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Skeena River Hydroacoustic Feasibility Study, 1994

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G. Cronkite

Science Branch
Department of Fisheries and Oceans
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6

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SKEENA RIVER HYDROACOUSTIC FEASIBILITY STUDY, 1994

by

G. Cronkite

Science Branch

Department of Fisheries and Oceans

Pacific Biological Station

Nanaimo, British Columbia, V9R 5K6

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ABSTRACT

Cronkite, G. 1995. Skeena River Hydroacoustic Feasibility Study, 1994. Can. Manuscr. Rep. Fish. Aquat. Sci. 2311: 53 p.

Data on salmon migration direction and speed is crucial for understanding the Tyee test fishery. Split-beam sonar systems can provide these data. The feasibility of operating a split-beam hydroacoustic salmon enumeration facility on the Skeena River was determined. The sites identified and studied were the Tyee area, Sankey Point and upstream of the Copper River. The site upstream of the Copper River proved the most suitable for shore-based split-beam enumeration. The salmon showed bank oriented migration at this site. The Tyee and Sankey point sites were not suitable for shore-based split-beam enumeration. Salmon detection at Sankey Point was poor. The Tyee area encompasses a large volume of water and is subject to large tidal changes. This would not allow effective enumeration with shore-based split-beam systems. Significant acoustically determined fish densities were present at Tyee during times when the test fishery was not active, however, there was no relationship between acoustic density estimates and the test fish catches.

RÉSUMÉ

Cronkite, G. 1995. Skeena River Hydroacoustic Feasibility Study, 1994. Can. Manuscr. Rep. Fish. Aquat. Sci. 2311: 53 p.

Pour comprendre les résultats des pêches expérimentales dans le secteur Tyee, il est essentiel d'avoir des données sur la trajectoire et la vitesse de déplacement des saumons durant leurs migrations. Les systèmes sonar à faisceau divisé peuvent nous donner cette information. Dans cette étude, il s'agissait d'évaluer l'intérêt que présente la méthode de dénombrement hydroacoustique à faisceau divisé dans la rivière Skeena. Les pêcheries étudiées ont été le secteur Tyee, la pointe Sankey et le secteur situé en aval de la rivière Copper. C'est ce dernier site qui a paru le mieux adapté à la méthode de dénombrement par faisceau divisé à terre, puisqu'à cet endroit la trajectoire du saumon semblait être orientée sur le rivage. Le secteur Tyee et la pointe Sankey n'ont pas semblé adaptés à cette méthode de dénombrement. Dans le cas de la pointe Sankey, le nombre de saumons détectés était très faible, tandis que dans celui du secteur Tyee, le volume d'eau est très important et soumis à de forte amplitudes maréales, caractéristiques qui ne sont pas propices à un dénombrement efficace par la méthode étudiée. Des densités significatives ont pu être détectées acoustiquement dans le secteur Tyee lorsque la pêche expérimentale n'était pas en cours, mais il n'y avait pas de corrélation entre les estimations obtenues par densité acoustique et les captures expérimentales.

1.0 INTRODUCTION

A request was made through the Skeena River Joint Technical Committee to determine the feasibility of operating a split-beam hydroacoustic salmon enumeration facility on the Skeena River. The advantages of using the split-beam system are that it provides direction of travel and three dimensional tracking of fish passage through the beam. In addition, some size class discrimination may be attained from target strengths.

A further request was to study salmon behaviour in the Tyee Test Fishery area to see if the behaviour may be affecting the test fishery's run size estimates. Presently the test fishery is the major enumeration technique used to manage the Skeena River salmon stocks. In recent years the test fishery has tended to under-estimate the sockeye escapement (Cox-Rogers *et al,* 1993).

