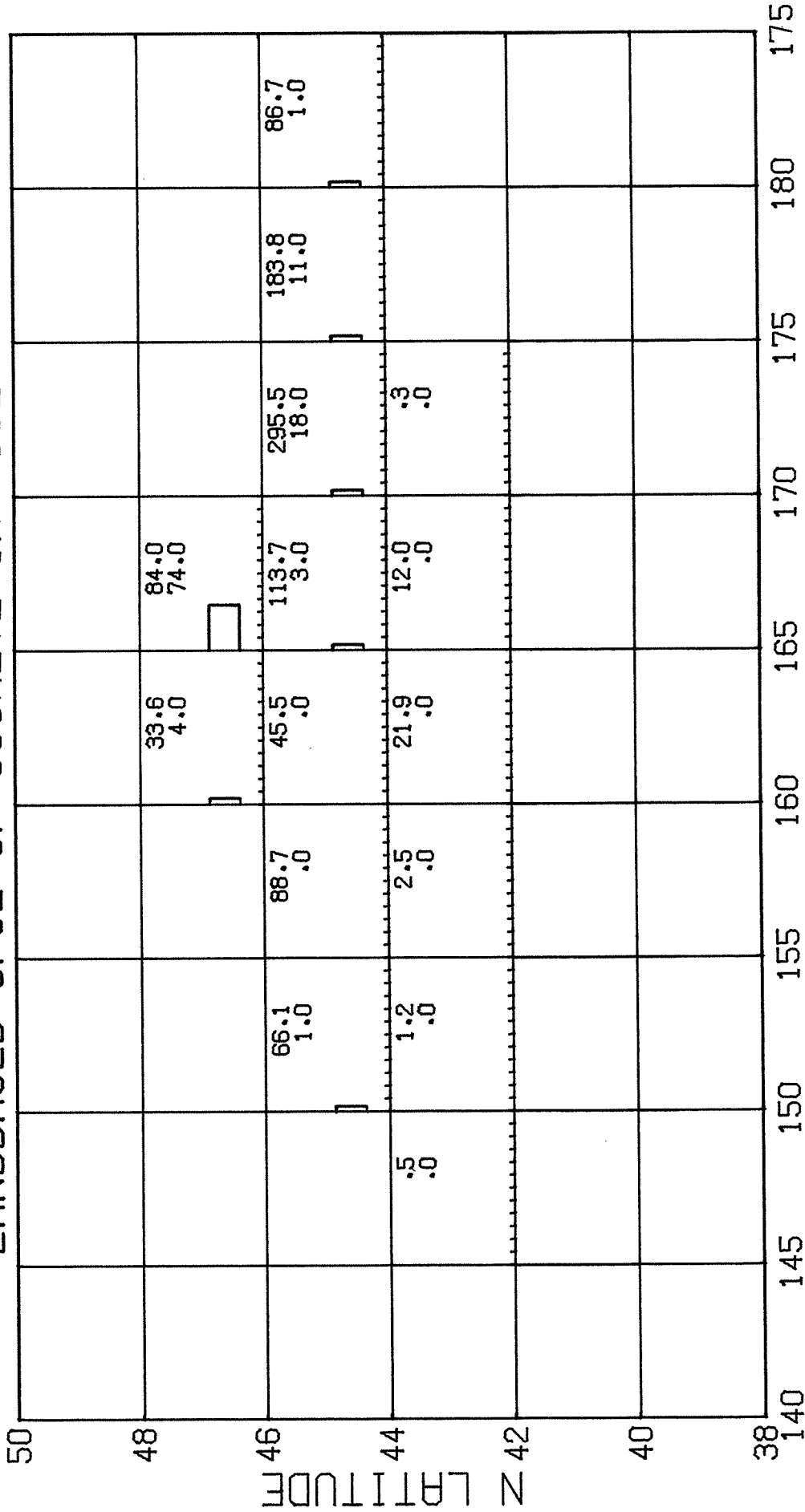


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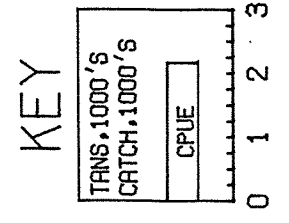
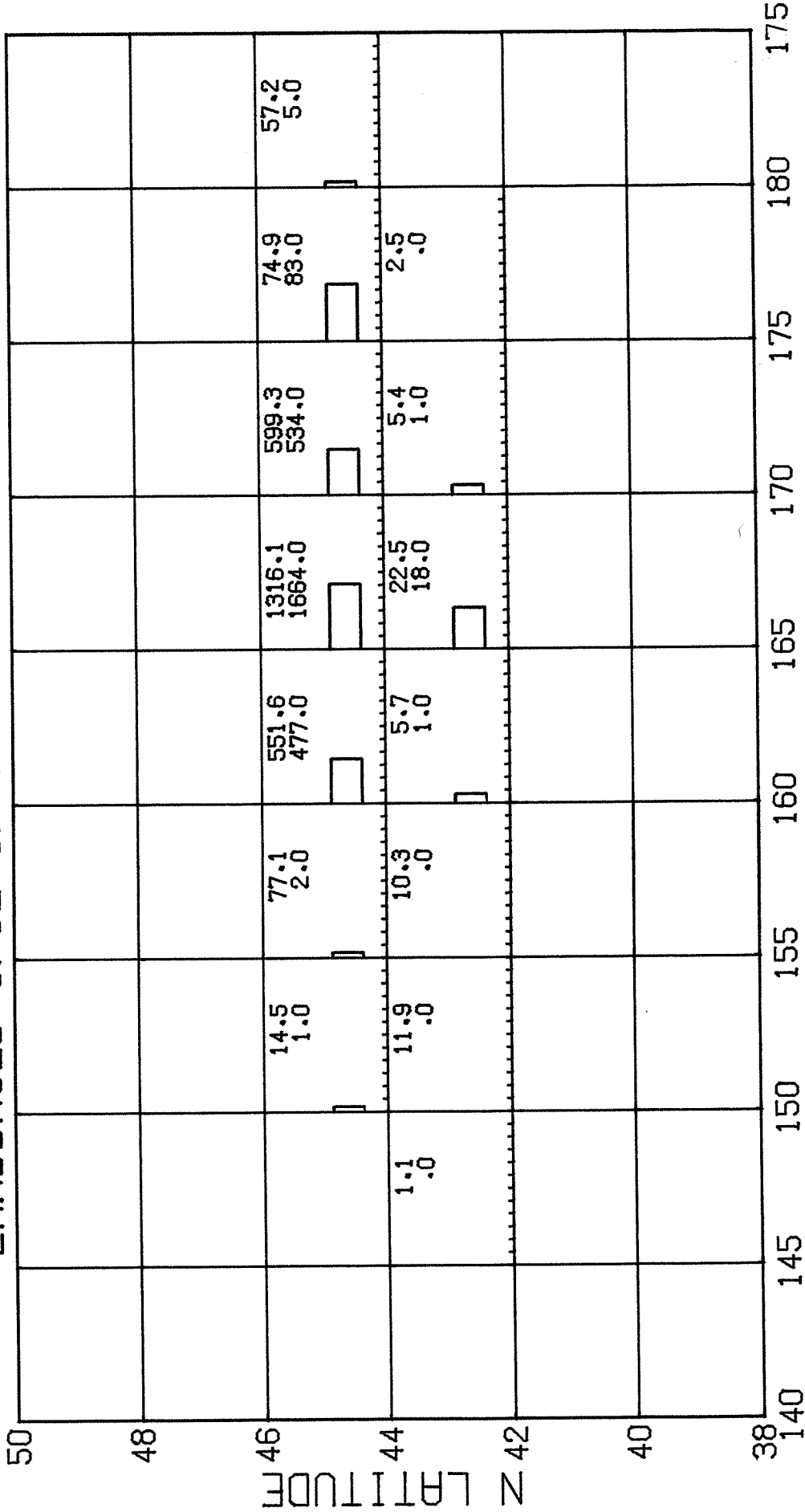
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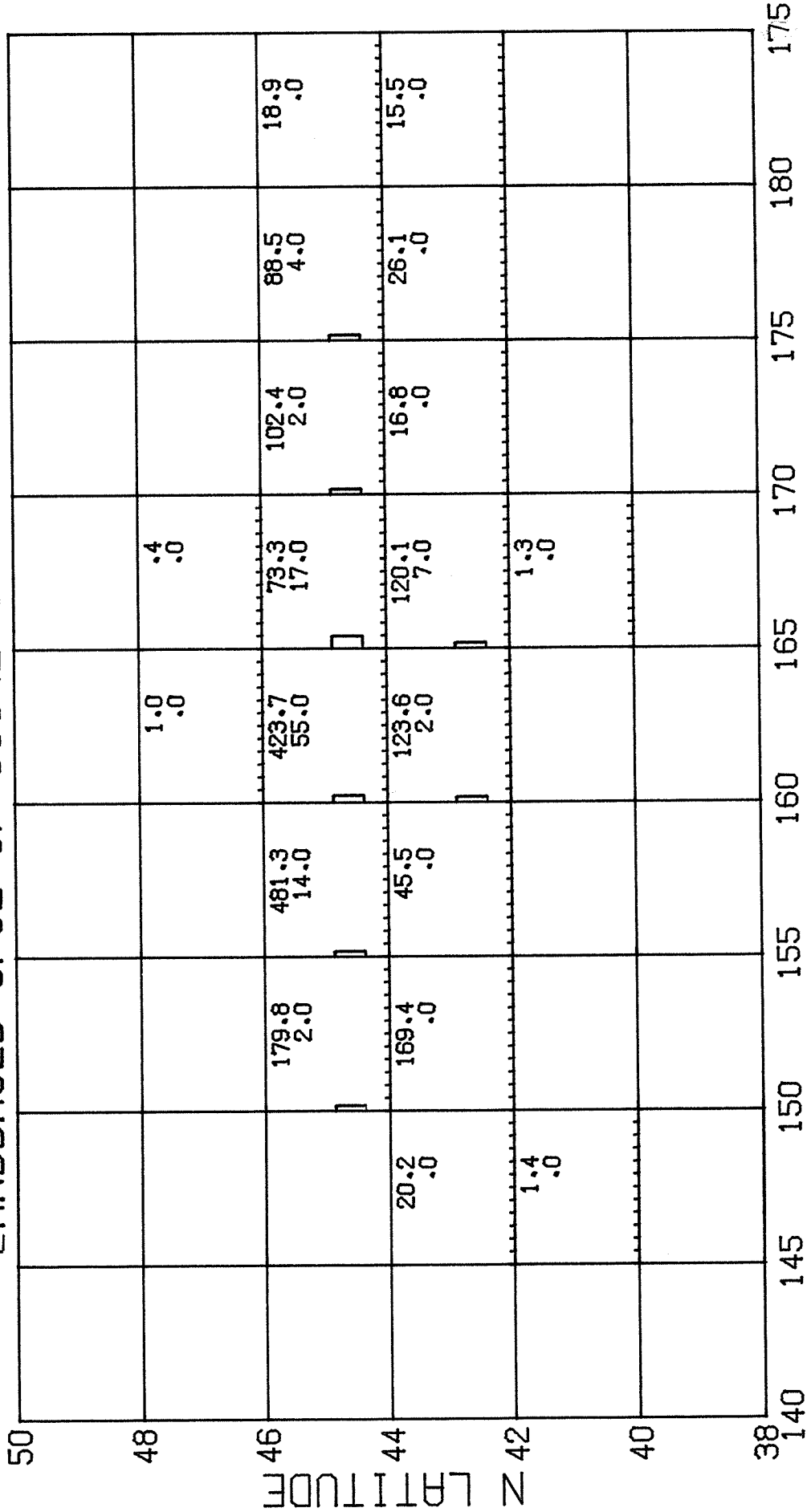
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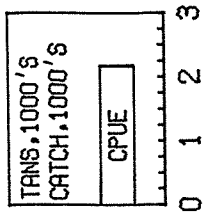


