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HYDROACOUSTIC SURVEYS OF THE DISTRIBUTION AND MOVEMENTS OF HATCHERY-RELEASED COHO SALMON SMOLTS IN THE COOS BAY ESTUARY

by

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INTRODUCTION

One of the major concerns associated with salmon ranching is the impact on the estuarine environment of large releases of hatchery reared fish. Critics of private salmon aquaculture have charged that smolts stay in the estuary too long before they go to sea, thus potentially stressing the carrying capacity of the environment to the detriment of natural populations.

Unfortunately, estuarine environments are very complex, and traditional sampling techniques lack the capability to effectively address this concern without inordinate cost. However, recently developed hydroacoustic techniques have been shown to be highly effective in mapping fish distributions in a variety of environments because of their high sampling power (Thorne 1980).

An investigation was made on the feasibility of tracking salmon smolts in Coos Bay, Oregon by use of hydroacoustic techniques. Since these techniques lack the capability to specifically identify fish targets, the study was predicted on the possibility that large concentrations of smolts could be followed by means of repetitive hydroacoustic surveys. Large quantities of coho salmon were simultaneously released into the estaury, and attempts were made to follow these large concentrations during their residence in the estuary. This report details in the results of the investigation which was primarily funded by Oregon Aqua-Foods, Inc., a subsidiary of Weyerhaeuser Co.

MATERIALS AND METHODS

The surveys were conducted in the Coos Bay estuary from June 24 to July 3, 1980. The surveys were coordinated with releases of coho salmon smolts from the Ore Aqua saltwater release facility at Coos Bay (Fig. 1). About 300,000 smolts were released within a 30-min period by draining an entire holding pond. Three such releases were made during the study period (Table 1). A release of 291,000 coho smolts had been made from the facility two days prior to the study, and an additional 74,000 fish had been released three days before the study from the Anadromous facility further up the estuary.

The hydroacoustic equipment was deployed in two different modes. Most of the effort involved surveys with a downward-looking system. The objective of this mode was to repetitively map the distribution of fish in the estuary in order to follow the movements of the large concentration of released fish. In addition, an uplooking system was deployed in a stationary mode. The stationary system allowed examination of the upper water column at a specific inshore location near the facility.

Equipment

Two hydroacoustic systems were used. The primary system consisted of a 420 kHz transceiver, a 22^{o} full angle transducer and a chart recorder (Fig. 2). The transceiver is the core instrument of the data acquisition system. It forms the pulses to be transmitted and conditions the acoustic returns for input to the chart recorder. The transceiver used was a Bio Sonics Model 101 Scientific Sounder. The transceiver was chosen because of its flexibility and high quality. It has several special features that make it especially suited for the juvenile fish assessment studies. Some of these features are: 1) a digitally controlled 40 log R time varied gain accurate to $\pm$ 0.5 dB, 2) linear

Figure 1. Oregon Aqua-Foods, Inc. saltwater release facility on the Coos Bay estuary.

Table 1. Timing and magnitude of coho salmon smolt releases immediately prior and during hydroacoustic surveys.

Date	Time	Number	Source
6/21	-	73,550	Anadromous
6/22	2145 - 2215	291,393	Ore-Aqua
6/24	2130 - 2200	305,722	Ore-Aqua
6/27	0100 - 0130	333,201	Ore-Aqua
6/28	0130 - 0200	300,884	Ore-Aqua

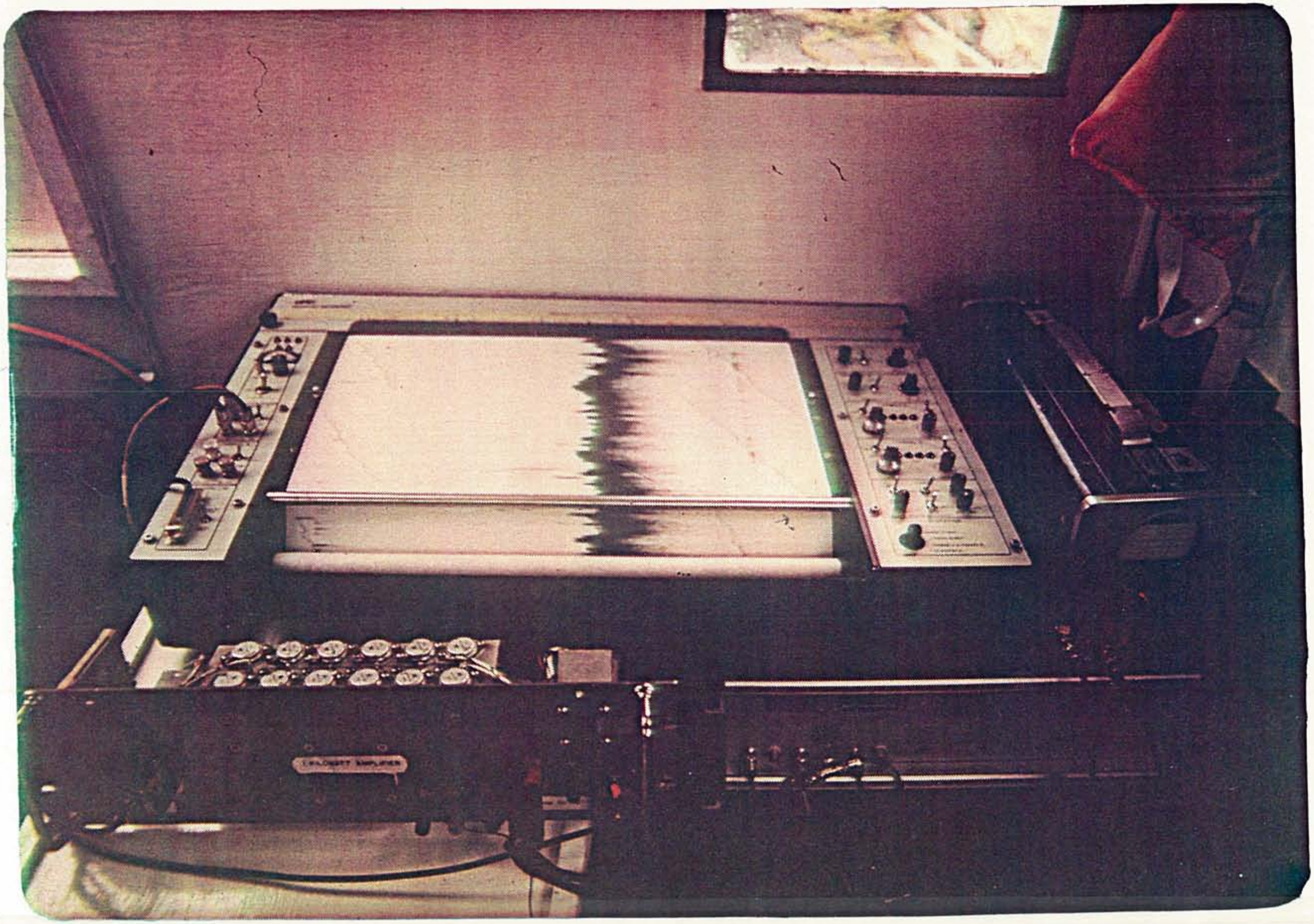


Fig. 2. EPC recorder and 400 kHz system inside the wheelhouse of the survey vessel.

amplifiers at all gain settings, 3) excellent noise figure, 4) receiver outputs at the operating frequency, 8 kHz (for tape recording) and a detected output (for input to signal processing instruments), 5) transmit power variable from 50 to 500 W in 3 dB steps, 6) an internal calibration circuit with internal level adjustment, front panel selectable levels and continuous or pulsed wave operations for monitoring through system operating condition as well as functioning as a signal generator for testing signal processing and data storage instruments, 7) selectable trigger interval from 0.1 to 99.9 sec in 0.1 sec steps, 8) selectable transmit pulse length from 0.1 to 9.9 msec in 0.1 msec steps and a X10 function switch, 9) selectable receiver bandwidths of 10, 5, 2, and 1 kHz to permit matching bandwidth to transmit pulse length or to aid in ambient noise reduction, 10) receiver gain variable over a 42 dB range in 6 dB steps in addition to internal amplifier gain adjustments.

The system chart recorder functioned as the primary non-human signal processing instrument used for the study. Acoustic returns were displayed on paper as they were received. The major function of the chart recorder was to output echo returns in a form that could be stored and be viewed later. All the data presented in this report were taken from echograms, the output of the chart recorder. The chart recorder used was an EPC 3200. This recorder was chosen because it is very flexible and because the chart marking threshold can be accurately set, a very important feature since the chart marking threshold is one of the most important thresholds affecting fish detection. The EPC 3200 is characterized by a very large paper size (19.2 in) and by an internal analog to digital converter. Because of the digital nature of the intermediate signal conditioning stages the acoustic returns could be scaled without distortion to use the full chart, which greatly enhances fish detection. The equipment settings during the study are detailed in Table 2. This system was used for surveys from June 26-July 3.

Table 2. Settings of primary acoustic system.

Receiver gain	12 dB (soon set to 0 and held)
Pulse length	.4 ms
TVG	20 log R, freshwater α
Blanking distance	.5 to 1.5
Repetition rate	.2 (5/sec)
Total range	12 m
Multiplexer switching	1500 pings
Chart recorder speed	1/32
Chart recorder gain	10.0 (maximum)
Chart recorder threshold	- minimum
Calibration gain	- 40 dB (receiver gain = 24 dB)
Calibration separation	4 m
Power	500 watts
Transducer	22^{o} WA15 mounted in towing fin

The second system was a 70 kHz Simrad EY. This system was deployed for surveys the first two days, June 24-25, then was used in conjunction with a 400-ft transducer cable for the stationary deployment from June 28-30. The advantages of this system were simplicity, portability, and low power requirements. The major disadvantage was lack of resolution.

The surveys were conducted with a 26-ft commercial troller, "Little Lass," skippered by Lee Estabrook (Fig. 3). The transducer was mounted in a plywood towing vehicle and towed from the vessel's starboard trolling pole just under the surface (0.5-1 ft) about 10 ft off the side. Towing speed varied with tidal current, but averaged 3.5 nmi/hr.

The stationary system was deployed directly off the facility, south of the fish ladder and just inshore of the water intake for the saltwater holding ponds (Fig. 4). The transducer was mounted in a heavy wire basket oriented upward (Fig. 5). The echosounder was placed in the back of a station wagon parked within the facility by the fence near the water (Fig. 6).

Survey Design and Procedure

Initial surveys were focused on the area around the release site. A primary transect was established along the west (facility) side of the channel, 20-25 ft depth, extending from west of the smokestack on the south end to west of buoy 18 on the north (Fig. 7). A contrasting transect was run on the east side of the channel. A second area of effort was in the upper estuary. A single transect was run down the middle of the channel usually from the East Highway Bridge to the Highway 101 Bridge (Fig. 8). Additional sections of the estuary were surveyed on occasion including runs between the two major areas and between the release site and the Charleston boat basin. A complete

Fig. 3. Commercial troller, LITTLE LASS, used for the hydroacoustic surveys.

Fig. 4a. Location of uplooking transducer on beach during low tide, looking west.

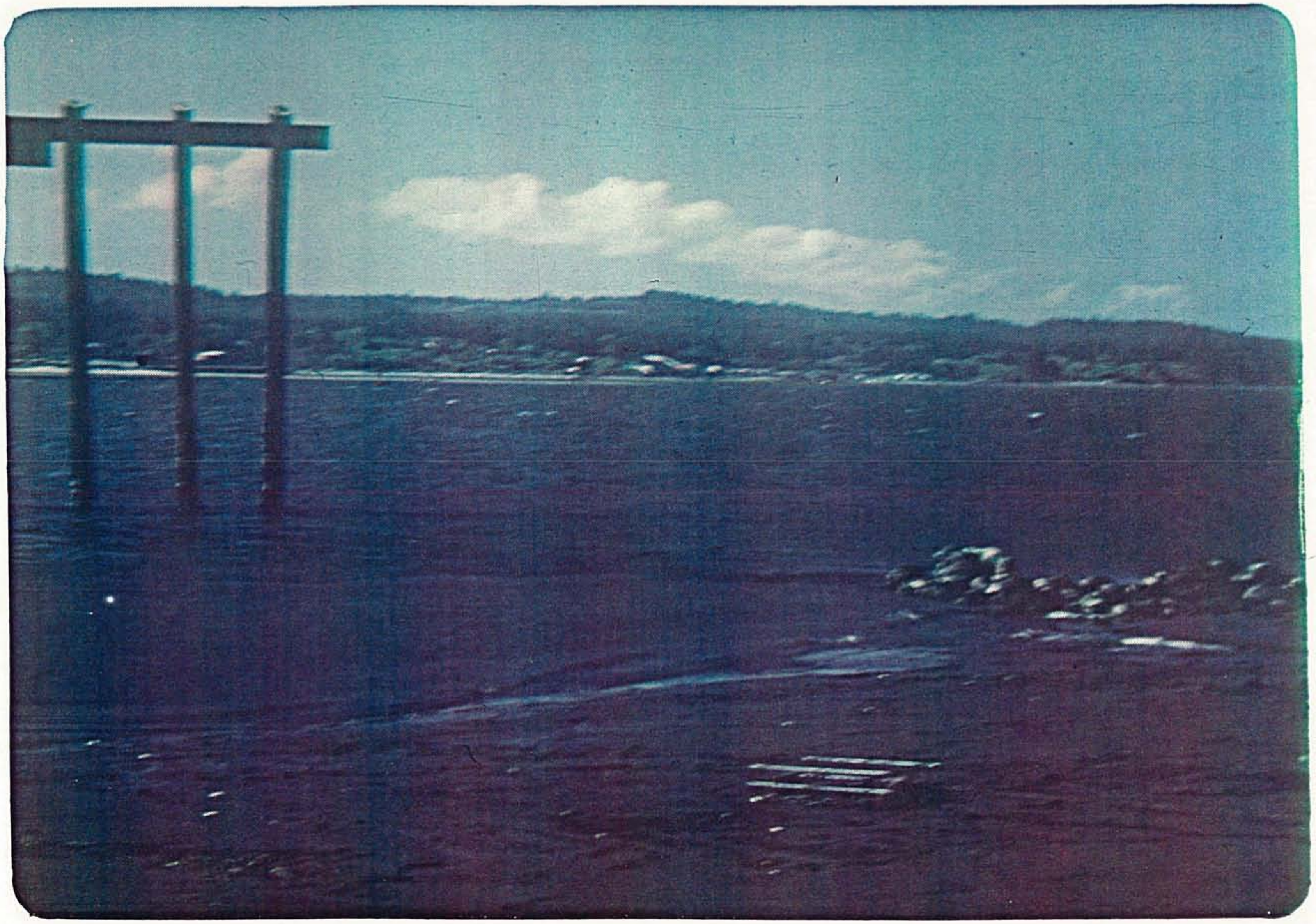


Fig. 4b. Location of uplooking transducer on beach during low tide, looking east.

Fig. 5. Uplooking transducer mounted on bottom in wire basket.

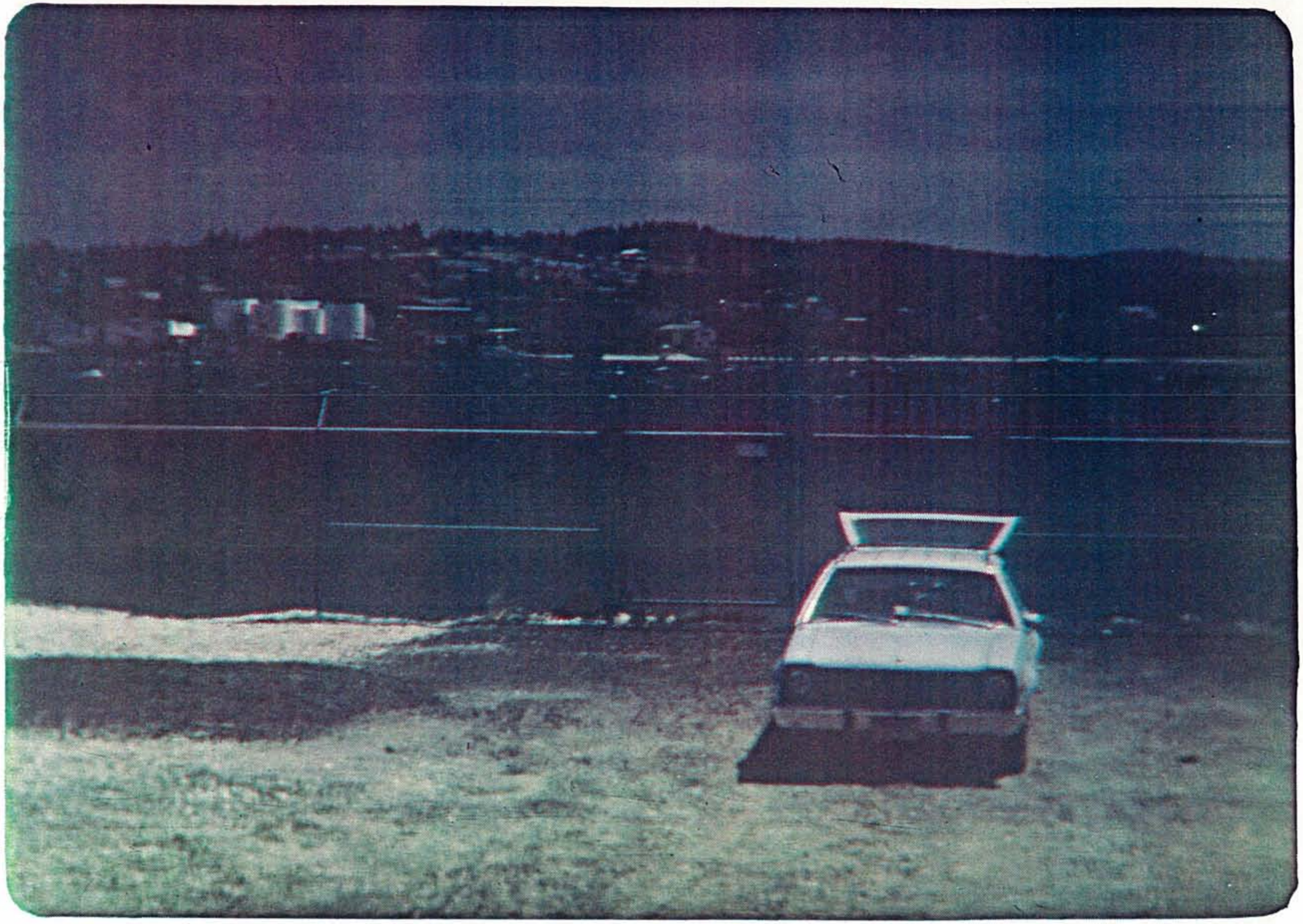


Figure 6a. Station wagon with echosounding equipment for uplooking deployment.

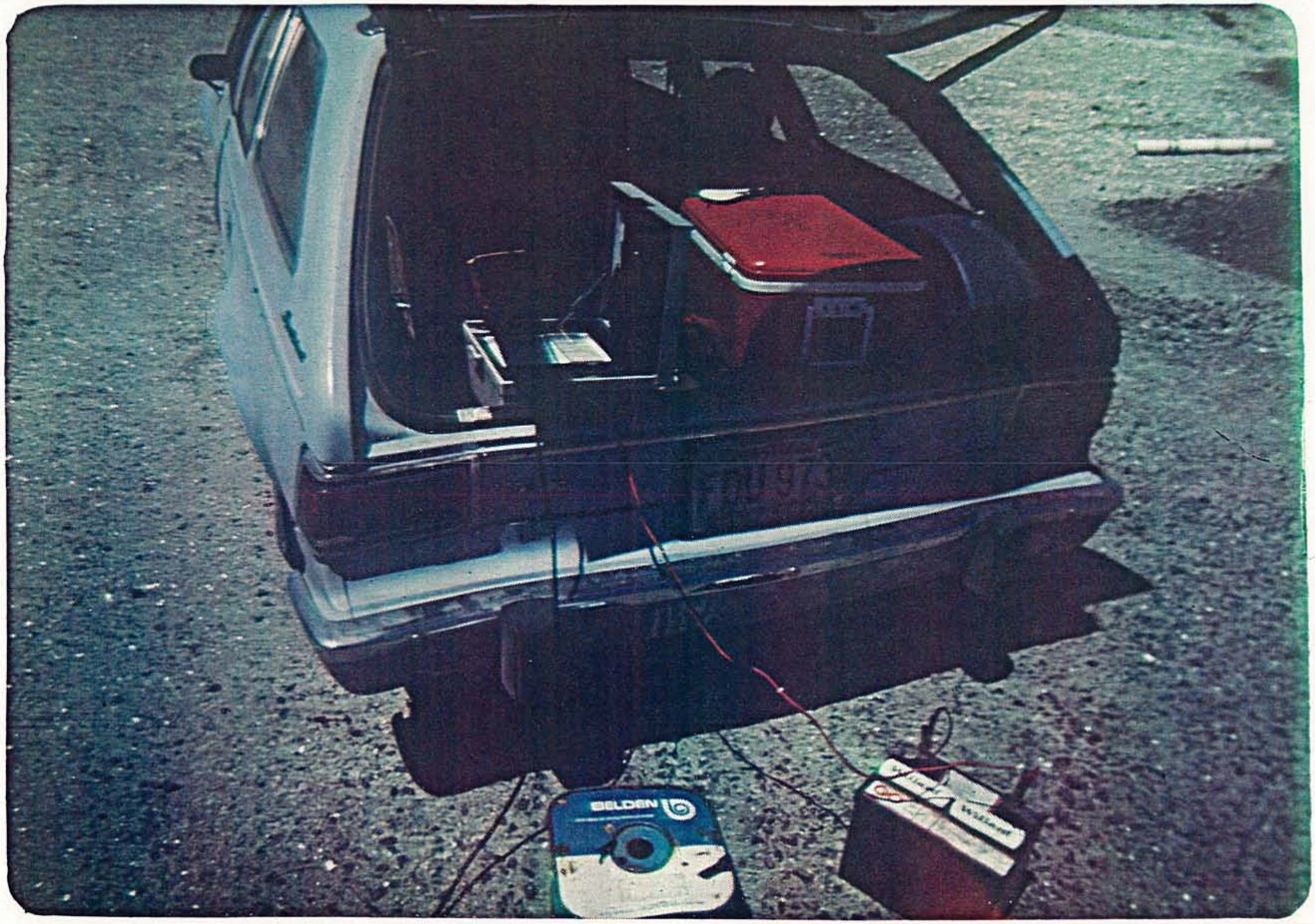


Fig. 6b. Echosounding equipment in station wagon.

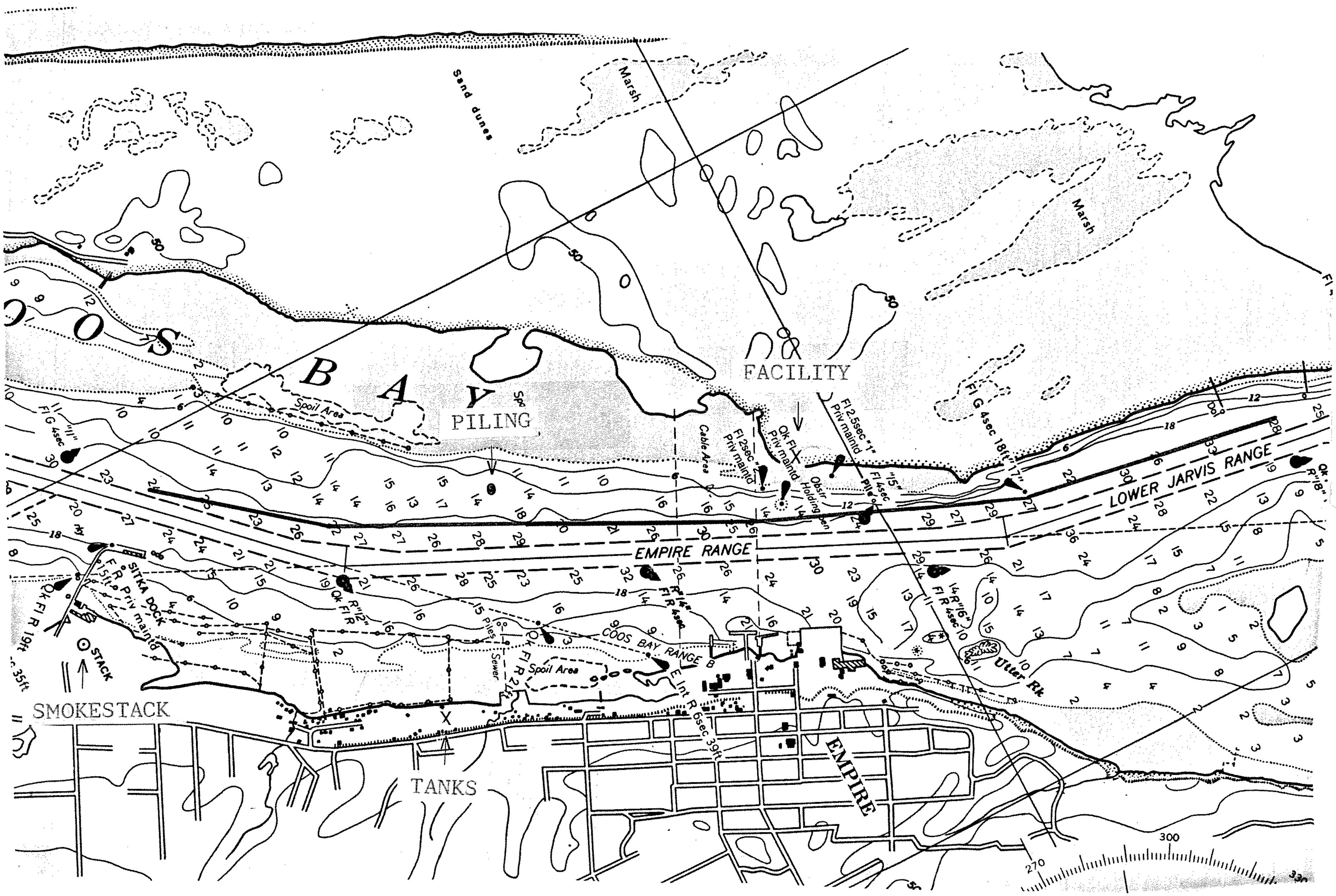


Figure 7. Lower Coos Bay estuary showing location of the primary transect by the facility.