Visits to the Skeena River were made to determine if sites existed for the operation of a riverine split-beam system similar to the one being tested on the Fraser River at Qualark Creek near Yale, B.C. Initial site visits involved helicopter flights to select sites on single channel reaches. Subsequent boat surveys using a single-beam acoustic system were done to obtain river bottom profiles. It is desirable that a split-beam system be located close to the commercial fishing boundary at the mouth of the Skeena River. This would provide timely data for management purposes. The need for timely data has to be balanced with a suitable acoustic site.

Three sites were identified for hydroacoustic assessment of passing salmon stocks. The sites listed in order of distance from the mouth are Tyee, Sankey Point and Copper River (Figure 1). These sites vary greatly in their physical structure and each possesses a unique set of challenges for operating hydroacoustic equipment. Each site was studied and the most feasible site was determined.

A brief description of each site is presented here.

Site #1 - Tyee

Profile:
- Width at transect2500 metres
- Minimum depth at thalweg 6 metres
- Maximum depth at thalweg 22 metres
- Daily tidal variation 7 metres

Advantages:
- Approximately 7km upstream of the commercial fishing boundary
- Good access
- Good substrate

Disadvantages: Shallow bottom profile on left bank
7m tides causing possible fish milling and difficult equipment deployment
Significant debris load
Site is very wide

Site #2 - Sankey Point
Profile: Width at transect 580 metres
Minimum depth at thalweg 8 metres
Maximum depth at thalweg 12 metres
Daily tidal variation 3 metres

Advantages: Approximately 34km upstream of the commercial fishing boundary
Good access

Disadvantages: Shallow bottom profile on right bank
Very steep left bank profile with large rock
3m tides causing possible fish milling and difficult equipment deployment
Significant debris load

Site #3 - Copper River
Profile: Width at transect 250 metres
Minimum depth at thalweg 2 metres
Maximum depth at thalweg 3 metres

Advantages: No tidal influence
Straight reach, fish milling unlikely
Good access
Good substrate

Disadvantages: Shallow profile
Approximately 130km upstream of the commercial fishing boundary
Significant debris load

2.0 MATERIALS AND METHODS

2.1 HYDROACOUSTIC SYSTEM

At the Tyee site a Radarsonics Inc. 22 degree transducer was used as this was the wider of the two transducers available and provided coverage of the largest volume of water. The transducer was mounted on the end of a steel pole that was clamped to the side of the skiff. The transducer mount was designed to allow rotation of the transducer up from the downward-looking position for use in a semi-sideways orientation when desired. The transducer was mounted in the downward-looking position for most of the work done from the skiff. The SIMRAD EYM echo sounder used for this study was a small portable unit with an operating frequency of 70 kHz. It has two time-varied-gain (TVG) controls of "40 log R" and "20 log R", which compensate for spreading of the echo signal. The sounder was used with the 40 log R TVG setting. The transducers were of the single-beam type and were calibrated at the Institute of Ocean Sciences (Galloway *et al*, 1994). The calibration showed that these transducers performed well with minimal side lobes. Prior to field work, experiments were done off the dock at the Pacific Biological Station with the complete system, using a 100 watt light bulb as a "fish-like" target to determine system operation, levels of gain required and the length of the blanking zone.

2.2 TYEE TEST FISHERY AREA

Most of the work carried out at the Tyee site was done in conjunction with the existing test fishery to determine if fish behaviour could be affecting the run strength estimates. The Tyee test fishery area was examined during the sockeye season from June 23 to July 30, 1994. The work at Tyee was predominantly carried out from a herring skiff with a shelter, chartered from the Tyee test fisherman. The Tyee test dock was used as the base of operations. During the initial days of operation one of the test fishermen assisted with the acoustic transect work by operating the skiff, providing site familiarization and local knowledge of fish behaviour, tidal flows and weather concerns.