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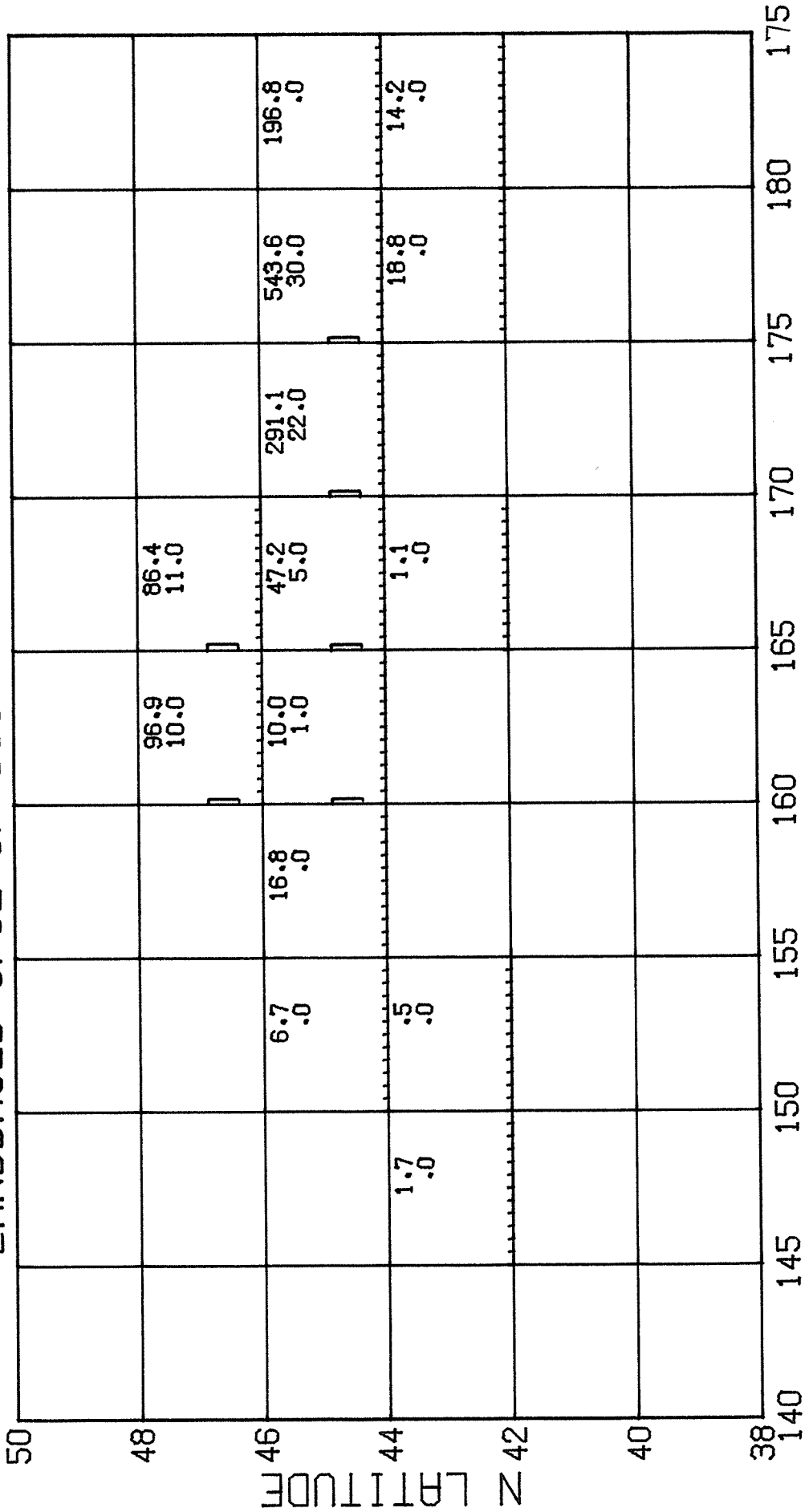


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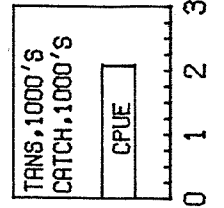
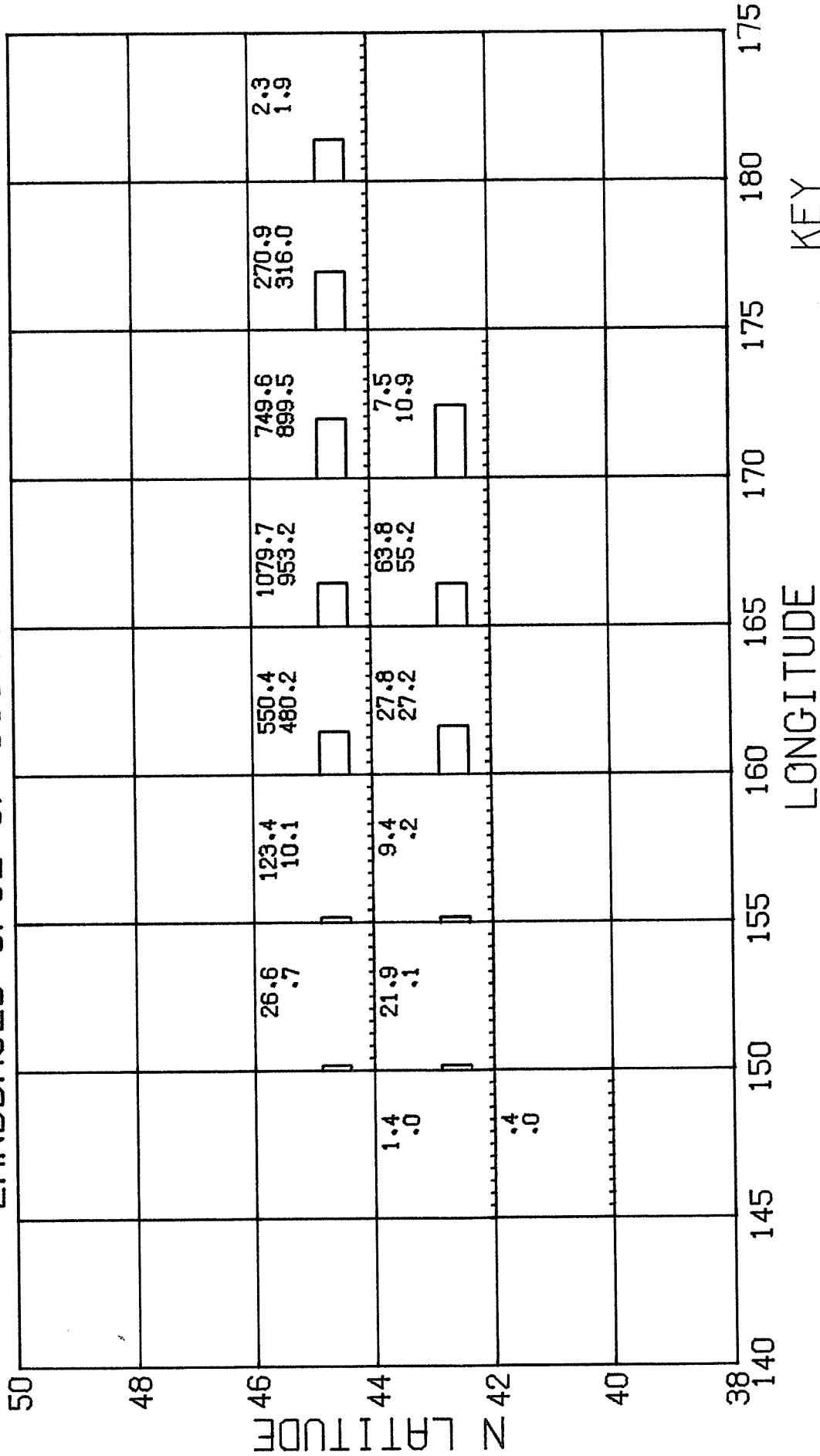


