Exxon Valdez Oil Spill
State/Federal Natural Resource Damage Assessment Annual Report

Kenai River Sockeye Salmon Restoration

Restoration Project 93015
Annual Report

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

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Study History: Restoration Project continues the study effort initiated in 1992 under Restoration Study Number 53 (same title).

Abstract: Sockeye salmon that spawn in the Kenai River system were injured by the *Exxon Valdez* oil spill. Greatly reduced fishing time in the Upper Cook Inlet area due to the spill caused sockeye salmon spawning escapement levels in the Kenai River system to exceed the desired amount by three times. The extremely high escapement may have initially produced more rearing juveniles than could be supported by nursery lake productivity. Restoration of Kenai River sockeye salmon stocks will be accomplished when production of sockeye salmon fry is matched with the food resources within the rearing lakes and overwinter survival of fry to smolt returns to normal levels (40 -80%). This will be evaluated through improved stock assessment capabilities, more accurate regulation of spawning levels, and modification of human use. The objectives of this study were to improve stock identification capabilities by combining parasite and genetic stock identification information data in algorithms to provide estimates of Kenai River stocks in the mixed stock fishery of Upper Cook Inlet and to provide more accurate estimates of abundance of Kenai River sockeye salmon within Upper Cook Inlet by increasing the sampling power of the offshore test fishing program.

Key Words: Escapement, *Exxon Valdez* oil spill, Kenai River, *Oncorhynchus nerka*, overescapment, overwinter survival, rearing, sockeye salmon, spawning, stock identification.

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Report Note: This is a report of studies that are in progress. All data and analyses provided are incomplete and preliminary. This report, as well as the data and analyses contained in the report should not be cited without an express statement of the incomplete and preliminary nature of the information.

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INTRODUCTION

Sockeye salmon *Oncorhynchus nerka* which spawn in the Kenai River system (Figure 1) were injured by the *Exxon Valdez* oil spill (EVOS). Greatly reduced fishing time in the Upper Cook Inlet (UCI) area due to EVOS caused sockeye salmon spawning escapement levels in the Kenai River system to exceed the desired amount by three times. The biological impact of EVOS on Kenai River sockeye salmon stocks may be one of the most serious documented. Data collected by Natural Resource Damage Assessment (NRDA) Fish/Shellfish Study 27, Sockeye Salmon Overescapement, indicated greatly reduced survival of juvenile sockeye salmon during the winter-spring rearing period (Schmidt et. al. 1993). The extremely high escapement may have initially produced more rearing juvenile sockeye salmon than could be supported by nursery lake productivity. In general, when rearing salmon abundance greatly exceeds lake carrying capacity, the species and size composition of prey resources are altered which affects all trophic levels. Because of such changes, juvenile sockeye growth is reduced, freshwater mortality is increased, greater proportions of fry remain in the lake for another year of rearing, and smolt condition is reduced and marine mortality is increased. Limiting sockeye salmon fry production by closely regulating the number of spawning adults may be the only way to restore the productivity of these rearing areas. However, the number of adult sockeye salmon returning from the 1989 escapement may be so low that a severe reduction, or complete elimination, of human use of this species may be necessary starting in 1994 to ensure minimum spawning escapements.

The goal of this continuing project (begun as Restoration Project 53) is to restore Kenai River, Alaska sockeye salmon stocks injured by EVOS. This will be accomplished through improved stock assessment capabilities, more accurate regulation of spawning levels, and modification of human use. Restoration of Kenai River sockeye salmon stocks will be accomplished when production of sockeye salmon fry is matched with the food resources within the rearing lakes and overwinter survival of fry to smolt returns to normal levels (40 -80%).

Results from the 1992 investigations (Tarbox et. al. 1994) indicated that modification to the 1993 proposed studies submitted in the fall of 1992 was necessary. Results indicated that new "off the shelf" salmon counting hydroacoustic equipment for use starting in 1994 was not available. Therefore, this phase of the project was dropped and the budget adjusted accordingly. In addition, a reduction in scope and cost was incorporated into the test fish portion of the project.

OBJECTIVES

The objectives of this study were to:

1) improve stock identification capabilities by combining parasite and genetic stock identification information data in algorithms to provide estimates of Kenai River stocks in the mixed stock fishery of Upper Cook Inlet (UCI).

2) provide more accurate estimates of abundance of Kenai River sockeye salmon within UCI

by increasing the sampling power of the offshore test fishing program.

METHODS

During the development of this project it was apparent that the most efficient way to handle data collection and reporting was to contract the offshore hydroacoustic work including report preparation. Therefore, attached as Appendix A is the contract report prepared for this phase of the project. A brief summary of methods and results are presented in this status report for overview purposes.

This report also details only the collection phase of the genetic stock identification program. Laboratory analysis and reporting of separation methods and results are covered under the status report prepared for Restoration Project 93012 (L. Seeb, personal communication, ADF&G, Anchorage).

Stock Identification

Sockeye salmon entering the major drainages of UCI were sampled for genetic and parasite characteristics in 1993. Thirty four baseline populations were sampled for genetic characteristics (Table 1: two populations were sampled twice). In addition, mixed stock samples were collected from two drift gill net fishing periods. Sample sizes for allozyme baseline collections were set at 100 (Allendorf and Phelps 1981, Waples 1990). Mixed stock sample sizes were set at 400 (L. Seeb, personal communication, ADF&G, Anchorage).

Muscle, liver, eye, and heart were dissected from recently killed sockeye salmon. Samples of these tissues were placed in labeled cryovials stored in liquid nitrogen until transferred to -80^{0}C storage freezers located at Alaska Department of Fish and Game (ADF&G) offices in Soldotna or Anchorage. Soldotna samples were shipped to the ADF&G Anchorage laboratory on dry ice or liquid nitrogen and again placed in -80^{0}C storage until processed.

The body cavity of each sockeye salmon was examined for the presence of the nematode *Philonema oncorhynchi* (Tarbox et al. 1991; Waltemyer et al. 1993).

Offshore Test Fish Program

In 1992 hydroacoustic equipment and techniques were tested in UCI offshore waters. Results of this work indicated that hydroacoustic techniques could detect salmon and provide a population estimate for "in season" management use (Thorne and Salomone 1993). However, the primary limitation identified in the study was vessel speed relative to limitations (signal/noise ratio) of the hydroacoustic gear. Examination of the data set indicated that a minimum of 12 random orthogonal transects within UCI would be needed to provide a useable estimate of adult salmon abundance. Therefore, in 1993 an increase of vessel speed was attempted while completing 12 randomly selected transects during a 48 hour period starting 14 July (see Figure 1 in Appendix A). Estimates of hydroacoustic derived salmon abundance were compared to the abundance estimates generated from the commercial harvest on 16 July. In addition, the vessel and hydroacoustic gear was deployed for six days (12 transects) in conjunction with the existing ADF&G test fish vessel at Anchor Point (Tarbox, 1994).

A Model 102 Dual-Beam Scientific Echosounder with 120/420 dual frequency was used to collect data to echograms and DAT tape. The 120 and 420 kHz transducer had a nominal beam widths of 7 and 6 degrees respectively. The BioFin towing vehicle was towed behind the vessel at a depth of approximately 3m. The transducers were oriented in the side-looking mode. Echogram range was 100m, and the acoustic threshold was -47 dB.

RESULTS

Stock Identification

A total of 4,936 sockeye salmon were sampled for genetic characteristics and parasites (Table 1). Sockeye salmon for baseline genetic samples were successfully collected in 34 systems. A total of 22 spawning populations were sampled for a second year and 12 new populations were sampled. Genetic samples were transferred to the Anchorage laboratory and are currently being processed. Preliminary results indicated significant differences between stocks within the Kenai and Susitna river drainages (L. Seeb, personal communication, ADF&G, Anchorage). A complete report detailing the results of these efforts will be prepared as part of Restoration Study 93012.

The parasite *Philonema* was present in all 34 systems sampled (Table 1). Infestation rates were variable ranging from 8% to 100%. As in previous years the Central District systems of UCI had infestation rates of greater than 95% while Northern District systems had more variable rates (Table 1).

Offshore Test Fish

A complete report detailing results, prepared by the contractor, is attached as Appendix A.
A total of 3,452 targets were detected during the survey. Mean target strengths followed the 1992 results with a range of -18 dB to -49 dB recorded. Mean values were slightly higher for the 420 kHz system and probably are the result of degradation of signal to noise ratio at greater ranges. In most instances the targets recorded were single targets. Although small schools (3 to 5 individual marks on the echograms) were noted in the study area. Detection of targets was a function of range, wind velocities, water depth, rips, kelp and other non-fish objects, as well as transducer orientation.

The real time population estimate was 448,000 with error bounds of plus or minus 179,000 fish. Almost 70% of the estimate came from the lower portion of the fishing district. Indications of underestimation in the northern portion of the district was evident because of reduced detectability with range caused by bottom intrusion in shallow water. Fish densities ranged from 0.36 to 0.04 fish/1000 sq m.

Comparison of the daily catch at the ADF&G test fish line with hydroacoustic index indicated a moderate linear correlation (0.69) when using all the data. Under calm weather conditions the correlation coefficient improves to 0.84.

DISCUSSION

Stock Identification

The number of systems sampled in 1993 exceeded the original plan and was the result of favorable weather conditions which minimized transportation delays and increased efficiency from having experienced sampling crews. All program objectives were met with the exception of sampling the commercial set net fishery.

Our original plan was to sample only one drift and set net area. However, because of State of Alaska insurance requirements for contracted vessels (including set net skiffs), not enough set net permit holders bid on the test fish contract. In contrast, drift gill net permit holders typically carry the required vessel insurance. Therefore, for set net sampling in the future we will contract a drift gill net vessel to conduct all test fishing.

No major technical issues were evident in the sampling phase of this project. Evaluation and use of this program for management in 1994-1996 should proceed pending the results from Restoration Project 93012.

Offshore Test Fish

The intent of this program is to provide salmon abundance estimates that are useful to UCI salmon management biologist at critical points in the commercial fishery. The assumption is that the more precise the run strength estimation the less probability of a management error in meeting escapement objectives.

Restoration of the Kenai River system assumes that fry production can be matched to lake productivity. Therefore, control of escapement levels is critical. Tarbox et. al. (1993) has indicated that fall fry production is directly correlated with number of spawners. In theory by controlling the spawning escapement the fry loading densities in the lake can also be controlled.

During low to moderate runs the existing ADF&G salmon test fish program has relative errors of greater than 30% early in the season. This program also relies on active commercial fishing to make the abundance estimates. Therefore, during extended commercial fishing closures this program is non-functional.

One scenario was envisioned for the 1994 to 1996 commercial salmon seasons in pursuing the hydroacoustic approach to abundance estimation. A low Kenai river return is forecasted which alerts management to a potential problem. Poor commercial harvests early in the season tend to confirm the pre-season forecast and management closes the commercial drift gill net fishery. At this point, with the present programs, management must wait for escapement numbers to make further decisions (unfortunately Kenai River sockeye salmon can hold and build in strength in the district and then enter quickly into the river; Mundy et al. 1993). This management approach therefore runs the risk of not meeting escapement objectives if in reality the run is stronger than forecasted and/or late in entering the district. In addition, lost harvest opportunity for other stocks may take place with unwarranted closures. Therefore, an in-district estimate independent of the commercial fishery was needed. The hydroacoustic estimate provides that tool.

In 1993, the hydroacoustic real time salmon population estimate was within reasonable proximity of the estimate of in-district abundance generated by the commercial harvest data. Mundy et al. (1993) indicated that the drift gill net fleet harvests between 35 and 45% of the available sockeye salmon stocks in a regular 12 hour fishing period. On 16 July 1993 the drift gill net fleet harvested 234,000 salmon. A total district population estimate would be between 520,000 and 668,000 fish. This compares favorably with the estimate of 448,000 fish even with the recognized underestimation of the northerly distributed fish (also note that fish continued to enter the district for over 12 hours after the survey and prior to the start of the fishing period).

The use of the hydroacoustic gear along the ADF&G test fish line is a questionable expenditure of money at this time. In a normal season increased sampling power may help reduce error in the run strength estimate. However, as noted, this program relies on commercial fishery data. Therefore, the most prudent expenditure of funds is to concentrate on the in-district surveys.

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Table 1. Genetic samples collected and the presence of the nematode Philonema in sockeye salmon of Upper Cook Inlet river systems, 1993.