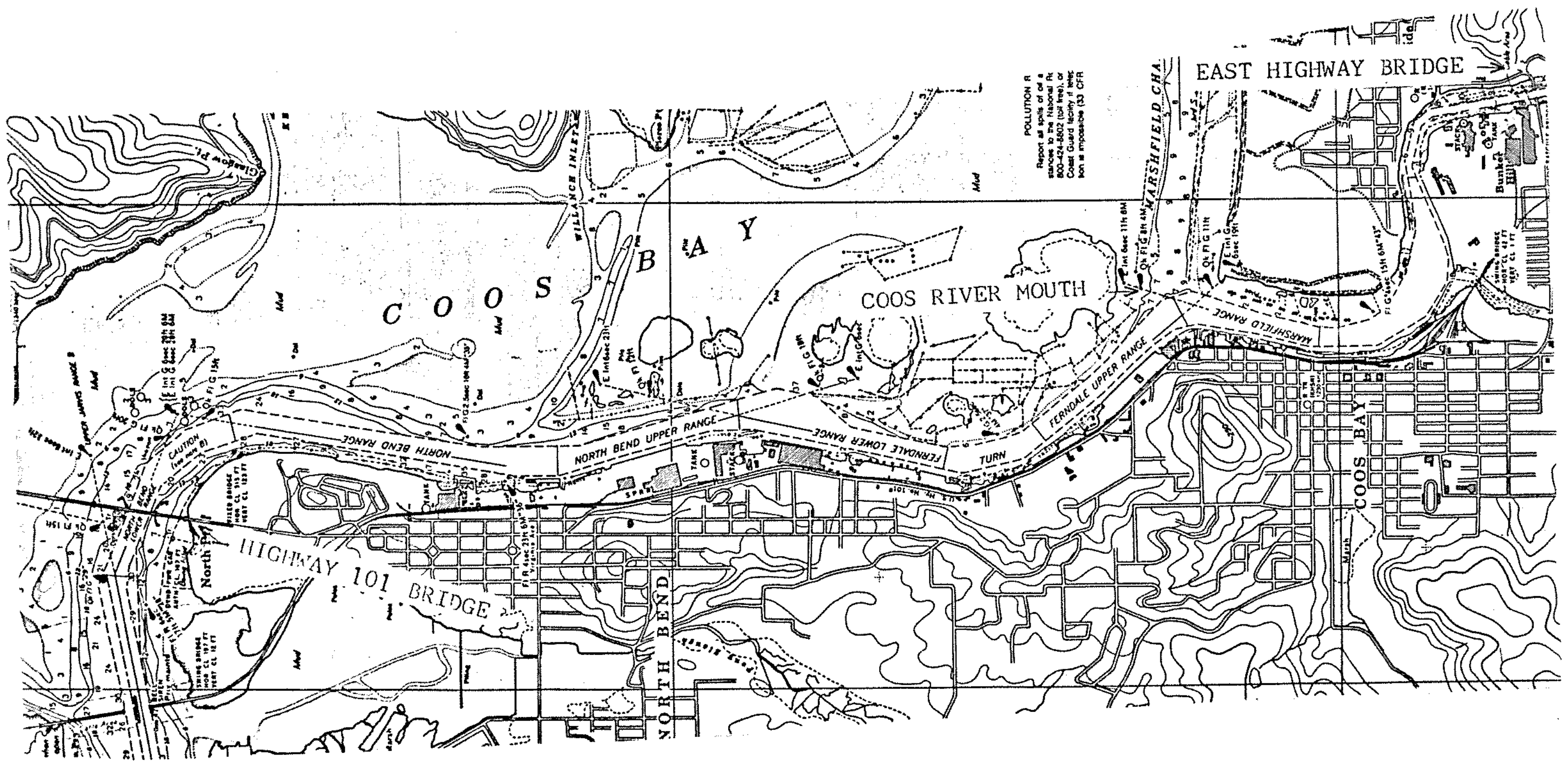


Figure 8. Upper Coos Bay estuary showing location of the primary transect in this area.

listing of all locations and times of transects is given in Appendix Table 1. Surveys were primarily conducted at night and concentrated around high slack tide. This timing was governed mostly by the timing of the releases, which are usually made just after dark to minimize predation from birds, and preferably just before ebb tide to take advantage of outgoing currents. In addition, fish are usually more accessible to hydroacoustic gear at night (Thorne and Dawson 1974) and high slack was optimal for transecting purposes because of maximum depth and minimum current. The characteristics of the tidal regime during the study period are given in Table 3.

Table 3. Uncorrected tide tables for study period. Corrections are + 5 mm for Coos Bay entrance, + 45 mm for Empire, + 90 mm for Coos Bay.

Date	Time	Height	Date	Time	Height
June 24	0436	0.4	June 29	0037	6.9
	1054	4.1		0755	-1.3
	1531	2.2		1439	5.0
	2209	6.3		1931	2.7
June 25	0518	-0.1	June 30	0119	6.8
	1147	4.3		0834	-1.3
	1636	2.4		1520	5.1
	2245	6.5		2021	2.7
June 26	0600	-0.5	July 1	0205	6.3
	1233	4.5		0916	-1.2
	1721	2.6		1600	6.3
	2320	6.7		2117	2.6
June 27	0638	-0.9	July 2	0252	6.3
	1319	4.7		1000	-0.9
	1803	2.6		1644	5.5
	2357	6.7		2217	2.4
June 28	0716	-1.1	July 3	0349	5.8
	1400	4.8		1045	-0.4
	1845	2.7			

RESULTS

June 24-25 Surveys

The initial run began at 2100 June 24 along the west side in front of the facility, beginning off the piling and ending by buoy 17 at 2120 (see Fig. 7). Moderate fish concentrations were seen on this run even though the June 24 release had not yet taken place. Tide was flooding, and the fish were mostly to the north (downcurrent) of the facility. It was still daylight at this time and the fish were mostly in midwater schools. Subsequent events were dynamic as both release and natural fish dispersion occurred with dark. Densities appeared to increase considerably and showed strong correlation with the location of the release facility, low densities upcurrent and high densities extending downcurrent at least to buoy 18 (Fig. 9). The location of this concentration changed with the tide, as illustrated by the run from the piling to buoy 18 from 2374-2378 after the current reversal (Fig. 10). With increasing ebb tide the concentration of fish moved further downcurrent past the facility (Fig. 11) and also dispersed until it was difficult to locate any center of abundance during the last run, which ended off the piling at 0137.

June 25 Surveys

The results observed during the June 25 surveys were similar. The first run was made along the primary transect from opposite the smokestack to opposite buoy 18 from 2001-2030. Conditions were daylight and flood tide, and the fish were located mostly in schools in the lower half of the water column and downcurrent from the facility (Fig. 12). This trend continued after dark, when the schools broke up and the fish dispersed throughout the water column. There was no release this night, and there appeared to be less fish in the area than the previous night. The final run from opposite buoy 18 to near buoy 11, 2220-2307,

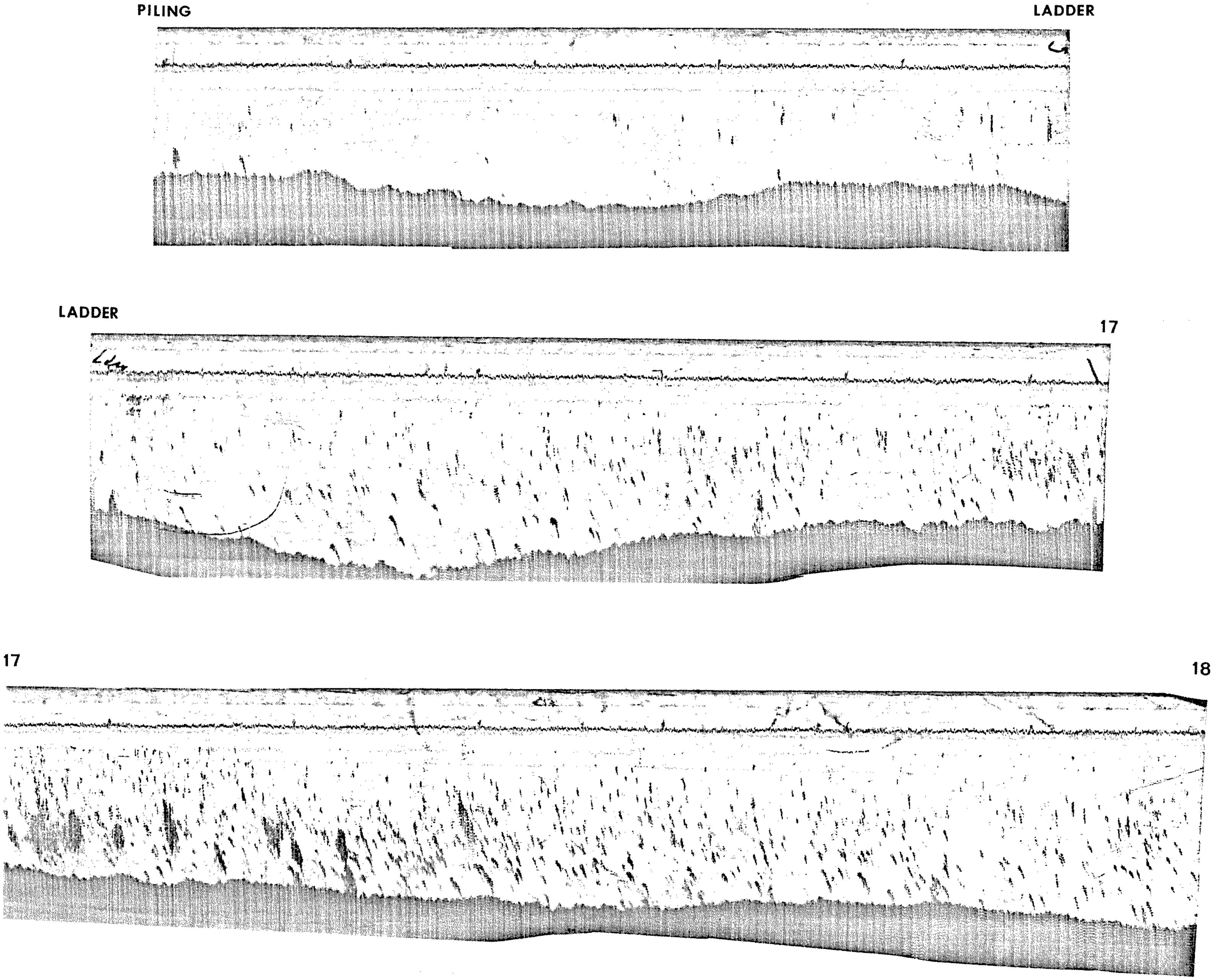


Figure 9. Echograms from primary transect, 2218-2242 June 24, showing concentration of fish down current of the facility.

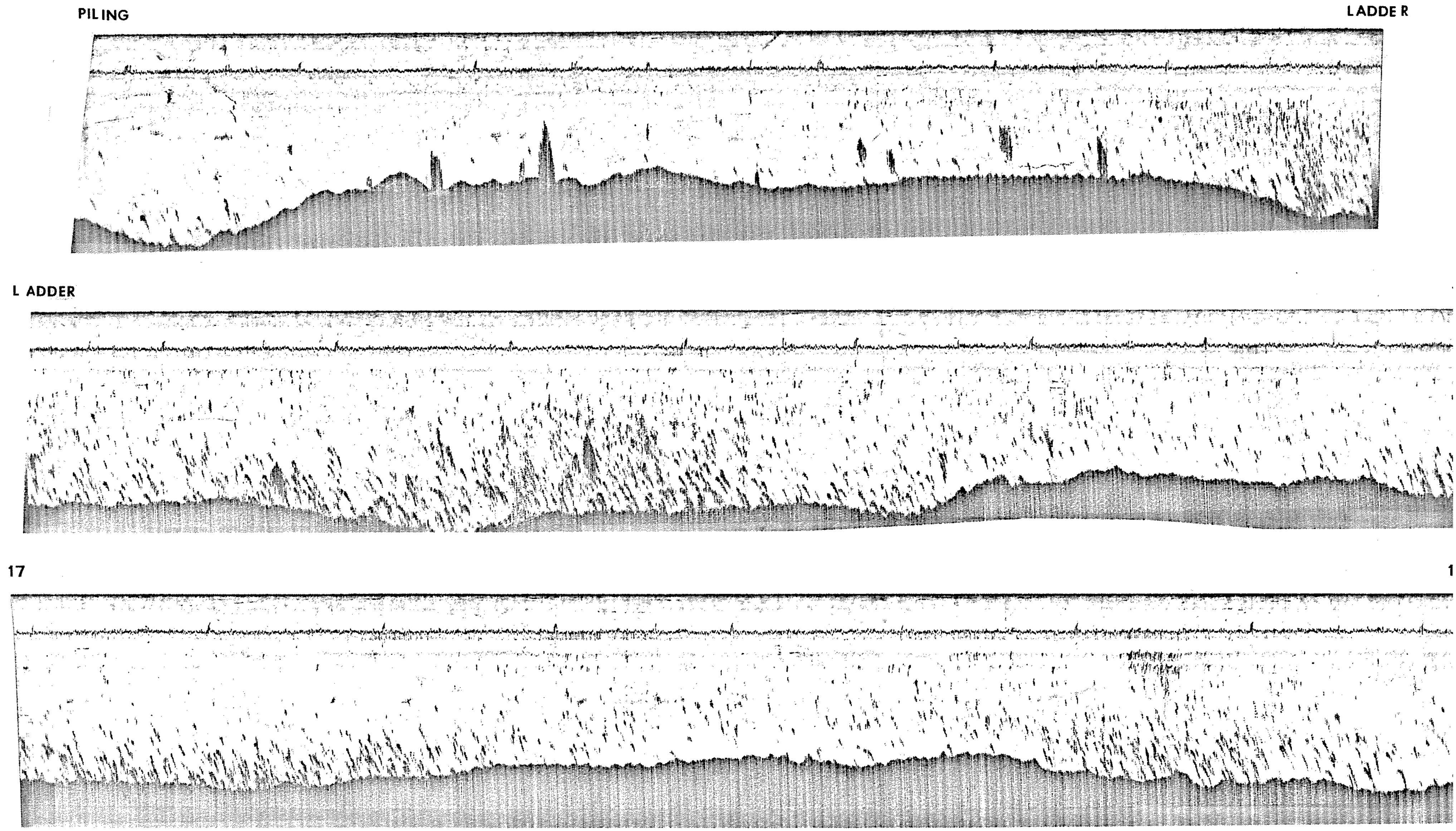


Figure 10. Echograms from primary transect, 2314-2348 June 24, showing shift in location of fish concentration with changing tide.

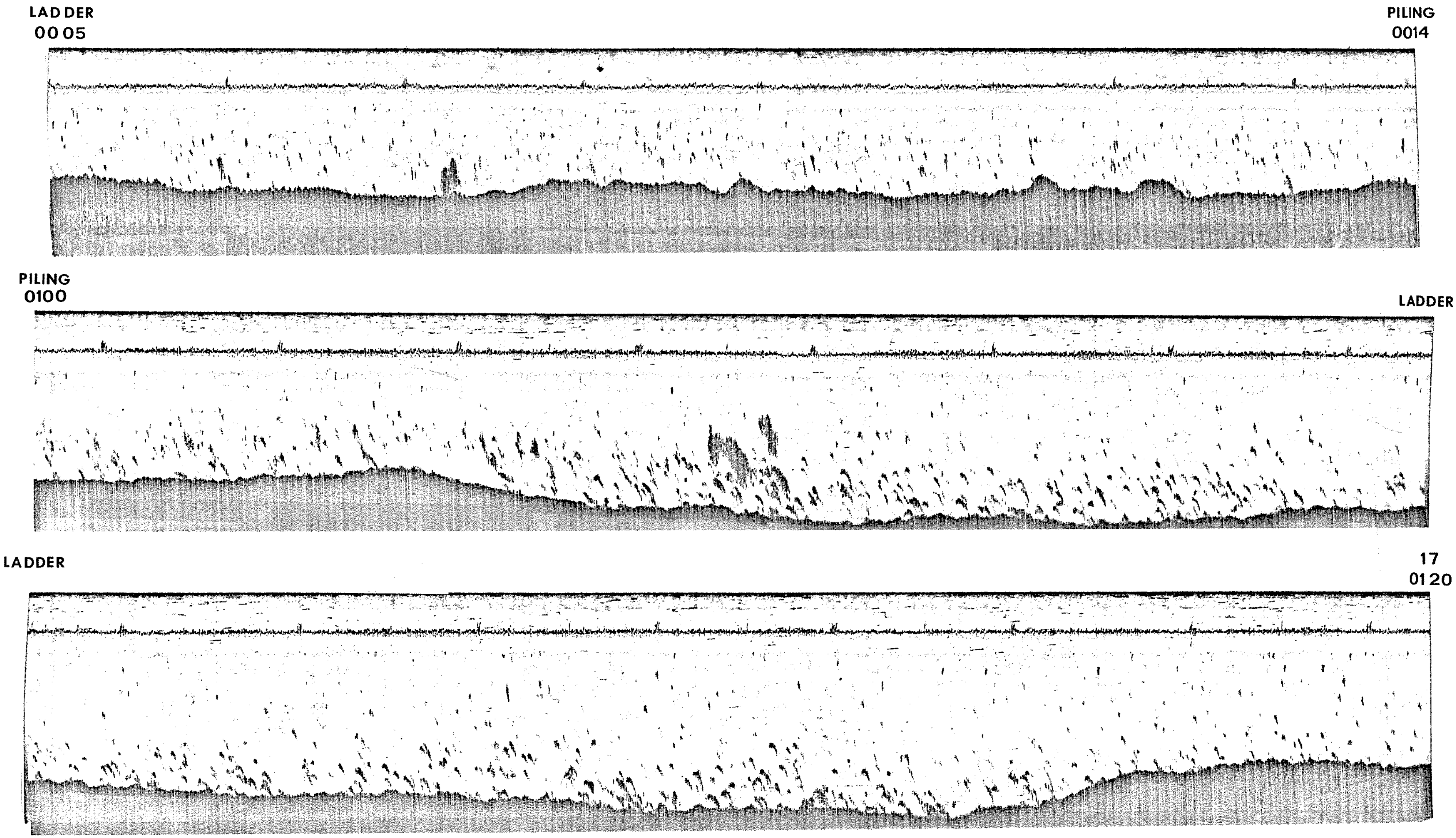


Figure 11. Echograms from primary transect, 0005-0120 June 24, showing continued shift of fish location with tide.

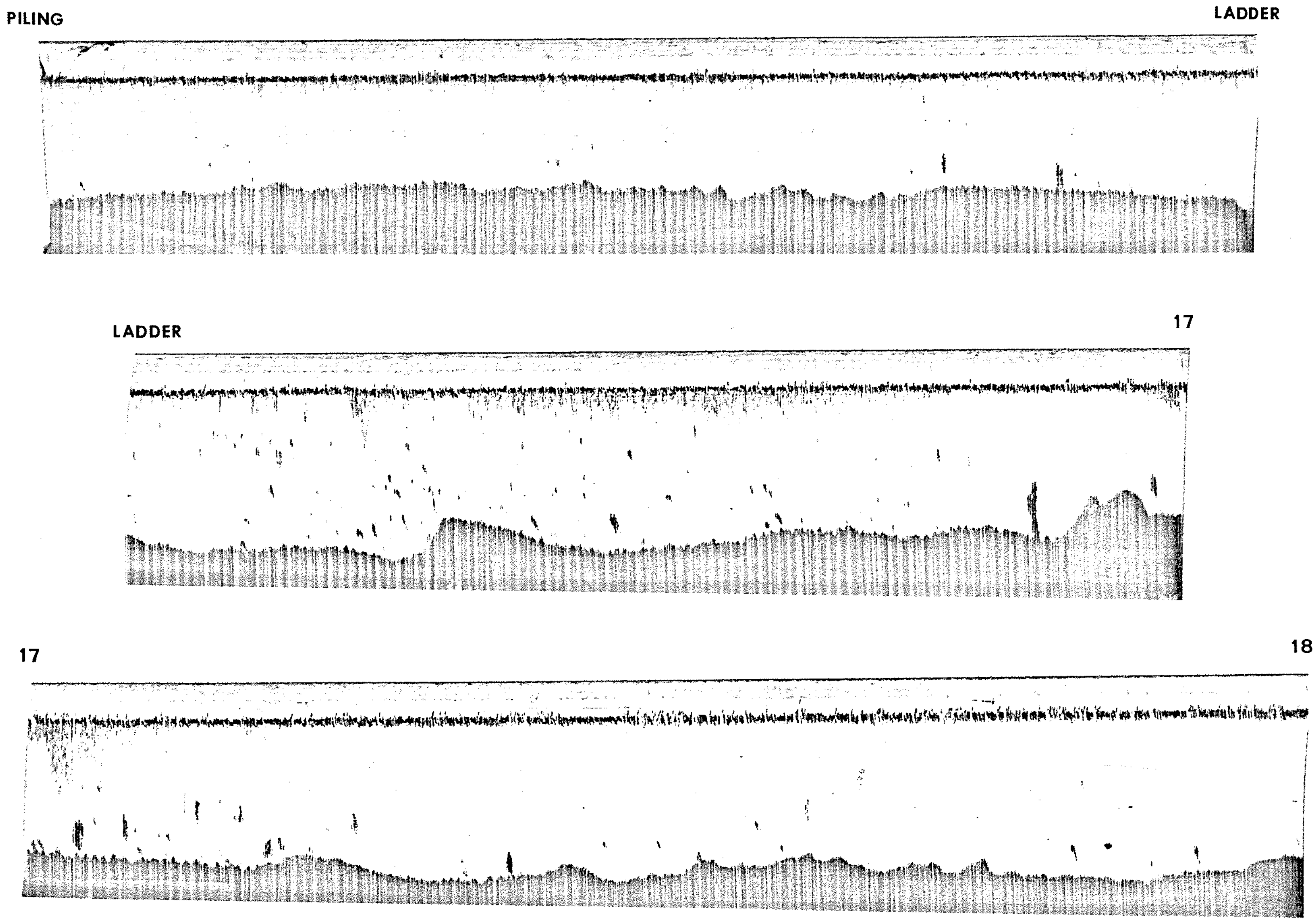


Figure 12. Echograms from primary transect, 2010-2030 June 25, showing concentration of fish down current of facility during daylight.

was made just before high slack tide and illustrates the contrast in fish distribution up and down current of the facility (Fig. 13). The transect continued to the Charleston boat basin, but few fish were observed south of the facility.

June 26-27 Surveys

This third night was the first with the 420 kHz system and again focused on the distribution around the facility. A release of 333,000 fish took place from 0100 to 0130, June 27. The transecting began at 2254, June 26 with three runs along the primary transect line. Fish concentrations were again observed downcurrent of the facility prior to the release, with highest density between the facility and buoy 17 and low densities upcurrent (Fig. 14). Densities on the east side of the channel were generally low (Fig. 15). After tidal reversal the concentration shifted so that the heavy concentration was observed from buoy 15 to just south of the facility during the 0037 to 0100 run along the west side (Fig. 16). A continuation of this southerly shift was seen on the subsequent west side run from 0114 to 0151. The high and shifting abundance of fish obscured the effect of the fish release. Another run on the east side from 0218-0235 again showed low densities with some higher density patches on the southern end of the run off the tanks, possibly indicating a crossing of the channel by the fish with the ebb tide. A final run was made along the west side from off buoy 18 to buoy 8, 0254-0331. Fish were now very dispersed. No concentrations were located, and the lower part of the water column was obscured by echoes from sediments entrained by the strong tidal currents (Fig. 17).