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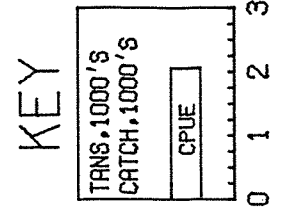
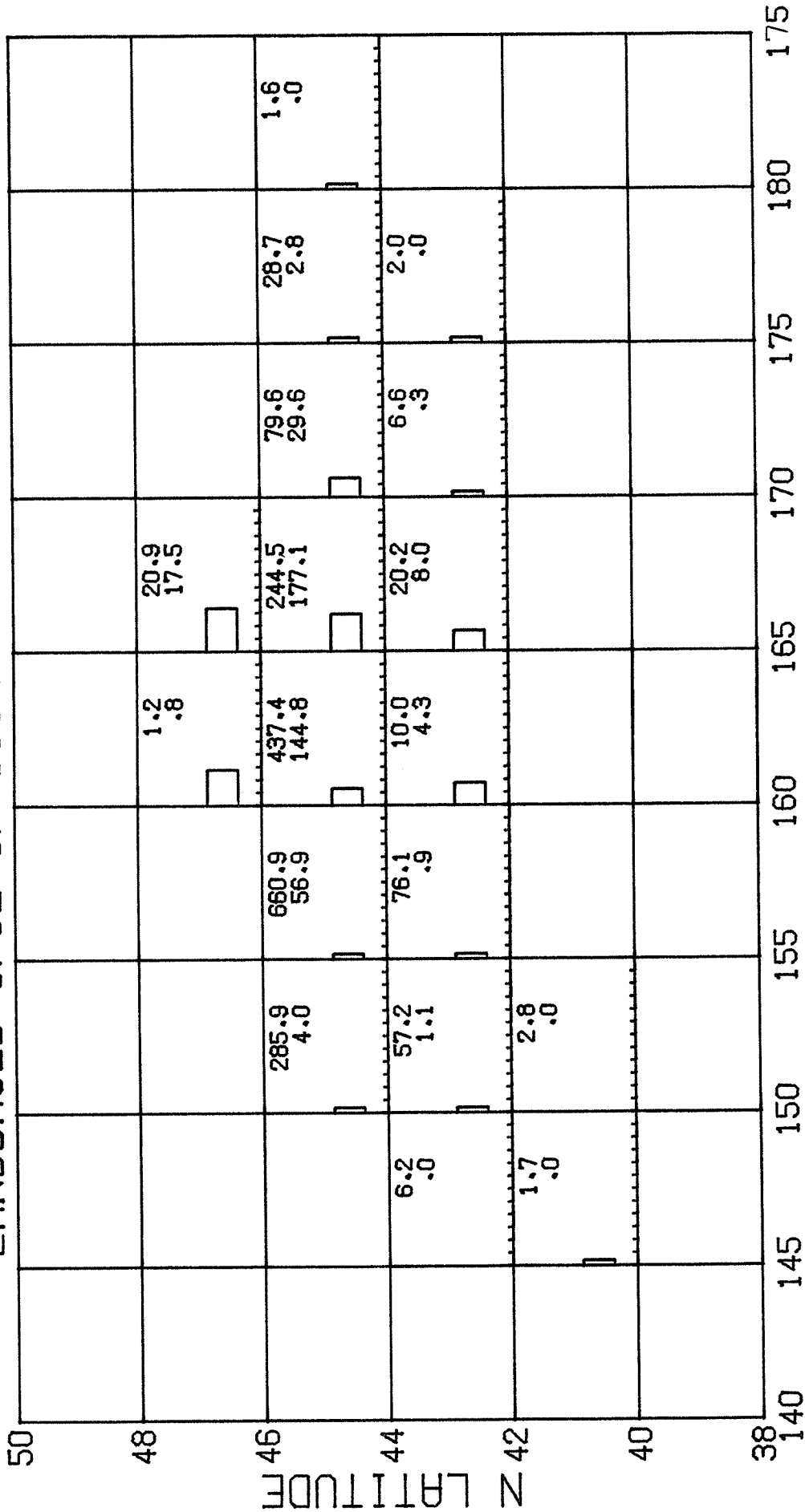
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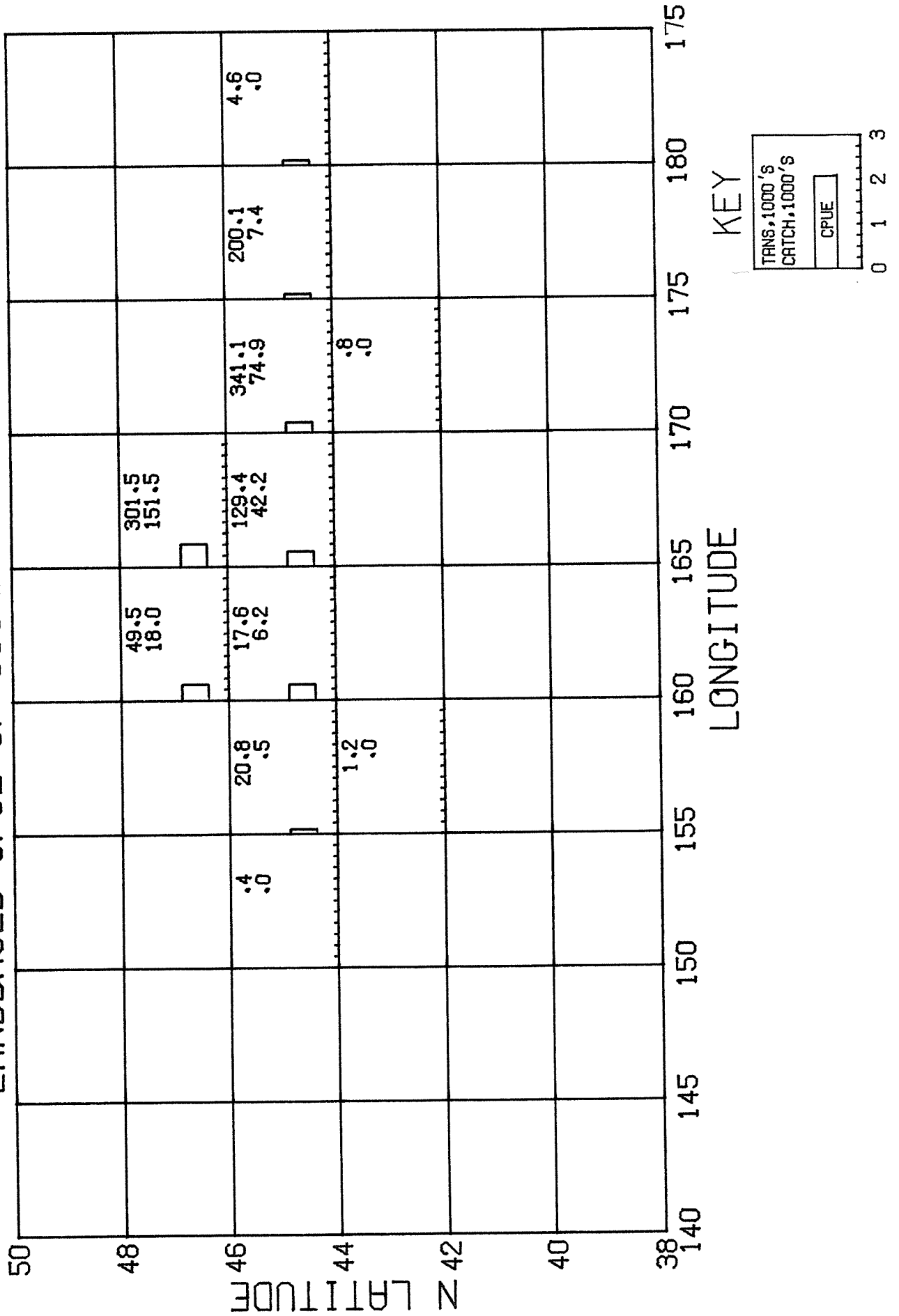
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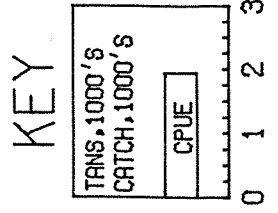
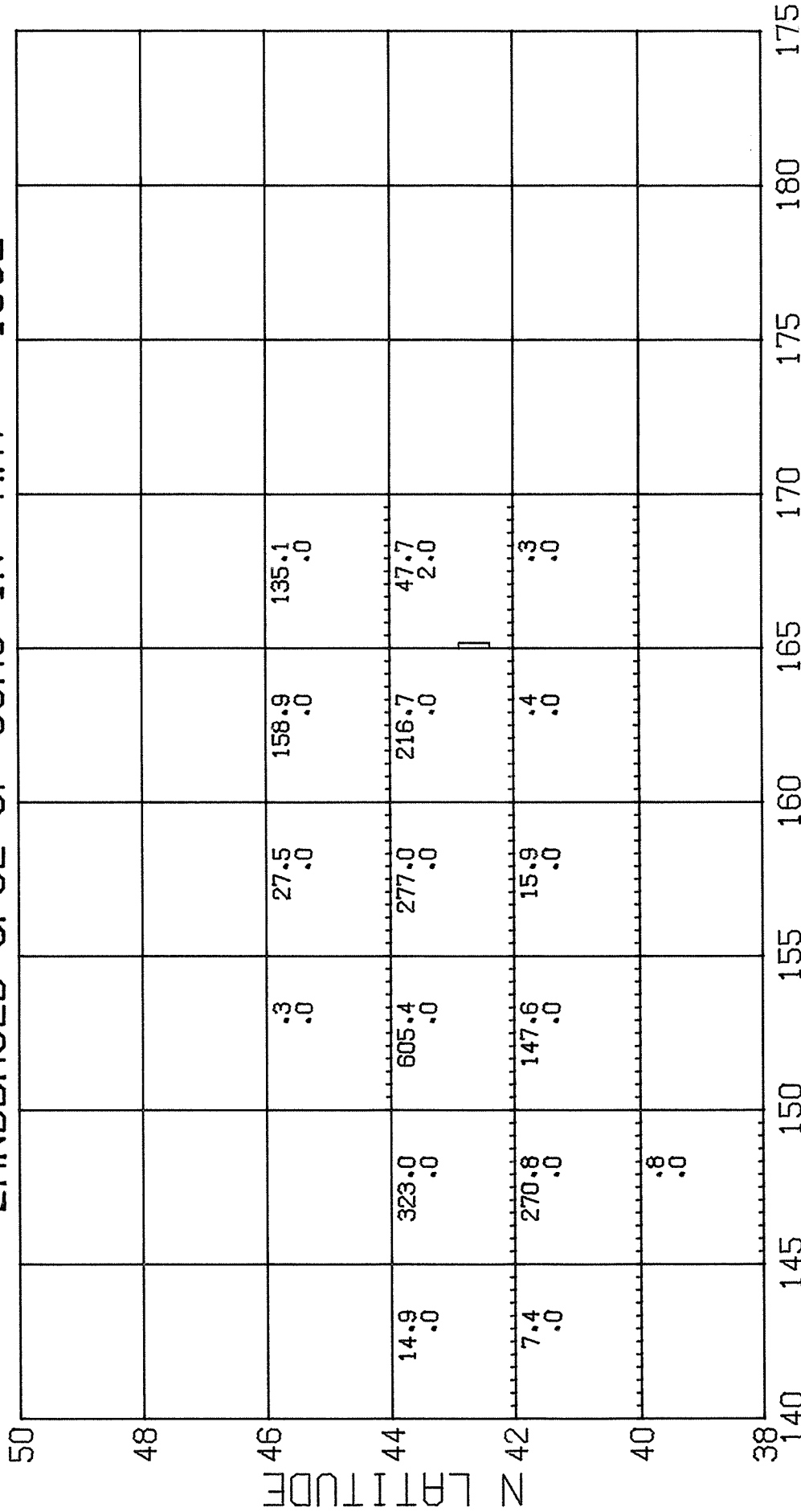
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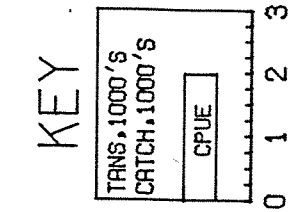
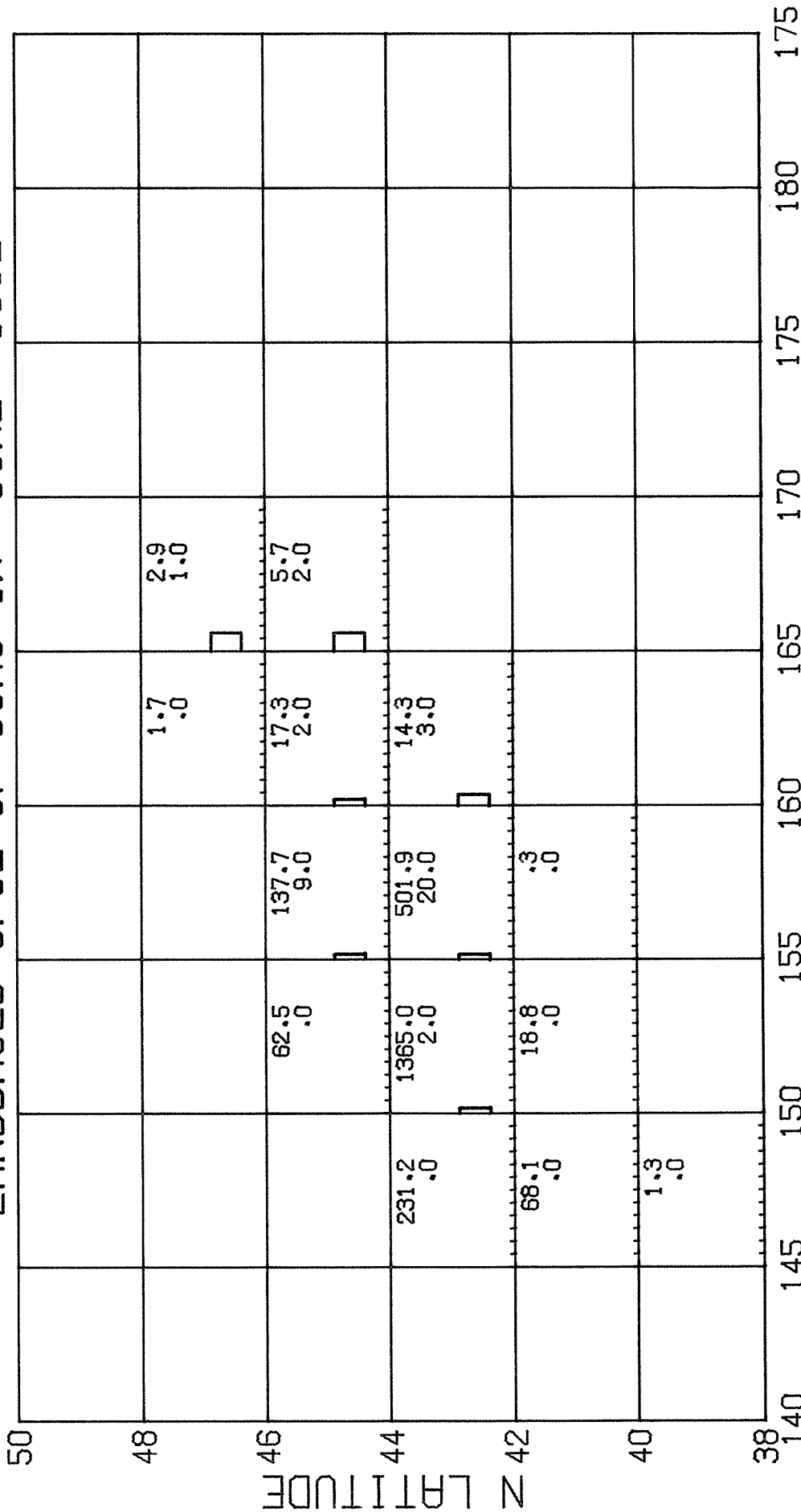
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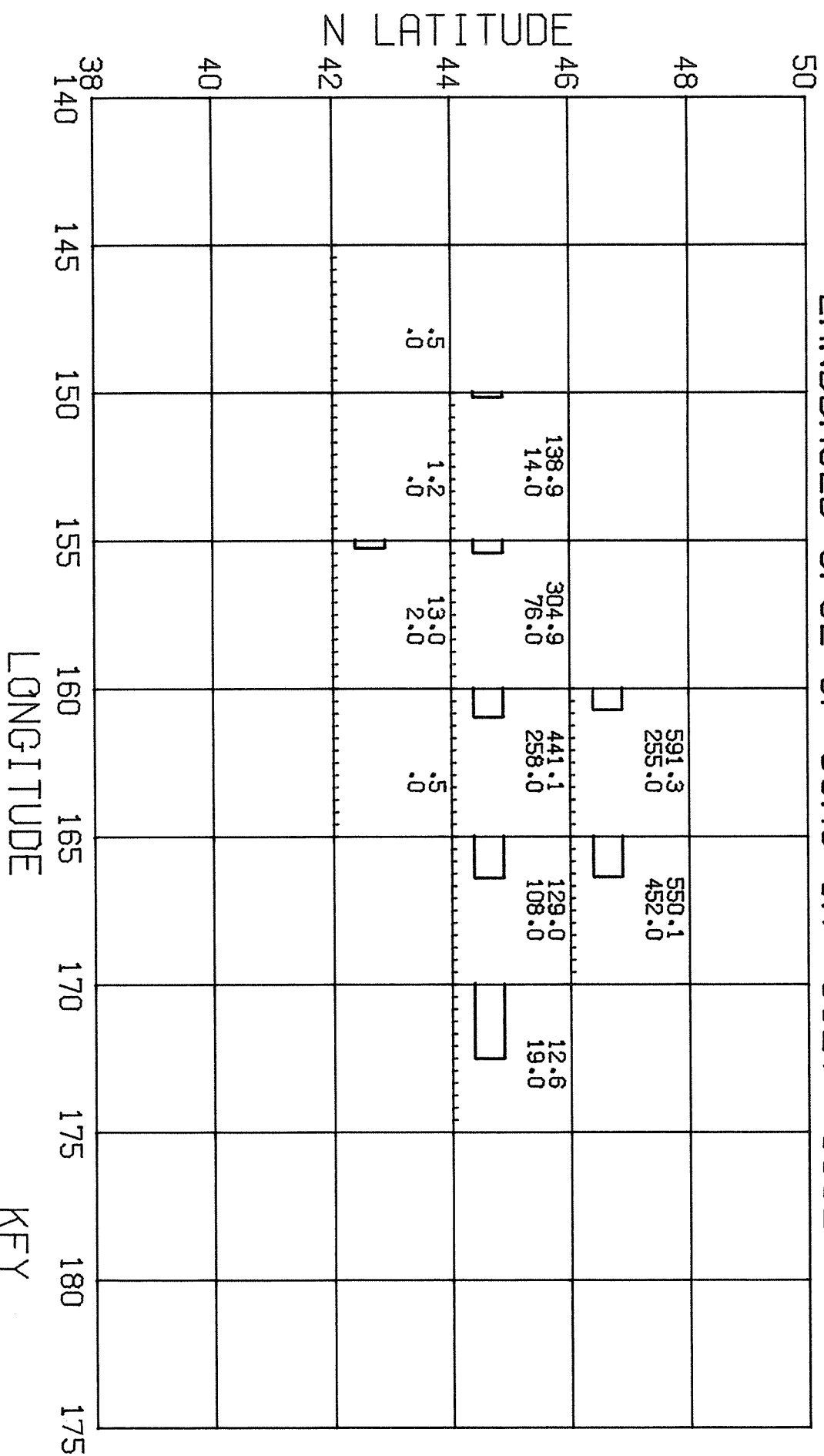
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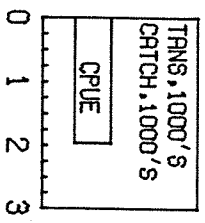
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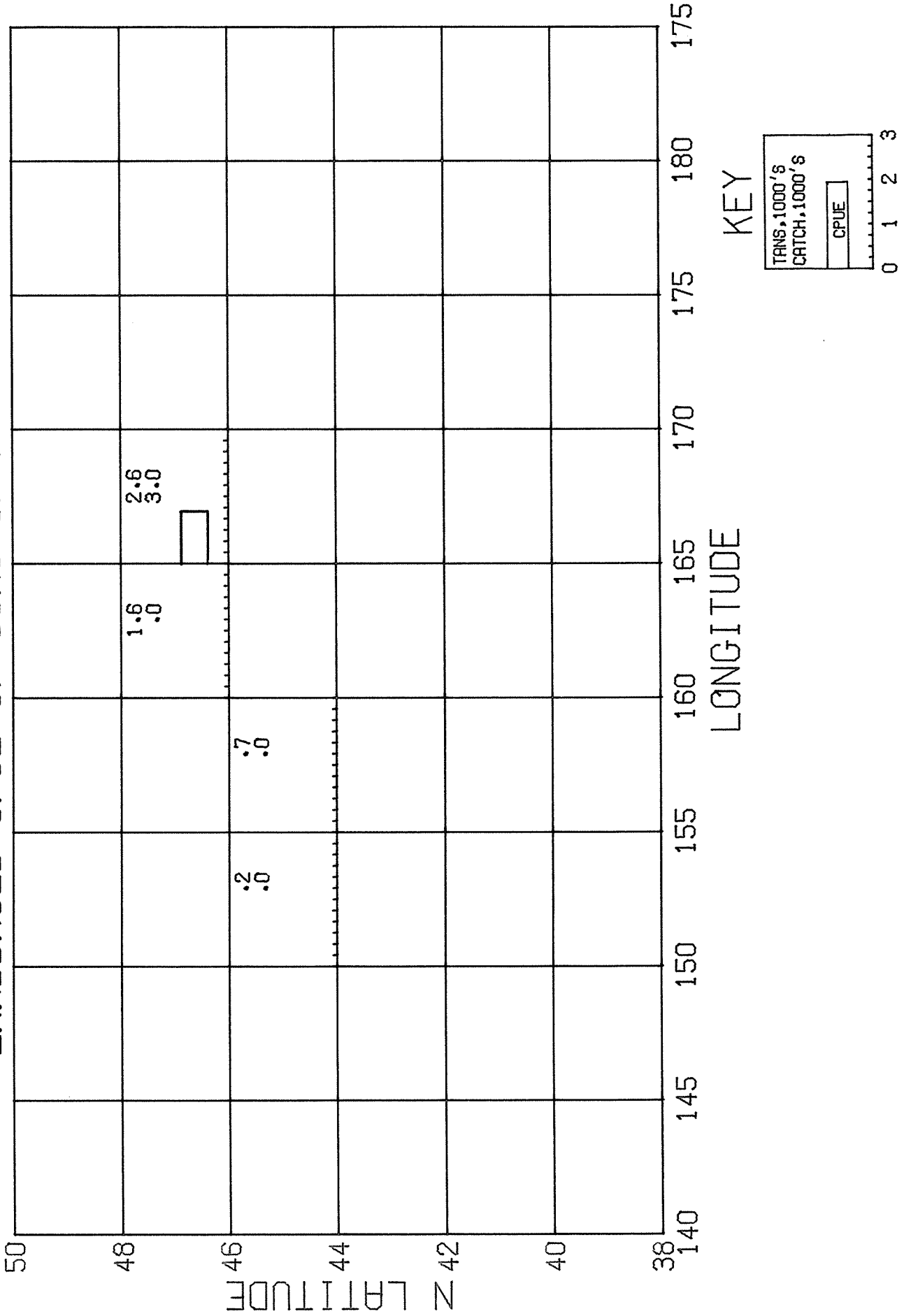
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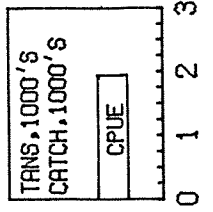
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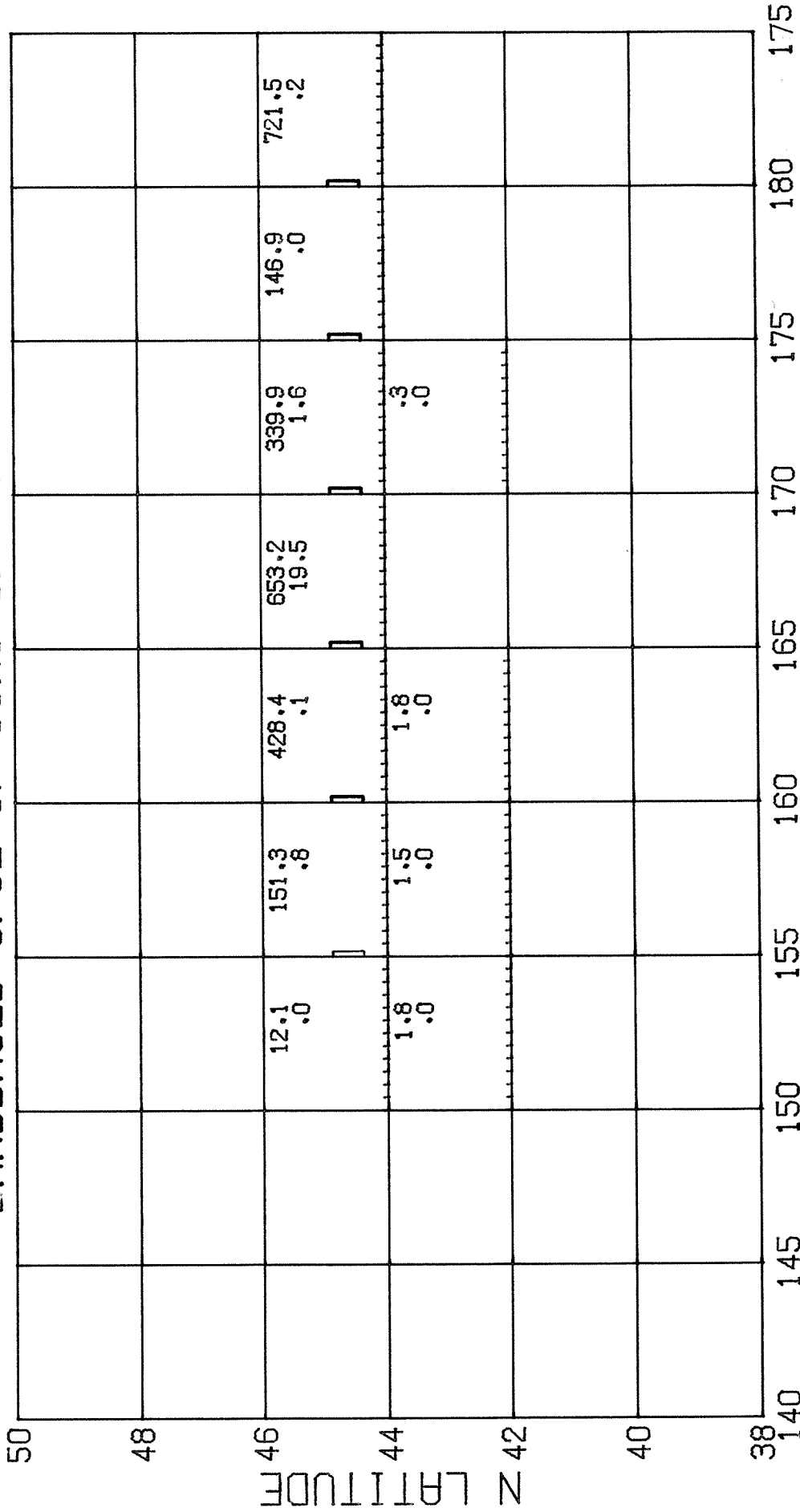
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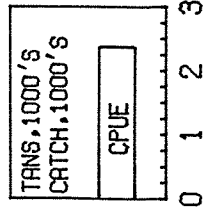