Date	Location	Location Code	Sample Size	Parasite Present	Parasite Absent	Percent Infested	Percent Absent
03 July	Wolverine Cr.	245-50-000-800	100	100	0	100.00	0.00
08 July	Crescent R.	245-30-400-904	100	100	0	100.00	0.00
12 July	CD Drift catch	244-00-000-932	399	298	101	74.69	25.31
14 July	Kenai R RM 19.5	244-40-200-902	52	52	0	100.00	0.00
14 July	Kasilof R RM 12	244-30-300-903	50	50	0	100.00	0.00
16 July	CD Drift catch	244-00-000-932	283	249	34	87.99	12.01
18 July	Yentna R. esc.	247-41-101-802	50	36	14	72.00	28.00
23 July	CD Drift catch	244-00-000-932	567	479	88	84.48	15.52
26 July	Russian R(above)	244-40-200-903	100	100	0	100.00	0.00
26 July	Packers Lk.	246-20-000-808	100	100	0	100.00	0.00
27 July	Nikolai Cr.	244-30-300-604	100	100	0	100.00	0.00
27 July	Quartz Cr.	244-40-200-601	100	100	0	100.00	0.00
27 July	Moose Cr.	244-40-200-607	100	100	0	100.00	0.00
02 Aug	Chelatna Lk.	247-41-101-811	100	96	4	96.00	4.00
02 Aug	Glacier Flat Cr.	244-30-300-605	100	100	0	100.00	0.00
03 Aug	Moose Cr.	244-30-300-607	100	100	0	100.00	0.00
03 Aug	Bear Cr.	244-30-300-606	100	100	0	100.00	0.00
04 Aug	Hidden Cr.	244-40-200-602	100	100	0	100.00	0.00
05 Aug	Ptarmigan Cr.	244-40-200-608	98	98	0	100.00	0.00
13 Aug	Between Sk/Ke L	244-40-200-604	99	99	0	100.00	0.00
13 Aug	Outlet Skilak L	244-40-200-605	100	100	0	100.00	0.00
16 Aug	Big Lake(FishCr)	247-50-000-801	100	13	87	13.00	87.00
17 Aug	Russian R(below)	244-40-200-903	100	100	0	100.00	0.00
18 Aug	Stream 12.4	247-10-000-705	100	96	4	96.00	4.00
18 Aug	Cottonwood Lk.	247-50-103-600	100	8	92	8.00	92.00
19 Aug	Birch Creek	247-41-100-913	67	39	28	58.21	41.79
20 Aug	Daniels Lk.	247-90-100-601	100	21	79	21.00	79.00
23 Aug	Bishop Lk.	247-90-100-602	100	11	89	11.00	89.00
23 Aug	Byers Lk.	247-41-106-701	100	100	0	100.00	0.00
24 Aug	Tern Lk.	244-40-200-606	100	93	7	93.00	7.00
24 Aug	Judd Lk.	247-41-101-810	100	100	0	100.00	0.00
25 Aug	WF Coal Cr.	247-30-100-600	100	92	8	92.00	8.00
26 Aug	Nancy Lk.	247-41-000-600	100	31	69	31.00	69.00
27 Aug	Skilak Lk Outlt	244-40-000-605	100	100	0	100.00	0.00
27 Aug	Between Sk/Ken.	244-40-200-604	100	100	0	100.00	0.00
31 Aug	Larson Lk.	247-41-105-701	100	100	0	100.00	0.00
01 Sept	Shell Lk.	247-41-102-600	100	95	5	95.00	5.00
02 Sept	Fish Cr.(Chums)	247-41-105-703	87	33	54	37.93	62.07
03 Sept	Whiskey Lk.	247-41-101-812	50	44	6	88.00	12.00
03 Sept	Trinity Lk.	247-41-101-915	100	89	11	89.00	11.00
08 Sept	WF Yentna R.	247-41-101-808	100	55	45	55.00	45.00
08 Sept	Stephan Lk.	247-41-105-702	100	86	14	86.00	14.00
15 Sept	Red Shirt Lk.	247-41-100-912	34	15	19	44.12	55.88
		Total Sampled:	4936				

APPENDIX 1 - TARGET DETECTIONS BY LOCATION

emplate for Anchor Pt Analysis

# of Targets detected

					Depth				
transect	Tape	odo	Freq.	0-20m	20-40m	40-60m	60-80m	80-100m	Comment
SP 1	1	1:20—28	420	56	153	124	242	173	60:15,1:51:44, along rio
									calm
			120	13	16	23	30	33	# of schools
AP 1		1st 30	420	0	1	11	7	6	calm
		2nd 30		3	14	17	33	19	
		3rd 30		4	12	15	16	15	
		Total		7	27	43	56	40	
		1st 30	120	0	3	9	10	8	
		2nd 30		2	9	12	18	16	
		3rd 30		3	5	3	7	9	
		Total		5	17	24	35	33	
	2	1st 30	420	1	8	5	7	16	slight chop
		2nd 30		3	4	9	5	4	
		last 15		0	1	0	1	1	
		Total		4	13	14	13	21	
			120						not useable
AP 2		to end	420	1	4	8	7	6	120 not useable
									weather moderate
	3	1st 30	420	1	0	3	0	1	
		2nd 30		0	3	3	4	1	
		3rd 30		0	2	2	3	5	
		last 38		2	2	6	10	2	
		Total		3	7	14	17	9	
			120						not useable
AP 3	4	1st 30	420	0	0	0	0	0	calm
		2nd 30		1	0	2	2	5	jumpers
		3rd 30		2	2	2	2	1	
		last 17		0	1	1	0	3	
		Total		3	3	5	4	9	
		2nd 30	120	4	15	15	14	13	jumpers
AP 4	5	1st 30	420	0	0	4	7	12	calm
		2nd 30		3	11	14	13	6	
		3rd 30		0	1	3	8	9	
		last 30		1	0	0	3	3	
		Total		4	12	21	31	30	
		1st 30	120	0	9	4	3	5	
		2nd 30		0	10	8	15	9	
		3rd 30		1	6	5	9	8	
		last 30		0	2	4	11	10	
		Total		1	27	21	38	32	
AP 5	6	1st 30	420	1	3	2	2	0	calm
		2nd 30		1	1	0	3	3	
		last 45		3	3	2	7	2	
		Total		5	7	4	12	5	
		1st 30	120	0	0	5	1	3	
		2nd 30		[illegible]	2	3	2	2	
		last 45			1	0	1	0	
		Total		2	3	8	4	5	
AP 6	7	1st 30	420	0	0	1	1	0	calm
		2nd 30		1	2	2	2	1	
		last 47		0	4	2	6	2	
		Total		1	6	5	9	3	

		1st 30	120	2	2	1	1	0	
		2nd 30		0	3	2	1	2	
		last 47		0	2	2	5	2	
		Total		2	7	5	7	4	
AP 7	8	1st 30	420	0	0	0	0	1	calm
		2nd 30		0	1	1	1	0	
		3rd 30		0	0	0	0	1	
		last 25		0	0	0	0	0	
		Total		0	1	1	1	2	
		1st 30	120	0	0	1	0	1	
		2nd 30		0	0	2	1	0	
		3rd 30		2	7	0	2	0	
		last 25		0	1	1	0	0	
		Total		2	8	4	3	1	
AP 8	9	1st 30	420	0	1				too rough for range
		2nd 30		1	1				
		3rd 30		0	0	2			
		4th 30		0	1				
		last 20		0	0	1	2	2	
		Total		1	3	3	2	2	
			120						too rough
AP 9/T-1	9	1st 30	420	9	10	45	24	7	moderate
		2nd 30		3	17	13	26	10	
		last 41		2	17	34	24	9	
		Total		14	44	92	74	26	
		1st 30	120	2	17	11	18	9	
		2nd 30		0	15	17	17	20	
		last 41		5	9	8	10	2	
		Total		7	41	36	45	31	
	10	0 – 27	420	2	4	11			too rough at range
			120						too rough
T-2		1st 30	420	1	4	6	9	4	calm
		2nd 30		0	7	5	4	4	
		3rd 30		0	3	6	2	5	
		last 40		3	8	3	2	1	
		Total		4	22	20	17	14	
		1st 30	120	6	16	17	8	6	
		2nd 30		0	9	12	5	2	
		3rd 30		6	7	9	6	2	
		last 40		0	6	9	7	7	
		Total		12	38	47	26	17	
3		1st 30	420	1	3	3	2	2	moderate
		last 42		2	2	7	7	7	
		Total		3	5	10	9	9	
		1st 30	120	2	4	5	6	6	2nd 30 too rough
	11	1st 30	420	0	4	2	4	9	
		last 46		1	6	9	5	4	
		Total		1	10	11	9	13	
			120						too rough
4		1st 30	420						too rough
		2nd 30		0	4	6	7	6	
		last 35		0	0	3	3	1	
		Total		0	4	9	10	7	
			120						too rough
5	12	1st 30	420	2	4	3			too rough at range
		2nd 30		1	3	3			
		3rd 30		1	2	1			

		last 26		2	2	3			
		Total		6	11	10	0	0	
			120						too rough
6		1st 30	420	6	10	7	6	7	bottom intrusion
		2nd 30		1	6	8	4	3	
		last 36		0	4	12	2	9	
		Total		7	20	27	12	19	
			120						too rough
7	13	1st 30	420	0	5	7	10	0	moderate
		2nd 30		1	10	6	10	3	some bottom
		last 40		5	22	5	2	0	bottom
		Total		6	37	18	22	3	
		1st 30	120						too rough
		2nd 30		2	22	24	7	0	
		last 40		5	31	13	1	0	
		Total		7	53	37	8	0	
8		1st 30	420	1	4	9	4	0	bottom
		2nd 30		1	6	8	14	2	
		last 47		1	1	3	8	3	
		total		3	11	20	26	5	
			120						too much bottom
9	14	1st 30	420	1	3	6	6	2	moderate
		2nd 30		0	1	3	9	0	
		last 27		1	5	1	2	2	
		Total		2	9	10	17	4	
			120						too much bottom
10		1st 30	420	0	9	2	5	2	moderate
		2nd 30		1	0	4	5	1	
		last 33		0	2	1	0	0	
		Total		1	11	7	10	3	
			120						too much bottom
11	15	1st 30	420	0	0	0	1	0	moderate
		2nd 30		2	2	4	5	0	
		last 20		0	3	0	0	0	
		Total		2	5	4	6	0	
			120						too much bottom
12		1st 30	420	0	0	1	2	2	moderate
		last 18		0	1	0	1	1	
		Total		0	1	1	3	3	
			120						too much bottom
AP 10		1st 30	420	1	1	2	1	2	rough
		2nd 30		1	1	4	6	4	
		last 23		0	4	4	7	9	
		Total		2	6	10	14	15	
			120						too rough
AP 11	16	1st 30	420	0	0	1	4	0	rough
		2nd 30		0	2	0	1	3	
		3rd 30		1	2	2	4	4	
		last 23		0	0	0	0	1	
		Total		1	4	3	9	8	
			120						too rough
AP 12		1st 30	420	2	5	3	4	5	rough
		2nd 30		1	7	3	3	6	

		last 26		1	1	6	4	5	
			Total	4	13	12	11	16	
		last section	120	1	2	10	2	5	rest too rough
SP 2	17	1st 30	420	1	10	7	9	5	rough
		2nd 30		4	8	1	1	1	moderate
		3rd 30		0	1	2	5	0	
		4th 30		0	2	4	7	1	
		5 th 30		0	0	1	3	3	
		6th 30		0	3	1	1	1	
		7th 30		1	2	1	1	4	
		last 26		2	3	9	2	2	
		Total		8	29	26	29	17	
		last 33	120	3	7	24	11	19	rest not useable
	18	1st 30	420	2	3	1	1	1	calm
		2nd 30		1	3	3	1		bottom
		last 19		0	6	1			
		Total		3	12	5	2	1	
		1st 30	120	2	6	18	26	16	
		2nd 30		1	3	7	3	1	
		last 19		0	2	1			
		Total		3	11	26	29	17	
SP 3		rest of 18	420/120						too rough
	19	1st 30	420						too rough
		2nd 30		0	0	0	0	0	
		3rd 30		0	1	0	0	0	
		4th 30		0	0	3	0	0	
		5 th 30		0	2	0	1	0	
		6th 30		0	1	0	0	0	
		last 19		0	2	0	0	0	
		Total							
			120						too rough
	20	1st 30	420	1	2	5			bottom
		2nd 30		1	1	1			
		3rd 30		0	2	1			
		4th 30		0	1	1	3		
		5 th 30		0	1	0	3	1	
		6th 30		1	0	1	1	0	
		7th 30		0	3	3	0		
		last 14		0	1	1			
		Total		3	11	13	7	1	
			120						too much bottom

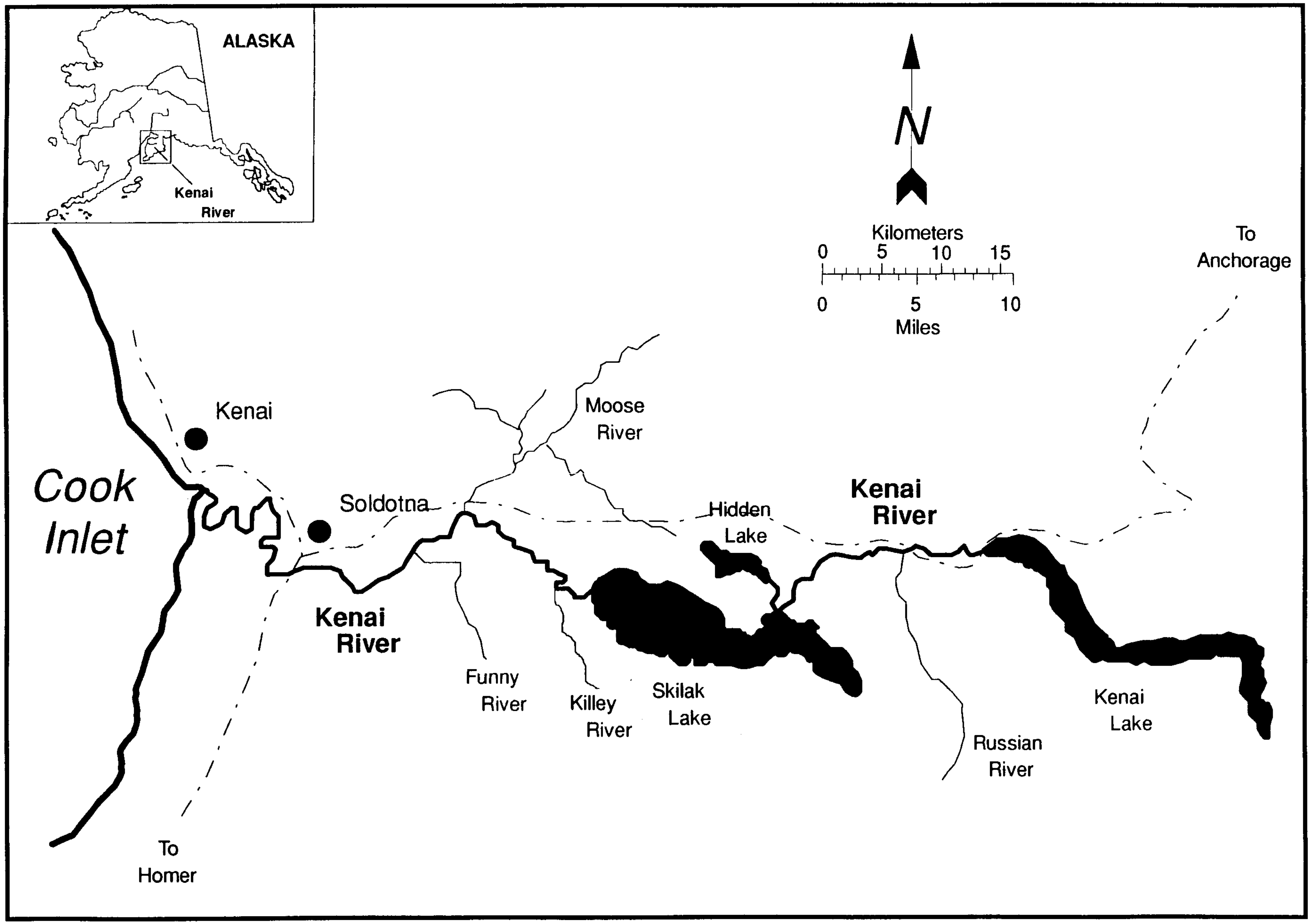

Figure 1. Map of the Kenai River drainage

Table 1. Genetic samples collected and the presence of the nematode Philonema in sockeye salmon of Upper Cook Inlet river systems, 1993.