Transects performed at the Tyee site were done to determine where the fish were travelling in the river. This meant that as much of the river as possible needed to be sounded during all stages of the tide. As information on fish location was acquired, efforts were concentrated on operating in the test fishing area prior to, during and after the test fishing sets. Transects were performed downstream of the test net in an effort to detect fish targets that were passing in the area covered by, to either side of, and below the net. Attempts were made to cover the large area towards the left bank to determine if significant numbers of salmon were migrating there. This area was never sampled by the test net due to the shallow water. The lengths of the transects across these shallow areas were limited by time since, if the sounding vessel travelled too far towards the left bank shore, then much of the activity in the area of the net was missed. At low slack tides the water was too shallow to take the boat across and fish detection was difficult due to the small size of the beam at close range, coupled with the presence of the blanking zone.

Data were recorded on echograms for each transect. Additional information recorded included date, time, weather conditions, status of test fishery, position of the net, tidal stage, length of transect (from GPS readings), location of transect and unusual observations. Fish traces were marked as they occurred. At the end of the day the information on the echograms was transferred onto a computer spreadsheet that stored all of the data for each transect and calculated target density by depth interval and total target density for each transect.

Echosounding was also done with the EYM system mounted on the Tyee dock with the transducer aimed sideways into the deep channel to see if further information could be gained on fish migration relative to the tidal stages. The system was operated in this orientation for a 17-hour period of significant sockeye migration.

When using an acoustic system in the downward-looking orientation with the fish near the surface, the probability of detection will be very low. This is due in part to the beam geometry. The conical nature of the beam means that the insonified volume of water is very small near the transducer. In addition, the first one metre or so, (depending on the system and transducer used), is subject to near field and receiver blanking effects. Fish cannot be detected in this range. For these reasons, tests were made to determine if salmon were migrating very close to the surface.

Two experiments were performed to determine the extent of surface oriented migration. The first involved attaching the transducer to the top of a stabilizing fin and lowering it down to a depth of 10 metres and towing it behind the skiff. This oriented the transducer upwards towards the surface. The second experiment involved lowering an acoustic system designed to sit on the bottom and look upwards to the surface. This system, called the WASP II, was built by Ocean Physics at the Institute of Ocean Sciences. It was designed for long term studies of plankton migrations under Arctic ice flows. It has also been used for studying diurnal plankton migrations in Kootenay Lake (Topham *et al*, 1993, unpublished). The WASP II uses a single-beam transducer with an integral data collection computer in a water proof canister. The transducer and canister were mounted on an "I" shaped steel channel. This mount orients the transducer in the upward direction and keeps the system from sinking into the substrate. Although not specifically designed to detect salmon sized targets, it was thought that it could be set up to help determine the extent of surface oriented salmon migration in the Tyee area.

The WASP II was lowered from the skiff on the end of a 90m x 5mm cable into the deepest part of the channel in the test fishing area. The system was located approximately 75m from the right bank and settled into 19m of water during a low slack tide. The cable was then strung back to shore, run through a drill hole in a large piece of rip-rap and cable clamped. The system had an expected battery life of two weeks continuous operation with the settings used. The system was pulled up after one week as there was some concern that it might have sunk into the bottom mud. It was then re-deployed in approximately the same position.

2.3 SANKEY POINT AREA

Sankey Point was examined on July 02, 27 and 28. This site had easy access with a boat launch and private dock one half a kilometre downstream. The site was transected in the same manner as Tyee, with the transducer mounted in a downward-looking orientation. An 18 foot Gregor jet boat was used instead of the herring skiff. Transects were performed at various locations within the single channel reach to determine the best location for observing fish targets. In addition, the boat was tied to the left bank rock face and the transducer was aimed sideways to look into the deep channel directly off the bedrock shore.

2.4 COPPER RIVER AREA

The Copper River site was examined from August 01 to August 10. The site had road access on both sides of the river and the Gregor jet boat was launched from the right bank at the Kitsalas Band's boat launch and river access area. Access to this site was by permission from the Kitsalas Band. Initially the site was transected similarly to the other sites downriver but due to its shallowness, a sideways-looking operation was chosen. The narrow beam (11 degree) transducer was used sideways from a shore-based tripod and from the transom of the boat.