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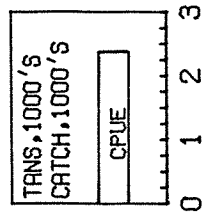
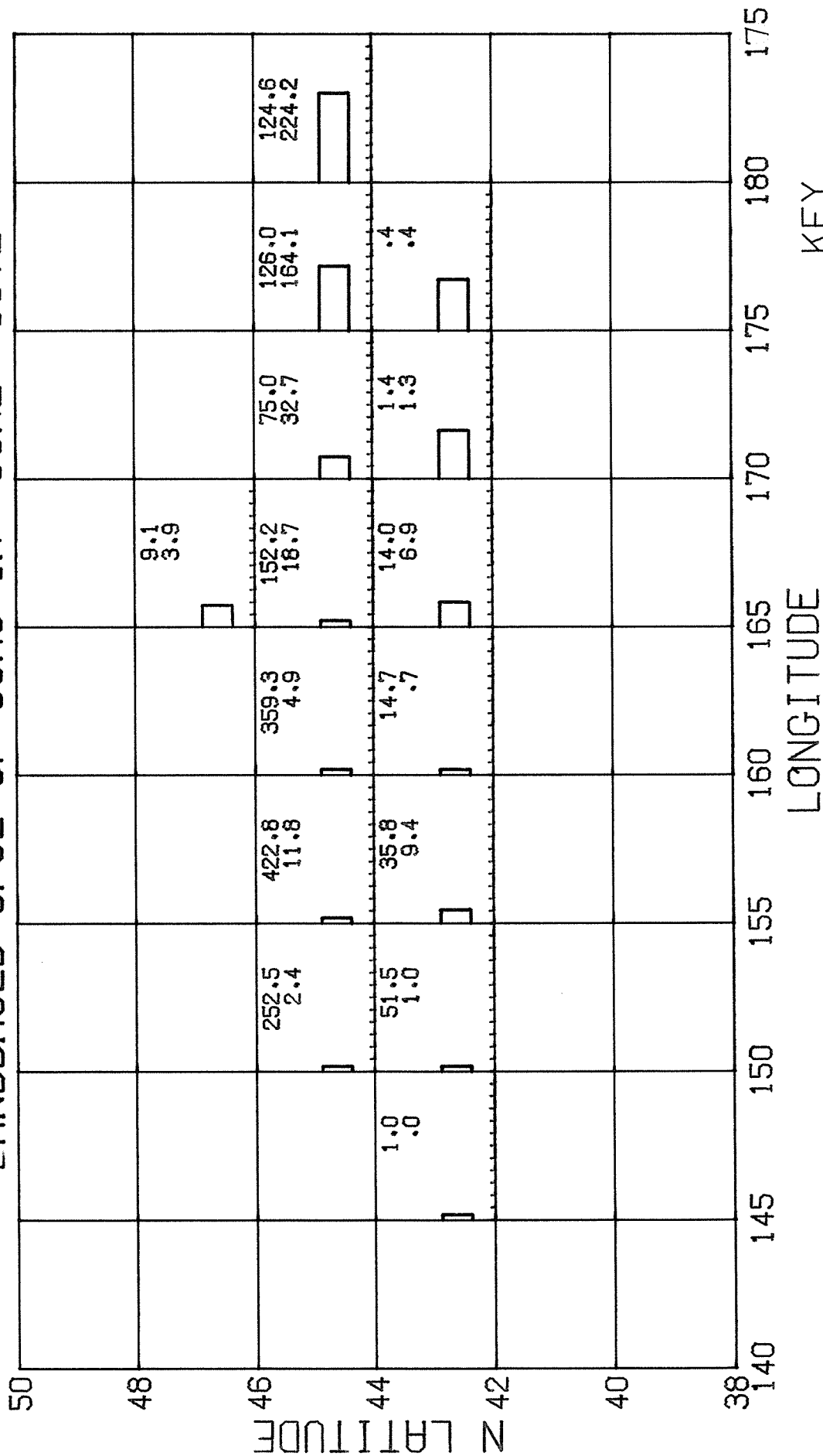