June 28 Surveys

The third and last fish release was made the night of June 27, but no survey was made because of rough water and equipment problems. The

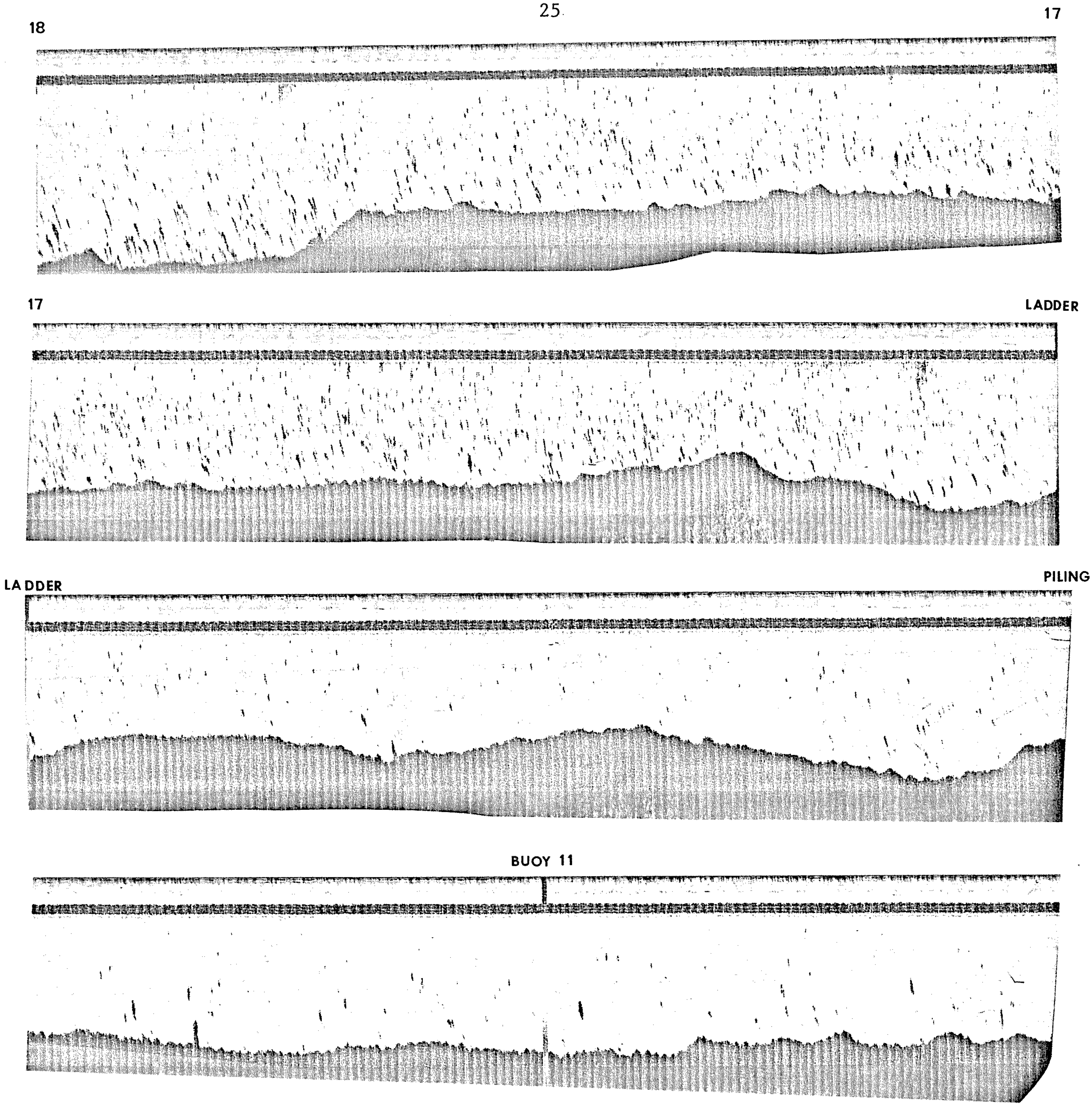


Figure 13. Echograms from primary transect 2220-2249 and near buoy 11, 2308-2317 June 25, showing associate of fish with location of facility.

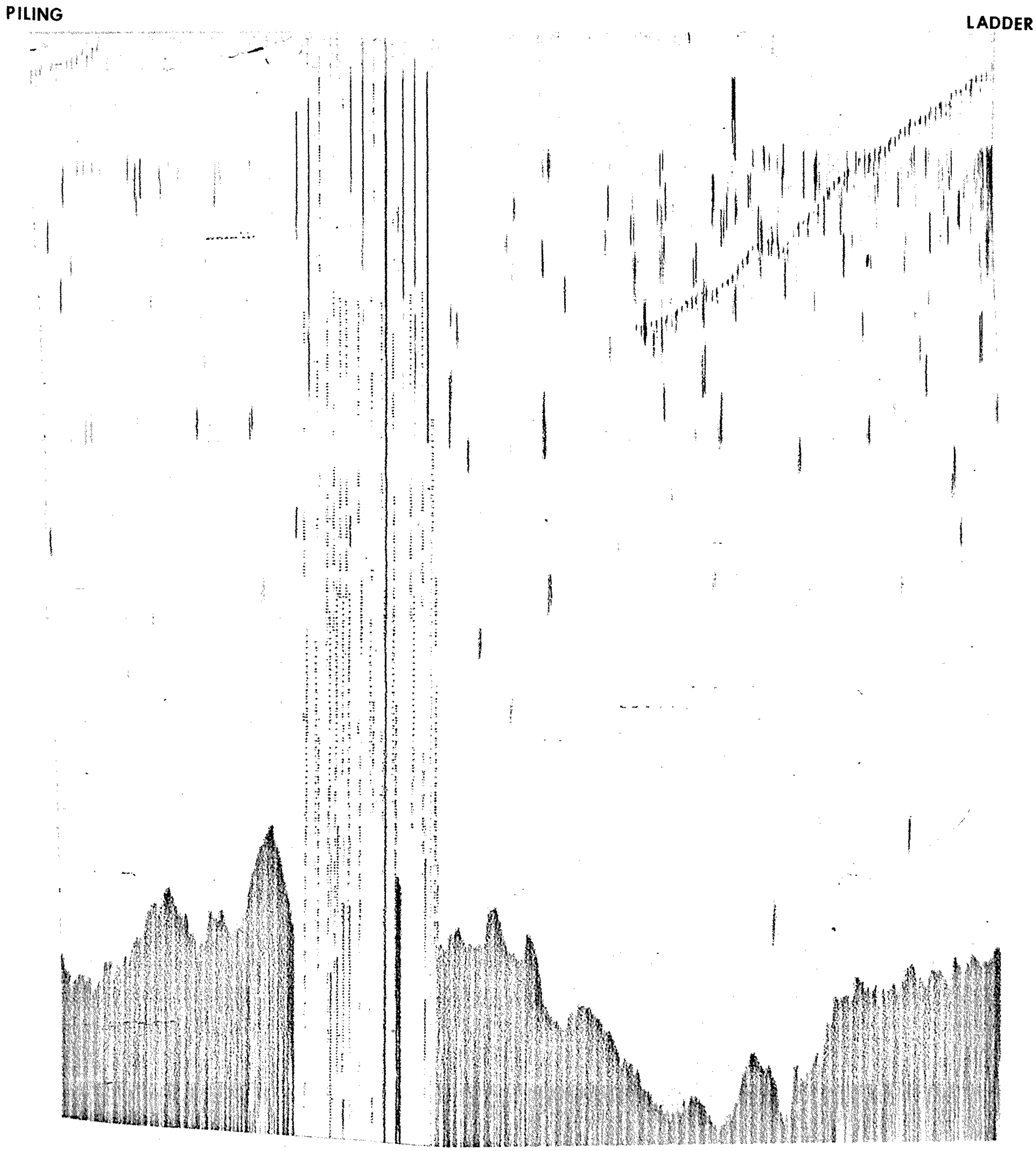


Figure 14a. Echogram from portion of primary transect immediately south (upcurrent) of facility, 2343-2350 June 26.

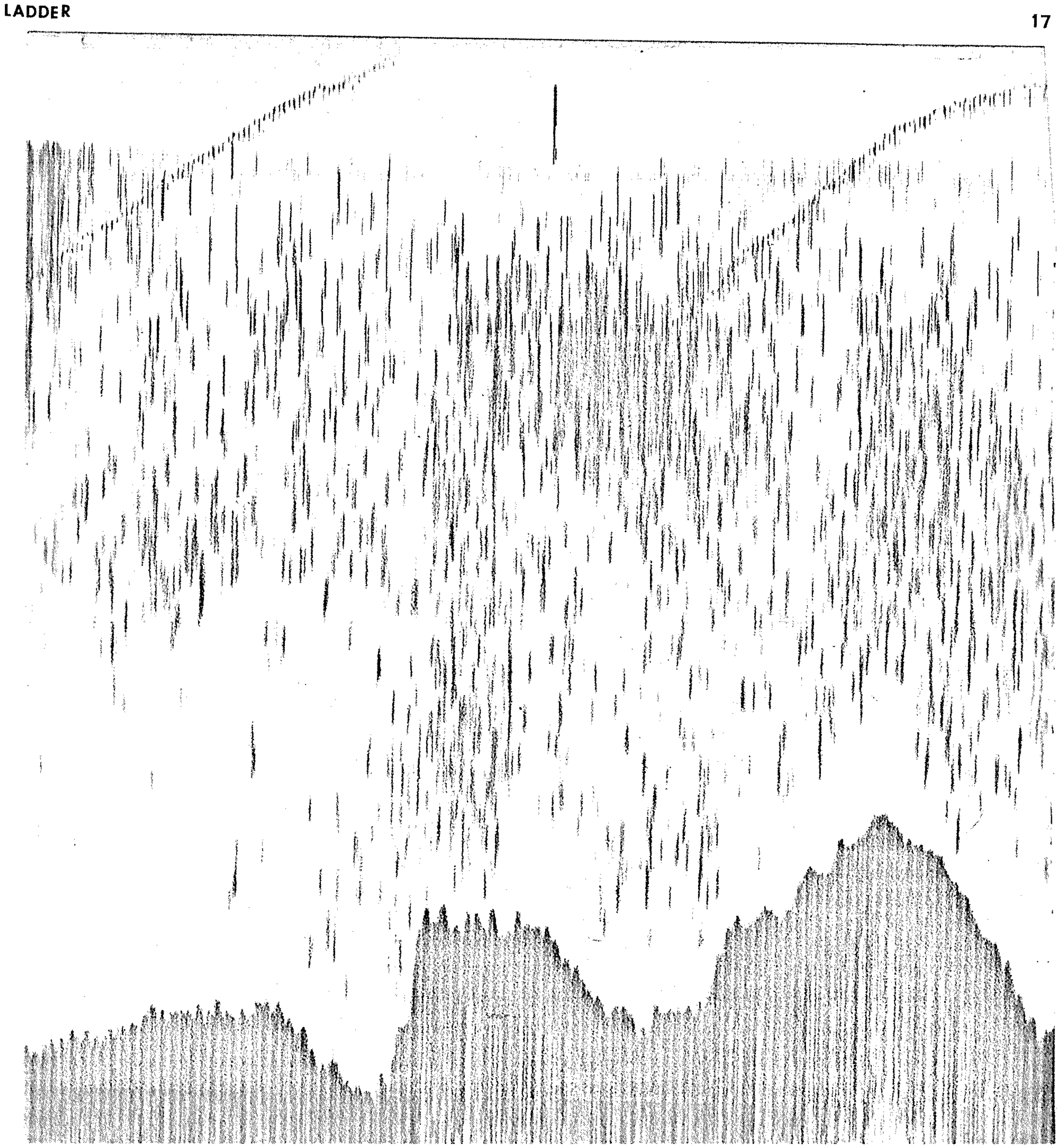


Figure 14b. Echogram from portion of the primary transect immediately north (down current) of the facility, 2350-2356 June 26.

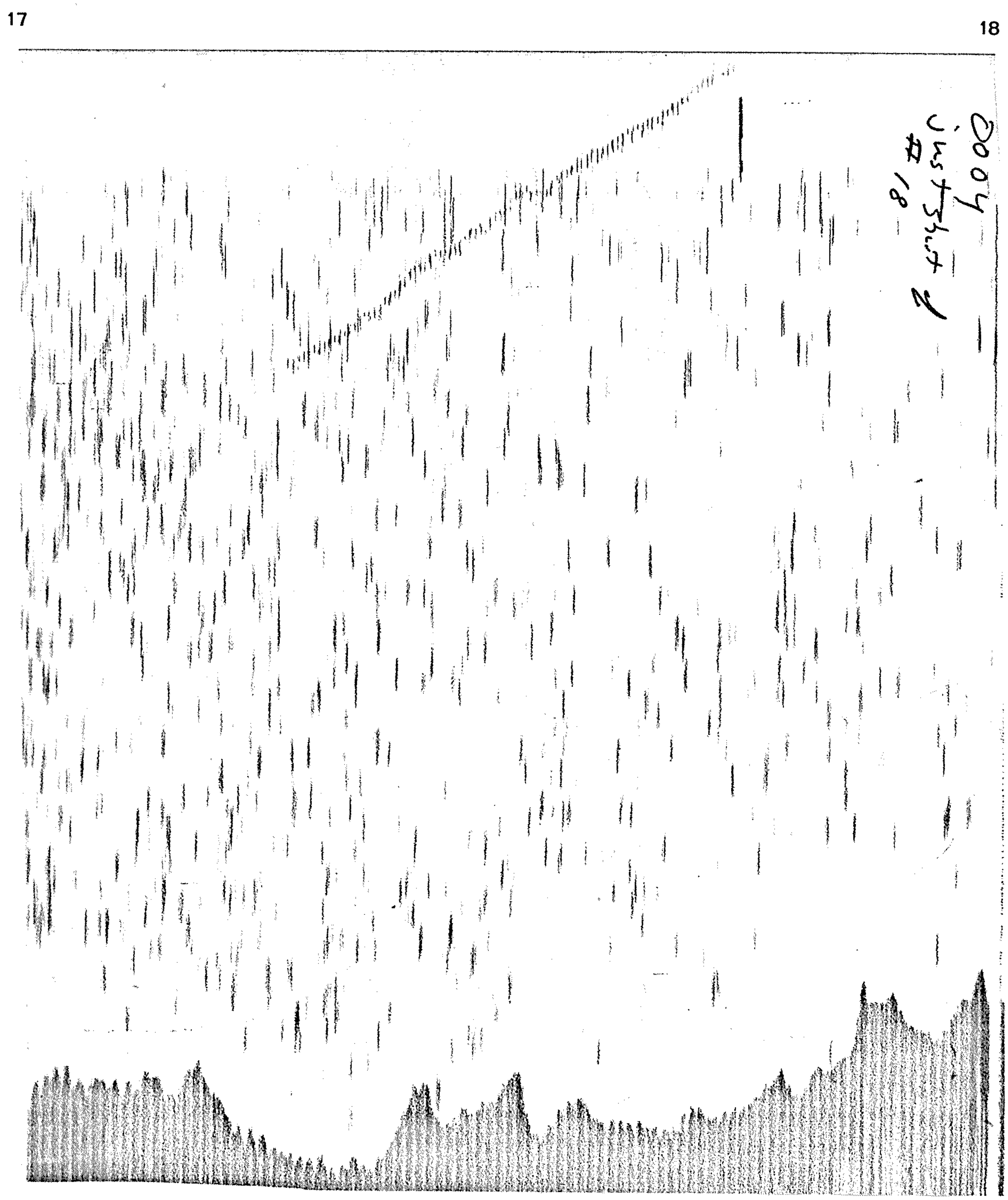


Figure 14c. Echogram from portion of primary transect between buoys 17 and 18, 2358-0004 June 26 and June 27.

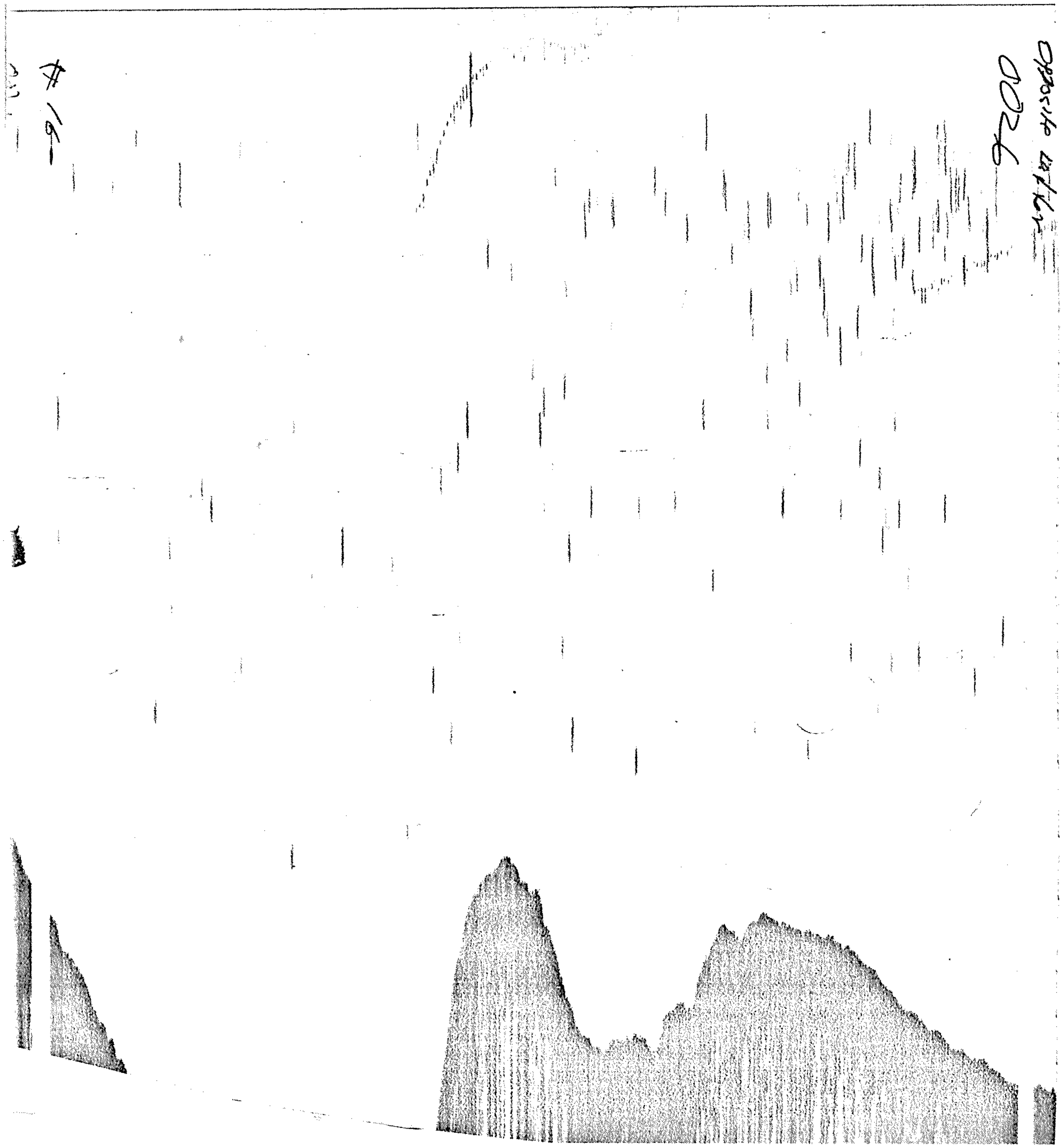


Figure 15a. Echogram from east side transect between buoy 16 and directly opposite the facility, 0021-0026 June 27.

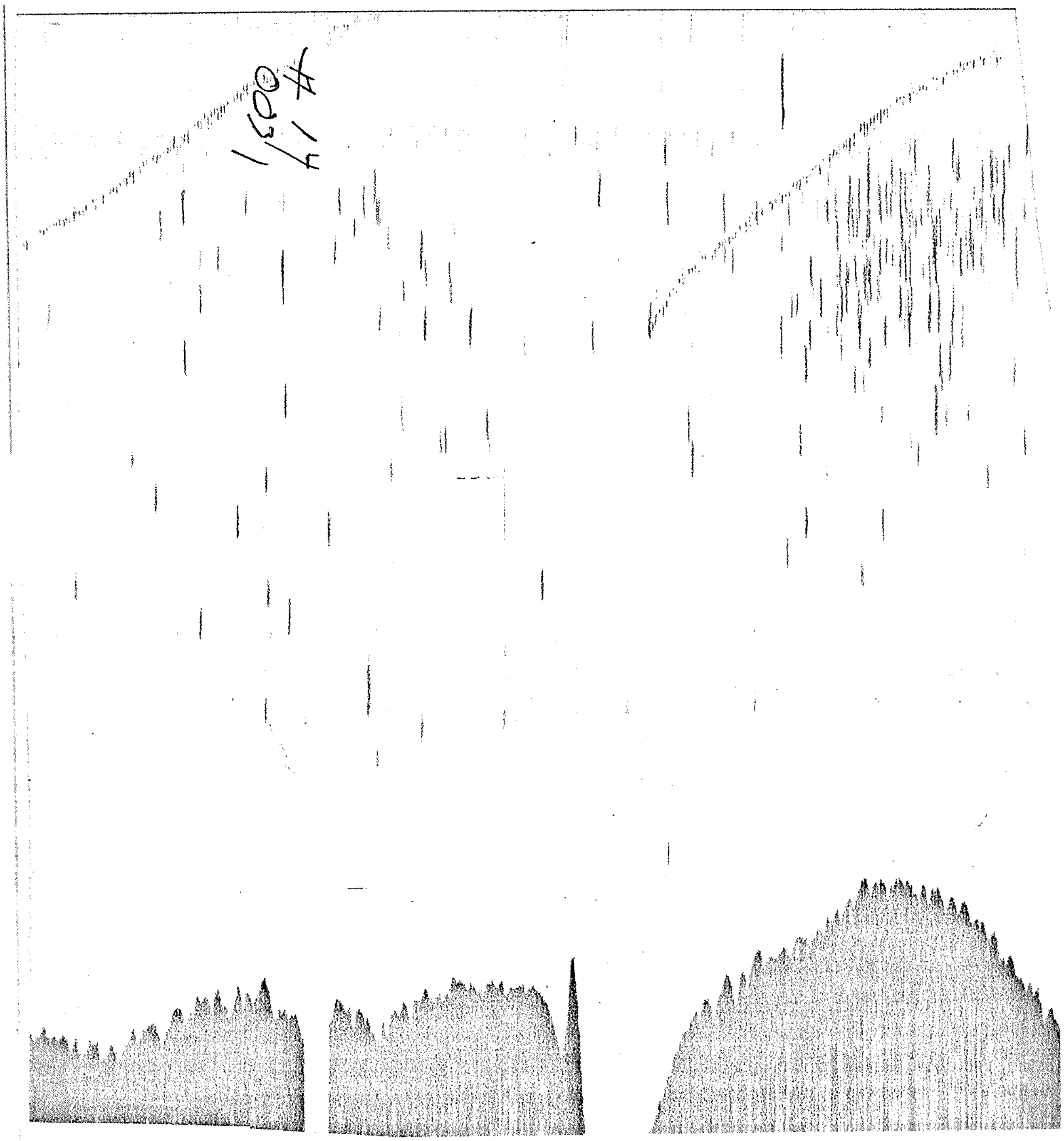


Figure 15b. Echogram from east side transect extending south from a point directly opposite to facility, 0029-0036 June 27.

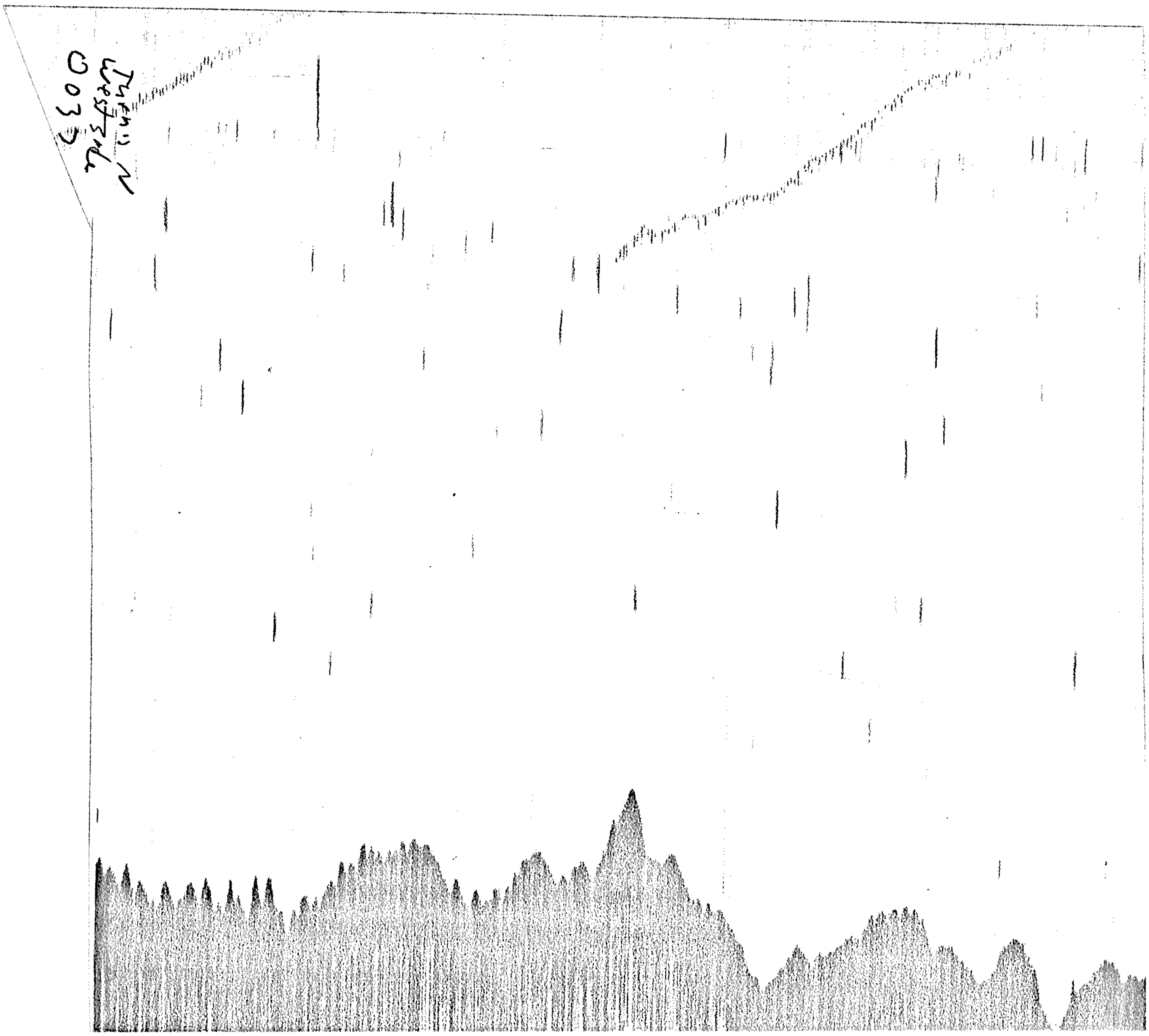


Figure 16a. Echogram from a portion of the primary transect, from opposite tanks to just south of the facility, 0037-0043 June 27.