Date	Location	Location Code	Sample Size	Parasite Present	Parasite Absent	Percent Infested	Percent Absent
03 July	Wolverine Cr.	245-50-000-800	100	100	0	100.00	0.00
08 July	Crescent R.	245-30-400-904	100	100	0	100.00	0.00
12 July	CD Drift catch	244-00-000-932	399	298	101	74.69	25.31
14 July	Kenai R RM 19.5	244-40-200-902	52	52	0	100.00	0.00
14 July	Kasilof R RM 12	244-30-300-903	50	50	0	100.00	0.00
16 July	CD Drift catch	244-00-000-932	283	249	34	87.99	12.01
18 July	Yentna R. esc.	247-41-101-802	50	36	14	72.00	28.00
23 July	CD Drift catch	244-00-000-932	567	479	88	84.48	15.52
26 July	Russian R(above)	244-40-200-903	100	100	0	100.00	0.00
26 July	Packers Lk.	246-20-000-808	100	100	0	100.00	0.00
27 July	Nikolai Cr.	244-30-300-604	100	100	0	100.00	0.00
27 July	Quartz Cr.	244-40-200-601	100	100	0	100.00	0.00
27 July	Moose Cr.	244-40-200-607	100	100	0	100.00	0.00
02 Aug	Chelatna Lk.	247-41-101-811	100	96	4	96.00	4.00
02 Aug	Glacier Flat Cr.	244-30-300-605	100	100	0	100.00	0.00
03 Aug	Moose Cr.	244-30-300-607	100	100	0	100.00	0.00
03 Aug	Bear Cr.	244-30-300-606	100	100	0	100.00	0.00
04 Aug	Hidden Cr.	244-40-200-602	100	100	0	100.00	0.00
05 Aug	Ptarmigan Cr.	244-40-200-608	98	98	0	100.00	0.00
13 Aug	Between Sk/Ke L	244-40-200-604	99	99	0	100.00	0.00
13 Aug	Outlet Skilak L	244-40-200-605	100	100	0	100.00	0.00
16 Aug	Big Lake(FishCr)	247-50-000-801	100	13	87	13.00	87.00
17 Aug	Russian R(below)	244-40-200-903	100	100	0	100.00	0.00
18 Aug	Stream 12.4	247-10-000-705	100	96	4	96.00	4.00
18 Aug	Cottonwood Lk.	247-50-103-600	100	8	92	8.00	92.00
19 Aug	Birch Creek	247-41-100-913	67	39	28	58.21	41.79
20 Aug	Daniels Lk.	247-90-100-601	100	21	79	21.00	79.00
23 Aug	Bishop Lk.	247-90-100-602	100	11	89	11.00	89.00
23 Aug	Byers Lk.	247-41-106-701	100	100	0	100.00	0.00
24 Aug	Tern Lk.	244-40-200-606	100	93	7	93.00	7.00
24 Aug	Judd Lk.	247-41-101-810	100	100	0	100.00	0.00
25 Aug	WF Coal Cr.	247-30-100-600	100	92	8	92.00	8.00
26 Aug	Nancy Lk.	247-41-000-600	100	31	69	31.00	69.00
27 Aug	Skilak Lk Outlt	244-40-000-605	100	100	0	100.00	0.00
27 Aug	Between Sk/Ken.	244-40-200-604	100	100	0	100.00	0.00
31 Aug	Larson Lk.	247-41-105-701	100	100	0	100.00	0.00
01 Sept	Shell Lk.	247-41-102-600	100	95	5	95.00	5.00
02 Sept	Fish Cr.(Chums)	247-41-105-703	87	33	54	37.93	62.07
03 Sept	Whiskey Lk.	247-41-101-812	50	44	6	88.00	12.00
03 Sept	Trinity Lk.	247-41-101-915	100	89	11	89.00	11.00
08 Sept	WF Yentna R.	247-41-101-808	100	55	45	55.00	45.00
08 Sept	Stephan Lk.	247-41-105-702	100	86	14	86.00	14.00
15 Sept	Red Shirt Lk.	247-41-100-912	34	15	19	44.12	55.88
		Total Sampled:	4936				

A.1. Feasibility Study of Acoustic Techniques for Adult Salmon Assessment in Upper Cook Inlet, 1993, by Richard E. Thorne, BioSonics, March 1994

FEASIBILITY STUDY OF ACOUSTIC TECHNIQUES FOR ADULT SALMON ASSESSMENT IN UPPER COOK INLET

-1993-

FINAL REPORT

by
Richard E. Thorne
BioSonics, Inc.
Seattle, WA

March 9, 1994

FEASIBILITY STUDY OF ACOUSTIC TECHNIQUES FOR ADULT SALMON ASSESSMENT IN UPPER COOK INLET

-1993-

FINAL REPORT

INTRODUCTION

BioSonics, Inc. contracted with Alaska Department of Fish and Game (ADF&G) for the second year of study on the feasibility of acoustic assessment techniques for adult salmon in Upper Cook Inlet. During the first year, 1992, various deployment modes and survey designs were explored. It was concluded that adult salmon could be detected with mobile side-looking acoustic techniques and that a randomized block design with orthogonal transects should produce an estimate with reasonable precision (Thorne and Salomone 1993).

The primary objectives of the second year of study, 1993, were twofold: (1) to conduct a 48-hr district-wide survey and real-time population estimate, and, (2) to run transects along the latitude of Anchor Point in association with the ADF&G test fishing vessel (see Tarbox and King 1991 for methods). The purpose of the second objective was to compare acoustic counts with test fishing catches and explore the potential of improving index precision with acoustic observations.

Additional objectives were to examine the signal to noise environment for acoustic detection of adult salmon, measure the target strength characteristics of the adult salmon, investigate the spatial characteristics of the salmon, and to evaluate the impact of the physical and chemical environment on the assessment techniques.

METHODS

Hydroacoustic data were collected from July 9-20. The acoustic equipment consisted of a dual-frequency (120 and 420 kHz) dual-beam BioSonics Model 102 Scientific Echo sounder, a BioSonics Model 111 Thermal Chart Recorder, a BioSonics Model 171 tape recording interface, a Sony Walkman Digital Analog Tape Recorder (DAT), and associated test equipment, cables, dual-beam transducers and a BioSonic BioFin towing vehicle. Primary settings and connections of the equipment are listed in Table 1. The equipment was loaded aboard the charter vessel, Angeline, on July 8 and 9. After installation, the equipment was checked out during a short cruise the evening of July 9. Transecting began July 10 and ended July 20.

Twelve runs were made along the Anchor Point latitude line during six days between July 10 and 18. The 48-hr area wide survey, consisting of twelve transects, was conducted during July 14-15 (Fig. 1). In addition, several other transects were run, especially along rip areas, to further determine the distributional characteristics of the adult salmon (Fig. 2).

The two acoustic transducers, one at 120 kHz and one at 420 kHz, were mounted on the BioFin towing vehicle in a side-looking mode, as in the 1992 study (Thorne and Salomone 1993). The nominal beam widths were 7 degrees for the 120 and 6 degrees for the 420. The vehicle was towed behind the boat at a depth of about 3 m. The two acoustic beams were oriented perpendicular to the vessel track, one looking starboard and the other port. Both frequencies were operated simultaneously. All data were recorded on the DAT. Echograms were produced in real-time on only one frequency at a time. Usually, the frequencies were alternated at 15 min periods, but on some occasions one frequency was used more often because of better propagation conditions. Echograms were produced for both frequencies for all sampling periods in post processing. Echogram range was 100 m, and the marking threshold corresponded to a -47 dB acoustic target strength.

Data for the real-time population estimate were obtained from the echograms in a similar fashion to the 1992 study. In 1992, data were examined over 5-m intervals and the best interval was selected. Improvements in transducer orientations resulted in greater overall ranges in 1993. Consequently, a 20 m interval was selected for the basic range unit in 1993. At the end of each transect, the number of fish detected over a 20 m wide range interval was counted. In most cases, the range interval from 40 to 60 m was used. Sampled area was calculated as 20 m times the length of the transect. Fish density was estimated as the number of detected fish along the transected divided by the sampled area. The fish population estimate for each transect was the fish density for the transect extrapolated over the total area represented by the transect.

The total surface area of the survey, 3,295 million square meters, was divided into three regions, south, central and north. Four orthogonal transects were randomly selected within each of the three areas. Means and variances were obtained for each area, then summed for the total population estimate as in the 1992 study (Scheaffer, Mendenhall and Ott, 1979; Thorne and Salomone, 1993).

Post survey analysis followed three avenues. First, the DAT tapes were used to produce echograms for all transects at both frequencies. These echograms were then examined to obtain echo counts in 20-m range intervals to 100 m. These data were used both to correlate echo counts on the Anchor Point transects with test fishing catches and to investigate detectability as a function of range and noise conditions. Criteria for target selection were more stringent for these relative comparisons than for the real-time population estimate, as per the recommendations of Thorne and Kuehl (1989). Second, portions of the taped data were processed with a BioSonics Model 281 Dual-Beam Signal Processor to investigate target strength characteristics of the adult salmon. Threshold for the target strength analysis was -49 dB. Finally, target characteristics were evaluated to examine the spatial characteristics of the salmon, especially schooling tendencies that would result in multiple target echoes.

RESULTS

Real-Time Population Estimates

The results of the real-time population estimate are given in Table 2. The number of fish detected ranged from 170 on the first transect to 7 fish on the last transect. Higher detection rates were observed in the southernmost area (#1), which also encompassed nearly half of the surface area. The total population estimate was 448,000 with error bounds of plus or minus 179,000 fish. Nearly 70% of the estimate was associated with area 1. The overall estimate is in reasonable agreement with other sources of information (Tarbox, personal communication) on the expected population size at that time, but there was some indication of underestimation in the two northern area blocks. Such underestimation may be the result of reduced detectability with range caused by bottom intrusion in these shallower portions of Upper Cook Inlet. For this reason, factors affecting the detectability with range were explored.

Evaluation of Factors Affecting Fish Detections

The numbers of fish detected at various ranges along various transect sections from the post processing of the echograms are given in Appendix 1. A total of 3,452 targets were detected. Several factors affected the capability of the acoustic system to detect fish. These included winds which affected the smoothness of the water surface boundary, reflections off the bottom from peripheral portions of the acoustic beam at shallower depths, rips, kelp and other non-fish objects, as well as the acoustic transducer frequency and orientation.

Figures 3-7 show the effects of winds on the detectability. Figure 3 combines all range detections for calm conditions (wind velocities below 6 knots, Beaufort Scale Sea States 0 to 2). Under these conditions, detections increased with range to a maximum in the 60-80 m interval, then decreased slightly. The increase occurs because of expanding depth coverage of the acoustic beam. The decrease after 80 m occurs because of deterioration in signal to noise due to sound attenuation (Fig 4). Figure 5 shows the detections under moderate conditions (wind velocities 7 to 16 knots, Beaufort Scale Sea States 3 and 4). Detections increase rapidly in the first 30 m, only improve slightly between 30 and 70 m, then fall off rapidly after 70 m. Figure 6 shows detections under rough water conditions (wind velocities over 16 knots, Beaufort Scale Sea States 5 and greater). Under this conditions, detections show very little improvement after 30 m because of the masking effect of surface reverberation (Fig. 7).

Figure 8 shows the effect of interference from bottom echoes. In this case, all observations with bottom intrusion into the 100 m range are pooled. Again, maximum detections are at 20 to 40 m, but detections decline precipitously at greater ranges. This reduction helps explain the apparent underestimation during the real-time population survey in the northern two areas where bottom interference is often encountered (Fig. 9).

Kelp was observed to return echoes that were often similar in magnitude to those from fish (Fig. 10). This was not a major problem as kelp were not widespread and were visually noted. However, there were a few occasions where both fish sign (jumpers) and kelp were in proximity. Rips provided a more serious problem. Fish were clearly associated with rips, and entrained air and debris could either return echoes that were similar to fish, or mask the presence of fish targets. However, fish appeared to be near the rips, but not actually in the rips, so separation appeared to be possible in most cases (Fig. 11).

In both the 1992 study and the 1993 study, the two transducers were oriented in opposite directions. In both years, optimal aiming angles for both transducers simultaneously was difficult to achieve. In 1992, most of the data were collected at 120 kHz because the 420 kHz transducer tended to point too near the surface for optimal detection. In 1993, the opposite was true, the 120 kHz transducer tended to point too near the surface. The problem may be associated with towing the vehicle directly behind the boat where it was subject to increased turbulence from the boat propeller. As a consequence, both years, one transducer produced good results while the other was more impacted by surface conditions. This problem made comparison between the two frequencies difficult to make. In general, the lower attenuation rate and slightly greater beam angle of the 120 kHz should have made this frequency more effective. However, the 420 was very effective out to 80 m, and the effectiveness of both frequencies was more impacted by orientation and surface water conditions than by differences between the two frequencies.

Comparison of Anchor Point Acoustic and Catch Data

The daily catch of the test fishing vessel is compared with the acoustic counts for the corresponding day in Table 3 and Figure 12. The acoustic data in each case were limited to the 420 kHz data and depth intervals with the best detection during various time intervals. The linear correlation coefficient of acoustic counts versus catch is 0.69, which indicates a moderate correlation.

Virtually the same result is obtained if acoustic counts are compared with the index numbers (weighted catches) However, the acoustic data are clearly effected by weather conditions. If the three rough water transects are removed, the correlation coefficient improves to 0.84 against catch and 0.82 against index number, which are strong correlations (Fig. 13). An additional problem is apparent from the results on July 18. Three acoustic transects were conducted that day. The first two were impacted by rough weather and had low counts. The third and last transect of the day also had relatively low counts although weather conditions had improved. The catch was moderately high, but 65% of the catch was obtained at one station (#5) after the acoustic boat had past the station. Shortly afterwards, the acoustic boat detected high concentrations of fish slightly north of the Anchor Point line at the start of special transect #3. It was clear that the fish were highly patchy, and that both catches and acoustic detections were affected by tidal movements of these bands of fish.