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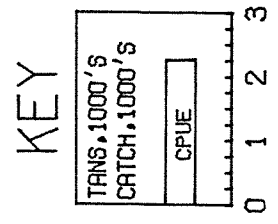
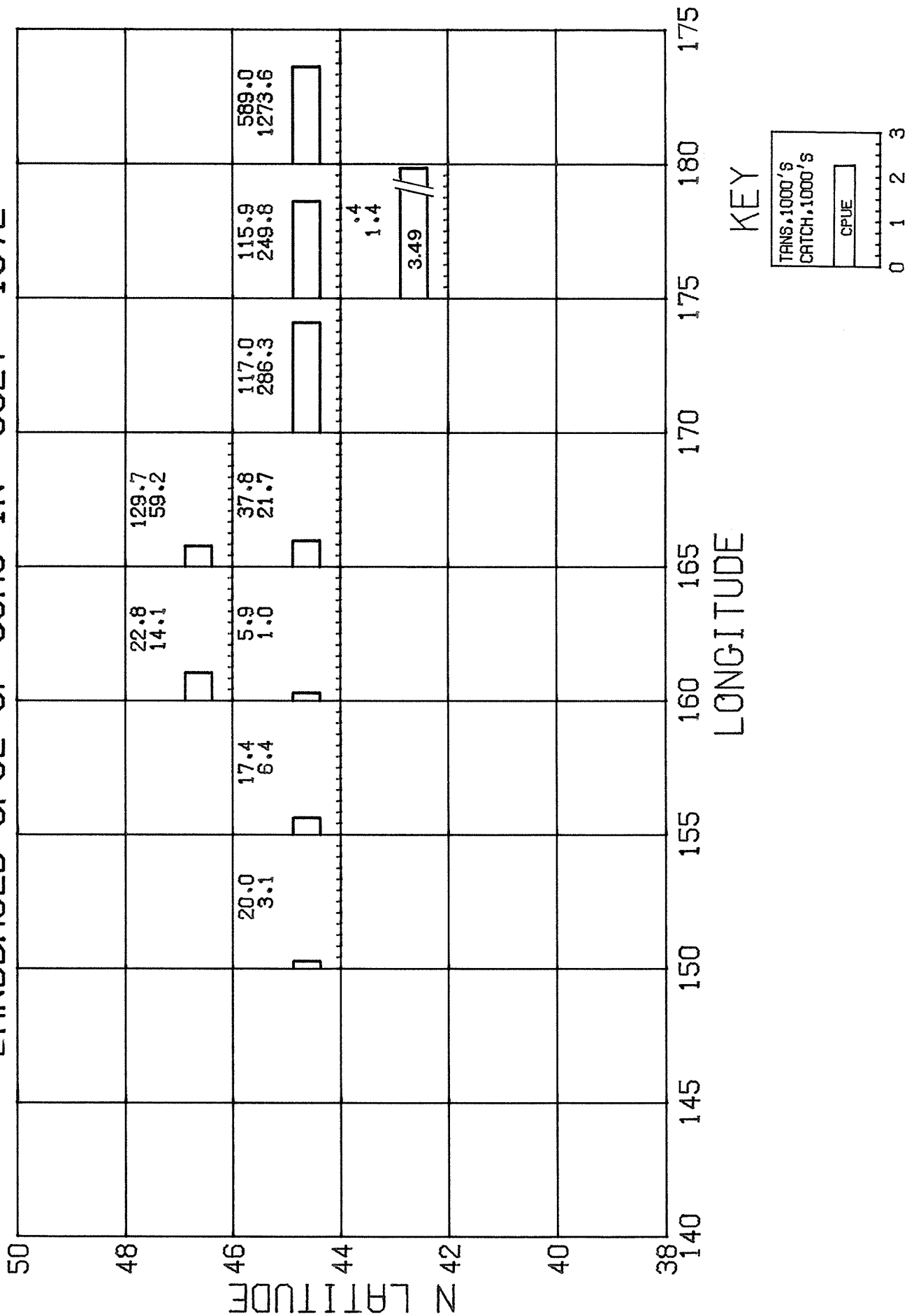
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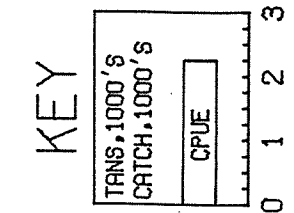
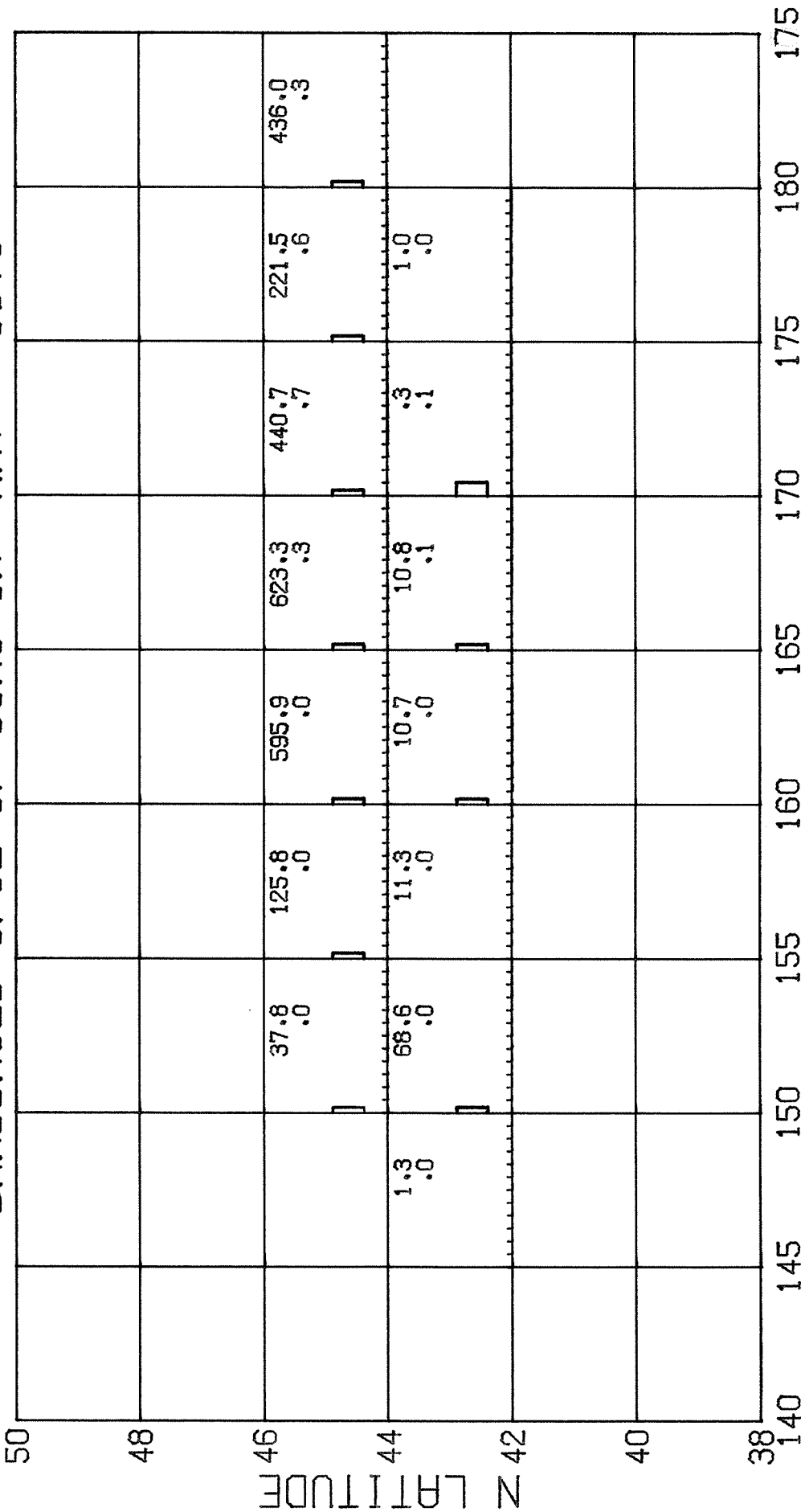
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LANDBASED CPUE OF COHO IN JULY 1972



LANDBASED CPUE OF COHO IN MAY 1973

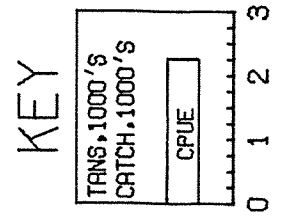
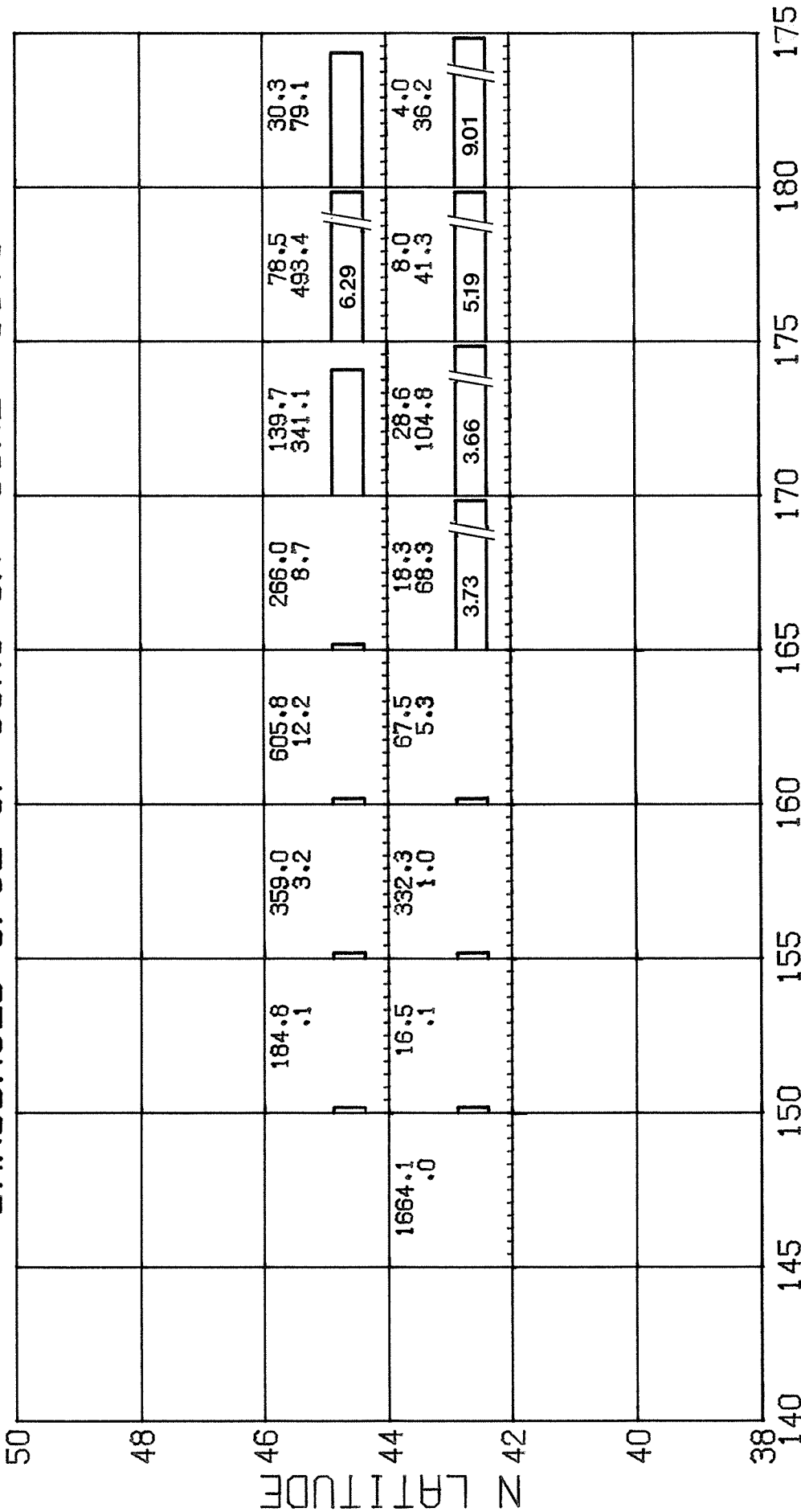


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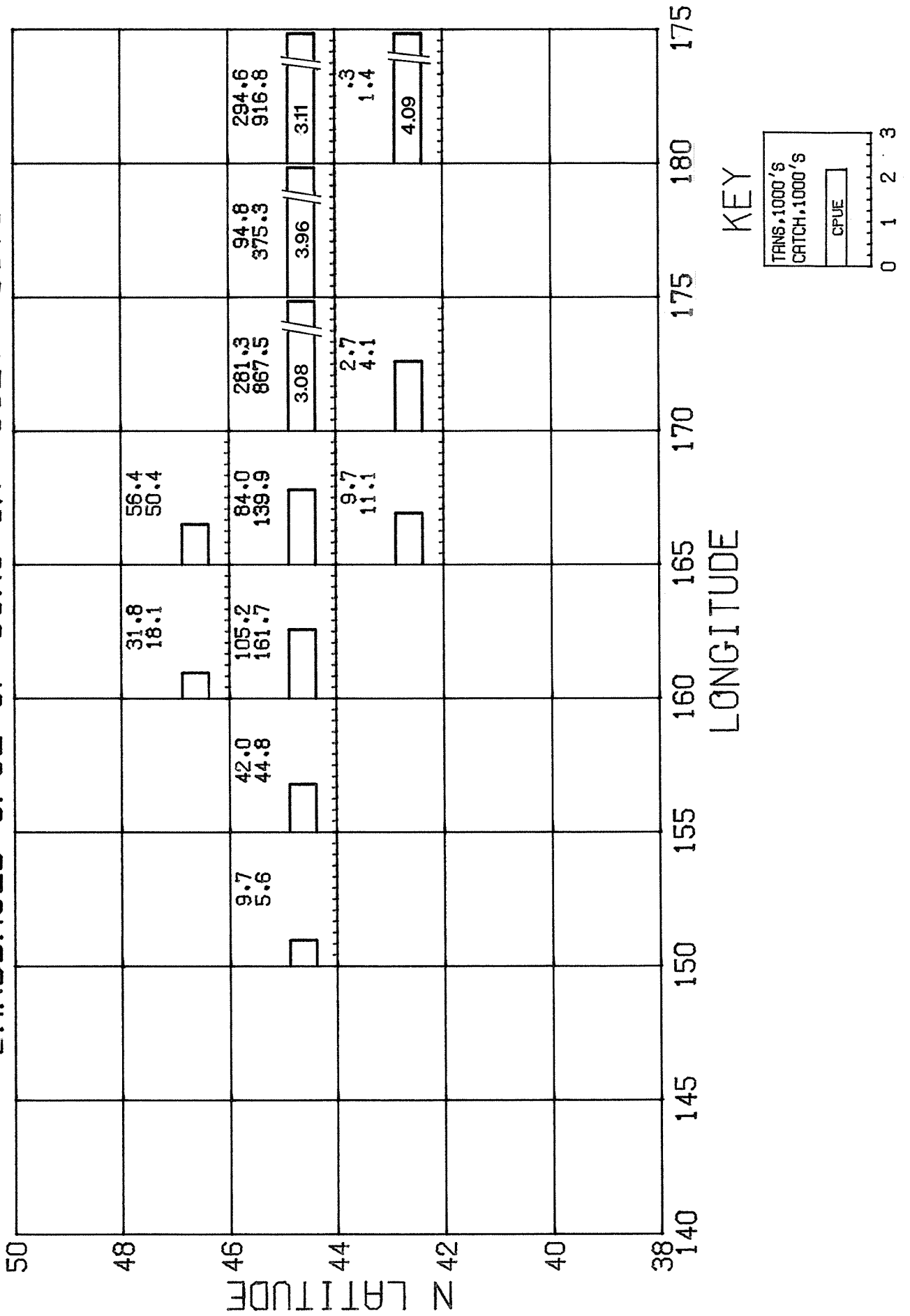
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LONGITUDE