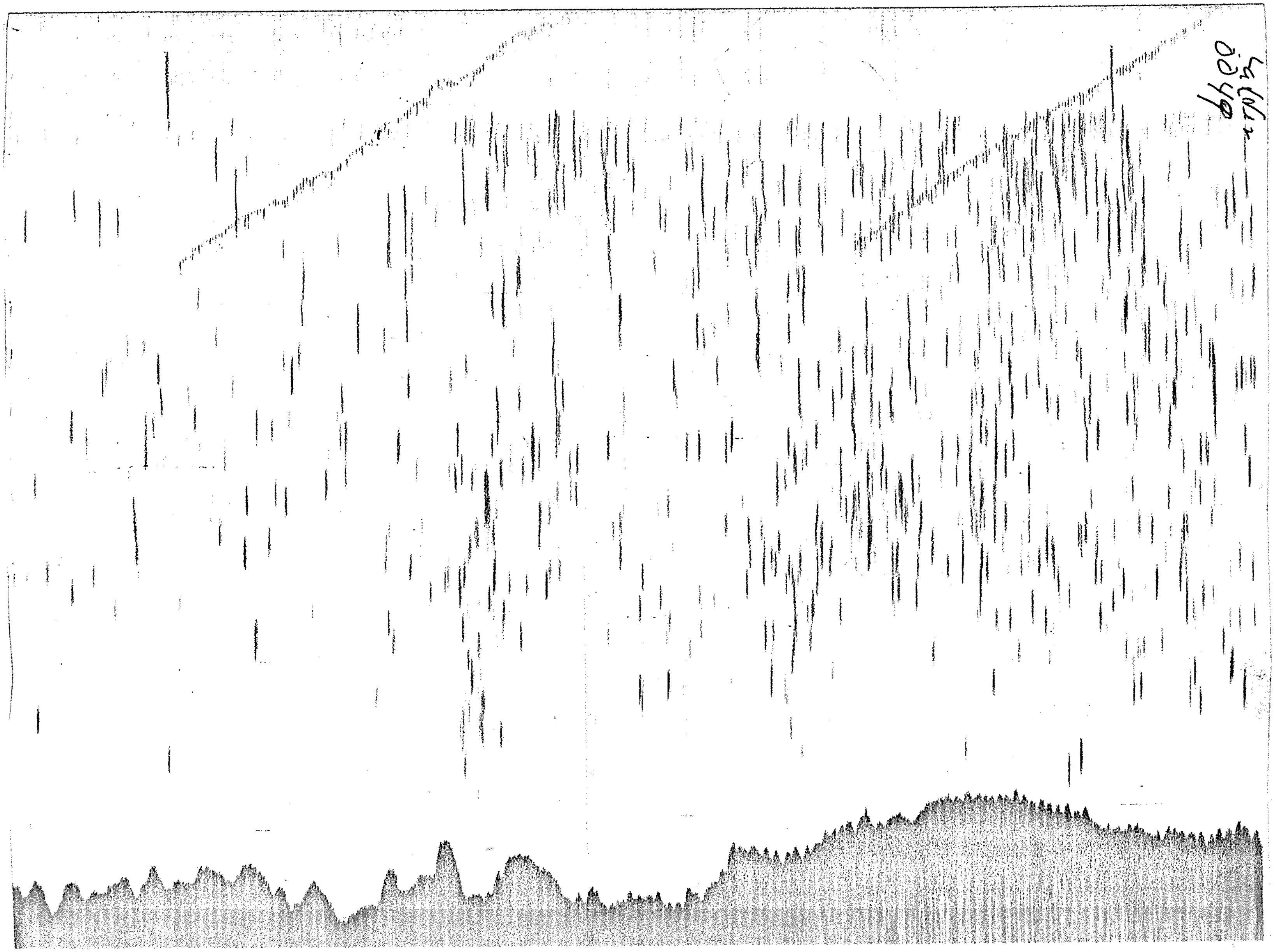


Figure 16b. Echogram from a portion of the primary transect, just south of the ladder, 0043-0049 June 27.

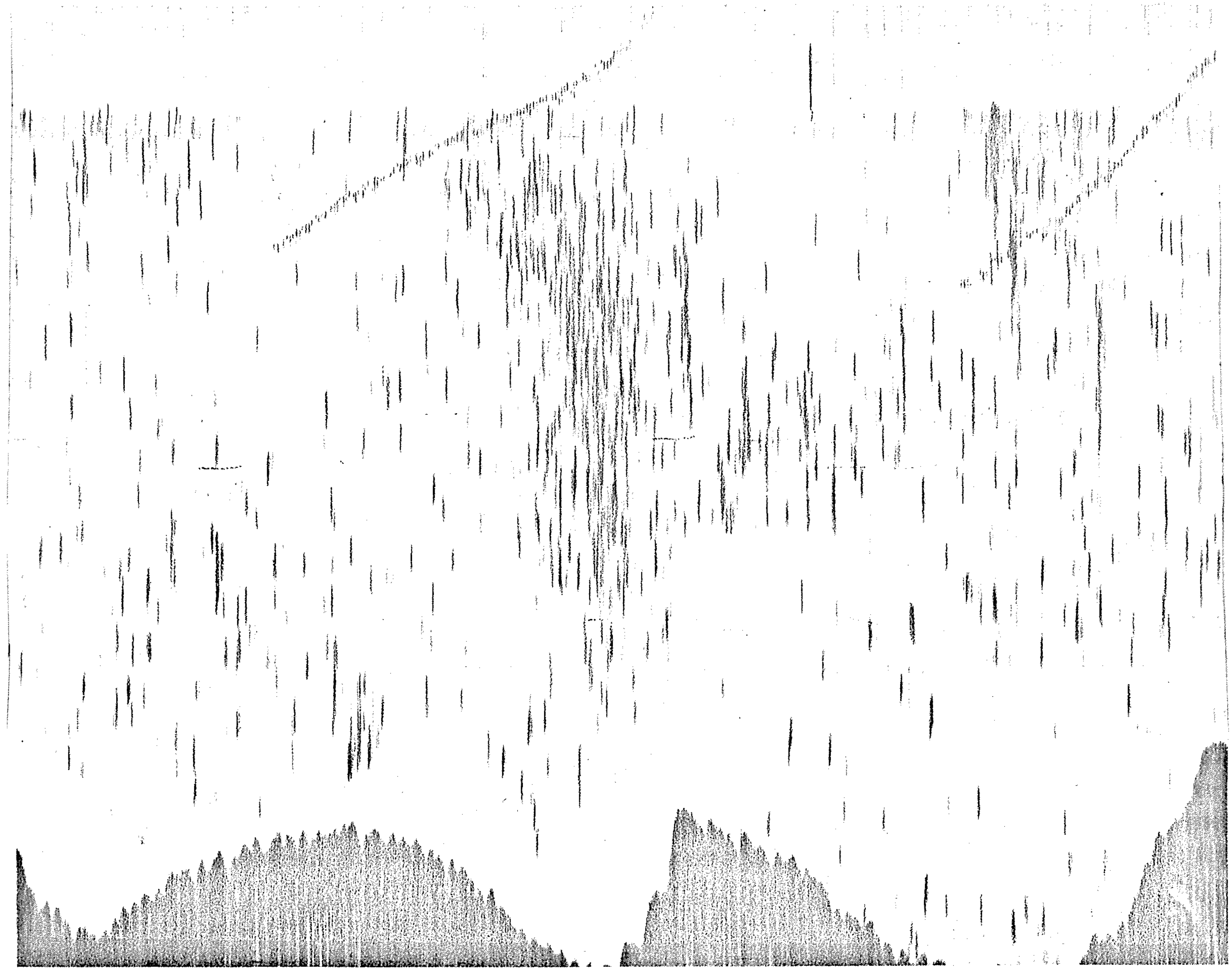


Figure 16c. Echogram from a portion of the primary transect, off the ladder to buoy 15, 0049-0055 June 27.

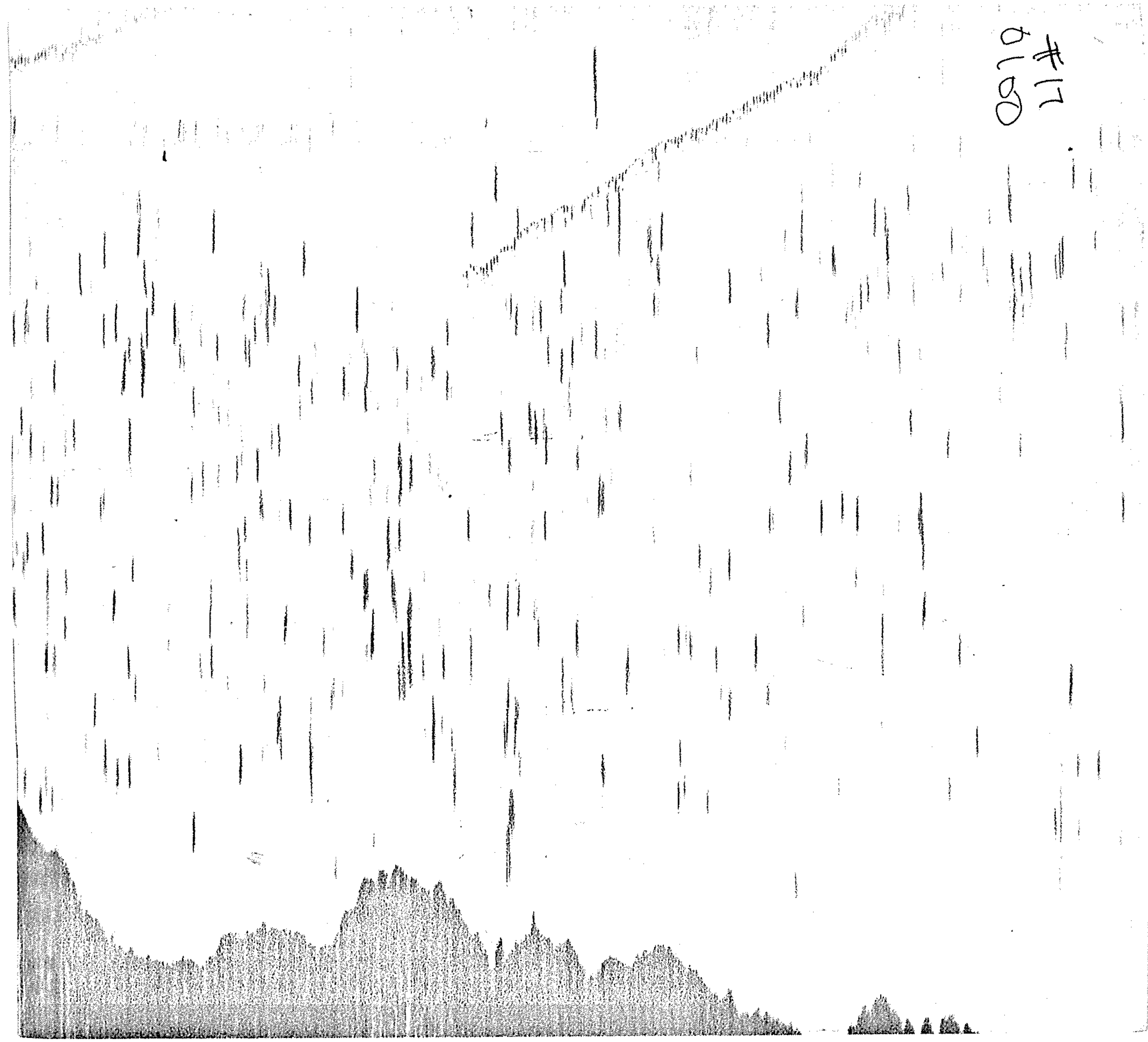


Figure 16d. Echogram from a portion of the primary transect, between buoys 15 and 17, 0055–0100 June 27.

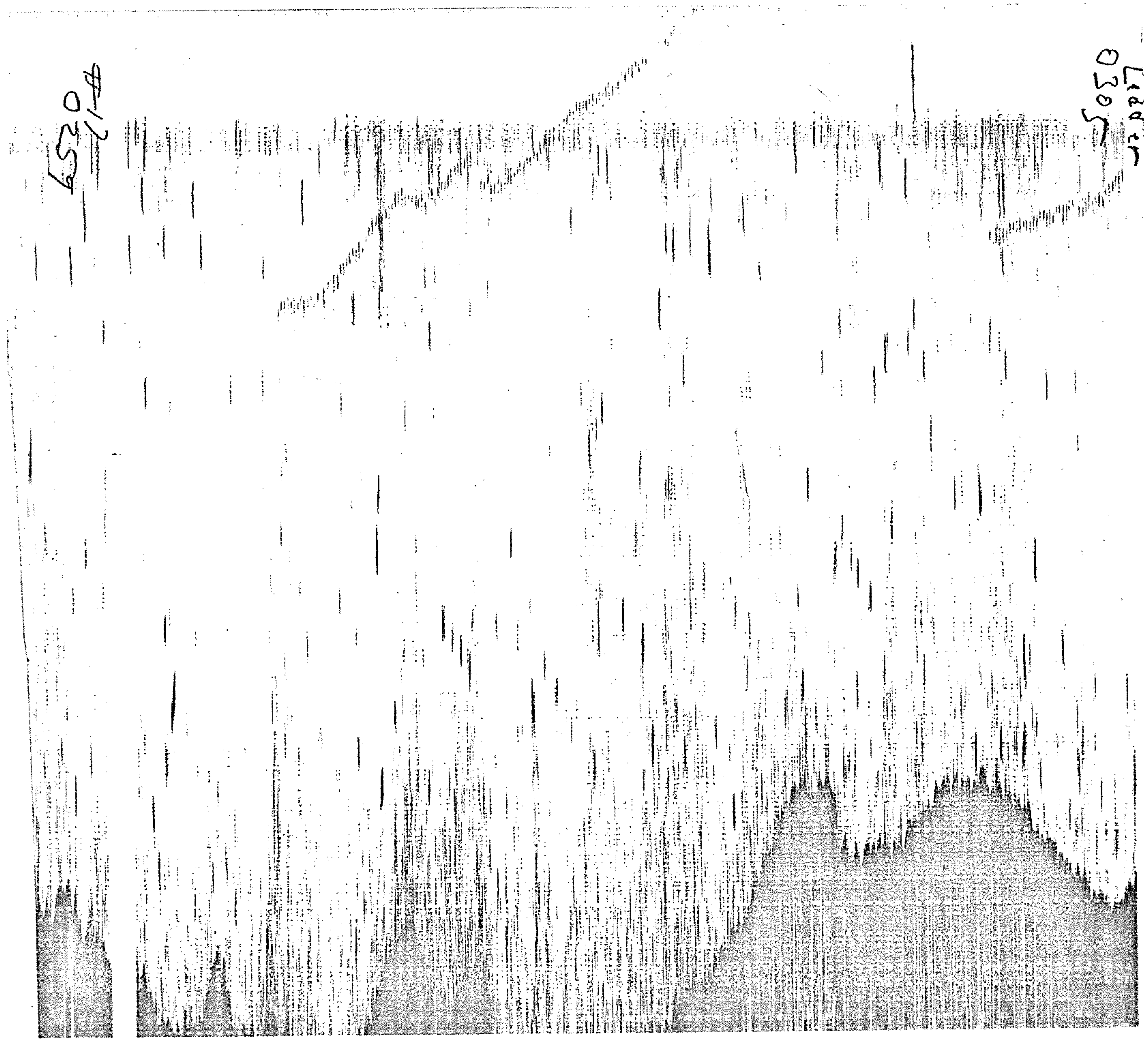


Figure 17a. Echogram from a portion of the final run, 0259-0305 June 27, between buoy 17 and the facility.

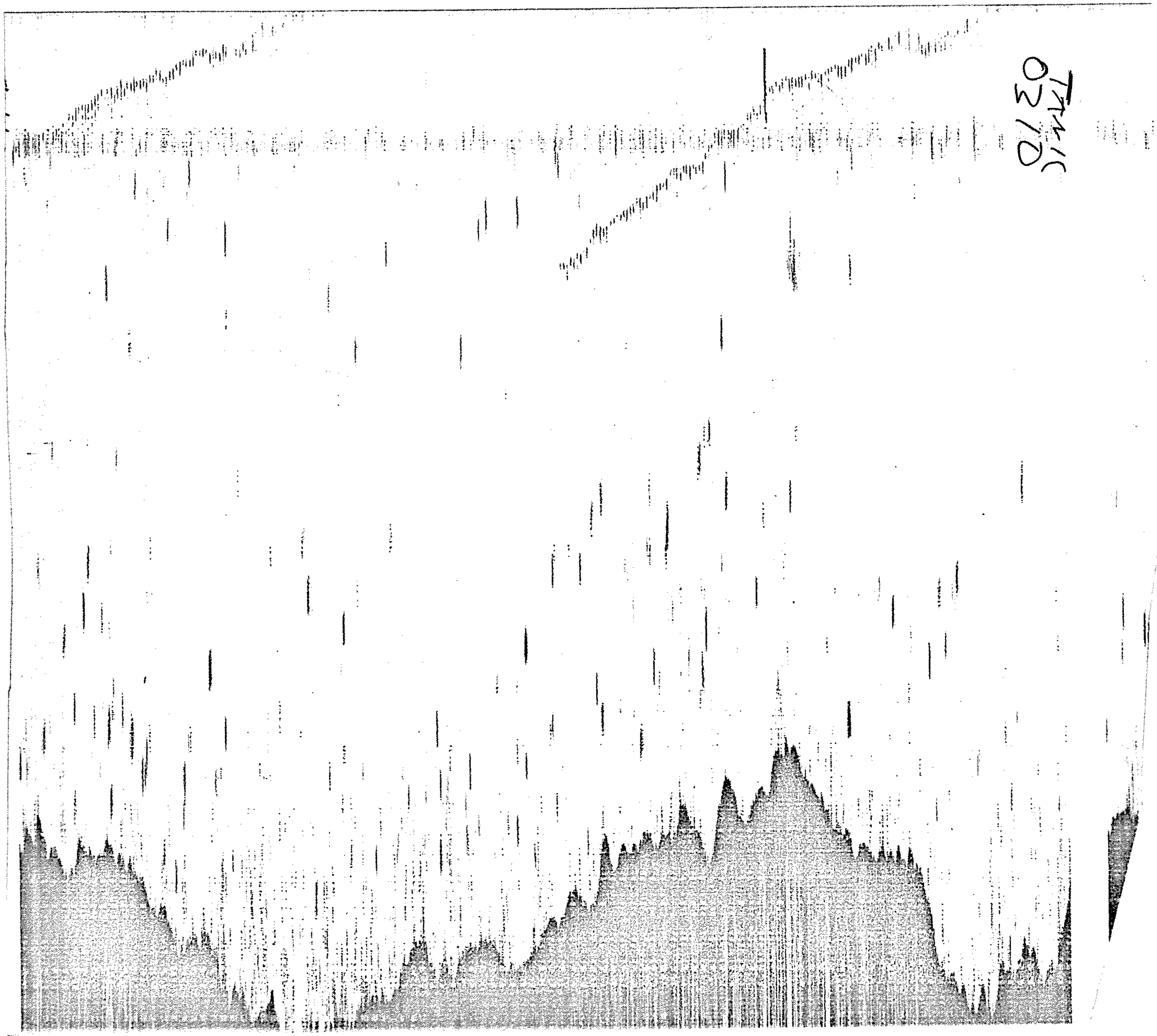


Figure 17b. Echogram from a portion of the final run, 0305-0310 June 27, between the facility and opposite the tanks.

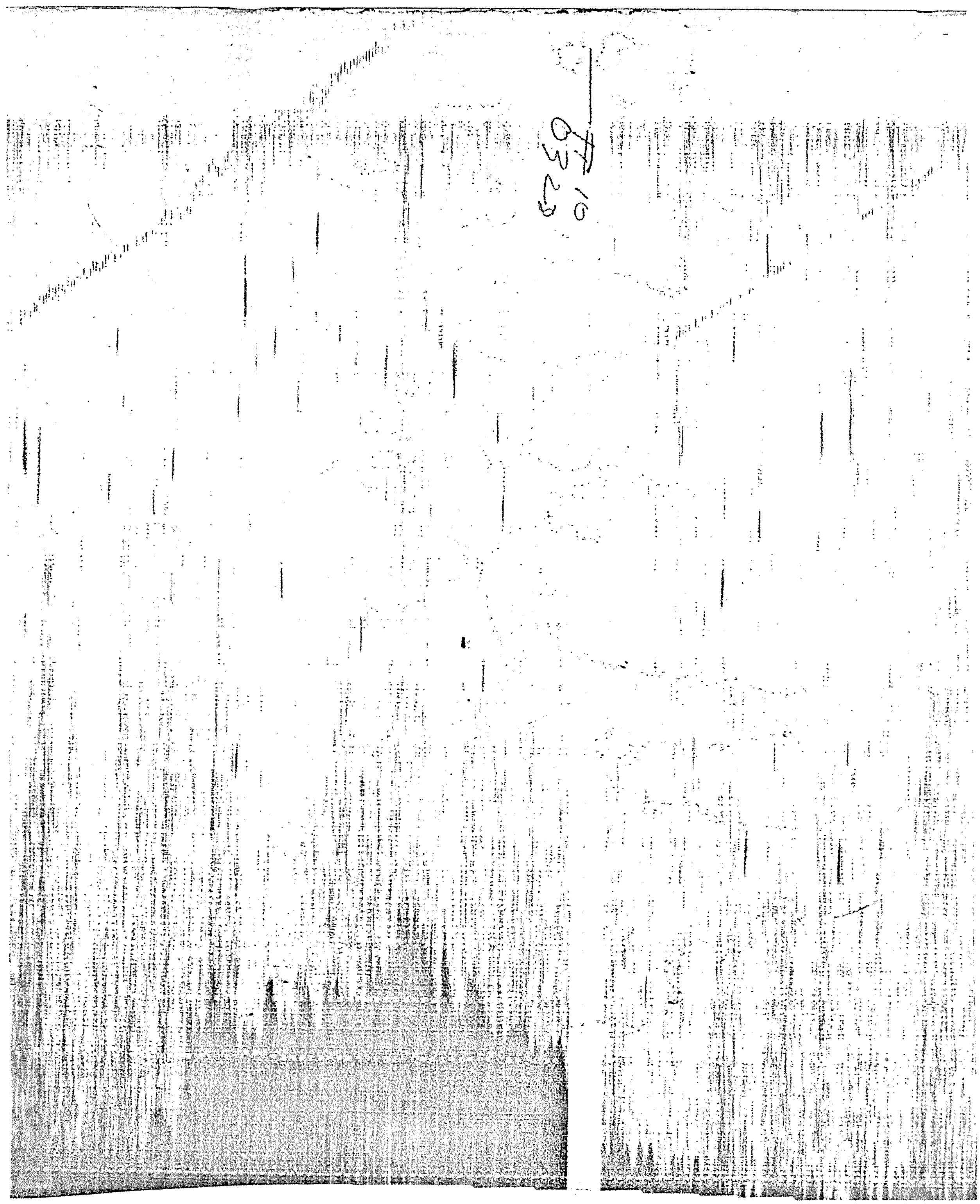


Figure 17c. Echogram from a portion of the final run, 0324-0330 June 27, between buoys 11 and 8.

next transect series took place the night following the release from 2145, June 28 to 0330, June 29. The series consisted of eleven runs centered around the facility, two on the east side of the channel and nine on the west side including a final run from buoy 17 to buoy 10. There appeared to be less fish than in the previous series, but the concentrations were again definitely associated with the facility. Runs during the flood tide showed very low concentrations up current of the facility and maximum around buoy 17 (Figs. 18 and 19). Runs on the east side showed low fish densities (Fig. 20). The location of the concentration again shifted with the tide and moved slightly southward, but again very few fish were observed in the southernmost areas on the last transect (Fig. 21).

June 29-30 Surveys

An exploratory search was made in the upper end of the Coos Bay estuary. The series began at 2211 June 29 at the Highway 101 Bridge, and consisted of a run up the estuary to the East Highway Bridge, a return run to the railway bridge (Fig. 8) and a final run by the facility from buoy 17 to opposite the smokestack. Several concentrations of fish were observed in the upper estuary, and many salmonids were seen jumping at the surface. One concentration was observed at the mouth of the Coos River (Fig. 22). Another major concentration was seen near buoy 35 (Fig. 23). Scattered fish were still present at both ends of the run, by the East Highway Bridge (Fig. 24), and the Highway 101 Bridge (Fig. 25). A concentration of fish was again observed down current of the facility on the last run (Fig. 26). The density appeared lower than the previous night, but the echo record was obscured by surface turbulence from rough water conditions in this area.