Target Strength Measurements

Target strength measurements were made along selected portions of transects with obvious fish concentrations and good signal to noise characteristics. The results are shown in Figures 14 and 15 for 420 and 120 kHz respectively. The results are very similar to the more extensive 1992 observations (Thorne and Salomone 1993). Observations ranged from -18 dB to -49 dB. Mean values were slightly higher for the 420 observations, as in 1992, and probably because the greater attenuation at this frequency degrades the signal to noise ratio at greater ranges. Side-aspect target strengths for salmonids in the size range of Cook Inlet should range from -18 to -34 dB (Dahl and Mathisen 1981). The upper end values observed in this study are consistent with that expectation. Lower values result from the smaller returns possible from head and tail orientations. More of these values are associated with the 120 kHz data because of the better signal to noise conditions for this frequency, while returns from these orientations were less detectable at 420 kHz.

Spatial Considerations

In most cases, the echoes appeared to represent individual fish. The most obvious exception was along transect SP-1. The targets in this case, the very first recorded transect on July 10, were clearly small schools (Fig. 16). Examination of the signals indicated that the targets were typically comprised of 3 to 5 individual marks. These observations were associated with a large area of actively jumping salmonids. Close examination of signals indicated other scattered occurrences of multiple target echoes, often sufficiently compacted so as to appear as a single mark (Fig. 17).

Although targets were distributed over a wide area, there were clearly concentrations associated with rips (see Fig 11).

DISCUSSION AND CONCLUSIONS

It is clear that the side-looking mode can both effectively detect adult salmon and has sufficient sampling capability to produce district-wide population estimates with reasonable precision in a useful time frame. The primary limitation is the need for relatively calm weather conditions over the 48-hr period required to obtain that estimate. Less than calm weather conditions both limit detectability and potentially add spurious targets from surface reverberation.

The 48-hr real-time estimate obtained during this study provided an estimate that was in general agreement with information available from the fishing fleet and test fish catches, except that the population in the two northern most areas appeared to be underestimated. The underestimation was apparently the result of reduced detectability caused by bottom echo intrusion into the optimal sampling range. The investigation of detectability as a function of range suggests a 30-50% underestimation as a result of this factor.

Other factors that affected the estimation process were kelp beds, rips and multiple targets. Kelp and rips have the potential to produce bias in either direction. Kelp can be detected visually and echoes edited from the count, but this may not always occur. When kelp and fish are intermingled, fish targets may be excluded from the counts, especially if there is no surface manifestation of the fish (jumpers). The same is true of rips. Rips usually have surface manifestation (turbulence and debris) and are acoustically obvious. Usually, there appears to be separation between the rip itself and associated fish, but this may not always be the case. Multiple targets (small schools) would cause underestimation unless the multiple nature of the echo is obvious. Echoes need to be closely examined during analysis. There were clearly cases of multiple targets during this study, as well as in 1992, that could not be resolved as individuals and tended toward underestimation. The extent of this factor and the potential for alternate estimation techniques (such as school echo integration) needs further investigation.

The acoustic counts correlated reasonably well with test fish catches, but were also subject to weather-related constraints. The addition of acoustics to the Anchor Point index would clearly increase precision, especially since the fish were very patchy even in this area. However, the weather conditions in this area were typically more difficult than the district as a whole, and kelp was much more abundant in the Anchor Point area than in the district in general. Further, the contribution to management of an index number is much less valuable than that of a district-wide absolute population estimate.

While acoustic capability could be readily added to the test fishing boat, we recommend that priority be given to district wide surveying. Based on the combined 1992, 93 studies, there appears to be opportunity to conduct two to four 48-hr surveys within the period of the salmon run, by a vessel dedicated to that purpose. The 48-hr survey in 1992 was not conducted under totally ideal weather conditions. During the 48-hr period, weather ranged from calm to moderate. Some sections of the 120 kHz data used in the real-time estimate were marginal and were later excluded in post-processing data base because surface reverberation was too high for quality target detection. There were much calmer 48-hr periods prior to July 14 when a higher quality estimate could have been obtained, and at least one period afterwards.

Analysis of the 48-hr survey data was rapid. Using a simple calculator, it was possible to complete the population estimate and variance within 20 mins of the completion of the survey.

Although the techniques developed during 1992 and 1993 worked reasonably well, we recommend one major change in the deployment. Both years the two side-looking transducers were configured with opposing orientations and towed behind the boat. The purpose was to double the sampling sweep. However, problems with the stability of the orientation resulted in the loss of about half of one of the frequencies each year. We recommend moving the position of the towing vehicle from behind the boat to the side, where it will not be impacted by propeller wash. Based on other experiences with these towing vehicles, this would improve stability. This alteration would require changing the opposing orientations. Both would have to look in the same direction, away from the side of the boat. However, it would be easier to maintain proper orientation with a single direction to be optimized, even without the improved stability of the towing vehicle. This would decrease the sampling sweep. However, only one transducer at a time was used because of the real-time limitation of a single chart recorder, so the precision that was achieved in this study would not be reduced. In contrast, the simultaneous scan of the same water with two different frequencies could improve interpretation of the echoes.

We recommend continuation of the two frequency operation for the above reason. At this point, there is no evidence to suggest that one frequency is superior to the other. Although attenuation of 420 kHz is much higher than 120 kHz in salt water, this frequency detected fish very well out to 80 m. Use of two chart recorders would improve the real-time data analysis.

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Table 1. Summary of Equipment Settings and Connections

BioSonics Model 102 Scientific EchoSounder

F1/F2 MPX, Tx = -3, pulse width = 0.5 msec, Blank = Normal
Blanking distance = 0.5 m, Range = 100 m, Internal trigger,
Trigger interval = 0.2 sec, X1 receiver gain = -6, X2 = -6
TVG = 40logR salt
10 kHz outs to Model 171 AC ins, Detected out to Model 111
Sync 1 out to 171 sync in
Sync 2 out to 171 bottom detect in

BioSonics Model 111 Thermal Chart Recorder

Range 0 to 100 m, threshold 0.3 v, Gray level 3, Paper speed 1/4
signal in dc, grid on, white line off

BioSonics Model 171 Tape Recorder Interface

All sync, normal, normal
Record sync # 1 to sync in, #2 to bottom detect

Table 2. Results of real-time estimate from 48-hr district-wide survey

Area	Transect	Count	Length (m)	Density (#/1000sq.m)	Population (thousands)	Error Bounds (thousands)
#1	1	170	23760	0.36		
(1518 mil.sq.m)	2	89	23220	0.19		
	3	95	26460	0.18		
	4	28	16920	0.083	309	175
#2	5	18	25920	0.035		
(1095 mil.sq.m)	6	40	18180	0.11		
	7	35	16380	0.11		
	8	39	20880	0.093	95	39
#3	9	26	15660	0.083		
(682 mil.sq.m)	10	23	18000	0.064		
	11	22	14580	0.075		
	12	7	8820	0.04	45	13
				Total	448	179

Table 3. Comparison of Acoustic counts and corresponding test fish catches for transect along the Anchor Point line.

AP Run	AP Count	AP Catch	AP Index	Weather
1	67	99	68.5	Good
2	23	99	68.5	Moderate
3	7	39	29.1	Perfect
4	30	39	29.1	Perfect
5	9	17	13.3	Perfect
6	7	17	13.3	Perfect
7	2	17	13.3	Perfect
8	3	93	70.8	Rough
9	83	209	138.9	Moderate
10	14	103	76.9	Rough
11	8	103	76.9	Rough
12	15	103	76.9	Good

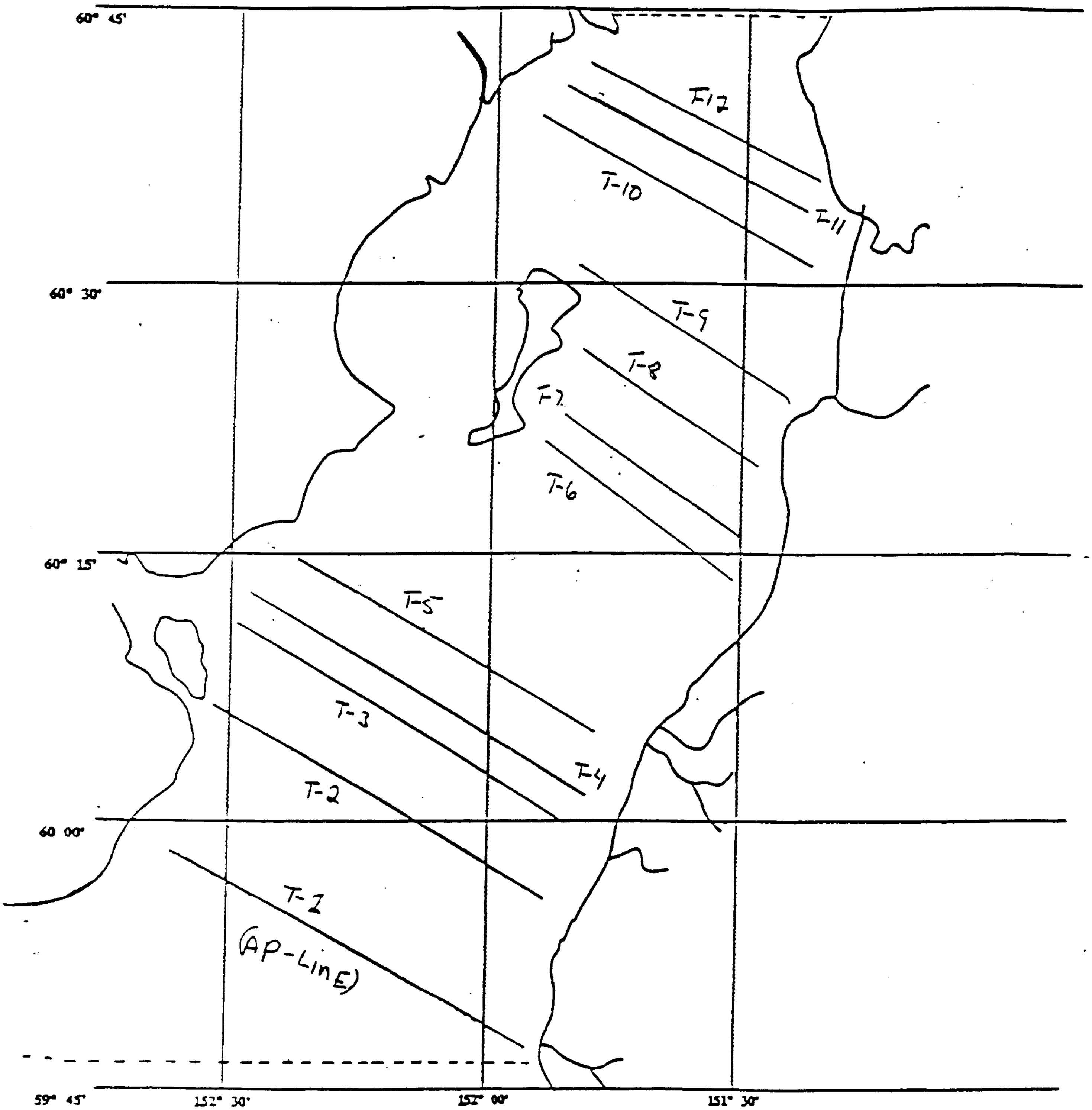

Figure 1. Location of Anchor Point transect line and 48-hr survey transects.

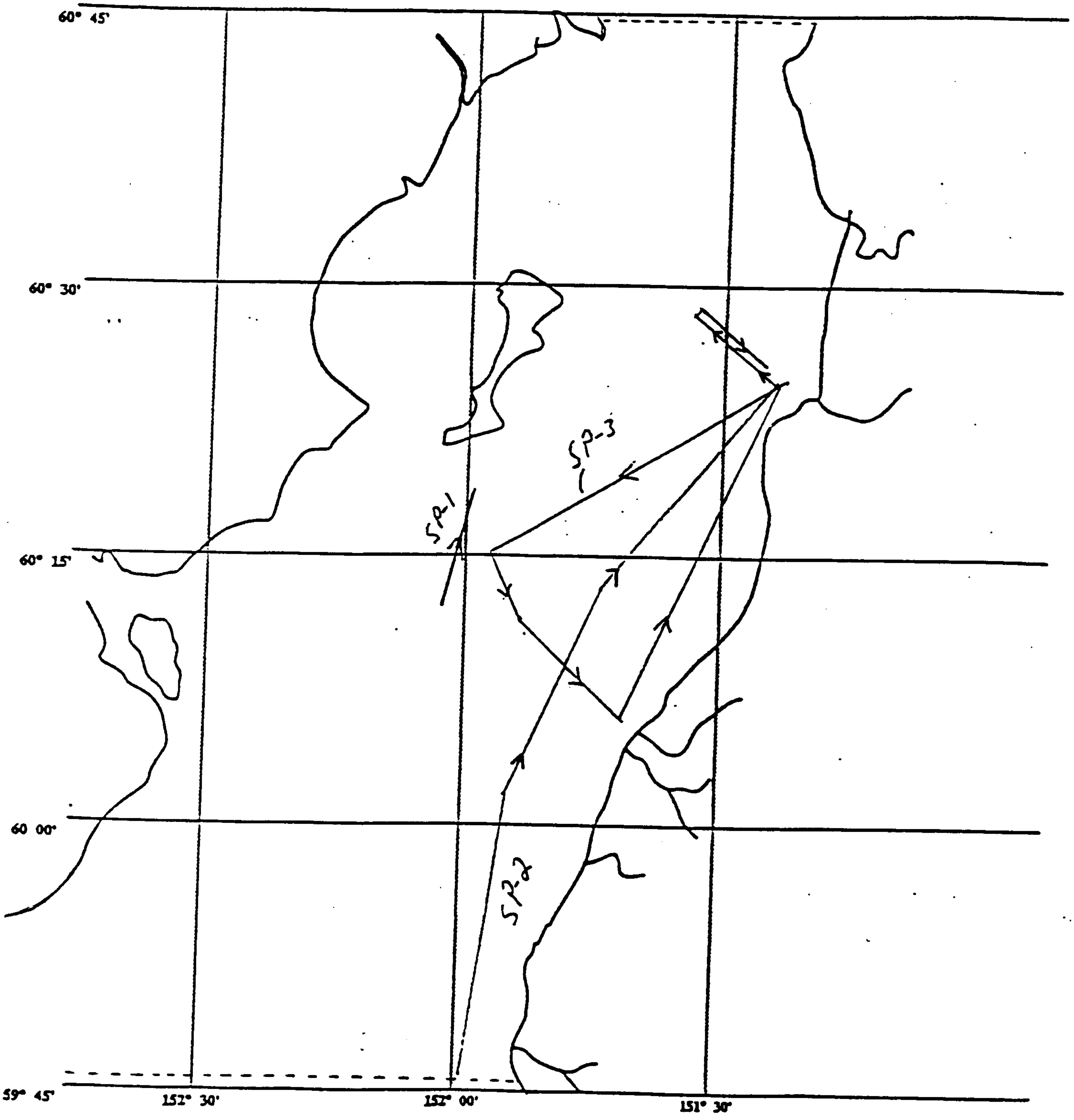

Figure 2. Location of extra transect runs.