LANDBASED CPUE OF COHO IN JUNE 1973



LANDBASED CPUE OF COHO IN JULY 1973

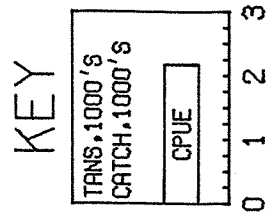
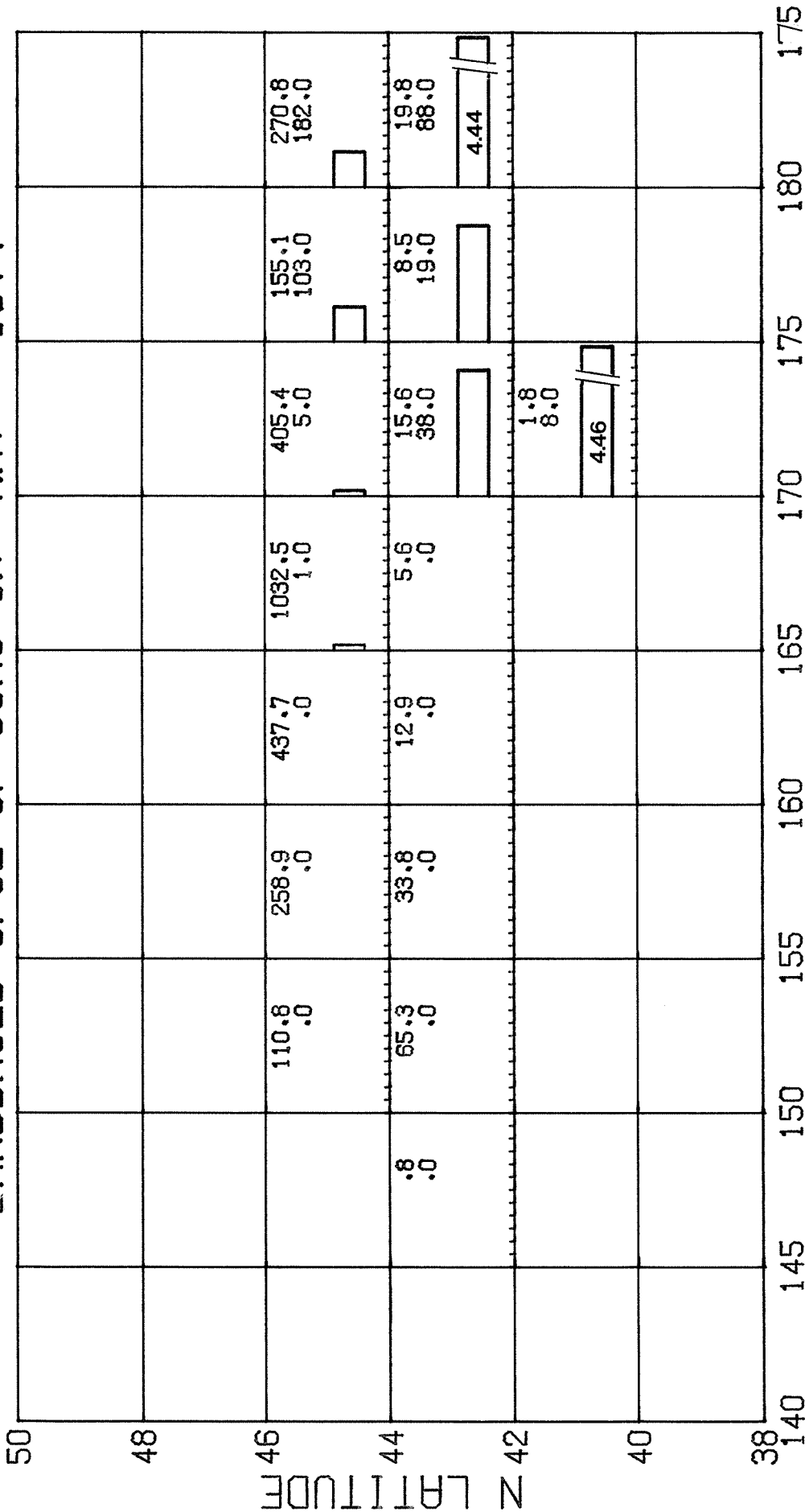


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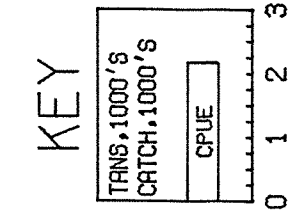
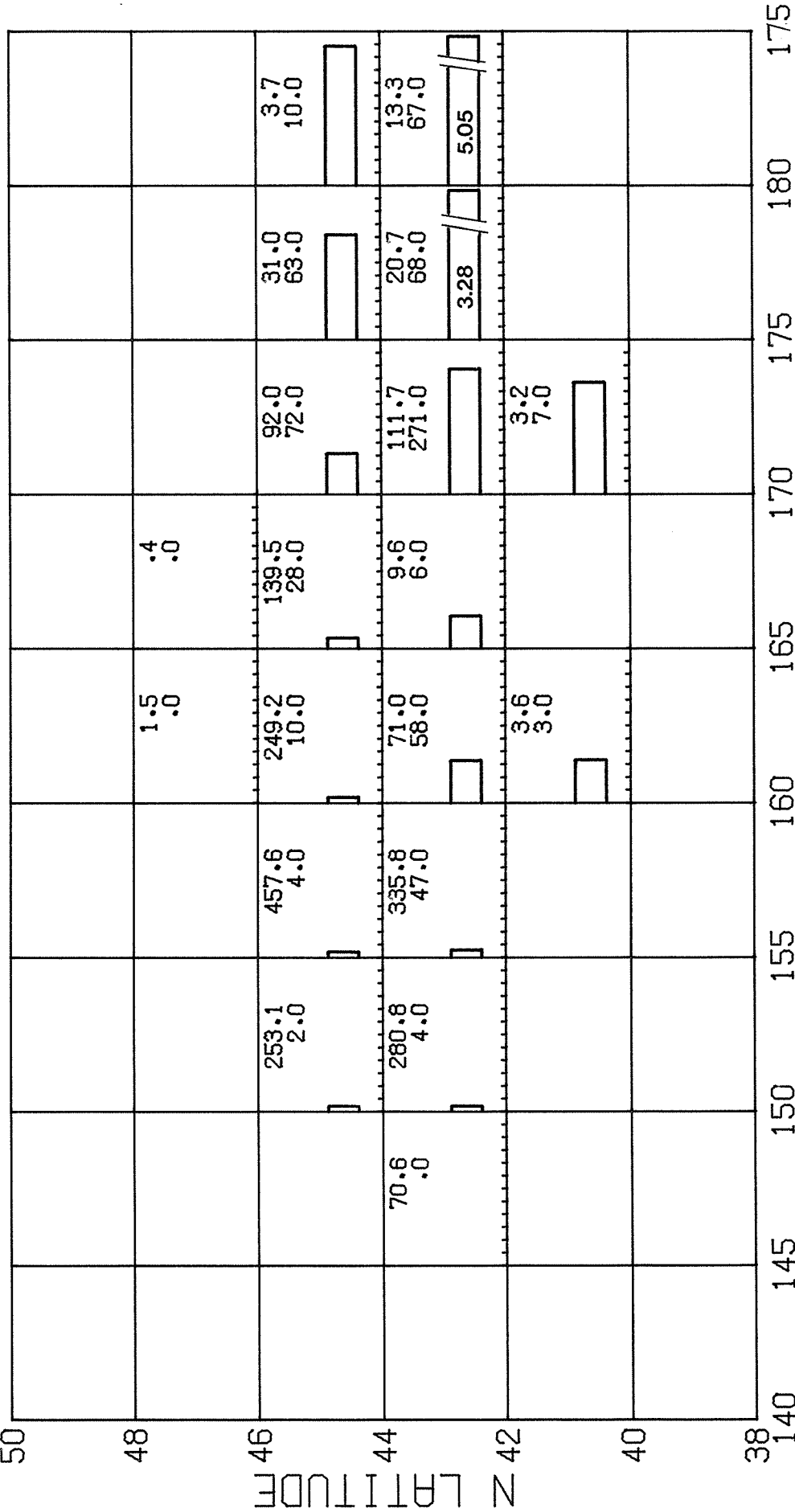
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CATCH, 1000'S
CPUE

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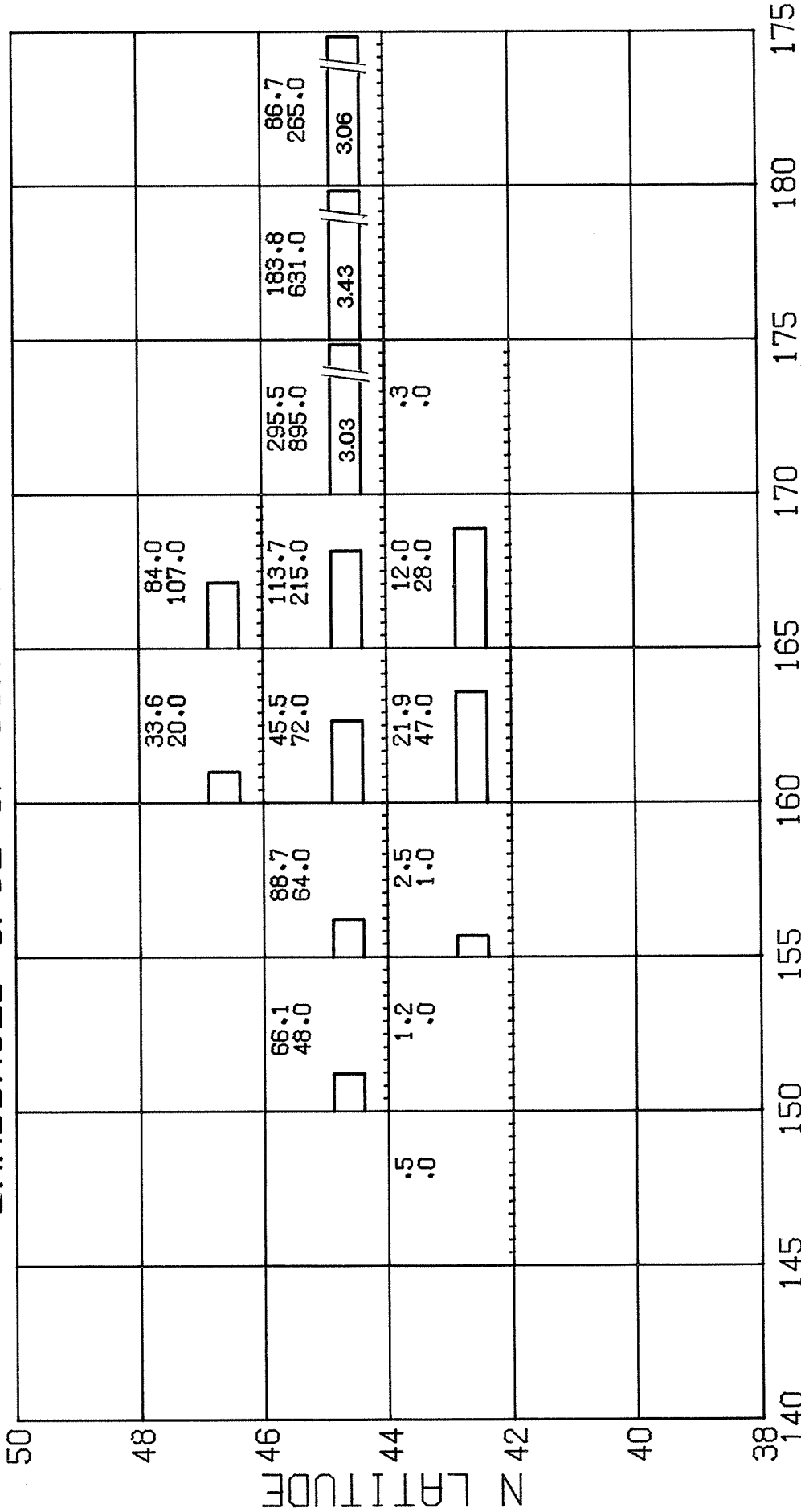
LANDBASED CPUE OF COHO IN MAY 1974