The shore-based transducer had a range of approximately twelve metres at this site. Beyond this range, the beam intercepted the surface and the bottom (Figure 2). Therefore, to cover the river cross section, the transducer was attached to the boat, and the boat was anchored at various locations across the river. Data were gathered at each location to give a combined estimate of fish densities in various portions of the river. Depth of fish travel could not be determined as depth information is lost when the single-beam transducer is aimed sideways. However, fish position with respect to shore was determined.

In addition to daytime soundings across the river, a 24 hour, shore-based data set was collected to examine the migration pattern. The transducer was mounted on the tripod for this time period and the echosounder was left in a protective box on shore. The system was monitored through the daylight hours during this experiment.

3.0 RESULTS AND DISCUSSION

3.1 TYEE TEST FISHERY AREA

3.1.1 Site Considerations

Due to extreme tidal influence and the 2.5 km width of the river with a deep channel and shallow bars, the Tyee site is not feasible for sideways-looking split-beam enumeration. Only a very small portion of the channel can be covered with a sideways-looking system. Furthermore, the extreme tides would require that the transducers be moved continuously. A multi-beam downward-looking system might be feasible but further study is needed to determine the extent of migration in the shallow areas of the river that would not be covered. Over half of the river is approximately 3 metres deep which makes detection of fish targets with a vertical system very tenuous.

3.1.2 Mobile Downward-looking Sounding

Overall seasonal acoustic densities relative to the test net were determined. The river cross sections relative to the net were divided into six bins with Bin #1 representing the area covered by the test net during any particular test set (Figure 3). Bin #2 was in the area covered by the net but below its reach and Bins #4 and #6 were below the net but to either side. Bins #3 and #5 were within the vertical reach of the net but to either side. The bin locations were determined by marking the echogram when the boat was abeam of the net combined with the known depth of coverage of the net from Jantz *et al*, 1990. All target densities were adjusted to account for changes in water depth and therefore volume of acoustic coverage over the transects. The purpose of this analysis was to compare the acoustically measured fish densities with the river cross section covered by the net.

Infrequent fish targets were detected in the shallower portions of the river. This shows that migration does occur throughout the river but, due to the limitations of the downward-looking acoustic system in shallower water, the extent of this migration cannot be quantified.

Fish densities to either side of the net but within the net's depth of coverage were similar to those deeper than the net. The highest fish densities were seen where the test net sampled (Figure 3). The average target density in the cross section sampled by the net was 1.33×10^{-4} fish per cubic metre. The mean target density for the cross section not sampled by the net, (bins #2 to #6 of Figure 3), was 5.86×10^{-5} or approximately 0.44 times the average target density in the cross section sampled by the net. This would suggest that the net was operated in the cross section of the river where the highest densities of fish were migrating.

Acoustically measured fish densities were not highly correlated with the test fishery catches (Figure 4(a) and (b)). Figure 4(a) shows the average acoustic fish density in the river cross section sampled by the test net (bin #1) versus the total test fishery catch per hour for the same time period. Figure 4(a) and (b) are plotted on log-log scales as errors are more likely to be proportional than to be additive and therefore a log-log plot should show a more uniform scatter around a trend line. A trend could not be detected in this plot and therefore a two way regression analysis was not performed. Figure 4(b) shows a similar comparison except that the acoustic fish densities in the whole river (all bins) are compared with the total test catch per hour for the same time period. Again the figure shows the two measurements of fish density are not highly correlated. This lack of correlation between the two measurements may be attributable to low detection during transects as the acoustic beam samples a small portion of the volume of water sampled by the drift gill net.