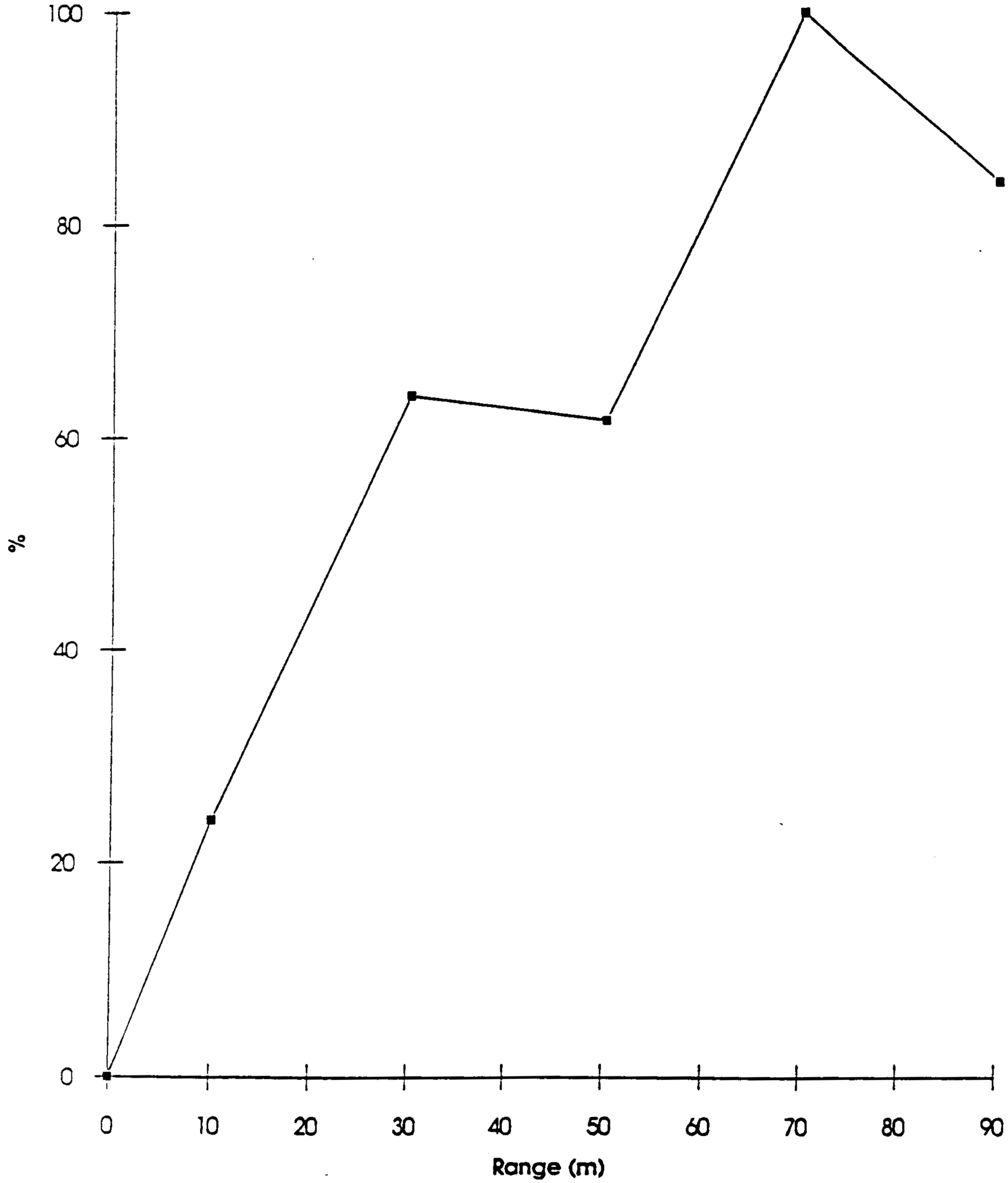

Figure 3. Detections (expressed as per cent of maximum) as a function of range under calm weather conditions.

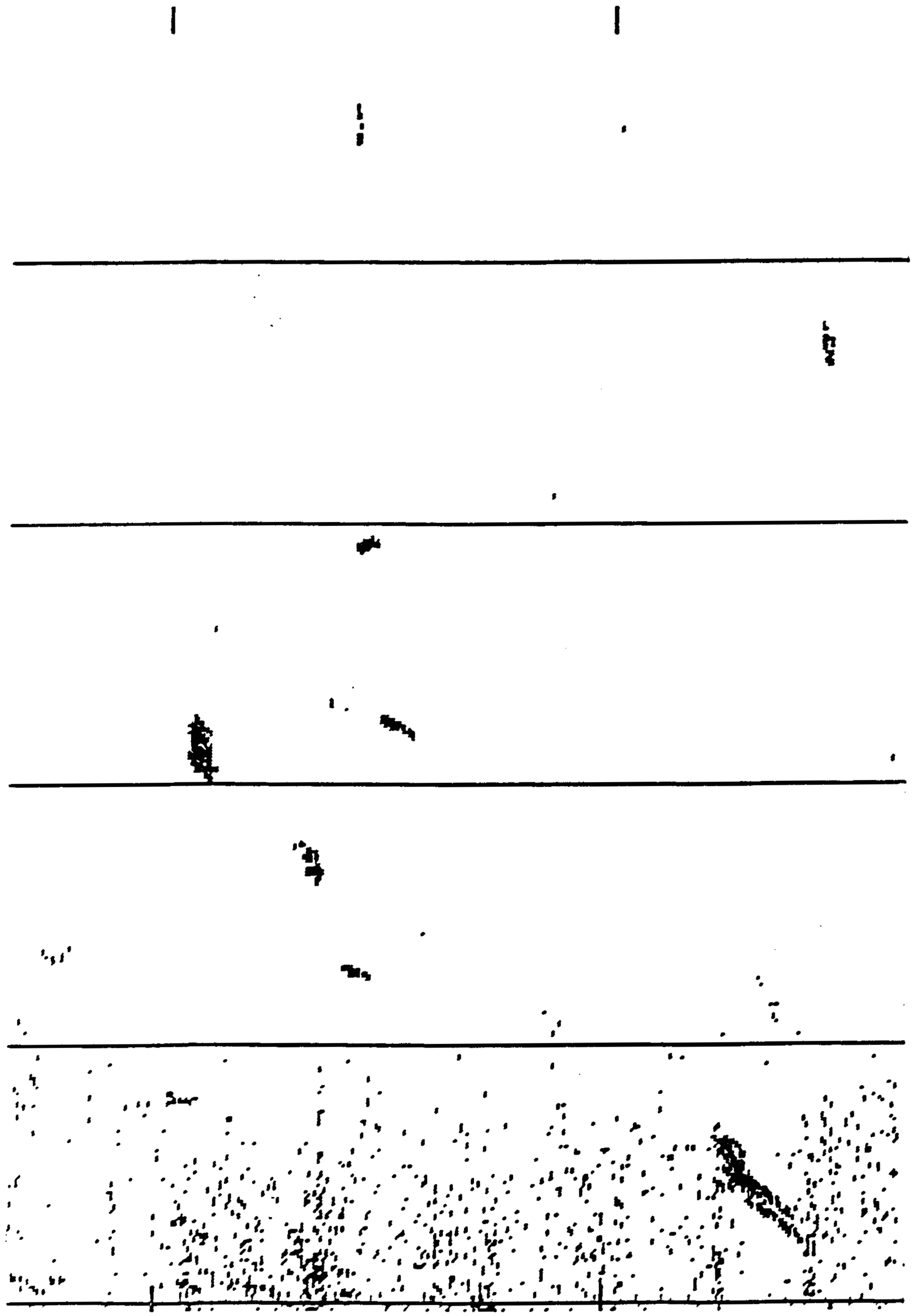

Figure 4. Echogram (-47 dB threshold) showing signal to noise conditions to 100 m under calm weather conditions for 420 kHz. Background noise appears in the last 20 m.

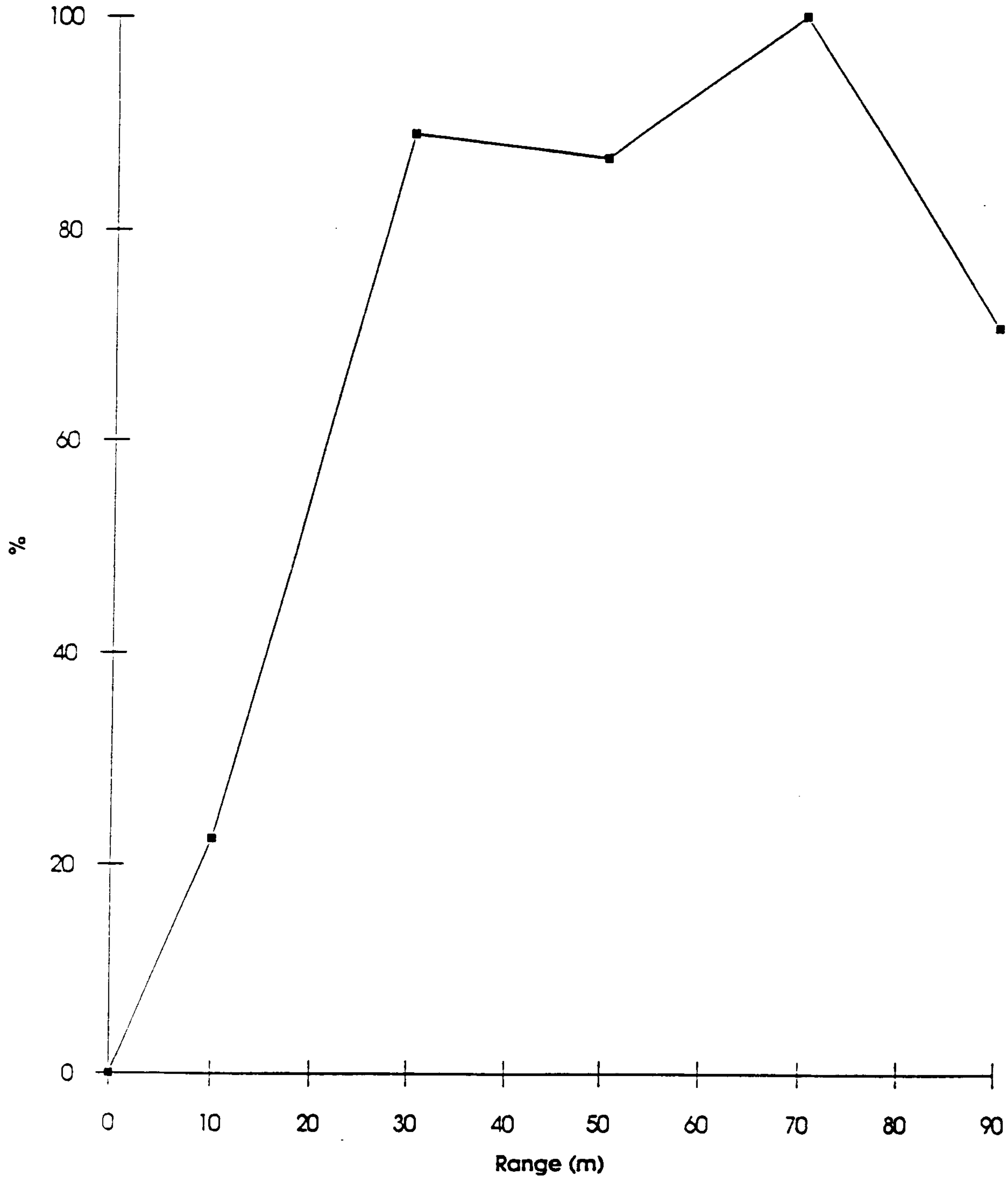

Figure 5. Detections as a function of range under moderate weather conditions.