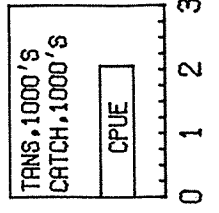
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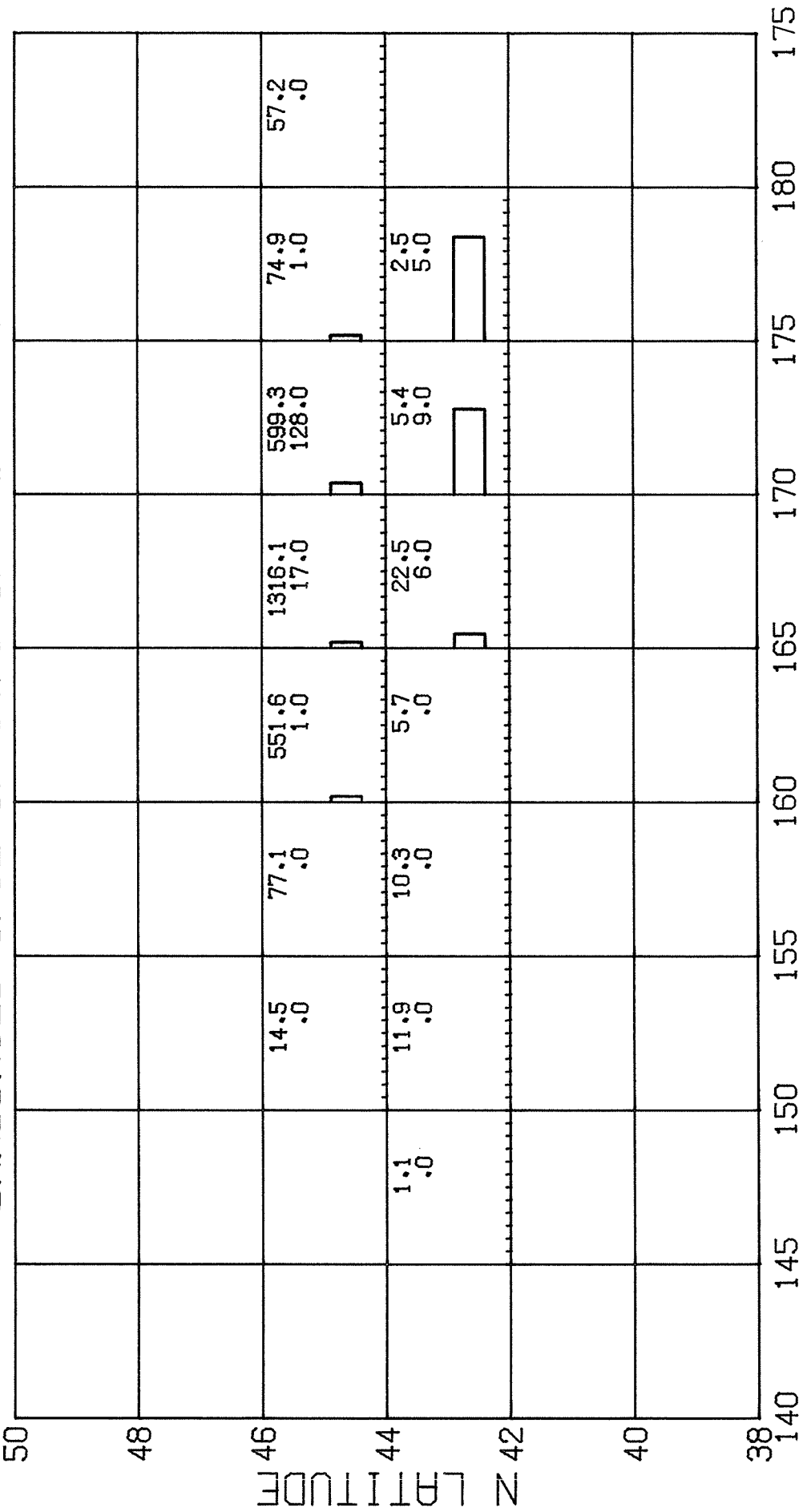
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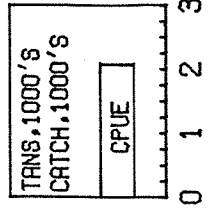
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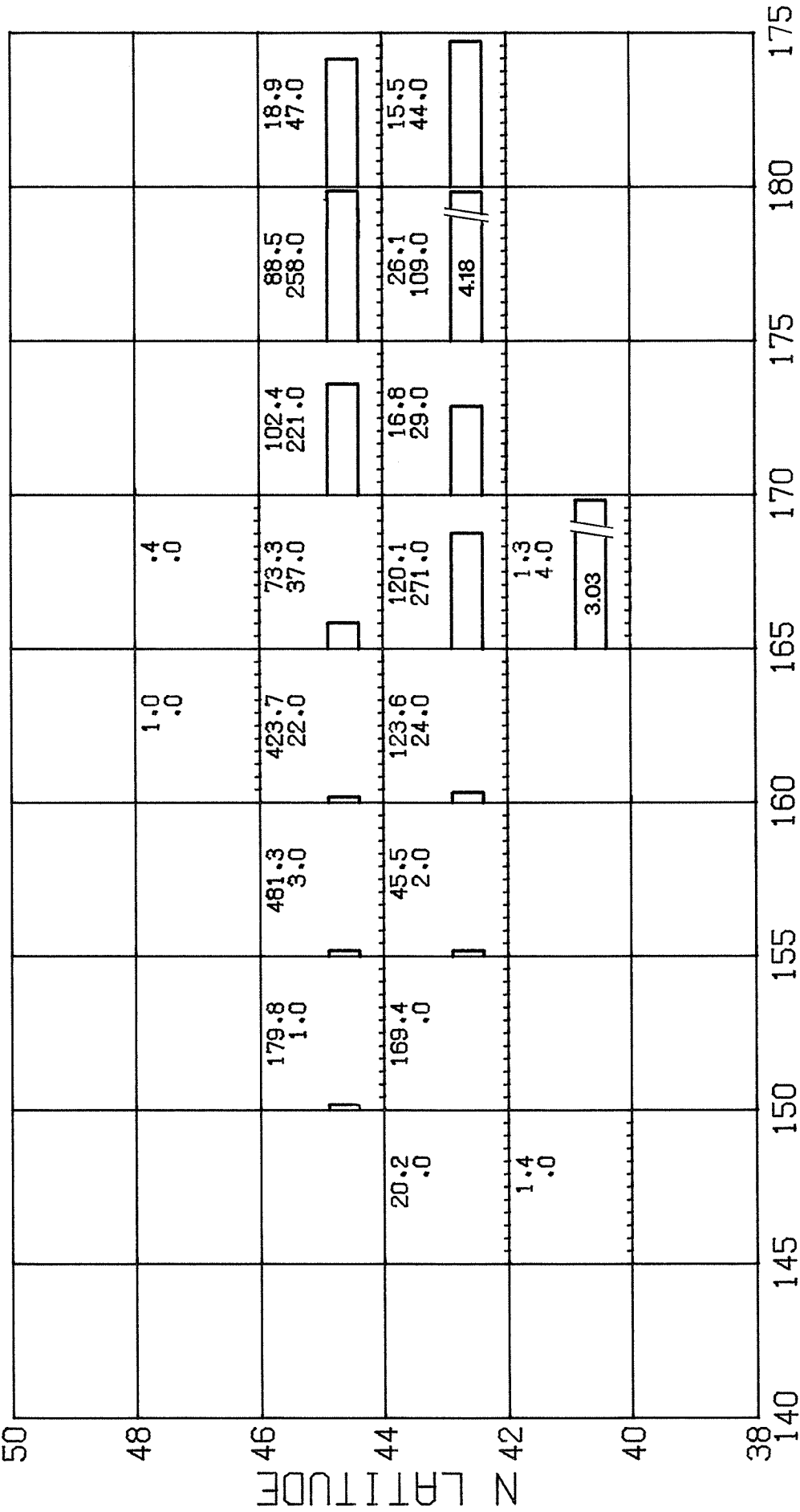
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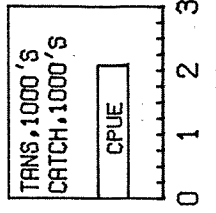


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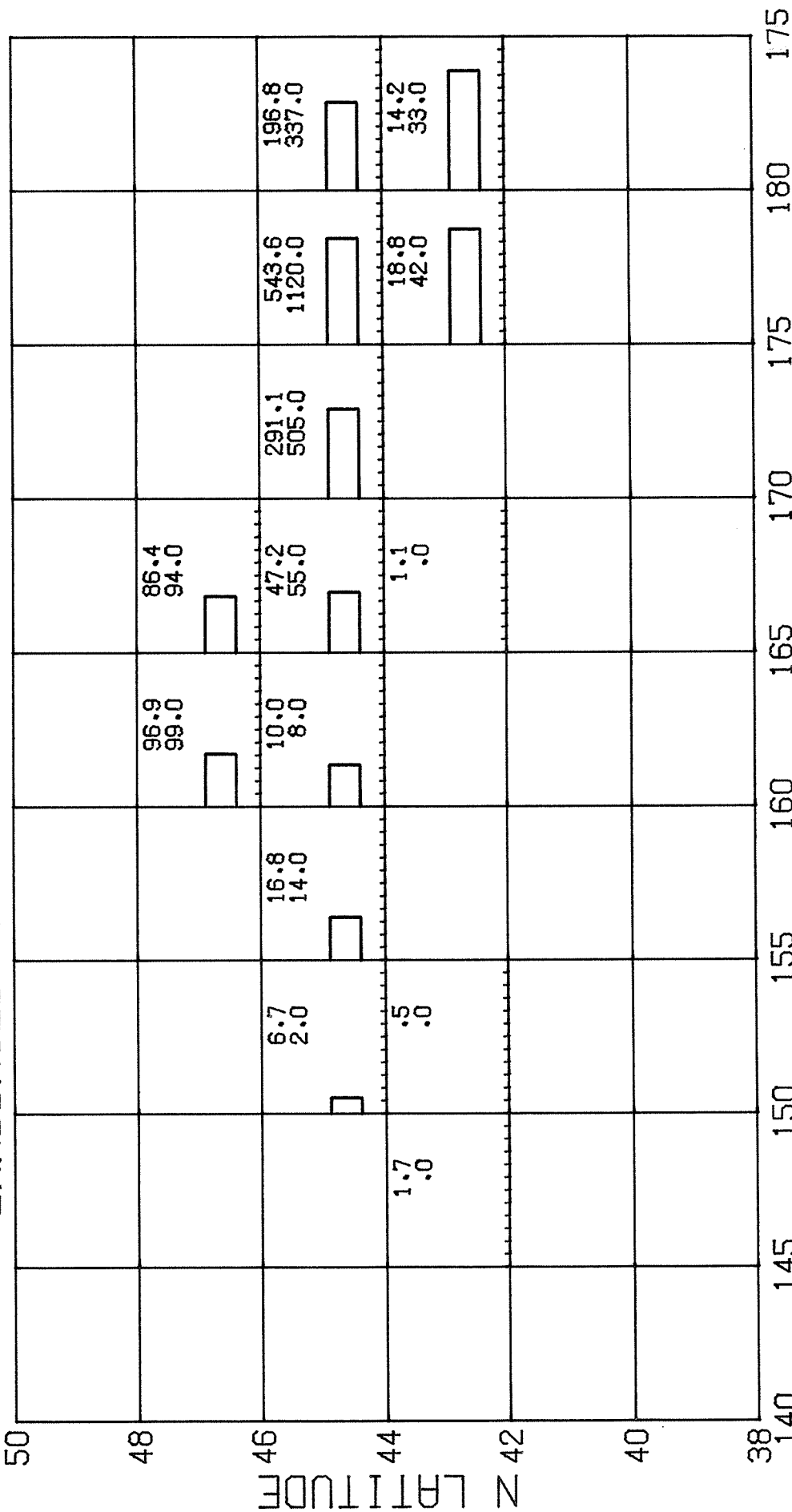


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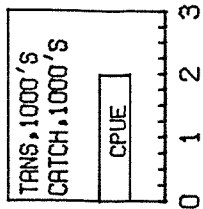


# LANDBASED CPUE OF COHO IN JULY 1975

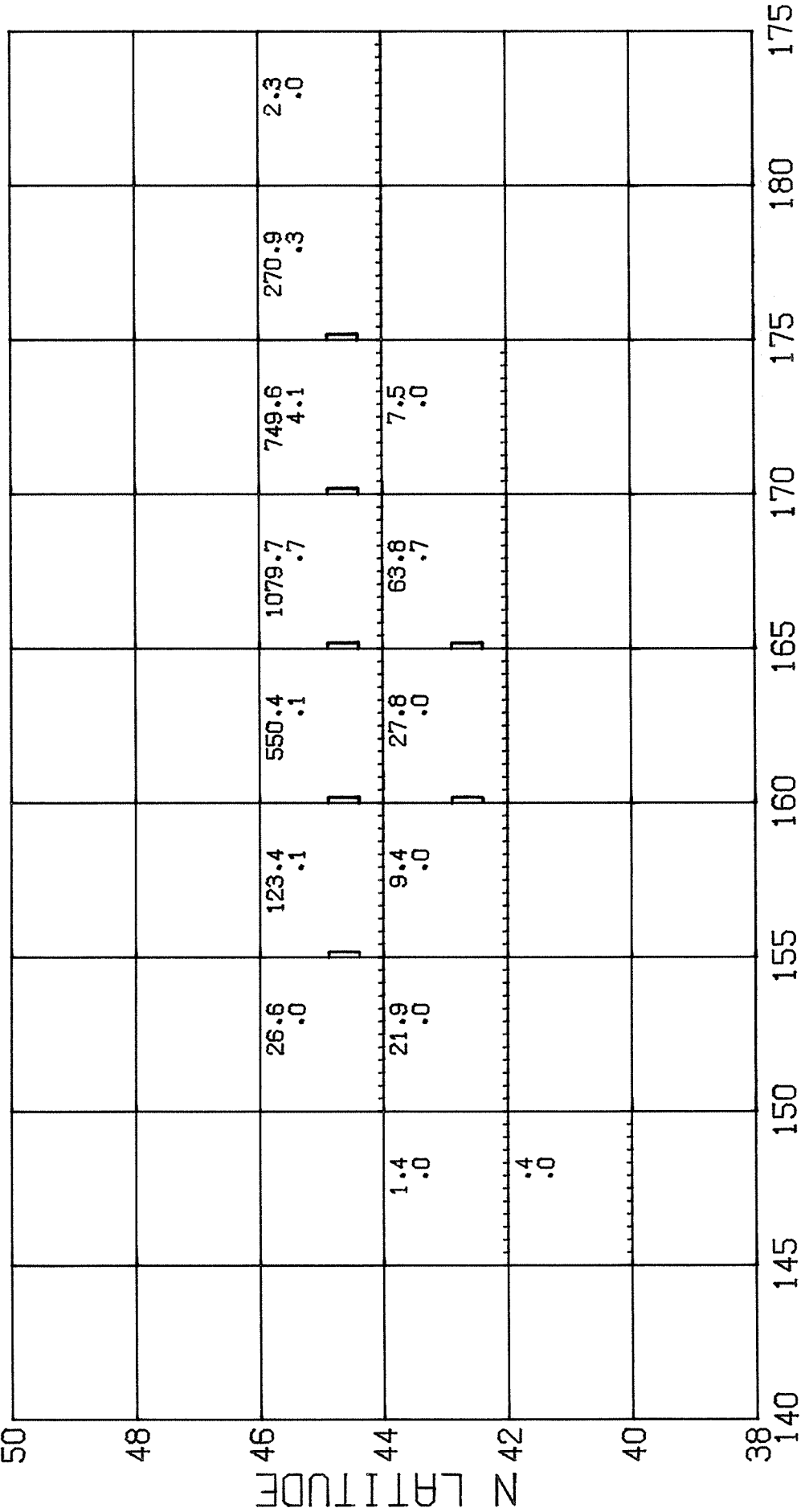


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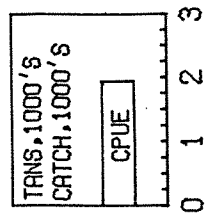