The results of comparing passage densities with tidal cycles showed that the highest target densities occurred during low slack and in the first 2 hours after the low slack tides (Figure 5). Highest fish densities tended to straddle the low slack water times but significant fish densities were also noted during full inflow and outflow tides. The next highest densities were observed during high slack tides. Figure 5 represents the seasonal average target densities over a full tidal cycle. For this reason the high slack average density is presented twice. Each bar on the graph represents the seasonal average density for sequential hours after each slack period. On average there were 6 hours between high slack and low slack tides and 3 hours between low slack and the next high slack. The low and high slack periods were the times in which the test fishery operated. The test sets were generally one hour in length. Figure 6 presents the density of fish per transect versus the tides for July 11. Each point on the graph represents the density detected for consecutive transects through the various tidal stages. Transects on this day were carried out for a complete tidal cycle. The results are similar to the seasonal average densities presented in Figure 5 with low densities during outflow, high densities for the first half of the low slack and medium densities during high slack. The one difference in this example is that there were no fish detected during the inflowing tide, although three transects were performed during this period.

Figure 7 compares the target densities at the various tidal stages. Higher target densities were detected on the low slack tide compared to the high slack tide over the season (Figure 7(a)). This may be due to the reduced water volume at this tidal stage. The densities at high slack tides tended to be less distinguishable from inflow and outflow densities than the low slack densities (Figure 7(d and e) and 7(b and c)). Outflow densities and inflow densities appeared very similar (Figure 7(f)). It is possible that as the tide turns from high slack to outflow, some of the fish that have moved into the river are flushed downstream. This is speculation as we cannot determine direction of travel with the single-beam system used. It appears that fish begin to move on the inflowing tide just prior to a high slack condition. This seems likely, as the slack tide moves progressively up the river and fish may be travelling with or ahead of this tidal stage. It was initially expected that salmon would migrate upstream during the inflowing tide to conserve energy. Fish densities during inflow were not as high as those during low slack (Figure 7(c)). However, comparatively high densities were detected during inflow. Rate and direction of travel are not known. If we assume that the fish are travelling upstream with the current, their speed may be comparatively high and the flux may be higher than for periods of equal density but lower migration speed. This is due to the fact that a faster moving fish has a lower probability of detection than a slower moving fish, as it spends less time in the beam.

To determine if the densities during test fishing times were representative of the densities seen through the tidal cycle the seasonal average density of the low and high slack periods were compared with the seasonal average density of all other tidal conditions. The result showed that the average densities observed during test fishing times are 1.83 times greater than the average densities observed during the inflow and outflow periods. The missing pieces of information in this analysis are the direction and speed of travel. Fish milling or passive migration with the tides may be occurring. This behaviour was noted by Groot *et al* 1975 during their ultrasonic tagging study. Without knowing the direction and speed of travel, any form of run strength estimator will have a high error.

3.1.3 Stationary Sideways-looking Sounding

For a 17-hour period, a transducer was operated off the Tyee dock looking into the deep channel to see if fish could be detected and to obtain some longer term observations of fish passage. During the first hour of the time series, the test fishery was operating on the low-low tide and obtained a catch of 32.17 fish per hour with the acoustic count being 19 fish per hour (Figure 8). As time progressed to the high-high slack test set the acoustic counts continually dropped and were at zero for a test fish catch of 12.28 fish per hour. The next slack was a high-low that occurred during the hours of darkness when the test fishery does not operate. Fish targets were observed throughout the incoming tide prior to this slack tide and a relatively high number of 17 targets were counted at the high-low slack. In the following hour the target count rose to 25 and then trailed off continually to the next low-high slack. If fishing had occurred during this nighttime high-low slack, the catch may have been similar to the earlier low-low slack catch of 32 fish per hour.

The next test set was on the low-high tide at which time the catch was 11.25 fish per hour and the acoustic count had dropped to 5 fish per hour. Some inconsistencies with the downward-looking sounding data are noted here including the apparent high passage during the outflowing and inflowing tides but again fish direction and speed of travel are not known. Milling behaviour may have occurred in the volume covered by the beam. Firm conclusions may not be made as more extensive data are needed to show distinct trends.