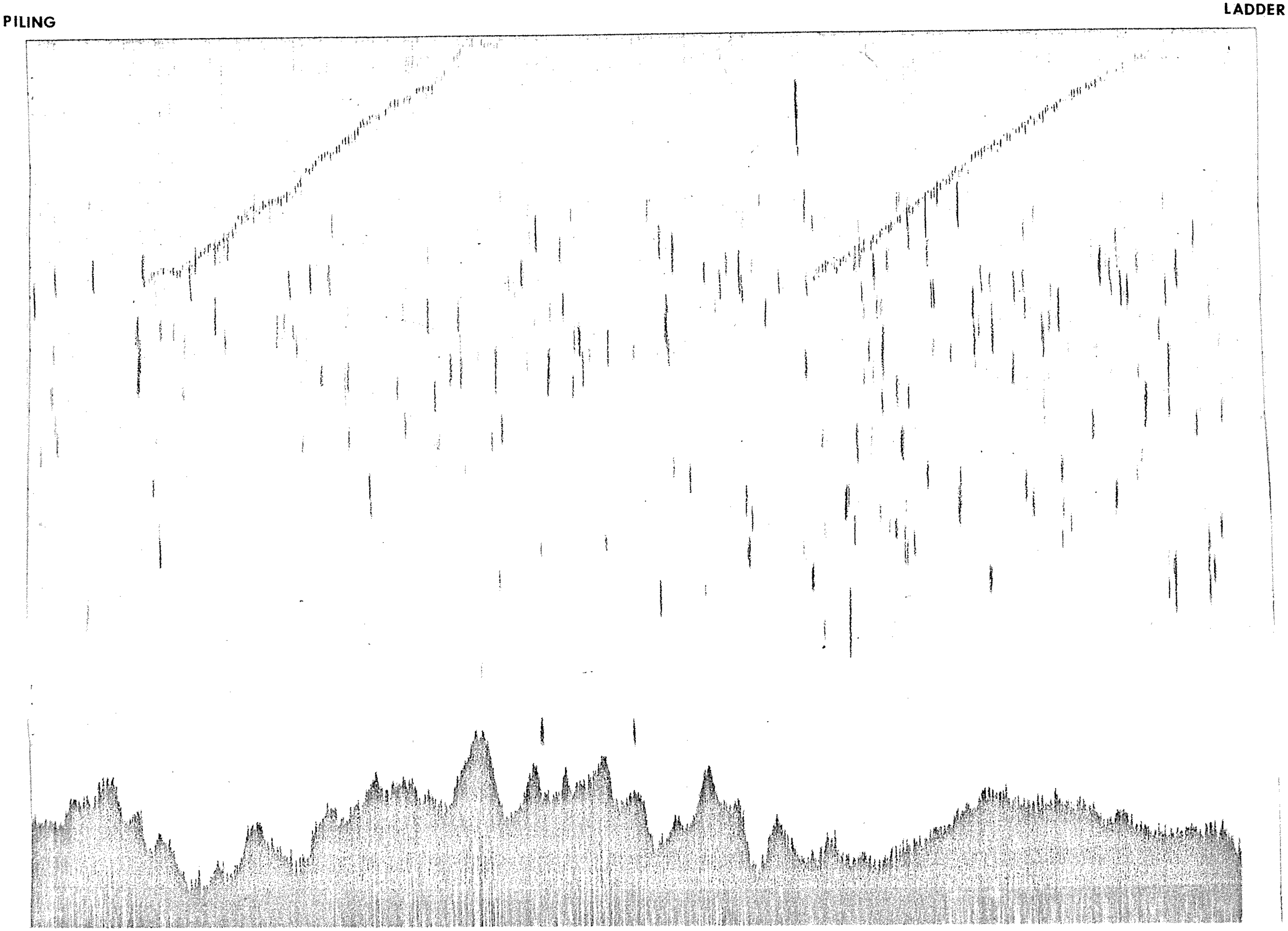


Figure 18a. Echogram from portion of primary transect immediately south (up current) of facility, 000-009 June 29.

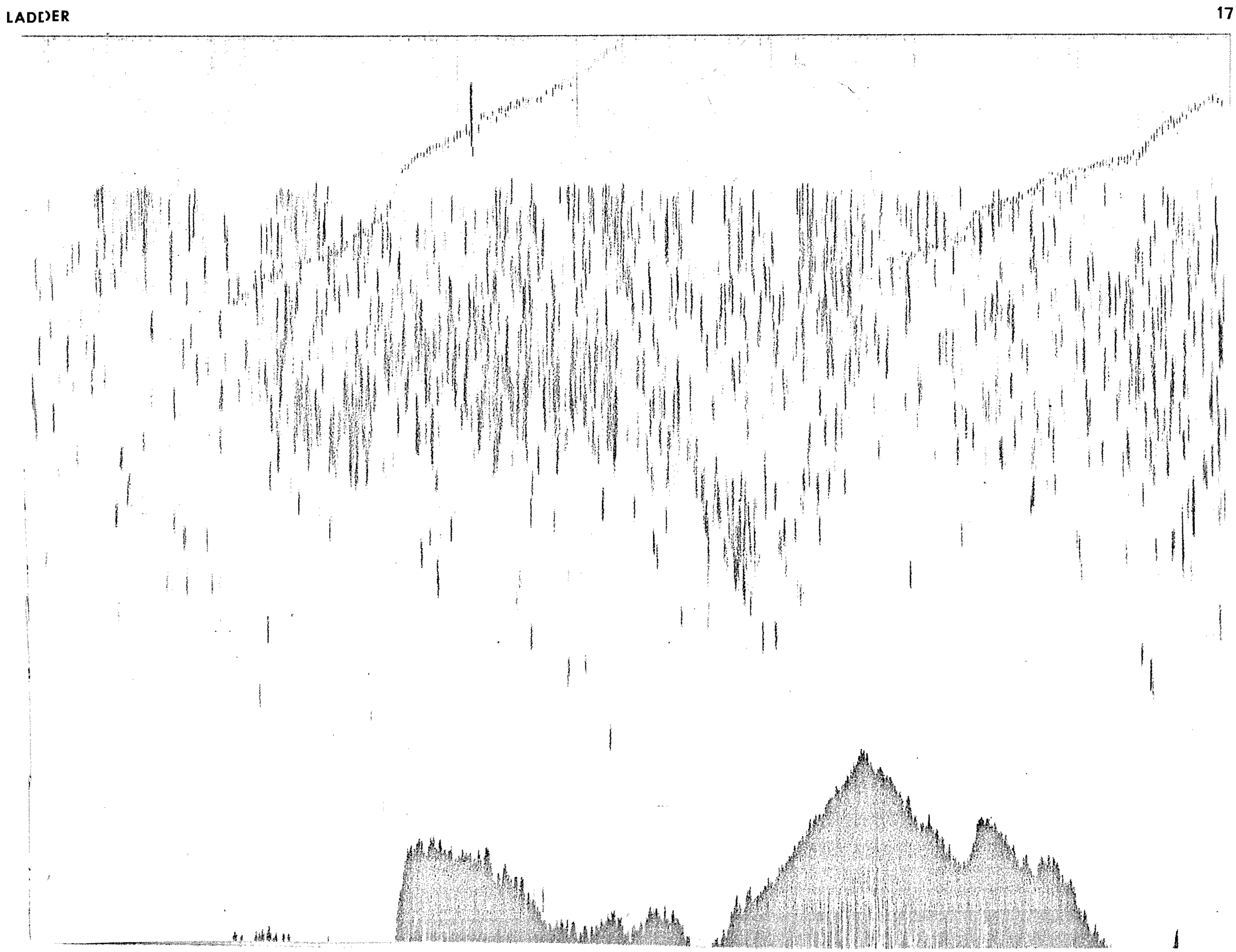


Figure 18b. Echogram from portion of primary transect between the ladder and buoy 17, 0009-0015 June 29.

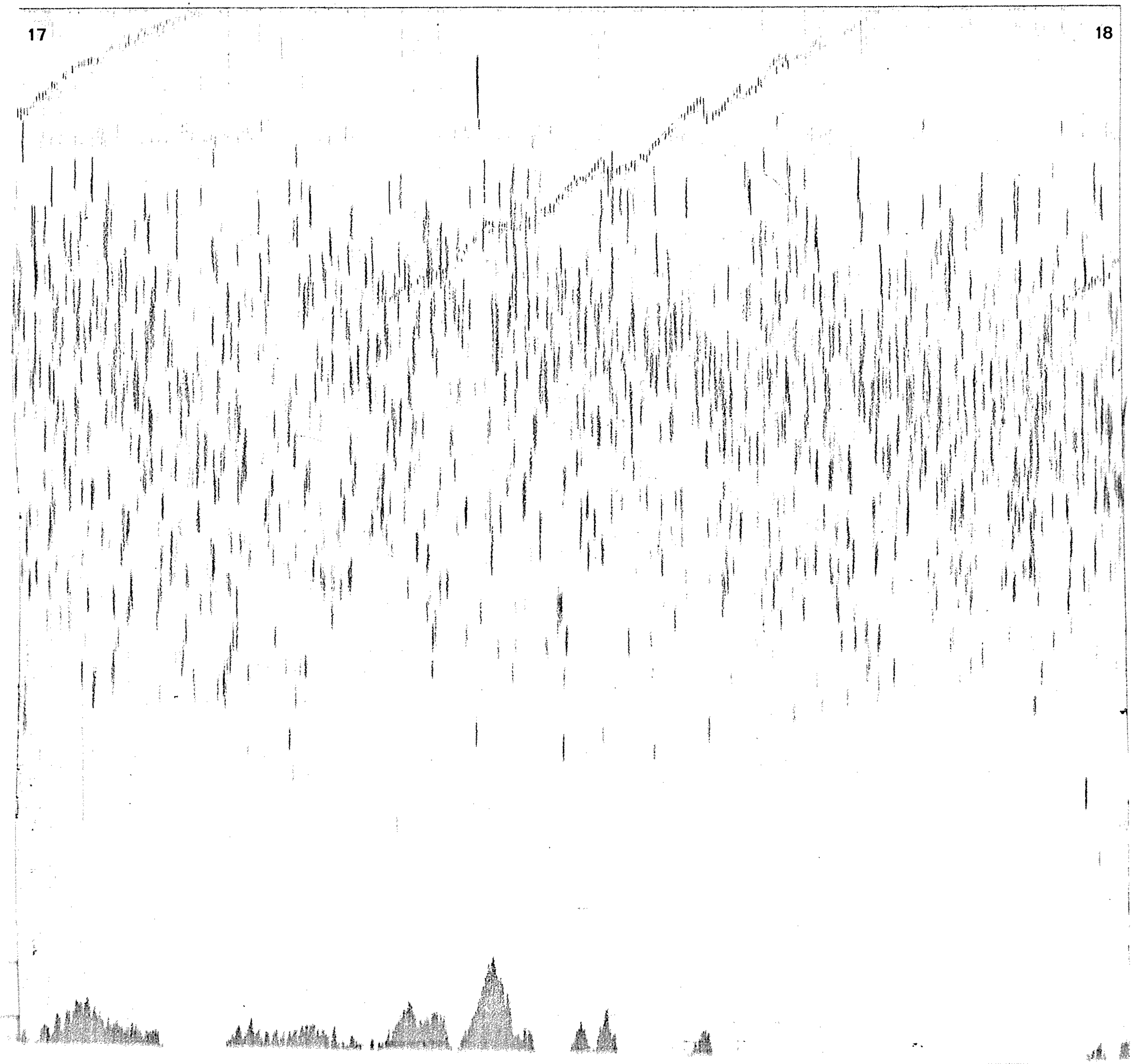


Figure 18c. Echogram from portion of primary transect between buoys 17 and 18, 0016-0022 June 29.

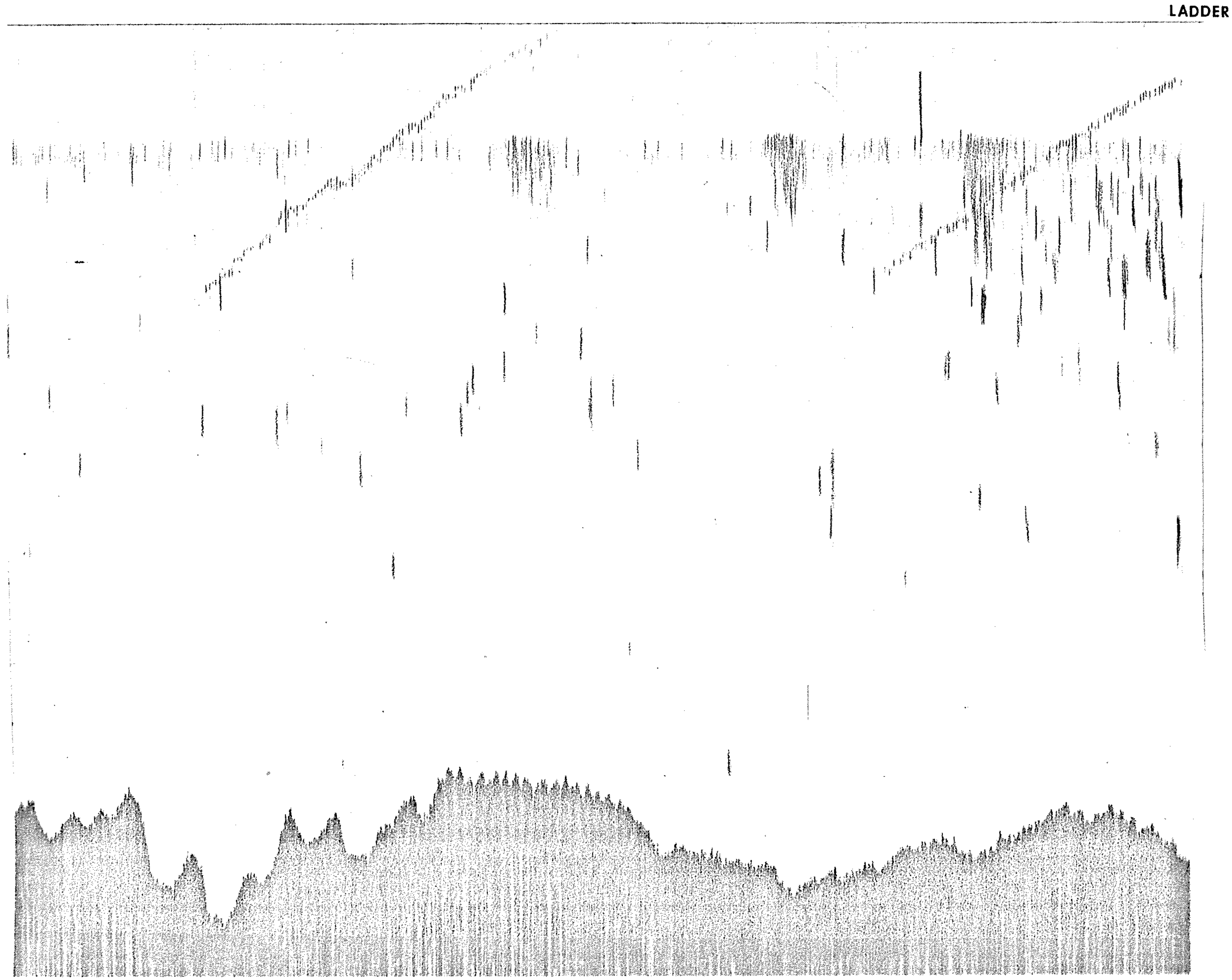


Figure 19a. Echogram from portion of primary transect immediately south of the facility, 0125-0132 June 29.

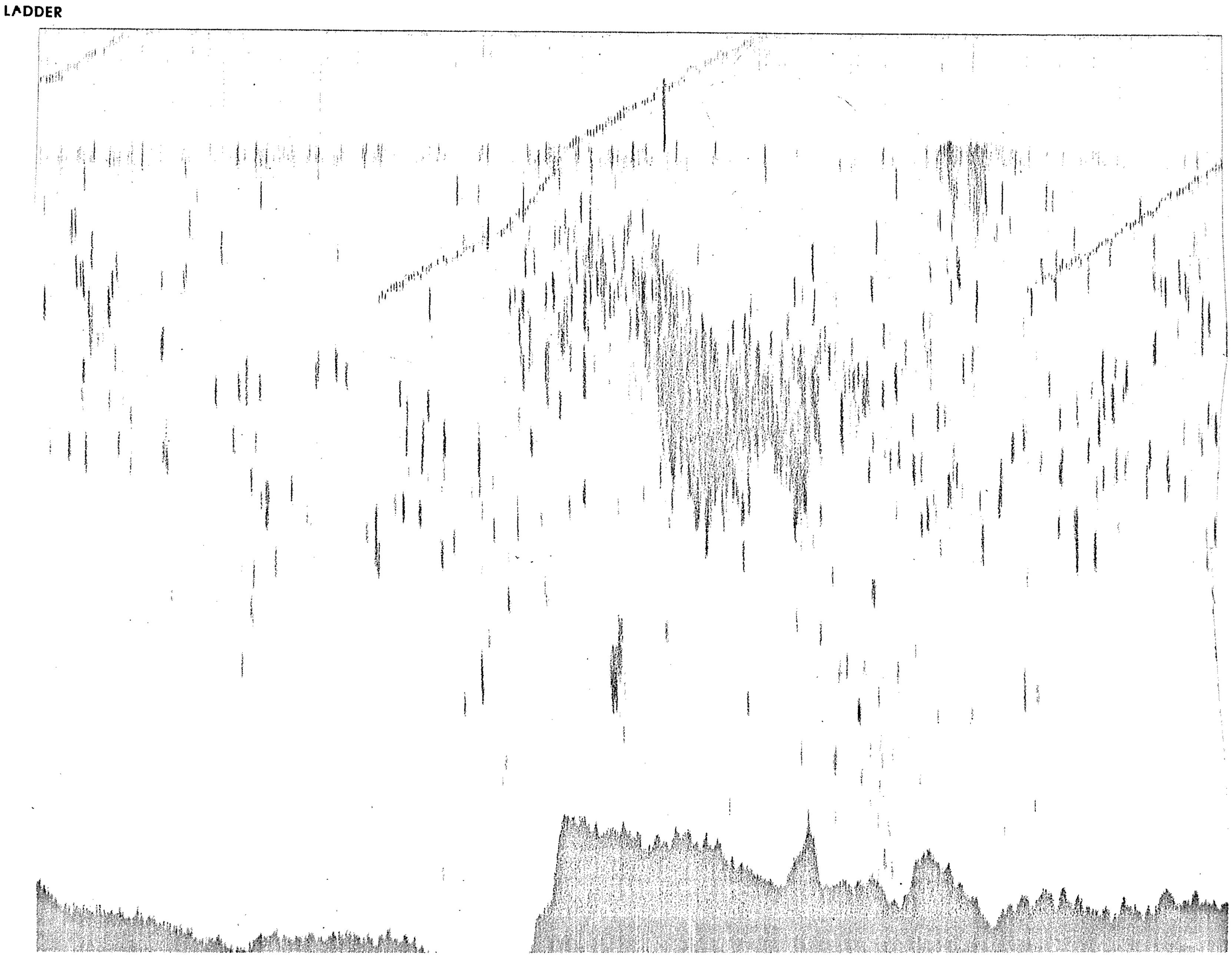


Figure 19b. Echogram from portion of primary transect immediately north of the facility, 0132-0140 June 29.

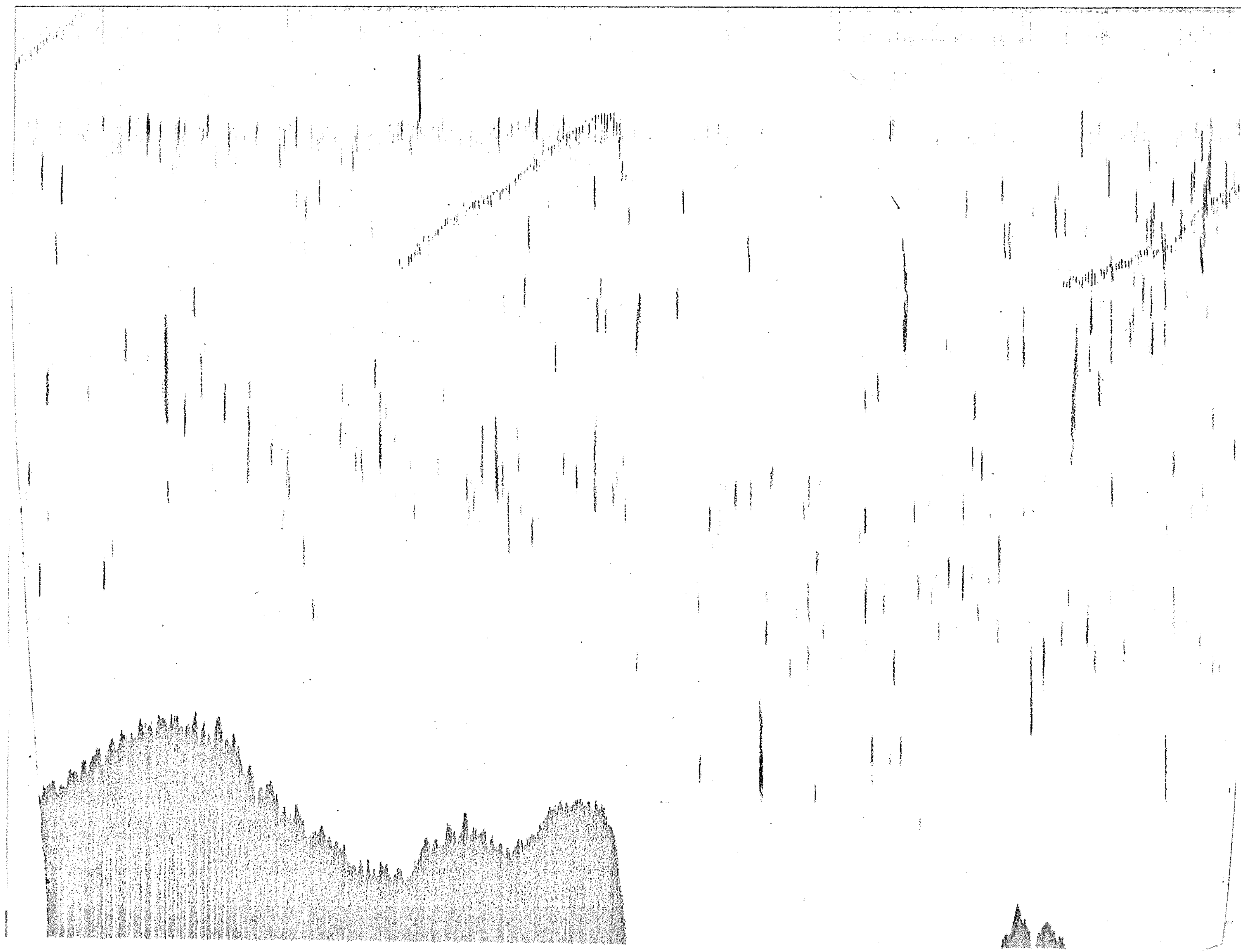


Figure 20. Echogram from run on the east side opposite the facility, 0148–0154 June 29.

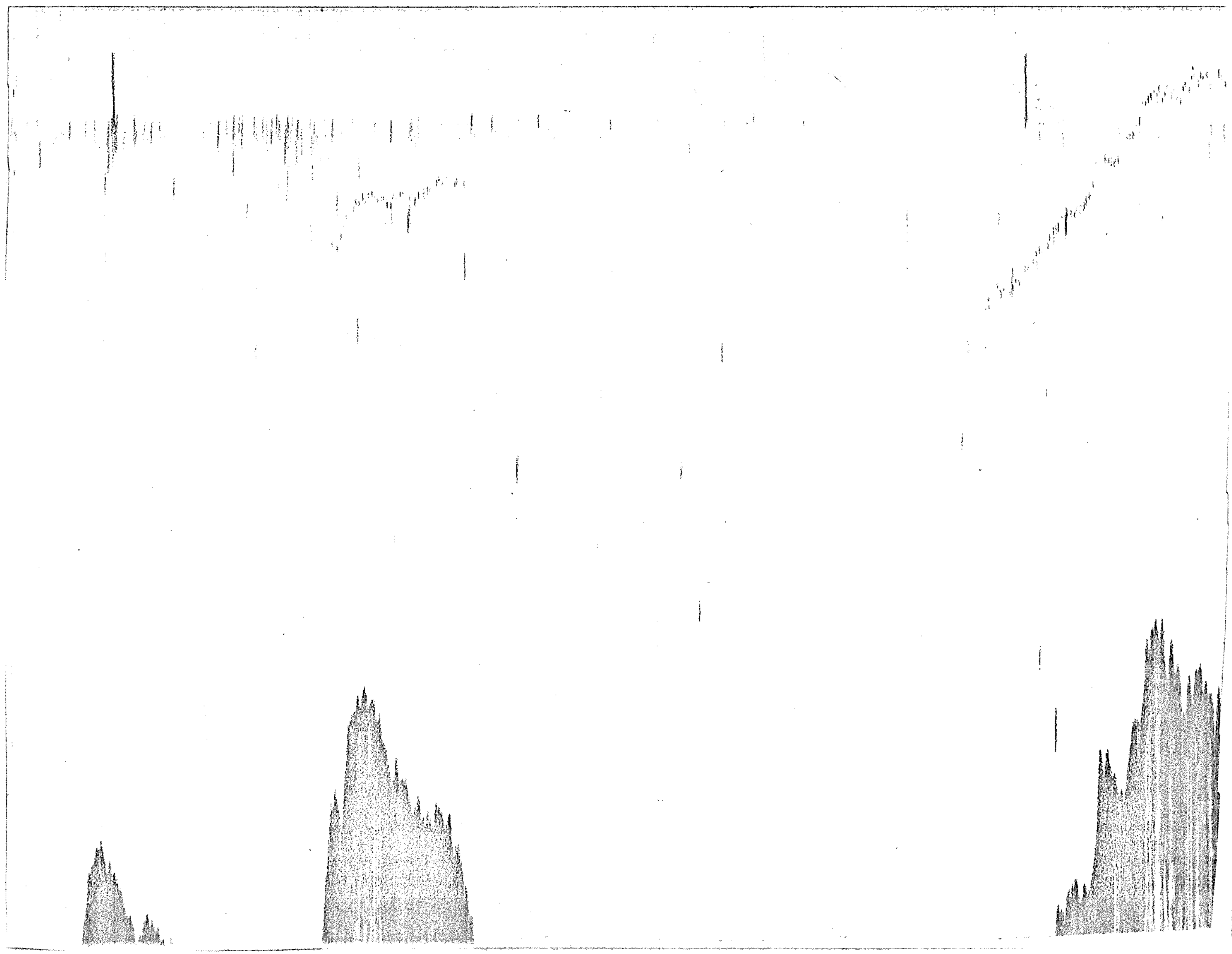


Figure 21. Echogram from run between buoys 11 and 10, 0310-0315 June 29.