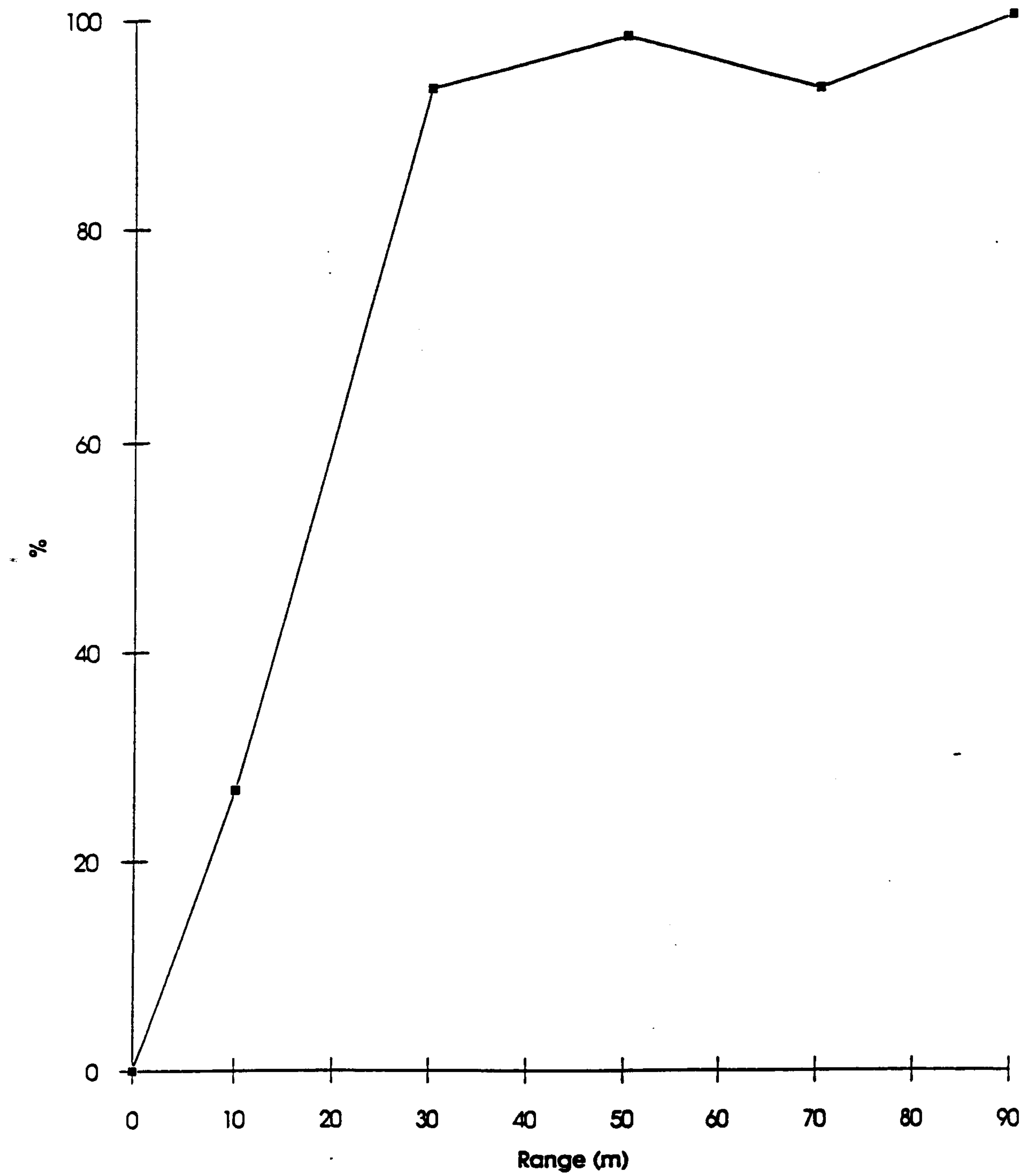

Figure 6. Detections as function of range under rough water conditions.

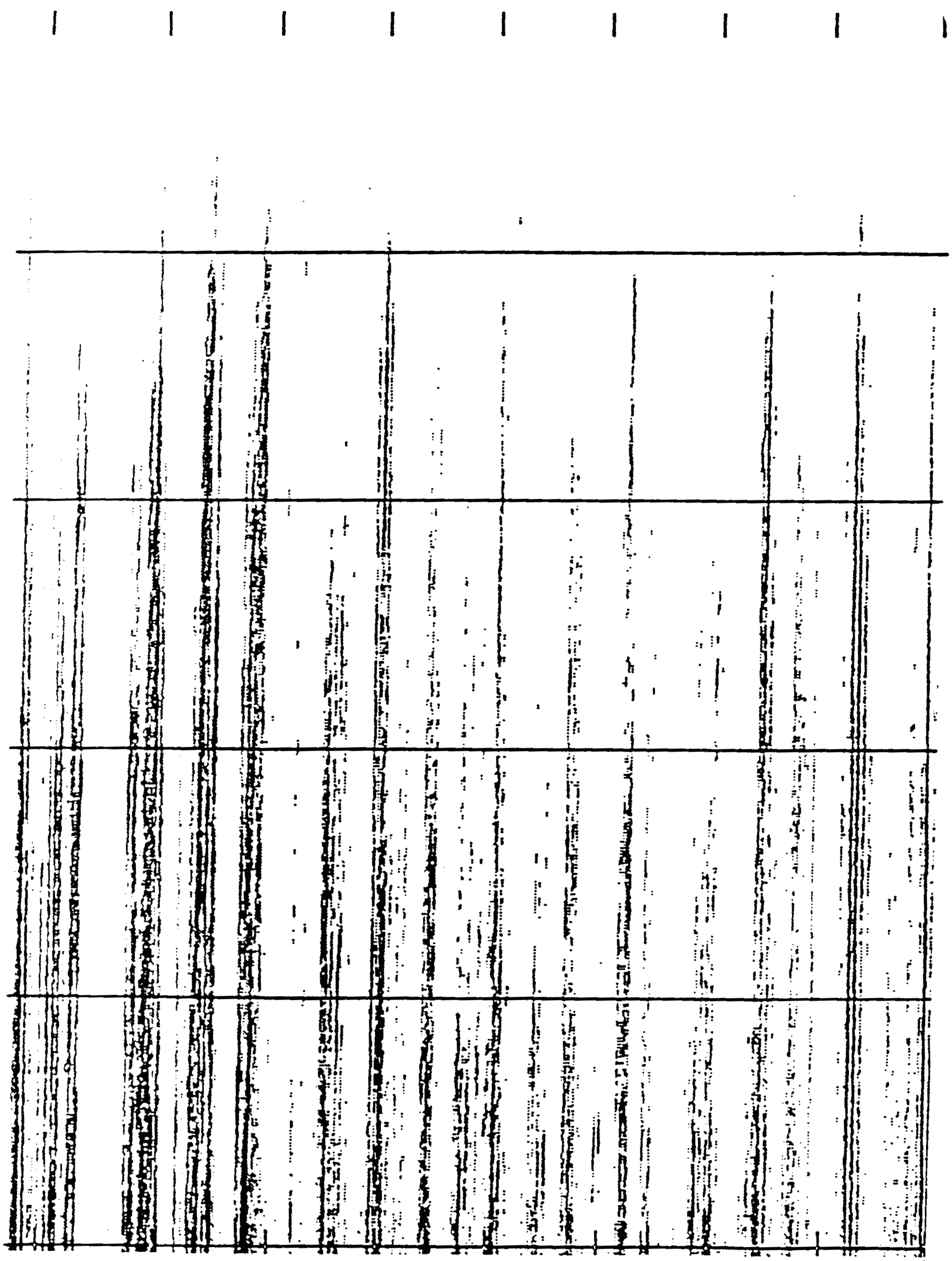

Figure 7. Echogram showing streaks of surface reverberation under rough water conditions. Range is 100 m.

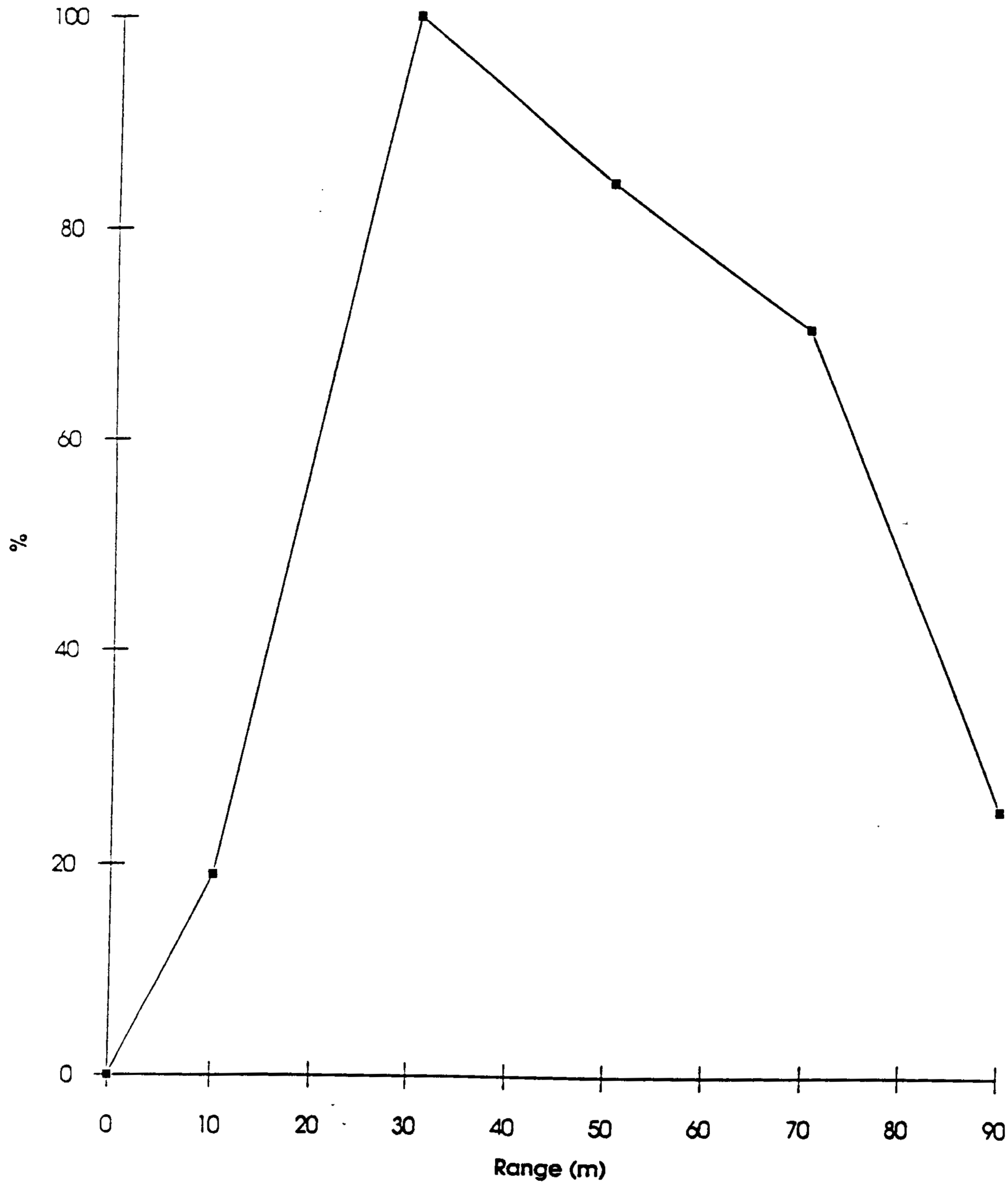

Figure 8. Detections as a function of range with bottom echo intrusion.

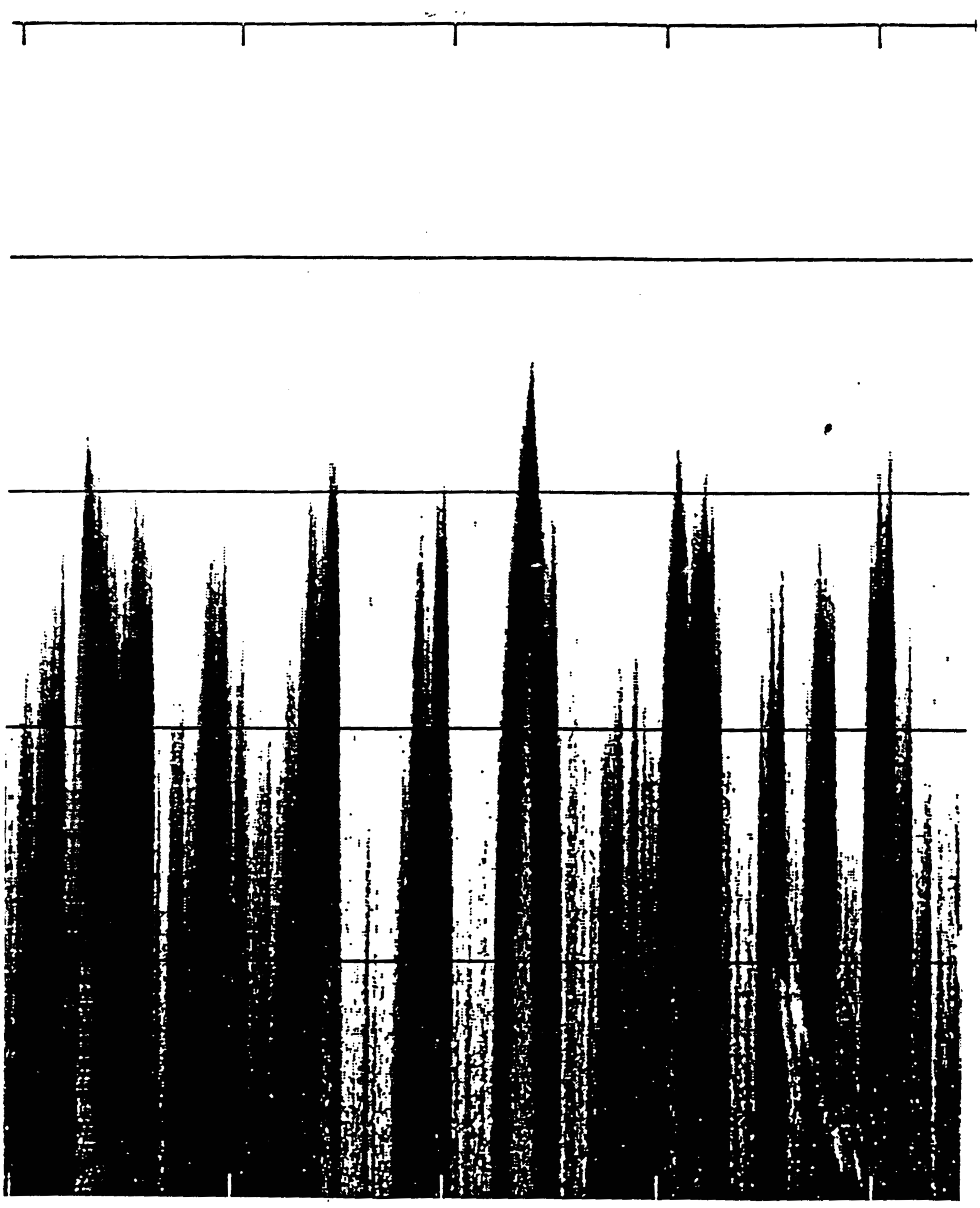

Figure 9. Echogram showing example of bottom echo intrusion. Range is 100 m.