LANDBASED CPUE OF COHO IN MAY 1976

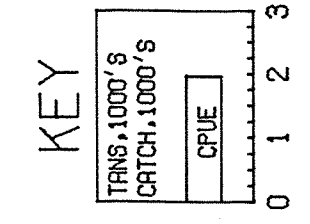
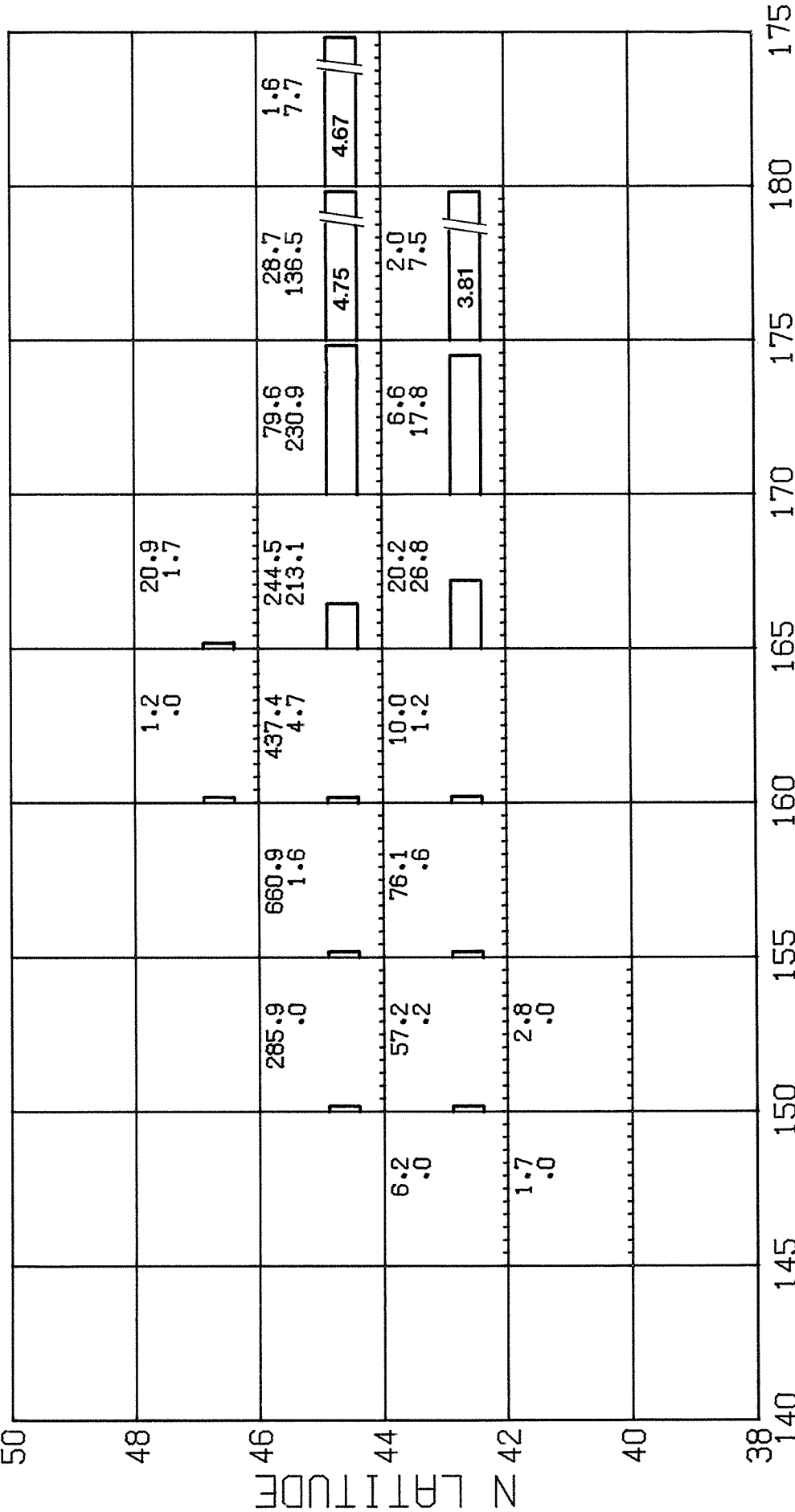


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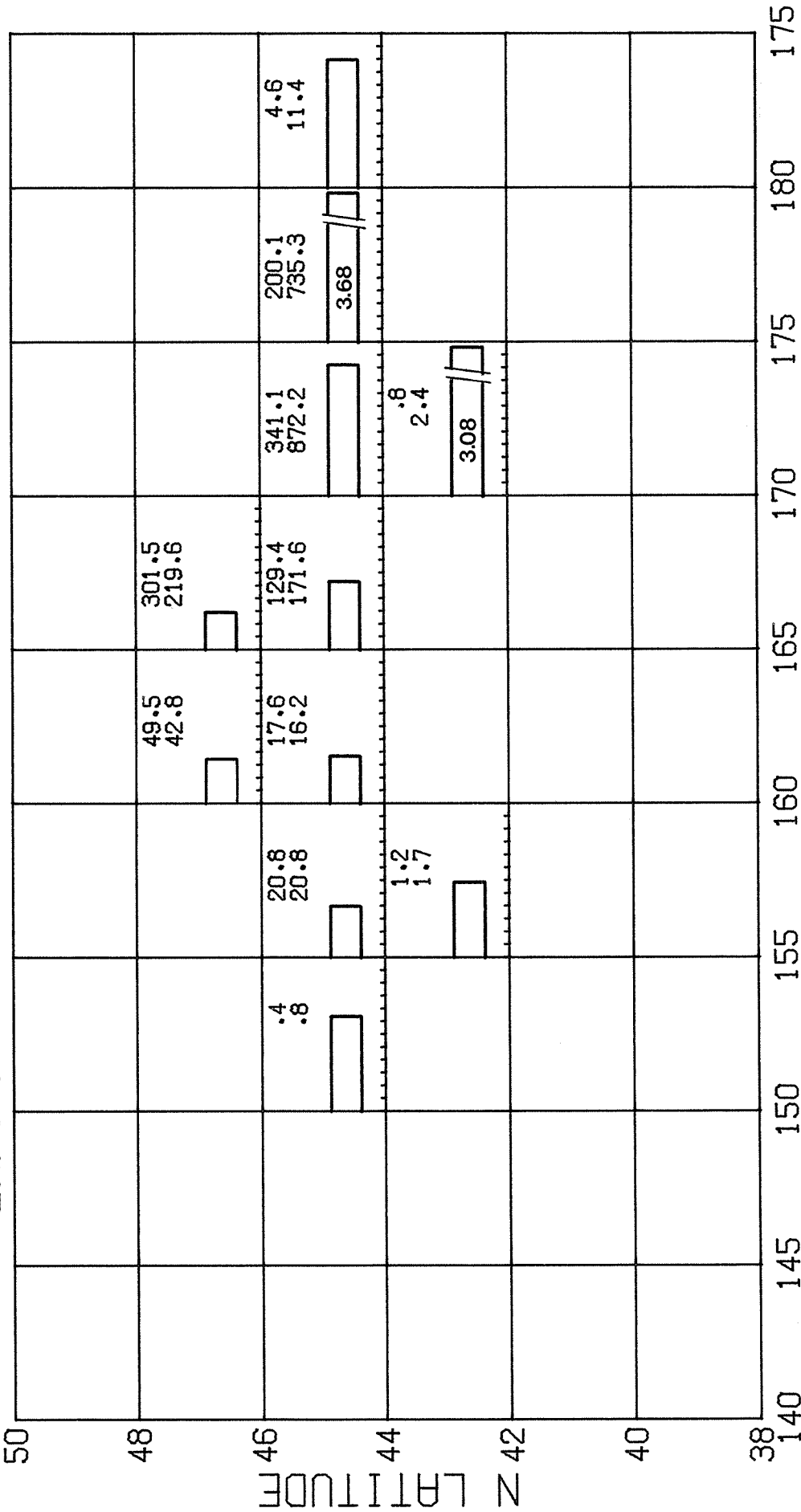
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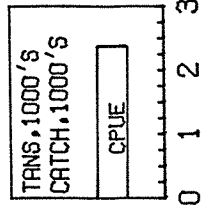
LANDBASED CPUE OF COHO IN JUNE 1976



LANDBASED CPUE OF COHO IN JULY 1976



KEY



Appendix 2

Data Tables

Appendix Table 1. Results of classifying scale samples collected from age 2.2 maturing sockeye salmon in 1975. Data as percentages with 90% confidence intervals.

Period	Area	Sample size	Bristol Bay	Gulf of Alaska <sup>1</sup>	Kamchatka Peninsula
May 1-10	E7548	18	50.2 ± 20.3	0	49.8 ± 20.3
	W7548	46	34.0 ± 12.9	65.2 ± 19.7	8.3 ± 11.4
	E6046	22	0		100
	E7046	45	8.0 ± 10.4		92.0 ± 10.4
	E6044	150	5.6 ± 8.7		94.4 ± 8.7
	E6544	148	6.8 ± 8.8		93.2 ± 8.8
	E6042	46	4.6 ± 9.7		95.4 ± 9.7
	E6542	53	0		100
May 11-20	E6546	17	0		100
	E6544	47	0		100
	E6542	20	10.9 ± 13.8		89.1 ± 13.8
May 21-31	E6548	76	1.9 ± 8.9		98.1 ± 8.9
	E7048	99	0		100
	E7548	94	19.6 ± 8.1	20.1 ± 14.4	60.2 ± 14.3
	E6546	90	0.7 ± 8.7		99.3 ± 8.7
	E7046	136	2.0 ± 8.7		98.0 ± 8.7
	E7546	41	0	6.1 ± 26.5	93.9 ± 26.5
	E6044	23	13.1 ± 13.8		86.9 ± 13.8
	E6544	15	0		100

<sup>1</sup>Gulf of Alaska category used only for samples collected east of 175°E.

Appendix Table 2. Results of classifying scale samples collected from age 1.3 maturing sockeye salmon in 1975. Data as percentages with 90% confidence intervals.

Period	Area	Sample size	Bristol Bay	Gulf of Alaska <sup>1</sup>	Kamchatka Peninsula
May 1-10	E6544	17	0		100
May 11-20	E6548	30	0.5 ± 13.7		95.5 ± 13.7
	E7048	18	4.4 ± 15.2		95.6 ± 15.2
May 21-31	E6548	102	52.2 ± 13.4		47.8 ± 13.4
	E7048	100	73.6 ± 14.4		26.4 ± 14.4
	E7548	29	55.0 ± 18.3	40.7 ± 22.1	4.4 ± 15.3
	E6546	27	4.4 ± 14.5		95.6 ± 14.5
	E7046	49	26.7 ± 15.0		73.3 ± 15.0

<sup>1</sup>Gulf of Alaska category used only for samples collected east of 175°E.

Appendix Table 3. Results of classifying scale samples from age 2.3 maturing sockeye salmon in 1975. Data as percentages with 90% confidence intervals.

Period	Area	Sample size	Bristol Bay	Gulf of Alaska <sup>1</sup>	Kamchatka Peninsula
May 11-20	E6548	36	0		100
May 21-31	E6548	96	9.5 ± 9.6		90.5 ± 9.6
	E7048	101	65.2 ± 11.0		34.8 ± 11.0
	E7548	25	40.2 ± 19.3	59.8 ± 19.3	0
	E6546	56	6.8 ± 10.3		93.2 ± 10.3
	E7046	27	28.6 ± 16.0		71.4 ± 16.0

<sup>1</sup>Gulf of Alaska category used only for samples collected east of 175°E.