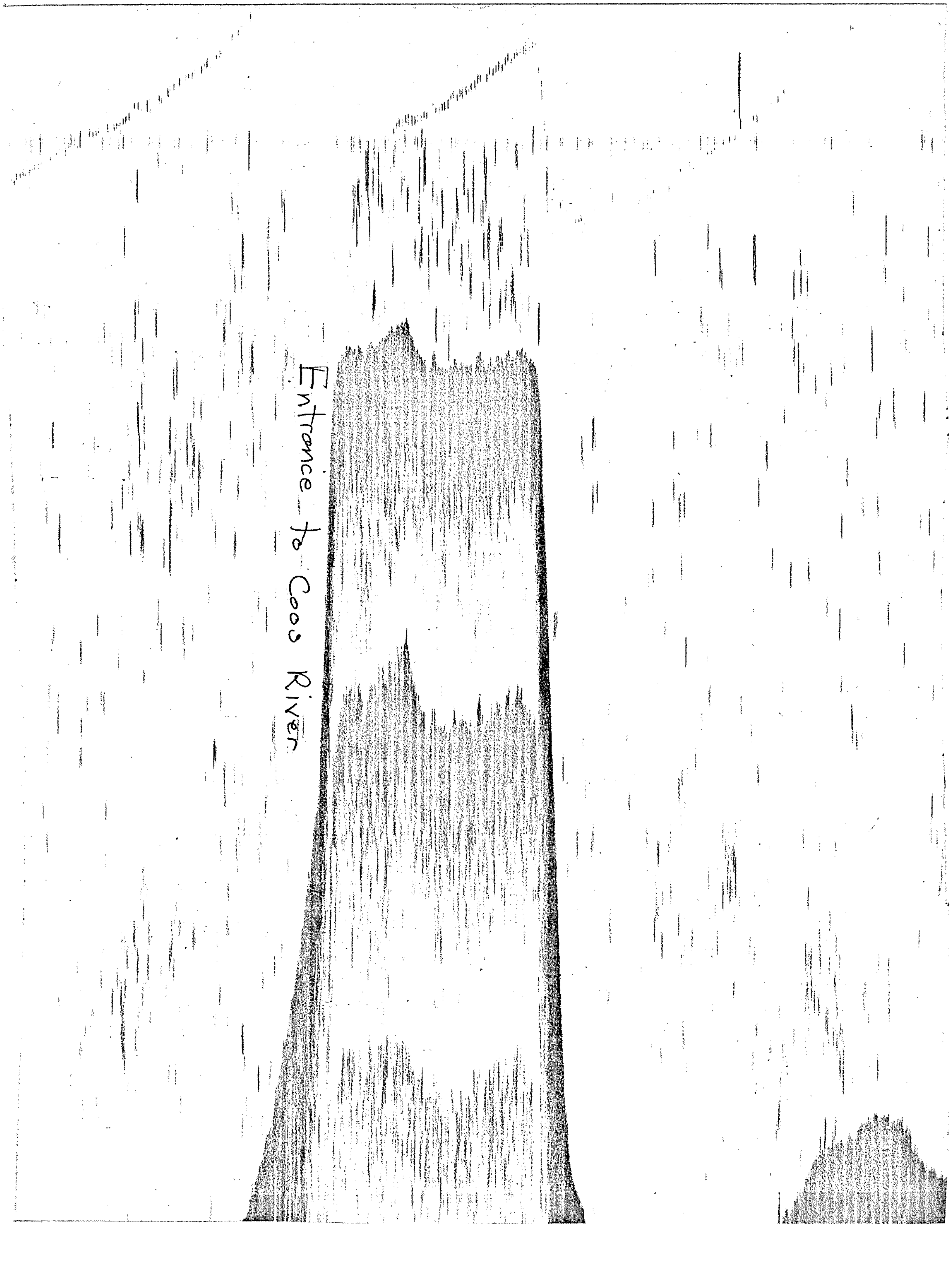


Figure 22. Echogram showing concentrations near mouth of the Coos River, 2250-2255 June 29.

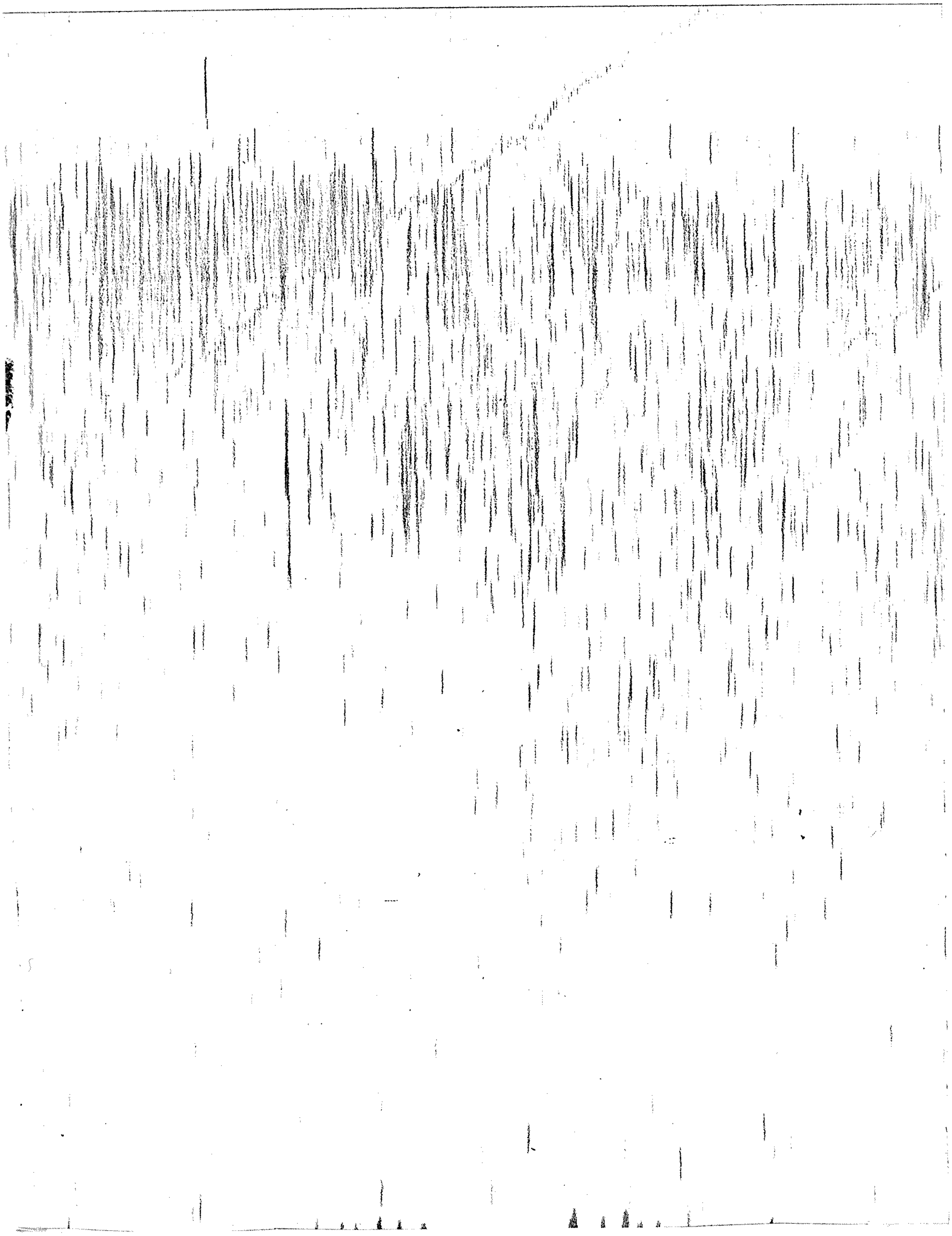


Figure 23. Echogram from upper estuary near buoy 35, 0006-0011 June 30.

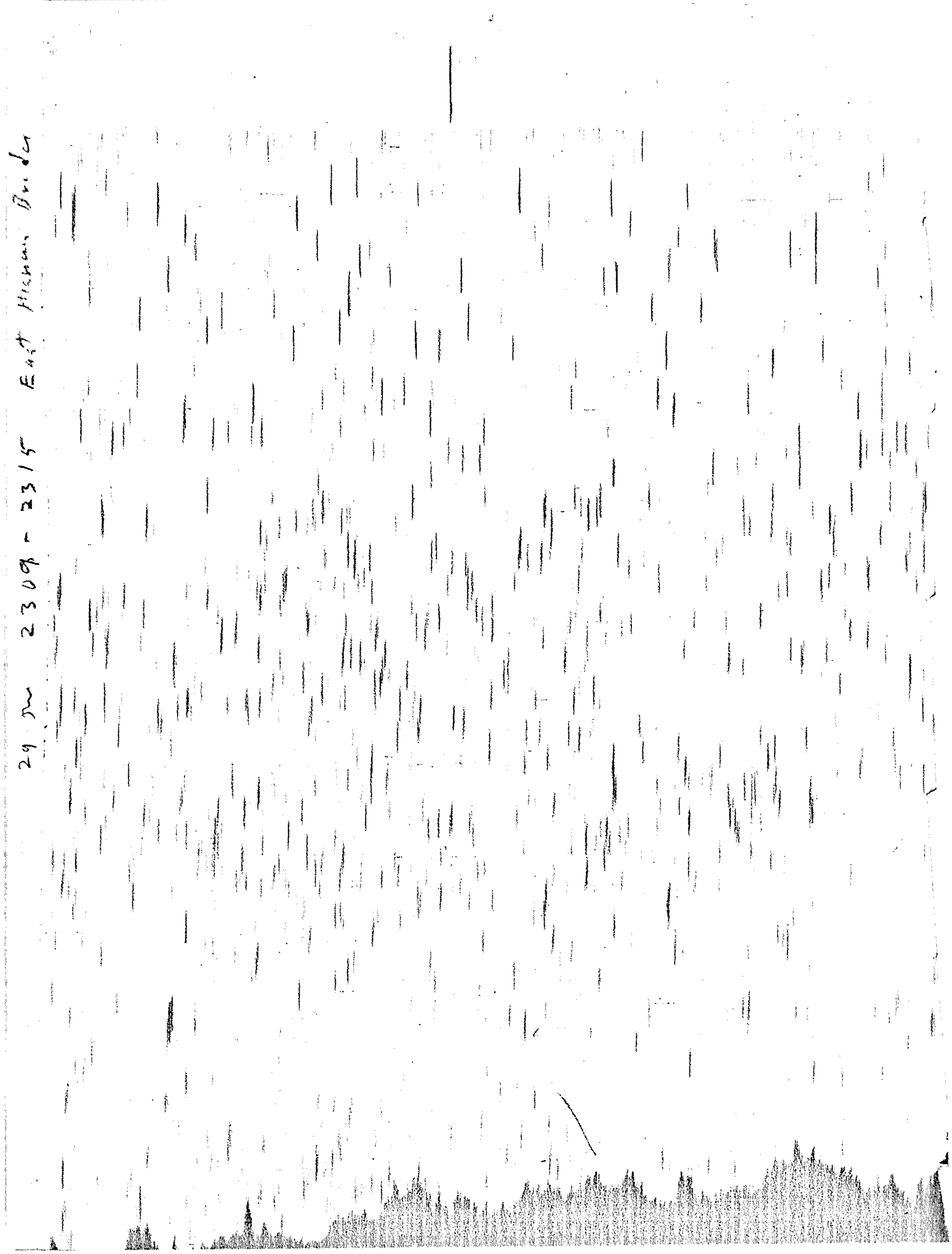


Figure 24. Echogram from upper estuary near the East Highway Bridge, 2309-2315 June 29.

Figure 25. Echogram from run between Highway 101 and railroad bridges, 0031-0036 June 30.

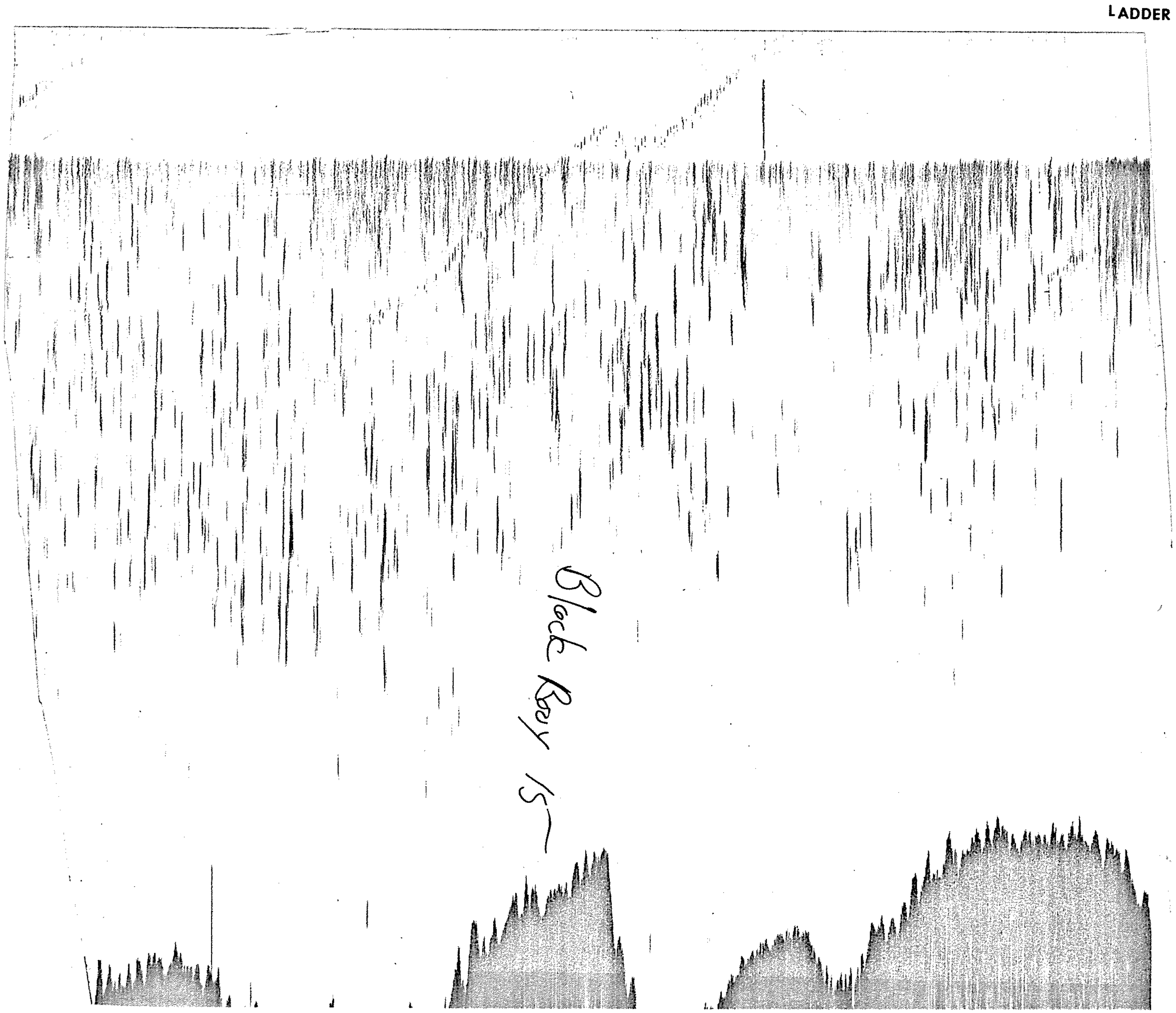


Figure 26a. Echogram from portion of the primary transect immediately north of the facility, 0116-0123 June 30.

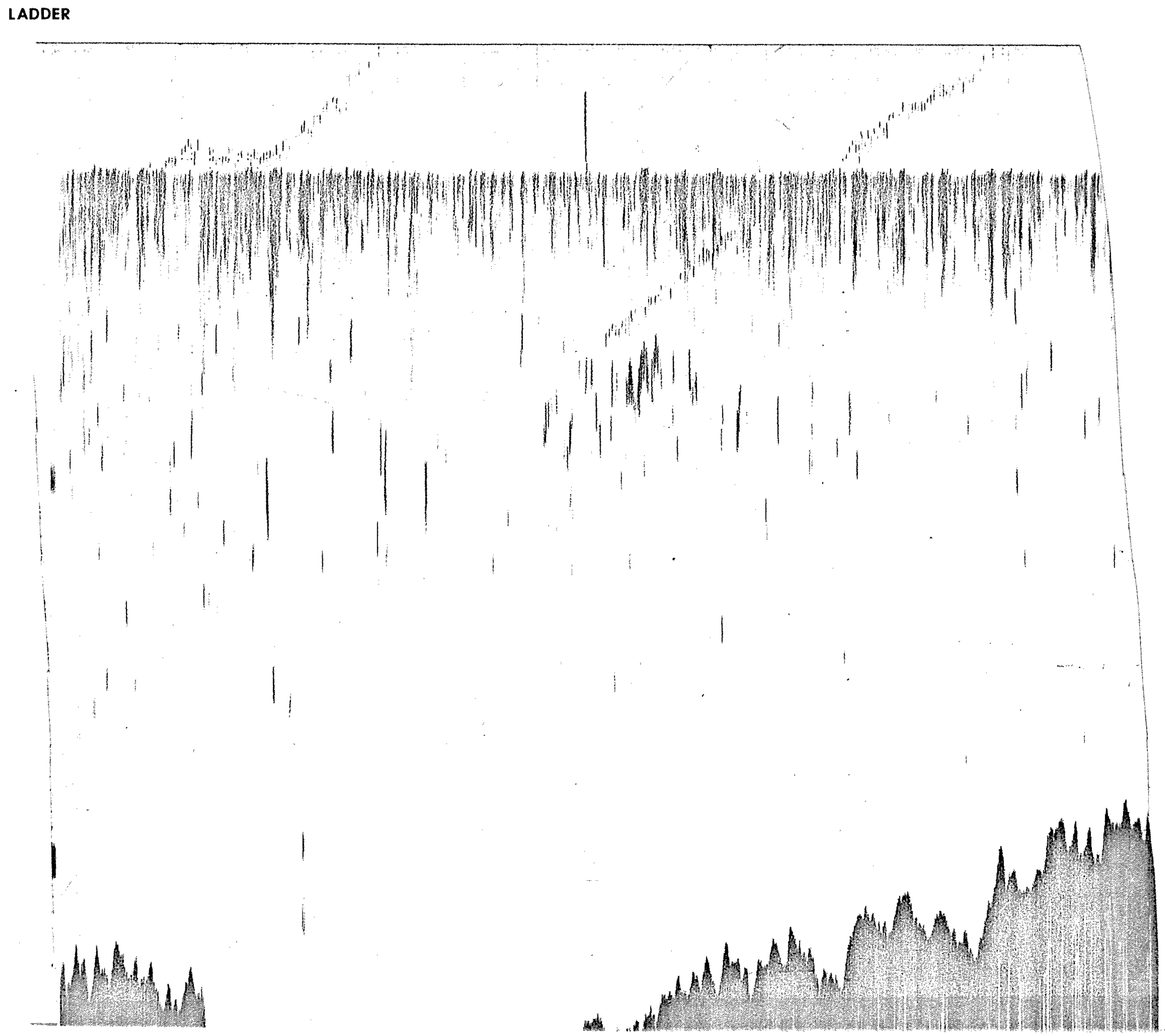


Figure 26b. Echogram from portion of primary transect immediately south of the facility, 0123-0130 June 30.

June 30 - July 1 Surveys

This series consisted of a single run down the estuary beginning at the East Highway Bridge and ending when the batteries failed by buoy 17. Results were similar to the previous night except less fish and less jumpers were seen.

July 1-2 Surveys

This series consisted of three runs. The major run was from the East Highway Bridge to buoy 27. In addition, two runs were made by the site: one on the way up the estuary beginning at buoy 14 at 2100 and ending at #17 at 2133, and a second from buoy 18 at 0145 to buoy 11 at 0240. Again scattered targets were seen at the uppermost location, by the East Highway Bridge (Fig. 27), and concentrations of fish were observed in a few upper estuary areas, particularly by the Coos River mouth (Fig. 28) and near buoy 35 (Fig. 29). A few jumpers were observed in these areas. Only scattered fish were seen from the Highway 101 Bridge to buoy 18 (Fig. 30). Again there were high concentrations clearly associated with the facility (Fig. 31). Some of the fish down current of the facility appeared from spotlight observations to be topsmelt rather than salmon. Again, very low fish densities were seen in the southern most areas (Fig. 32).

July 2-3 Surveys

The last series began just after midnight at the East Highway Bridge and consisted of a run down the estuary to just beyond buoy 21, and a final run by the facility from buoy 17 to opposite the tanks. In general, there were fewer fish and jumpers than previously, but there appeared to be more large single targets, possibly striped bass (Fig. 33). The highest density in the upper estuary was between #35 and the Highway 101 Bridge (Fig. 34). No jumpers were seen in this

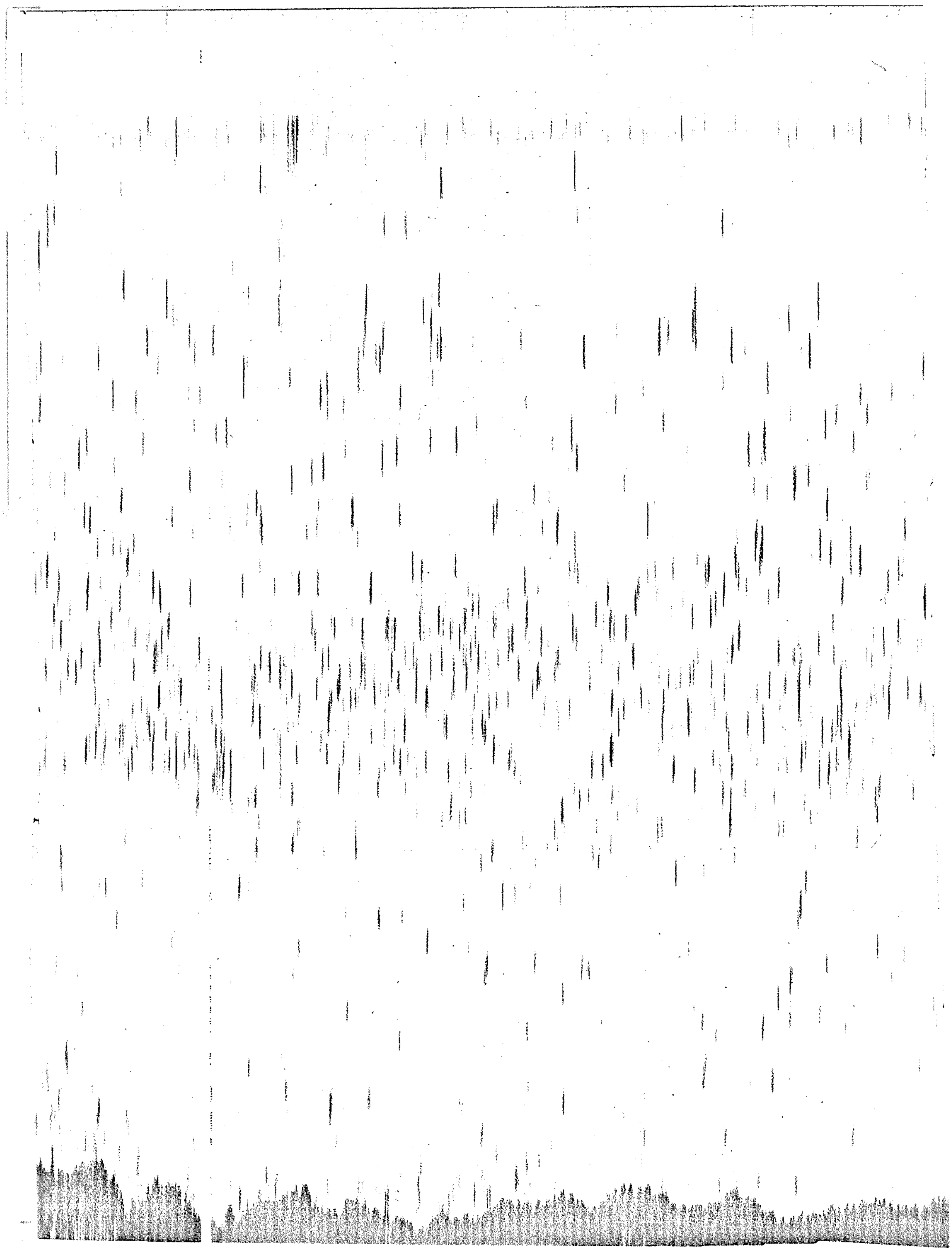


Figure 27. Echogram from upper estuary near the East Highway Bridge, 2315-2320 July 1.