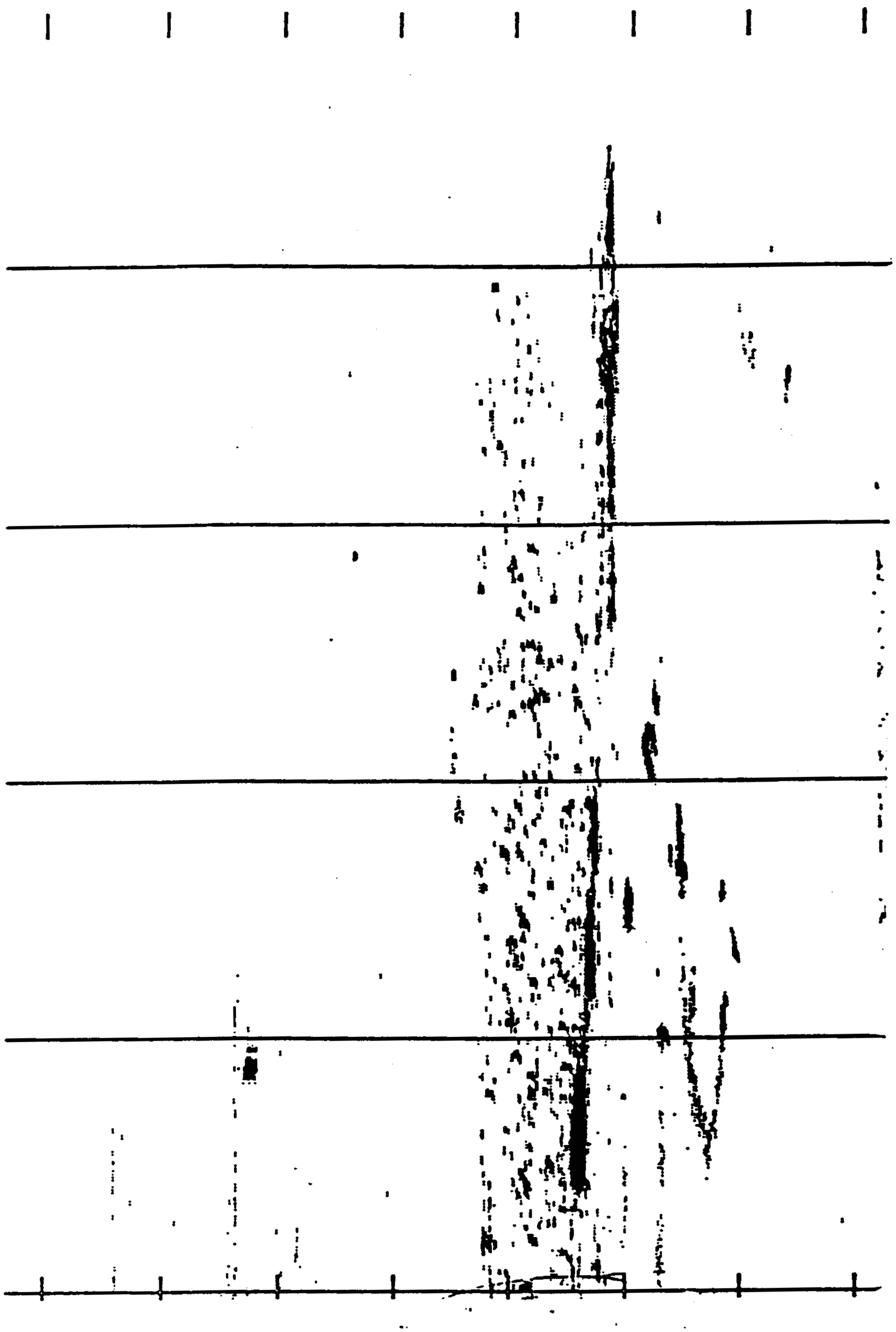

Figure 10. Echogram showing fish-like echoes from concentration of kelp. Range is 100 m

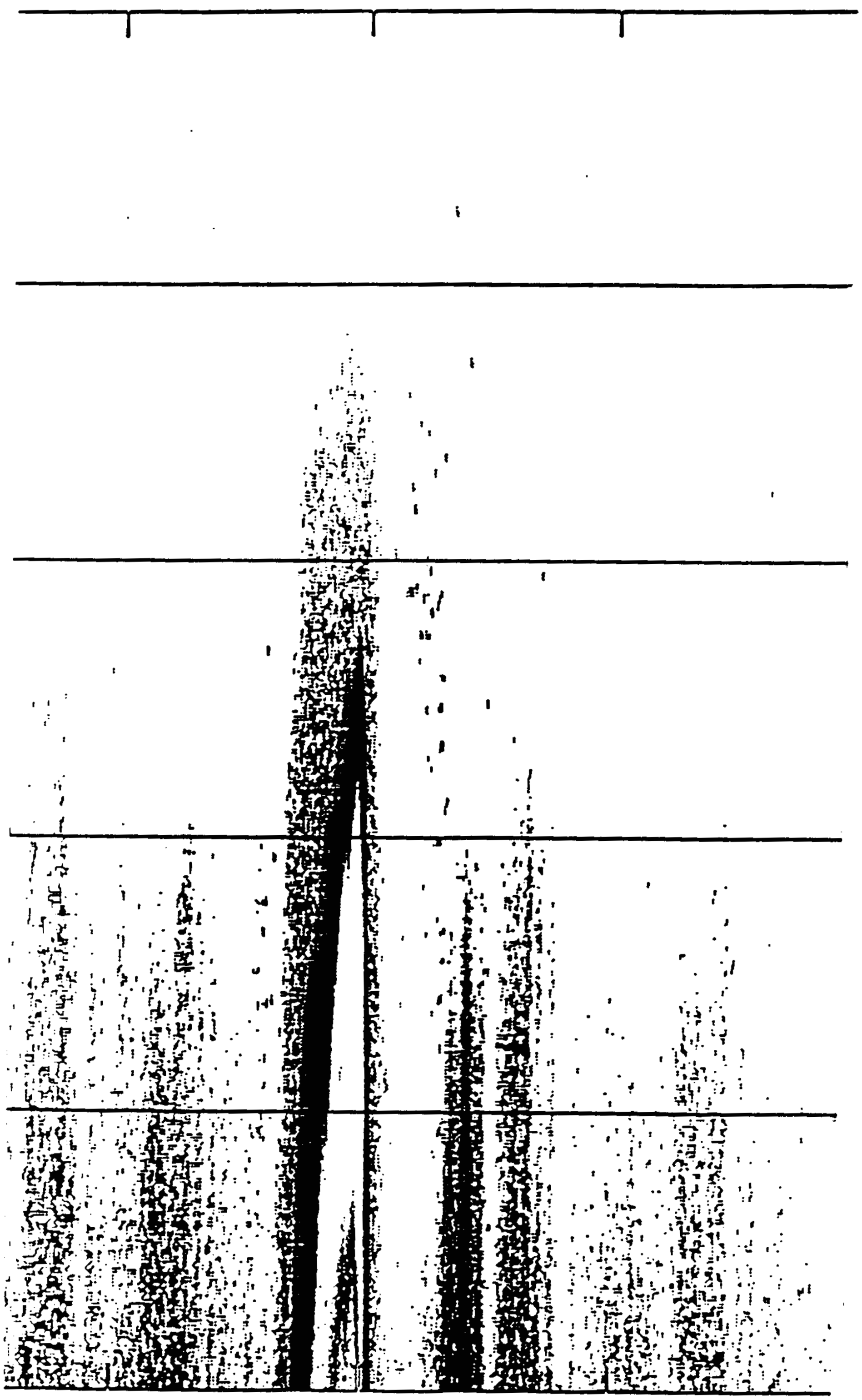

Figure 11. Echogram showing echo from rip and associated fish targets. Range is 100 m.

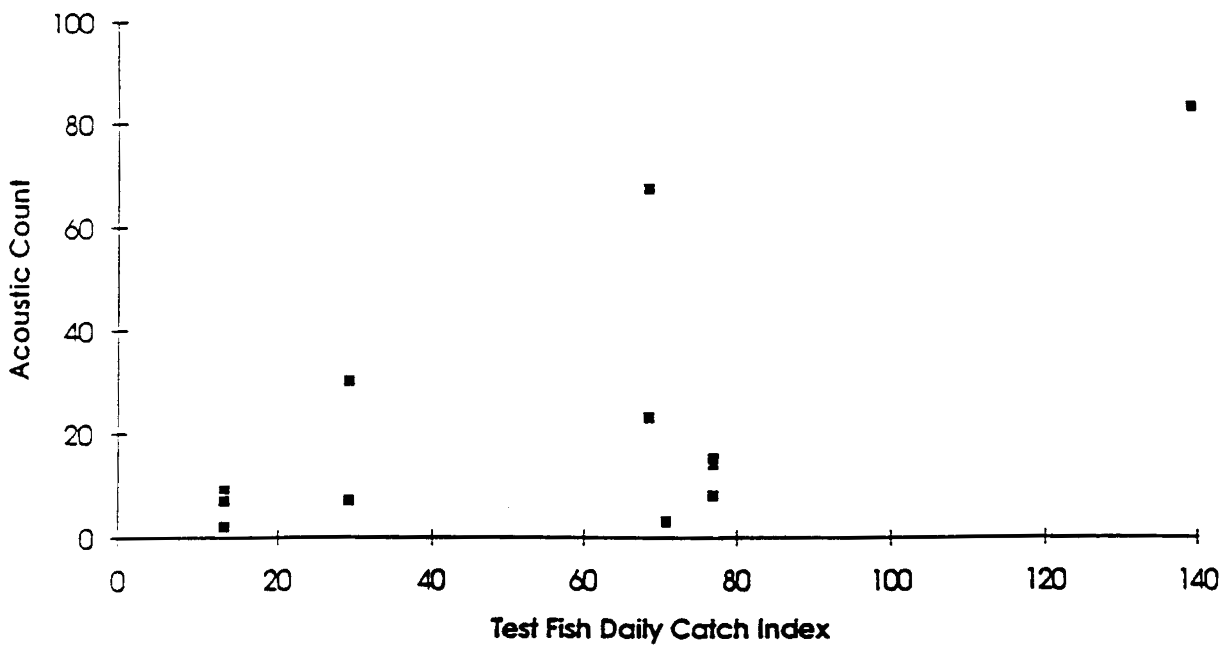

Figure 12. Comparison of acoustic counts along Anchor Point transects with corresponding daily test fishing catch index, all observations.

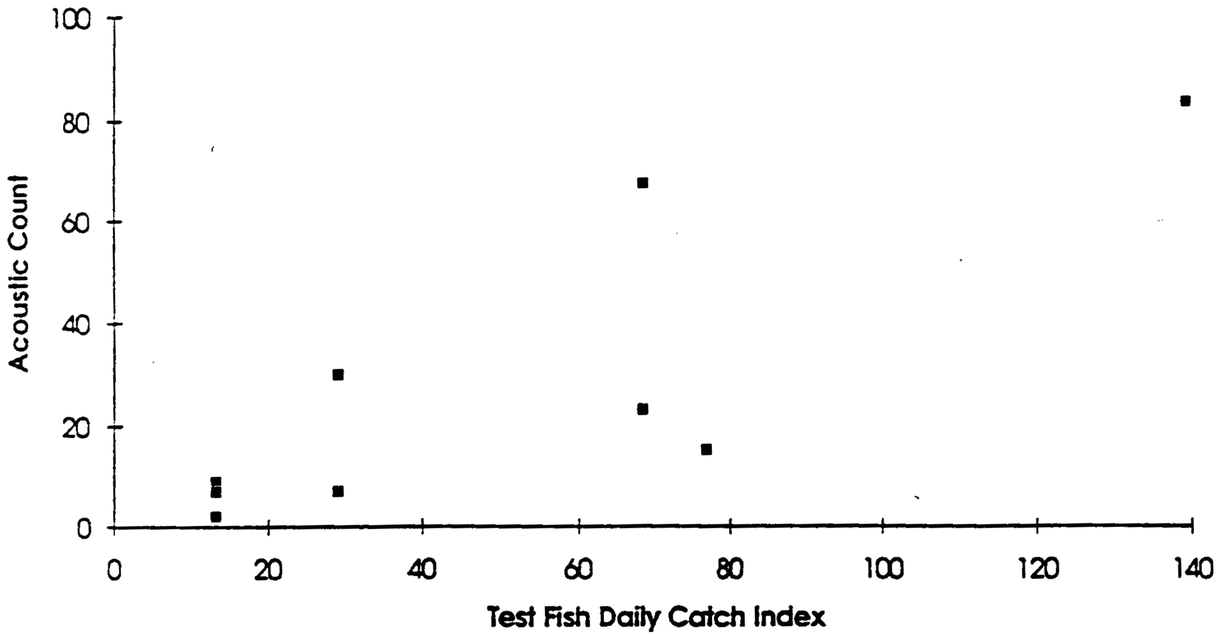

Figure 13. Comparison of acoustic counts along Anchor Point transects with corresponding daily test fishing catch index, rough water observations excluded.