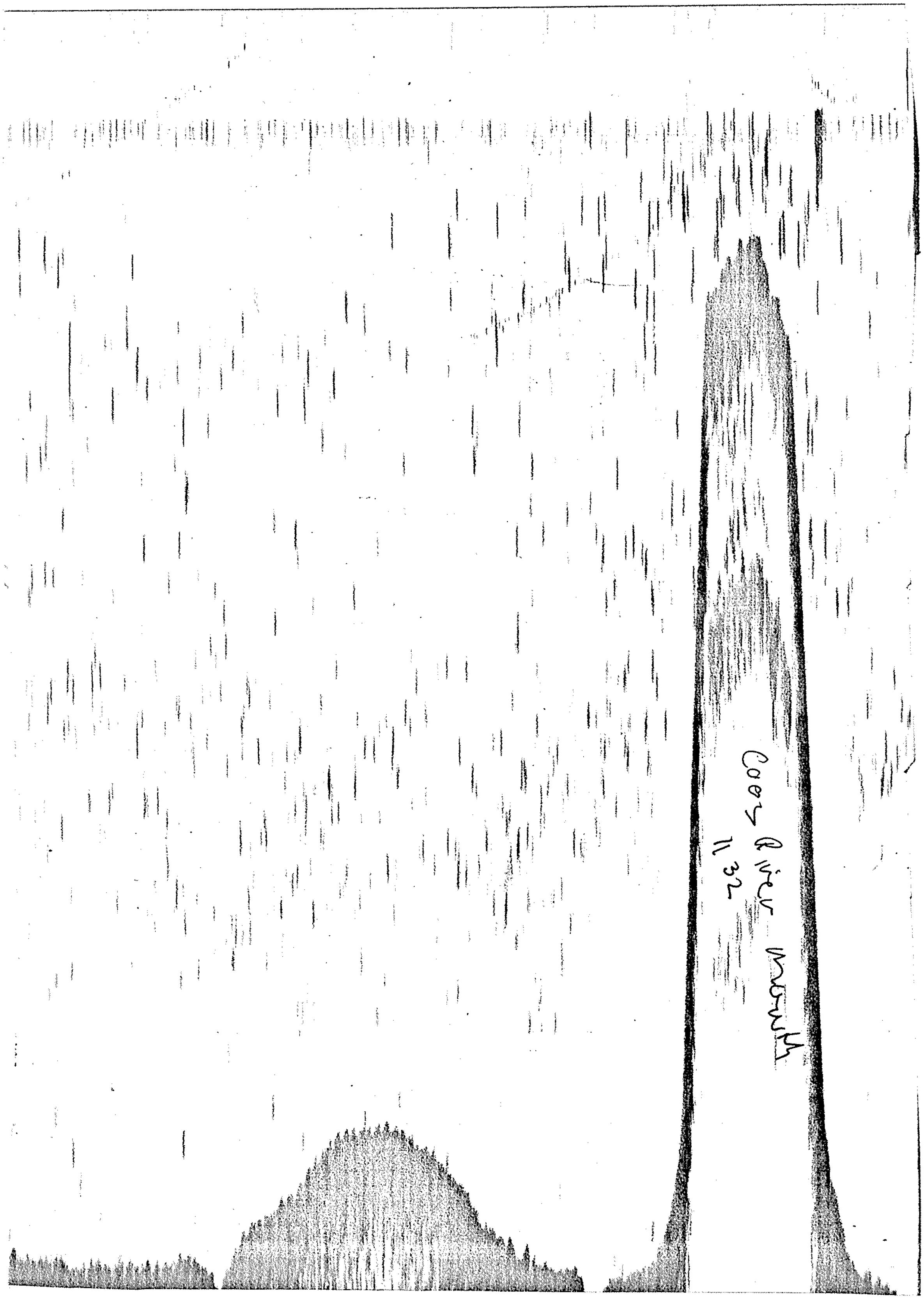


Figure 28. Echogram from area around the mouth of the Coos River, 2329-2335 July 1.

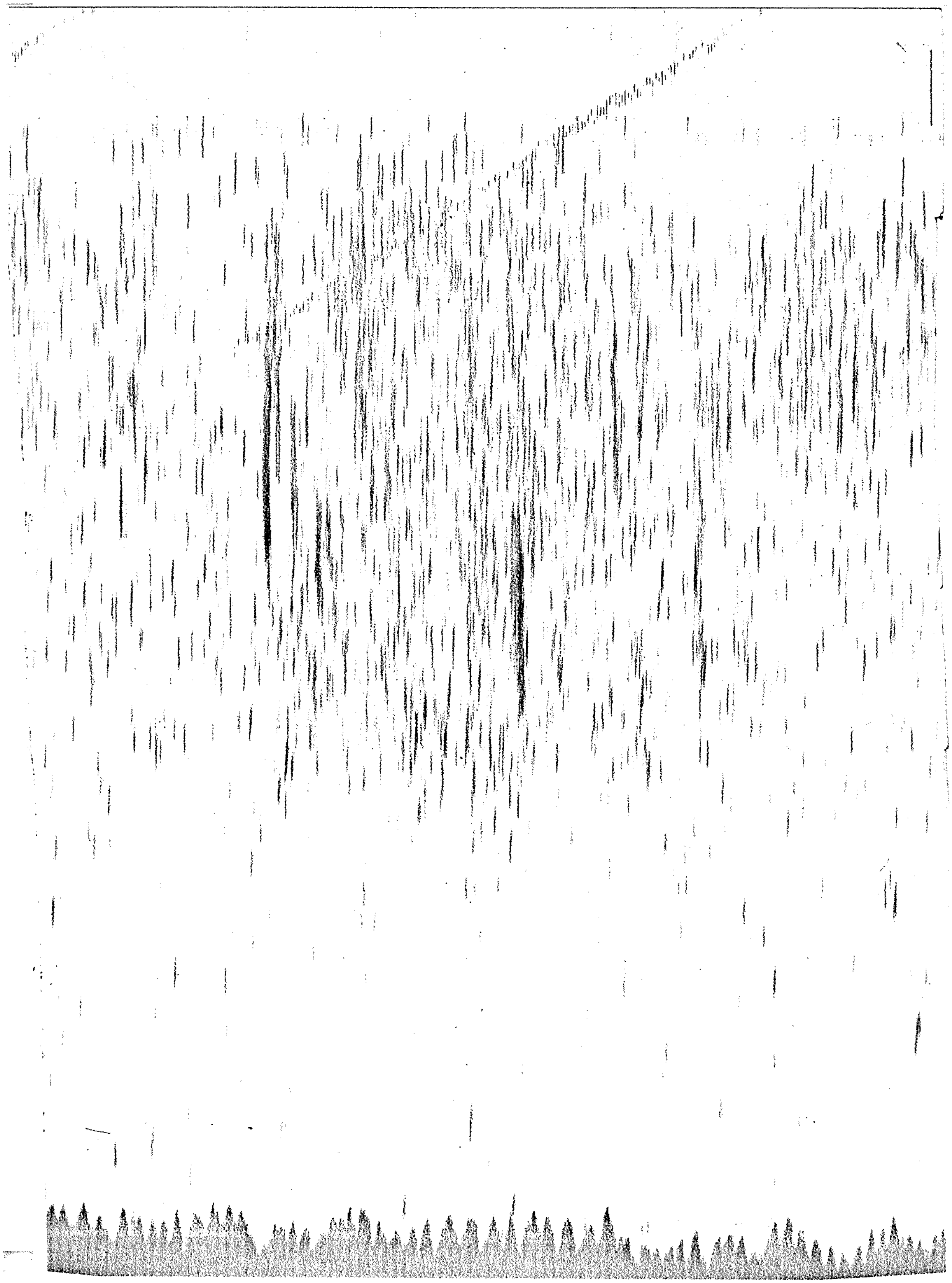


Figure 29. Echogram from upper estuary near buoy 35, 0043-0048 July 2.

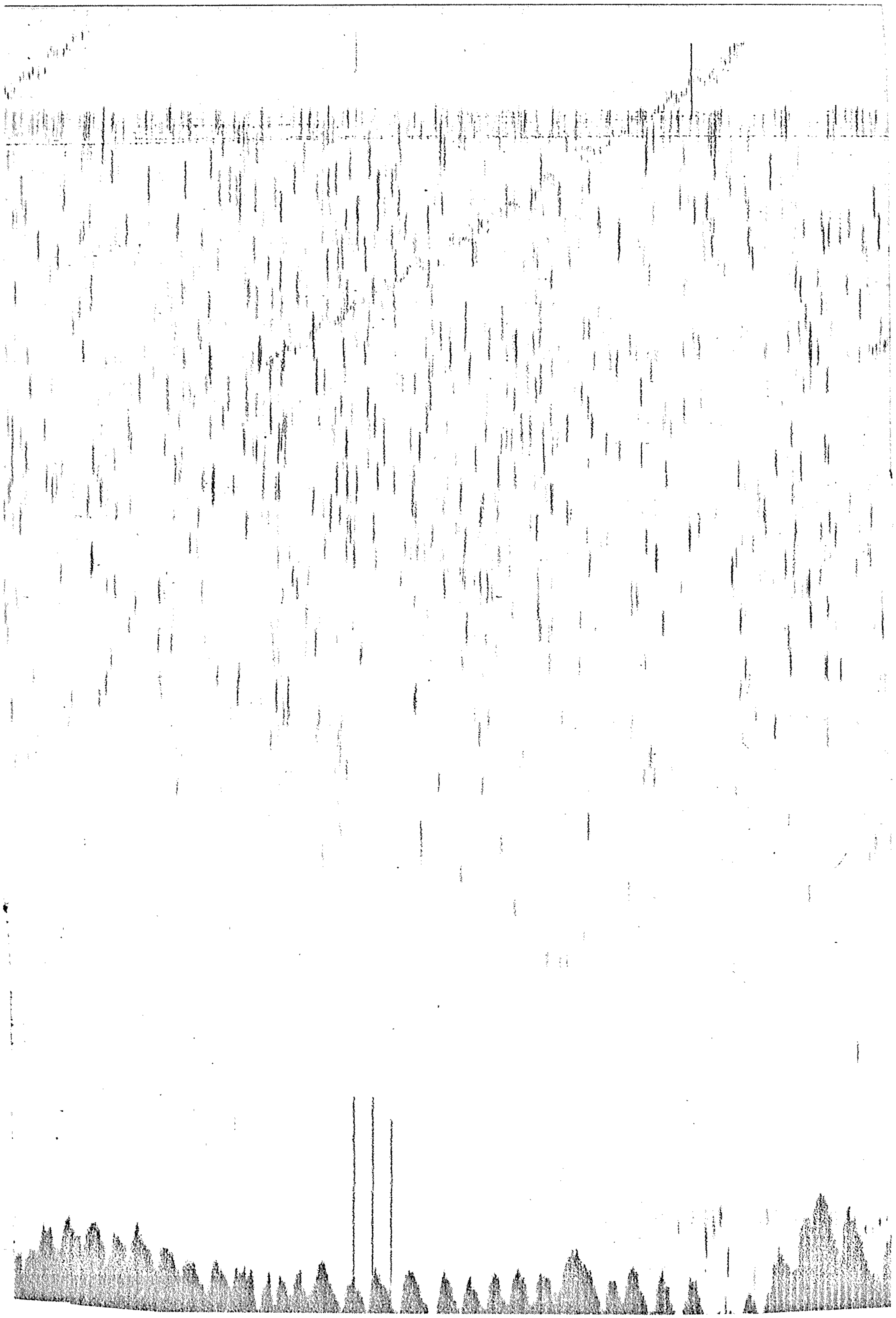


Figure 30. Echogram from area near buoy 27, 0113-0119 July 2.

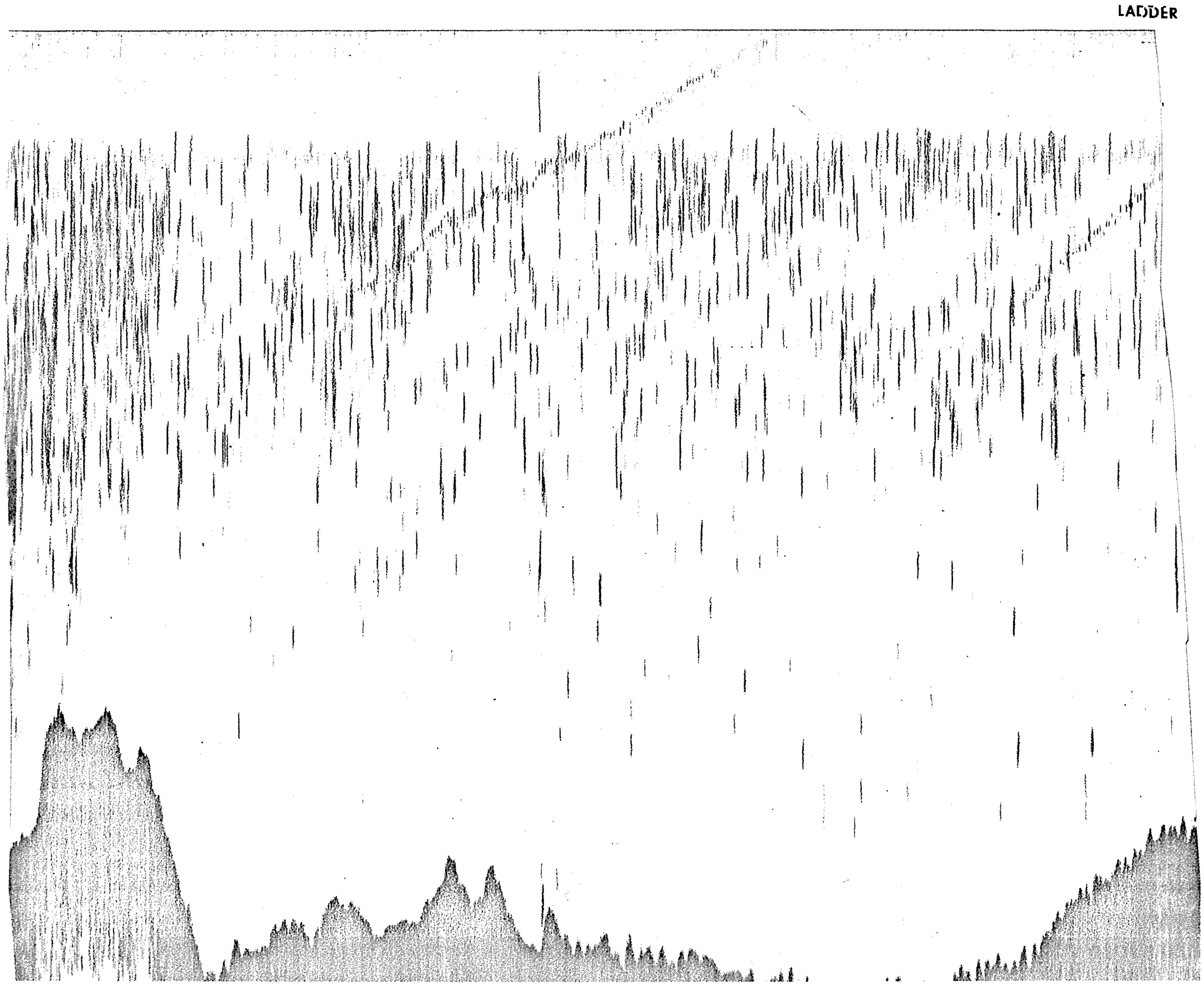
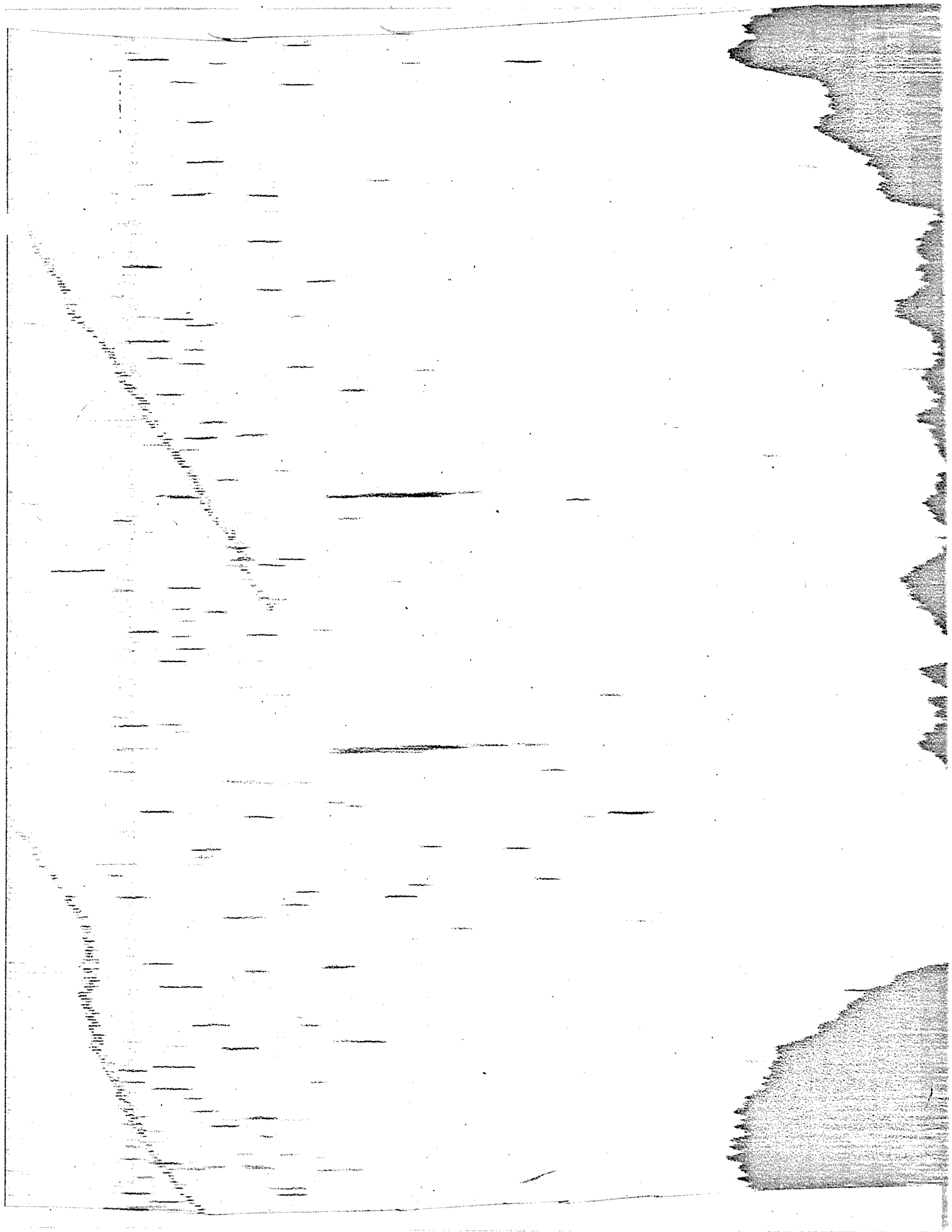


Figure 31a. Echogram from portion of primary transect immediately north of the facility, 0157-0203 July 2.



LADDER

Figure 31b. Echogram from portion of primary transect immediately south of the facility, 0204-0210 July 2.

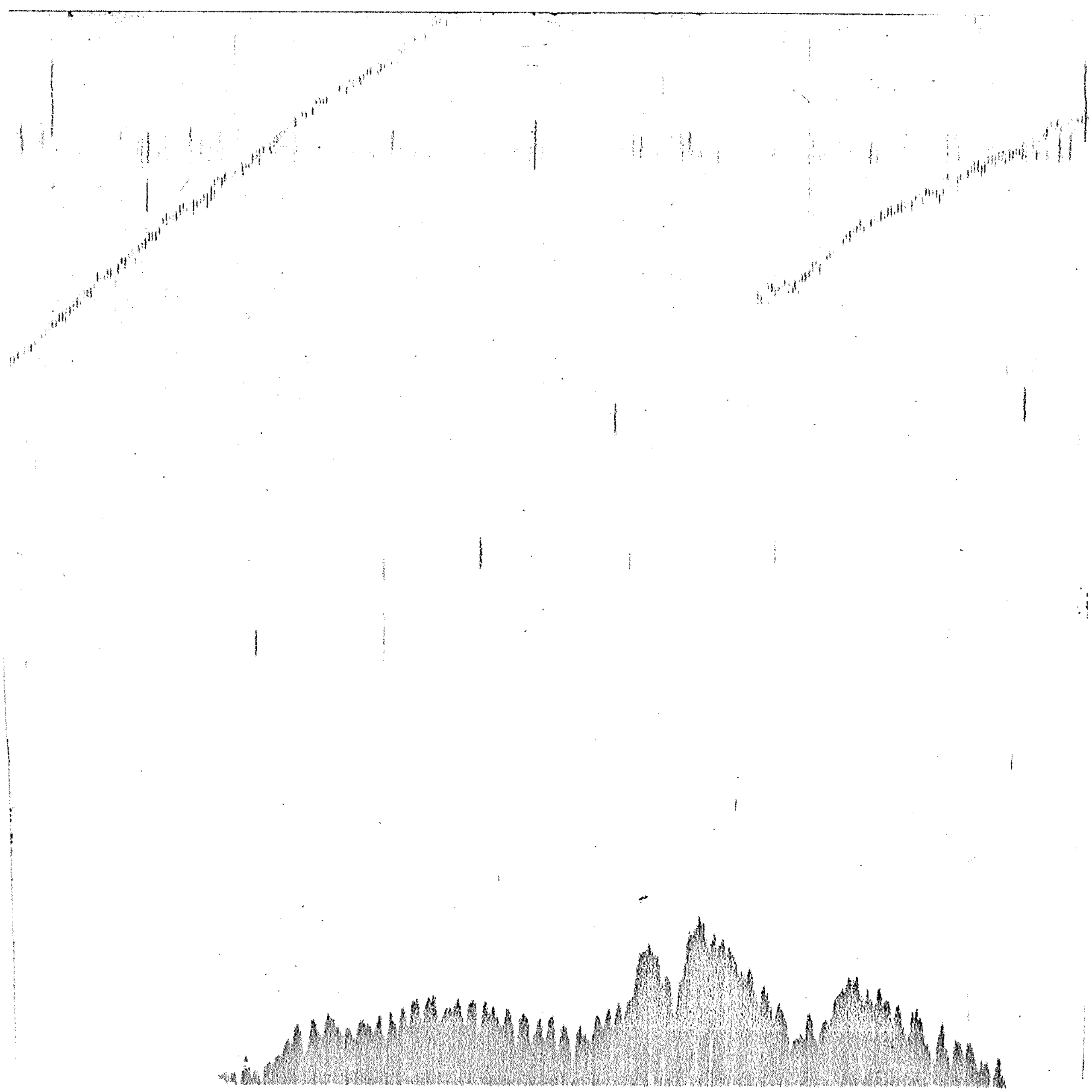


Figure 32. Echogram from area just south of the smokestack, 0233-0240 July 2.

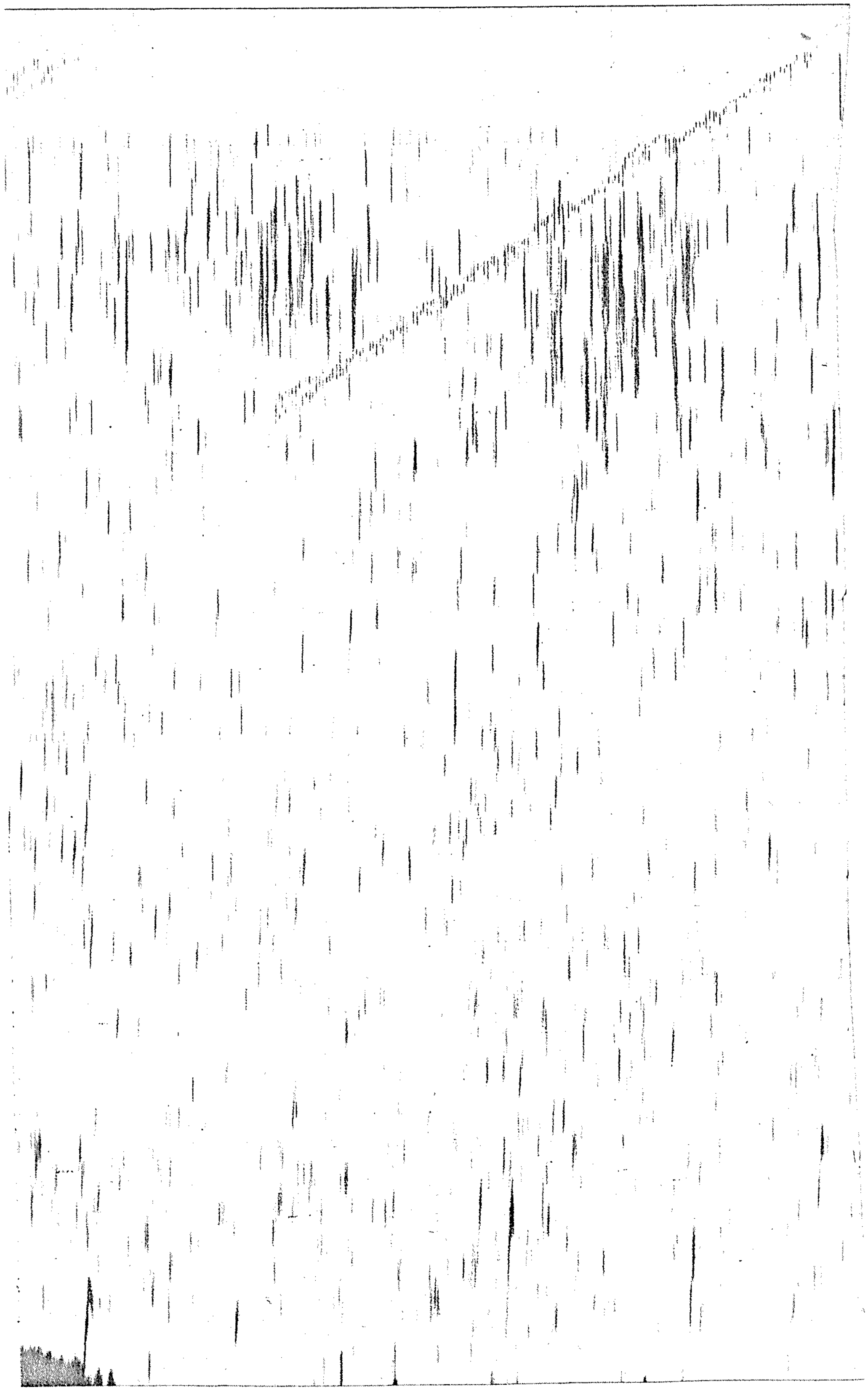


Figure 33. Echogram from area between buoys 37 and 35 0033-0038 July 3, showing large single fish targets.

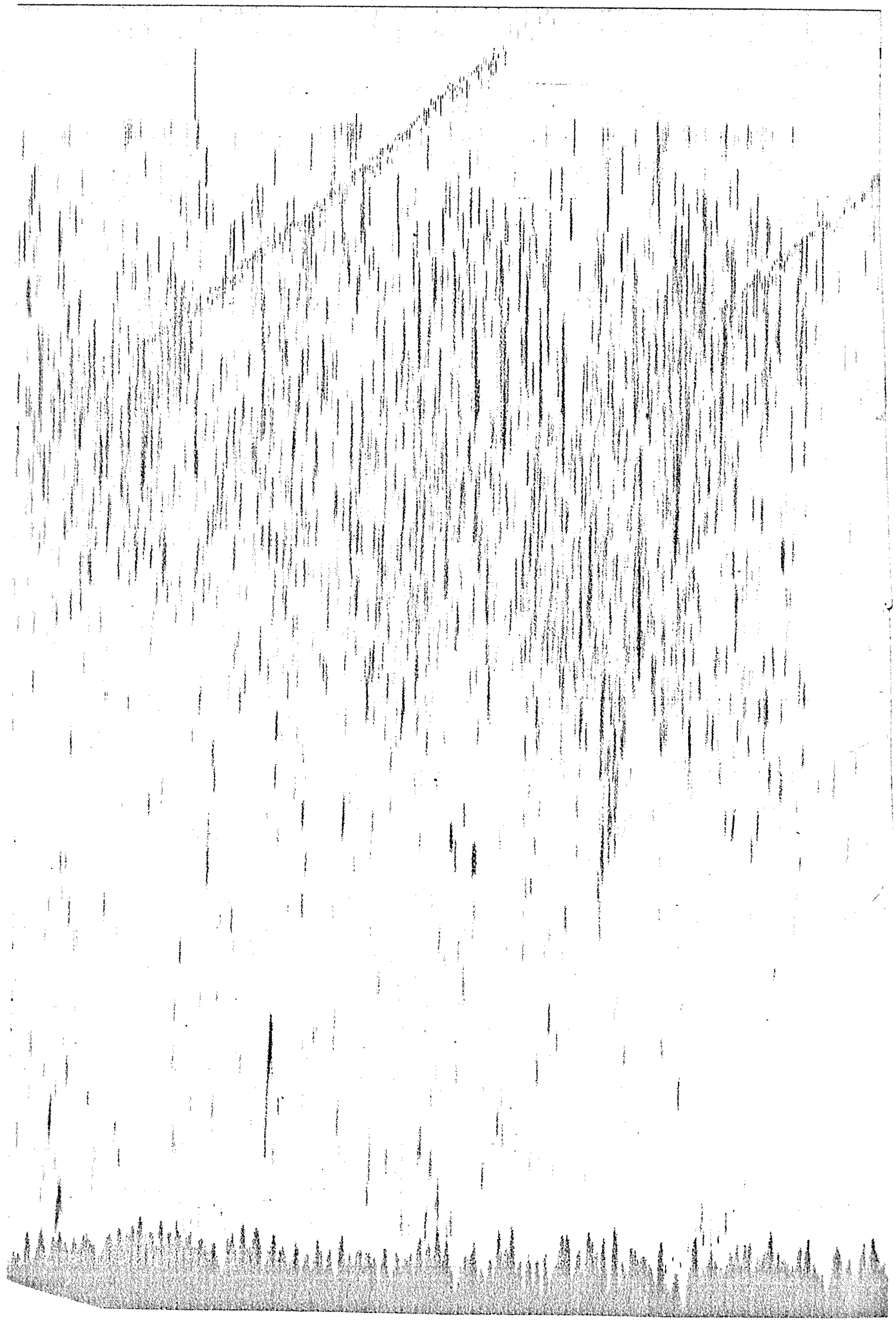


Figure 34. Echogram showing concentration of fish between buoy 35 and the Highway 101 Bridge, 0100-0107 July 3.

area. Only scattered targets were seen below the Highway 101 Bridge except for the usual concentration just down current from the facility, where again high densities were seen from buoy 17 to the ladder and low concentrations south of the facility (Fig. 35).

Uplooking Series

The first series with the uplooking deployment extended from 2310 June 27 to 0300 June 28. Although some scattered near surface targets were observed between 2310 to midnight, very few were seen prior to the fish release from the facility at about 0130 (Fig. 36a). Subsequent to the release, many targets were observed (Fig. 36b). Targets continued to be detected until turbulence or particles entrained by the swift ebb tide currents obscured the echogram (Fig. 36c).

Daytime observations were attempted from 1330-1400 June 28, but turbulence from wind waves rendered the data useless (Fig. 36d). Observations began again at 0037 June 29, and fish were observed consistently throughout the night until tidal currents again obscured the observations.

The next day the transducer was repositioned further out and the system was operated from 0040-0400 30 June. Unfortunately, there was interference, possibly from nearby eel grass beds (Fig. 36e). The interference was minimal at high slack tide, and occasional fish were detected during this period.

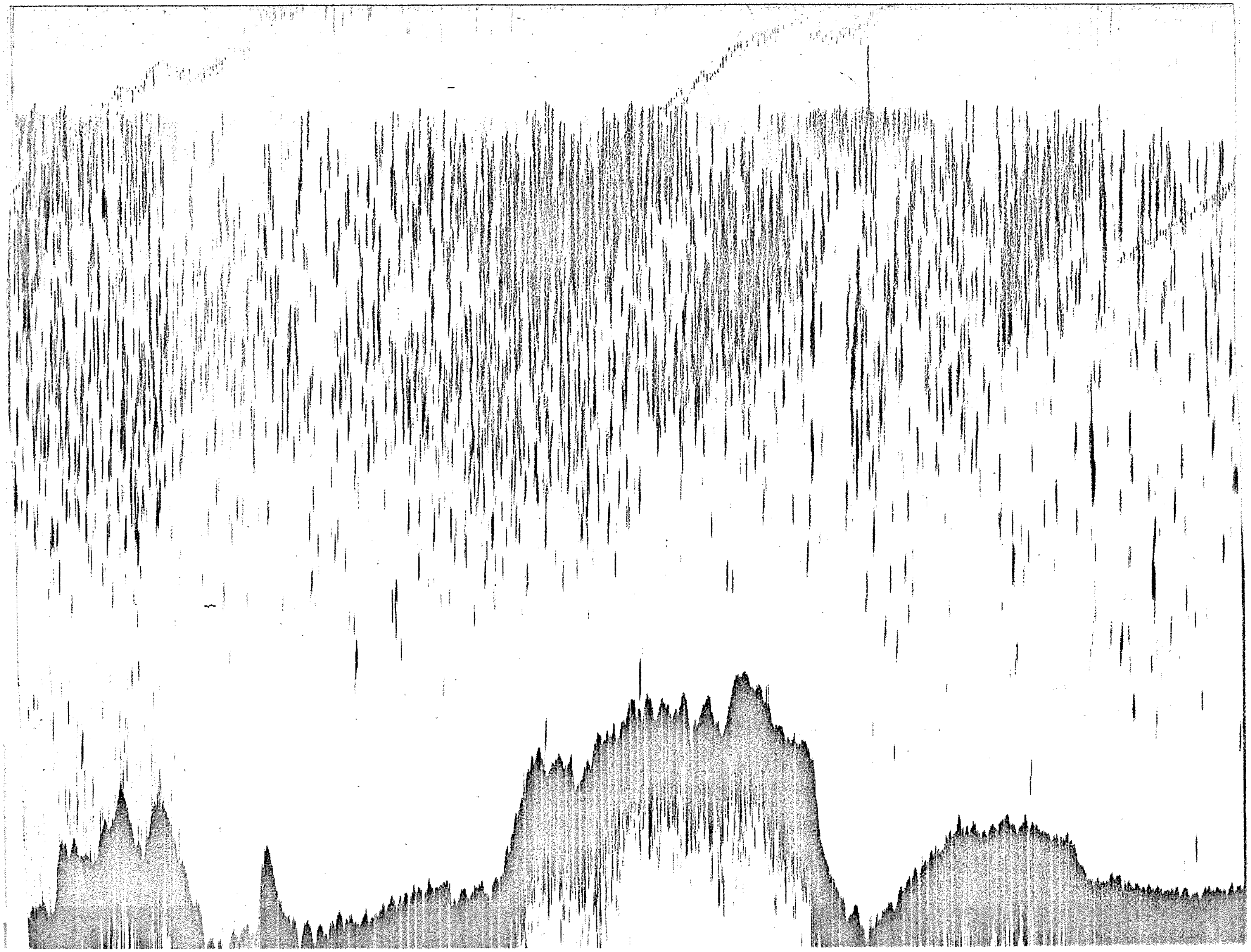


Figure 35a. Echogram from portion of primary transect immediately north of the facility, 0216-0223 July 3.

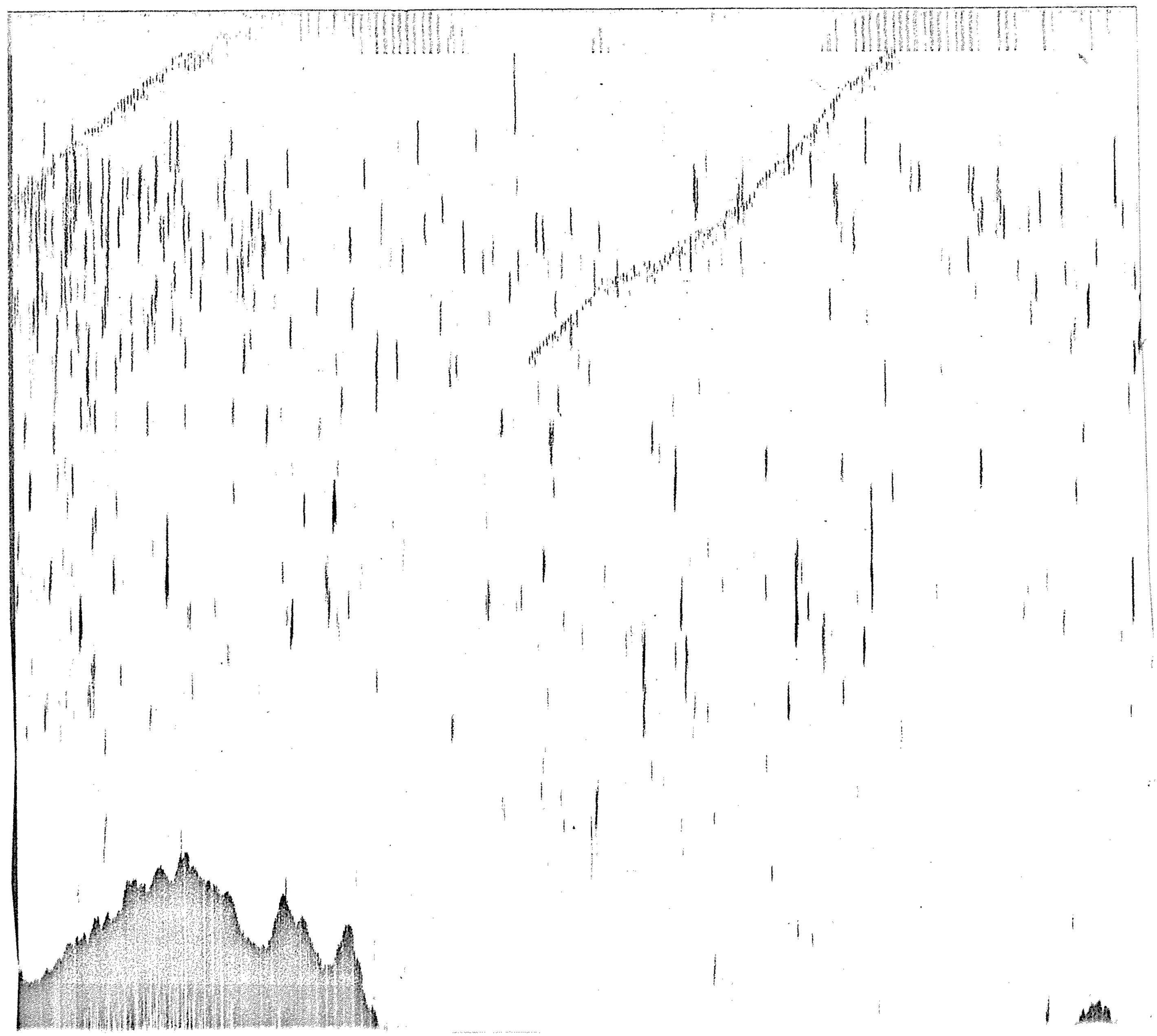


Figure 35b. Echogram from portion of primary transect immediately south of the facility, 0223-0230 July 3.

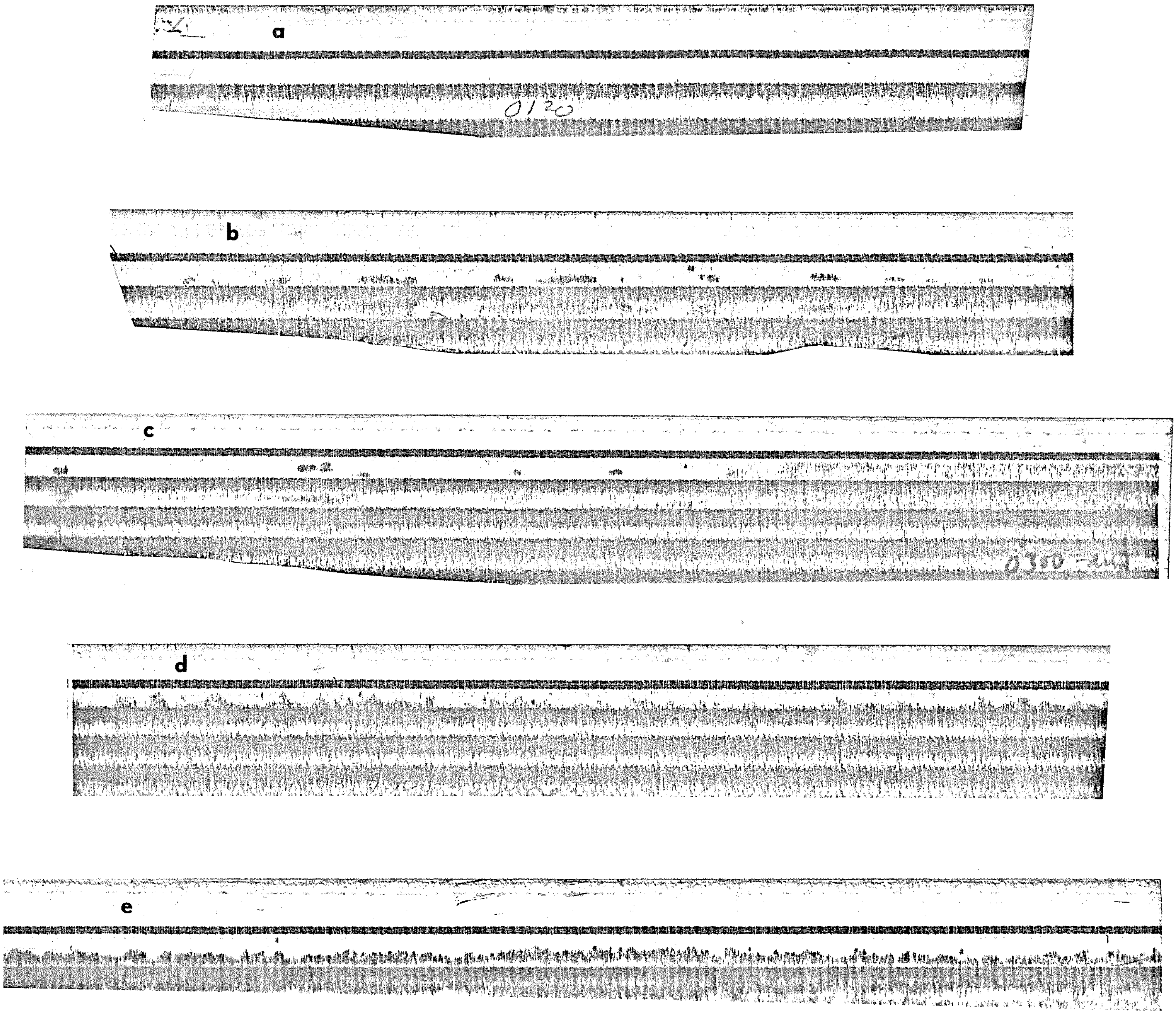


Figure 36. Echograms from uplooking system just before (a), and after (b) release, and 0250-0300 (c), and 1325-1335 28 June (d) and during night of June 30 (e).

DISCUSSION

The primary objective of the study was to investigate the feasibility of hydroacoustically tracking salmon smolts in the estuary, in order to determine their distribution and residence time. The initial requirement for this is the ability to detect the fish with the hydroacoustic system. While data on salmon smolt distribution and behavior is meager, there is indication of a preference for near surface and nearshore; areas where typical hydroacoustic systems are less efficient. The primary hydroacoustic system employed in this study was designed for shallow water use. The system has a very short pulse length and favorable directivity characteristics for this purpose. Consequently, it was possible to detect targets only 2 ft below the surface under the calm water conditions which were usually encountered during this study.

Although verification of target identification was generally not possible because of lack of direct capture capability, there were strong inferences that the hydroacoustic system was able to detect the salmon smolts. These inferences were: 1) the strong correlation between fish abundance and the facility, 2) the increase in abundance usually associated with the fish releases, and 3) the correlation between visual observations of salmon jumpers and hydroacoustic detection of near surface fish concetrations.

The uplooking system indicated that the salmon were present inshore and near surface. Undoubtedly, some of the salmon were not detectable with the downlooking hydroacoustic system, but apparently a sufficient proportion were detectable for the major distributional trends to be discerned.

The most striking observation was the strong correlation of fish abundance with the salt water release facility. This phenomenon was consistently observed throughout the study. The mechanism for this attraction is unknown. Visual observations with the spotlight indicated that some of the fish were not salmon. Possibly the water discharge from the facility contains food particles which attract both salmon and other species. Predators may then also be attracted to the fish concentration. The concentration was very persistent throughout the study, even in the absence of releases and despite major disruption by strong ebb tide currents.

The second major observation was the presence of juvenile salmon in the upper estuary, well above the release site. These concentrations were observed hydroacoustically and visually verified from jumpers. The abundance in the upper estuary appeared to decrease after the first survey in this area on June 29. Unfortunately, the number of large individual targets, presumably striped bass, increased during this same period.

The source of the juvenile salmon could not be determined with certainty because of the confounding effect of the release from the Anadromous site, which is much closer to the upper estuary. This release might account for the presence of juvenile salmon in this area, both because of its proximity and the fact that it was an emergency release due to equipment failure, thus, presumably included a much higher proportion of presmolts, which would migrate up estuary. On the other hand, the abundance of fish in the upper estuary appeared to be very substantial, possibly more than could be accounted for by a release of only 74,000 fish 8 days earlier.

A third and similarly disturbing observation was the lack of fish concentrations down estuary from the release site. The surveys showed that the fish concentrations associated with the facility were shifted down estuary by the ebb tide and were dispersed. However, concentrations were always located the next day by the facility, even without an intervening release, and no concentrations were ever detected further down the estuary.

CONCLUSIONS AND RECOMMENDATIONS

The study was apparently successful in detecting concentrations of salmon smolts and, to a limited extent, in tracking the movements of these concentrations, especially the shift of the concentrations by the facility with tide. However, it was not possible to follow the smolts out of the estuary. There are several potential explanations for this failure: 1) the smolts may migrate out in small, dispersed groups, 2) the migration may be along the shoreline, 3) the smolts may not have migrated out of the estuary during the period of the study. The latter possibility is suggested by the presence of juvenile salmon in the upper estuary, and the high concentration of fish still present by the facility the last day of the study.

In any case, the objective of the study was to investigate the feasibility of the hydroacoustic techniques for studying the behavior of salmon smolts in estuaries. It would have been fortuitous to have actually determined the residence time of the smolts given the time frame and innovative nature of the study. However, several recommendations for improvements in the procedures can be made on the basis of the experience gained in this study.

The first major recommendation is the addition of net sampling capability. In general, sampling with nets is inefficient. However, the combination of hydroacoustic surveys and hydroacoustically directed net sampling is very efficient. A few appropriately placed net samples in conjunction with the hydroacoustic surveys this year would have greatly increased the value of the results. A small lampara seine is recommended for this purpose. In addition, beach seining down estuary of the facility would close a potential gap in the survey coverage.

The second major recommendation for future studies is for no releases during a 2-week period prior to hydroacoustic surveys. In addition, 2 or 3 days of hydroacoustic surveys should be conducted prior to release in order to determine the abundance and distribution of nonsalmonids in the estuary. The results this year were confounded by the presence of salmon smolts during the first survey, and especially by the unavoidable emergency release from Anadromous, which confounded interpretation of the concentrations in the upper estuary.

Third, the timing and magnitude of the releases should be modified. The multiple releases this year were designed to provide several chances to track the fish. However, because many of the fish apparently remained in the area, the multiple releases actually confused interpretation of the data. A single large release 2 or 3 days after the beginning of the surveys, followed by 2 weeks of hyroacoustic survey ànd occasional net sampling would be much more effective.

The uplooking system provided some interesting information, but has even less sampling power than nets. Arrays of remote, stationary systems will eventually be feasible and will solve the low sampling power of uplooking systems (Thorne 1980), but their present value is limited. Probably the major immediate value of uplooking systems is to estimate the proportion of near surface fish which is not detected by the downlooking system, thus establishing a basis for quantification.

This leads to the final recommendation. The present system is able to indicate relative abundance, thus discern distributional trends. However, echograms are not suitable for absolute estimates of abundance. It would be extremely valuable to be able to quantify the abundance of salmon, especially if they do not migrate out in large, trackable concentrations,. With quantitative hydroacoustic data processing equipment, it would be possible to monitor the decrease in salmon abundance in the estuary, thus indirectly determine residence time.

Independent of the capability to track the salmon smolts out of the estuary, the present study pointed out some areas of concern which need to be addressed more fully. Both the attraction to the facility and the presence of juvenile salmon in the upper estuary indicate behavior which is probably undesirable in that it increases residence time in the estuary and exposure to predation. The reasons for this behavior need to be determined. The hydroacoustic techniques in conjunction with limited net sampling provide a sampling capability which can help evaluate these behavioral characteristics.

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Thorne, R. 1980b. Application of stationary hydroacoustic systems for studies of fish abundance and behavior. Proc. Oceans 80:381-385.

Thorne, R., and J. Dawson. 1974. An acoustic estimate of the escapement of sockeye salmon into Lake Washington in 1971. J. Fish. Res. Board Can. 31:222-225.

Appendix Table 1. Times and locations of acoustic transects.

Time		Location
2100	June 24	below site
		ladder
		buoy 17
		ladder
2140		pilings
		ladder
2151		buoy 17
		ladder
2218		south end pilings
2226		ladder
2232		buoy 17
2242		buoy 18
2255		buoy 17
2303		ladder
2314		pilings
2327		ladder
2332		buoy 17
2348		buoy 18
2358		buoy 17
0005	June 25	ladder
0014		pilings
0018		red buoy 12
0032		pilings
0110		ladder
0126		buoy 17
0131		ladder
0137		pilings
2001		smoke stack
2010		pilings
2016		ladder
2022		buoy 17
2030		buoy 18
2045		buoy 17
2057		ladder
2114		pilings
2120		ladder
2125		buoy 17
2136		ladder
2149		piling
2156		ladder
2210		buoy 17
2219		buoy 18
2231		buoy 17
2240		ladder
2255		piling
2307		smoke stack
2311		buoy 11
2344		boat basin
2254	June 26	pilings
		ladder
2318		buoy 18
2326		ladder
2340		tanks
2350		ladder
2353		buoy 17
0004	June 27	buoy 18
0017		buoy 17 (turn East)
0021		buoy 16 (East side)
0026		ladder (East side)
0031		buoy 14 (East side)
0035		tanks (turn West)
0037		turn N. (West side)
0049		ladder
0100		buoy 17
0114		buoy 18
0125		buoy 18
0132		buoy 17
0137		ladder
0144		tanks
0151		smoke stack
0218		buoy 18
0224		buoy 17
0230		ladder
0235		tanks
	Head South on West side	
0254		buoy 18
0259		buoy 17
0305		ladder
0310		tanks
0317		smoke stack
0326		buoy 11
0328		buoy 10
0331		buoy 8
2145	June 28	buoy 17
2151		ladder
2203		tanks
		ladder
2215		buoy 17
2217		buoy 17
2229		ladder
2241		tanks
2243		tanks
2249		ladder
2256		buoy 17
2304		buoy 18

Appendix Table 1. Times and locations of acoustic transects - continued.

Time		Location
	June 28	
	Other side	
2307		buoy 18
2349		red buoy 14
2353		tanks
	West side	
2356		tanks
0009	June 29	ladder
0015		buoy 17
0025		buoy 18
0052		buoy 17
0105		ladder
0118		tanks
0132		ladder
0143		buoy 17
	East side	
--		buoy 17
0157		buoy 14
0204		tanks (West side)
0228		ladder
0241		buoy 17
0245		ladder
0253		tanks
0300		smoke stack
--		buoy 11
--		buoy 10
0330		end
2211	June 29	highway bridge
	Range=15m	green dolphin 35
2226		WEYCO Mill
2239		green dolphin 37
2246		Thunderbird Motel
2257		Coos Bay city dock
--		green dolphin 3
2309		end at East highway bridge
2317		green dolphin 43
2332		Thunderbird Motel
2338		green dolphin 37
2351		WEYCO Mill
0006	June 30	green dolphin 35
0029		highway bridge
0037		railroad bridge
0116		buoy 17
0123		ladder
0134		tanks
--		red buoy 12
0150		smoke stack
2320	June 30	Eastside bridge
2329		changed rep rate to 2 sec^{-1}
2343		Thunderbird Motel
0007	July 1	WEYCO Mill
0028		green dolphin 35
0055		highway bridge
0110		railroad bridge
0133		chip loading dock
0143		black buoy 23
0153		green buoy 19
0158		red buoy 18
0210		buoy 17
dead batteries		
2100		red buoy 14
		ladder
		green buoy 17
2313		Eastside bridge
2332		Coos River mouth
2339		Thunderbird Motel
2348		Standard Oil tanks
0046	July 2	bend above highway bridge
0056		highway bridge
0108		railroad bridge
0113		buoy 27
0145		buoy 18
0156		buoy 17
0204		ladder
0216		tanks
0232		smoke stack
0240		buoy 11
0021	July 3	Eastside bridge
0023		Coos River mouth
0029		buoy 37
0054		green dolphin 35
0115		highway bridge
0128		railroad bridge
0130		buoy 27
0147		Roseburg chip pile end
0216		buoy 17
0223		ladder
0245		tanks