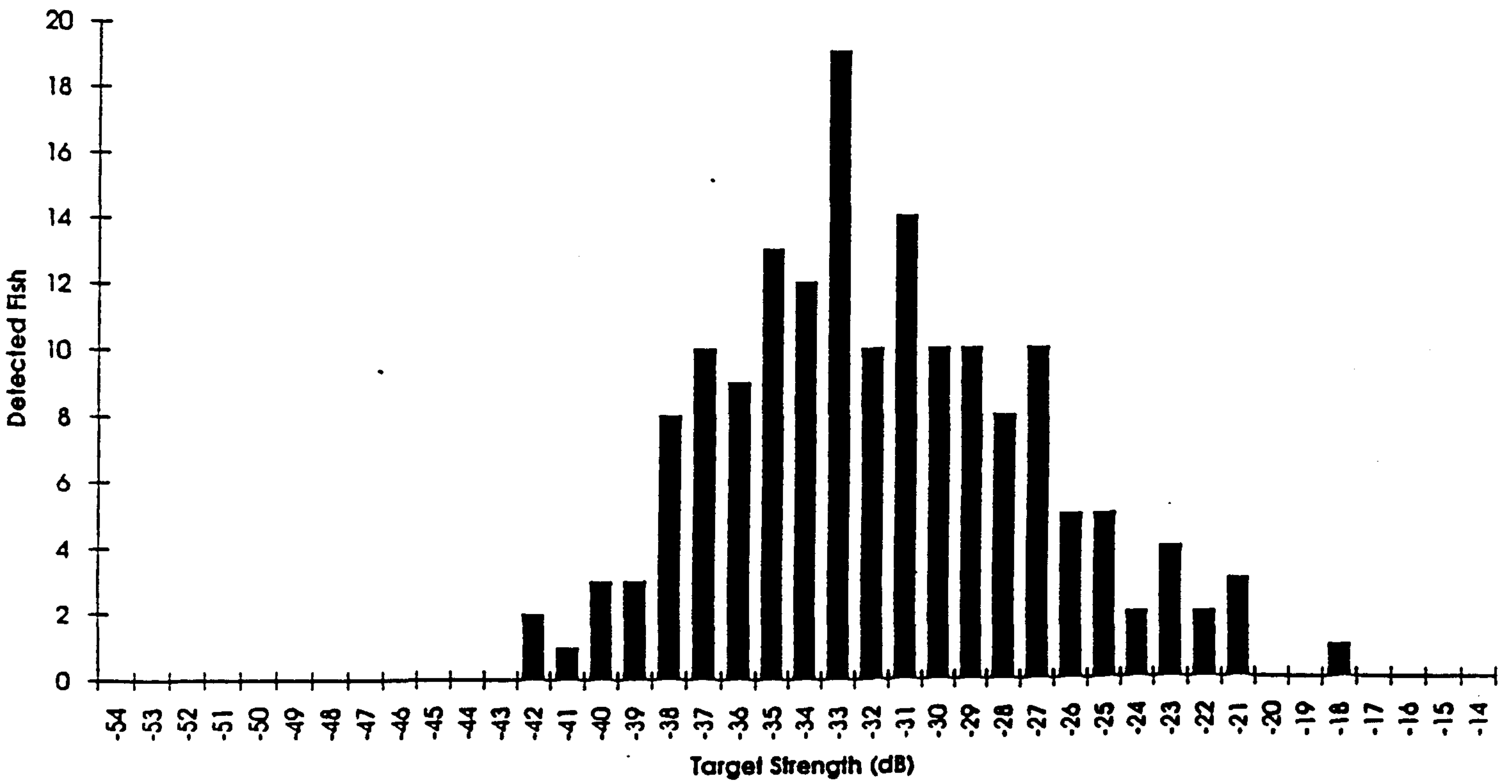

Figure 14. Target strength distribution for all 420 kHz observations

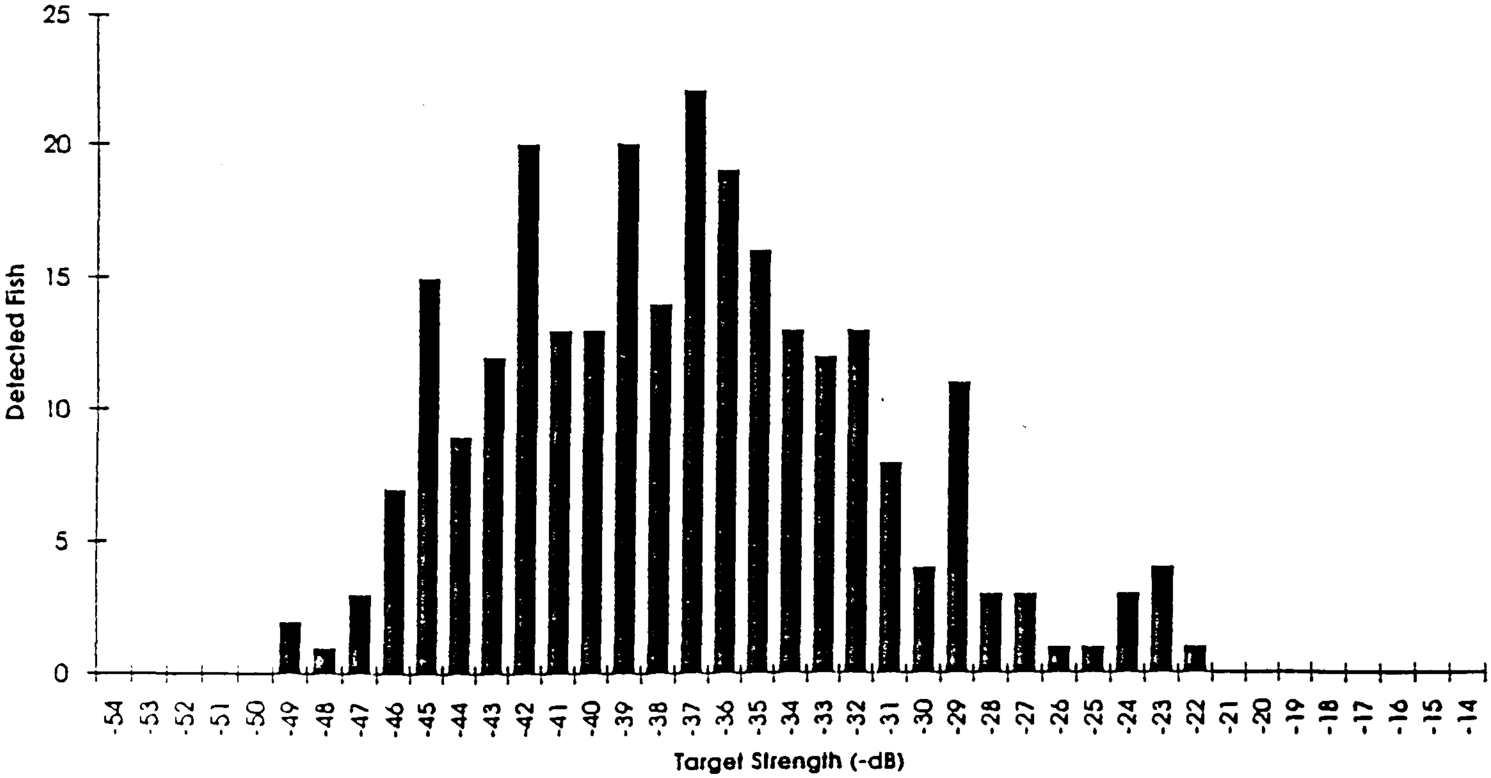

Figure 15. Target strength distribution for all 120 kHz observations

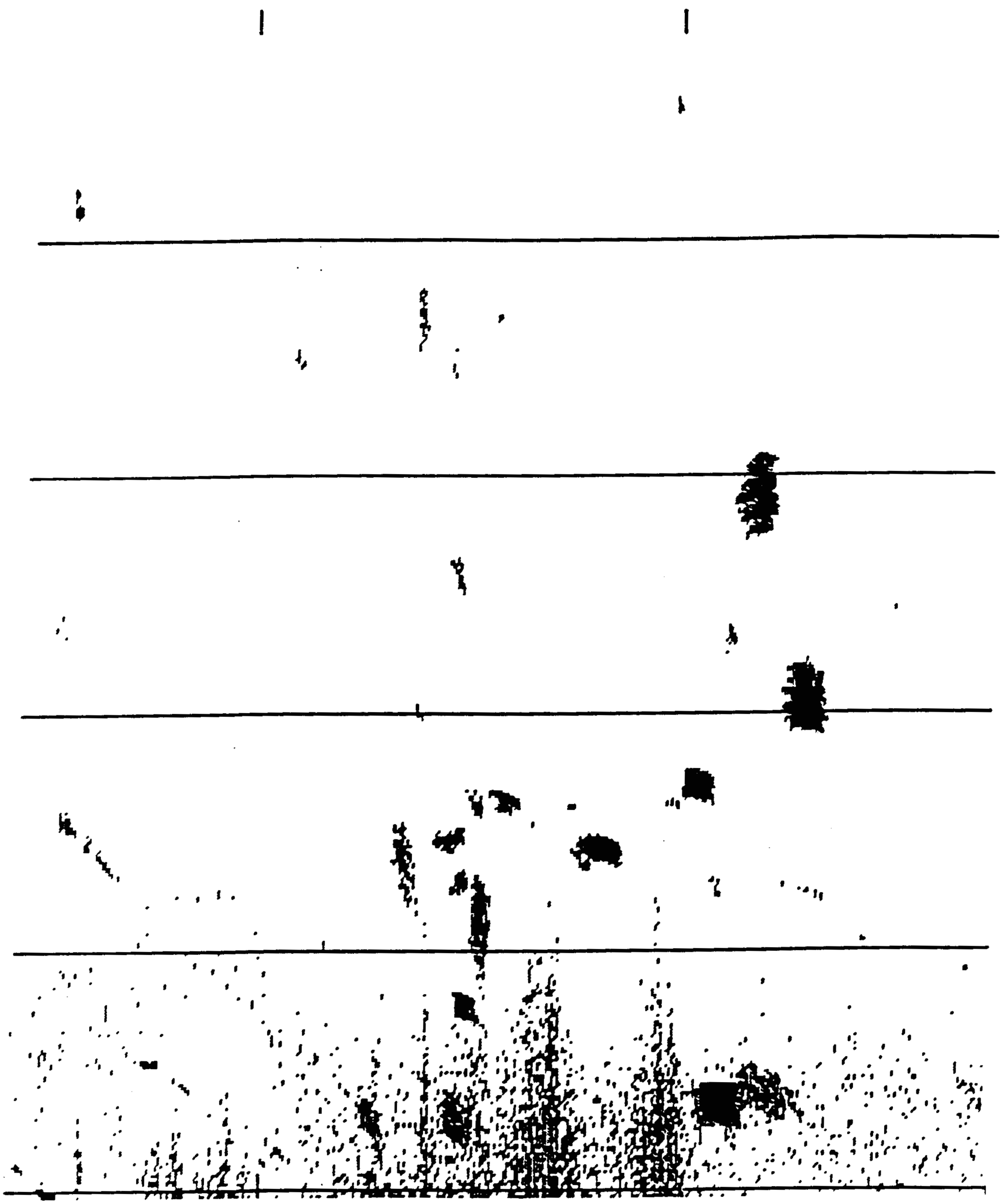

Figure 16. Echogram illstrating schooled fish targets, from transect SP-1. Range is 100 m.

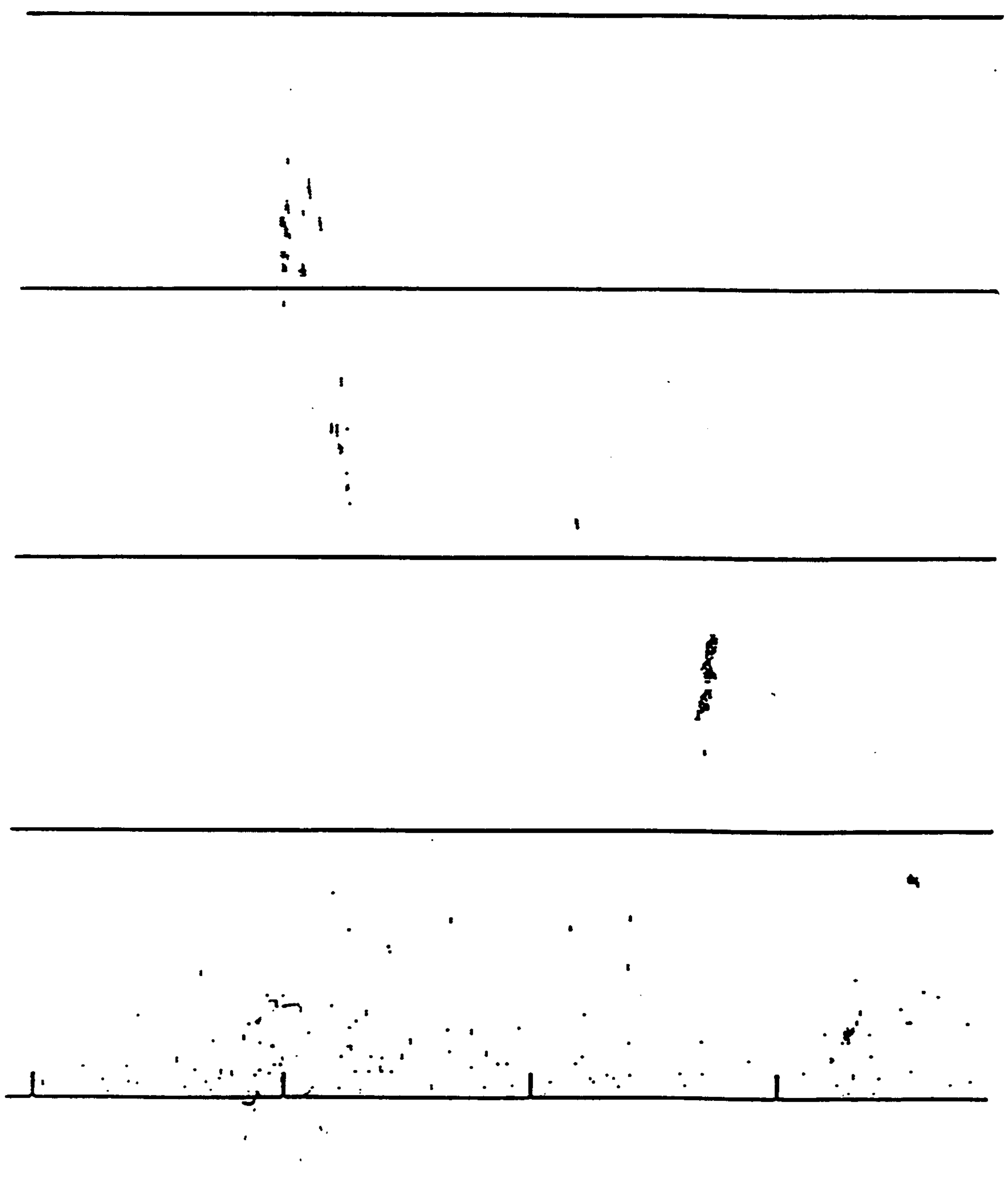

Figure 17. Echogram example from fish agregations with mixed individual and school characteristics. Range is 100 m.