3.1.4 Stationary Upward-looking Sounding

One area of concern with the boat-based downward-looking sonar work at the Tyee site was that, if the salmon were very surface oriented, detection would be difficult. This is due to the small size of the beam near the surface and the effect of beam blanking. Any fish travelling within the first few metres of water would have a very low probability of detection. To test for near-surface migration, the WASP II was deployed on the bottom at the thalweg in the test fishing area. With this equipment we attempted to observe surface targets over a two-week period during the peak of the sockeye run. The WASP II collected usable data for only the first three days of its deployment as a battery malfunction occurred after this time.

A number of additional problems arose with the WASP II system that affected the way in which it collected data and the utility of this information. The first problem was the system gain. The system had not been previously calibrated by I.O.S. personnel to determine how the field settings affected the data collection. Upon post season calibration, it was found that the system was saturated with a herring size target within the range of detection used at Tyee. This meant that the size of the targets could not be determined except to say that those that appeared to be fish were approximately herring size or larger. When thresholds were set post-season to remove noise and the detection of very small targets, remaining targets could not be identified as being definitely salmon size. For this reason, analyses of the echograms were limited and the only results that could be derived were if fish (of herring size or larger) were located near the surface.

Vertical distributions for test fishing times are shown in Figure 9(a to f). The examples presented have a threshold of 510 mV applied to leave only herring size or larger targets and are from slack water periods when test fishing occurred. Figure 9(c) is the only time period found that showed numbers of surface oriented targets. These may or may not be fish, and are abnormal in that they appear in unusually high density. Figure 9(g) shows a low slack period during darkness when test fishing did not occur. A great deal of surface noise is present in this echogram and may be due to wave action or large debris. Surface noise was extensive on windy days due to wave action entraining air bubbles. It must be noted that not all the targets on these echograms are fish, as air bubbles and debris would give similar results. Perusal of the data suggests that the fish were not surface oriented and that very few targets are present within the first few metres of the surface. If extensive surface oriented migration was occurring, then it is expected that surface targets would be seen.

The WASP II echograms showed that during the outflow tide when current velocities are high, the acoustic noise level in the river is extremely high (Figure 9(h)). This was due to several factors that include entrained air bubbles, debris and turbulent current flow. At times this noise interference extended from the surface to the bottom. Times straddling the low slack tides showed very quiet acoustic conditions (Figure 9(a and b)). Echograms covering inflowing tidal periods prior to high slack tide showed a cloud of targets coming into the river and increasing in total height over time (Figure 9(f)). This appears to be related to the inflow of ocean water forming a salt wedge and halocline with the fresh river water. This intruding salt wedge contains a dense distribution of targets which may be small organisms. In some instances this believed salt wedge shows a spiral pattern at the boundary with the overlying fresh water layer (Figure 9(i)). Figure 9(i) is not thresholded to show this pattern.

In addition to the WASP II deployment the transducer used for the downward-looking work was "flown" on a fin with the transducer oriented upwards in about 10 metres of water to see if it was possible to detect fish targets in this manner. Only one fish target was detected and the target was located four metres from the surface. This provides support for the findings of the WASP II as extensive surface migration was not detected.

3.2 SANKEY POINT AREA

3.2.1 Site Considerations

Sankey Point is the next single channel site upstream of Tyee. Sankey Point is under tidal influence and fluctuates by approximately 3 metres under some tidal conditions.

The site is not suitable for shore-based split-beam sonar work for several reasons. The bottom contour is very steep on the left bank and much more gradual on the right bank, being very wedge shaped with a generally uneven bottom. The few fish targets that were observed were in deep water and usually associated with underwater features such as large rocks. Most of the targets detected at this site were present during the chinook season and may have been chinook using eddy currents behind rocks to conserve energy. Fish milling behaviour may be occurring at this site and this would pose problems for sideways-looking split-beam enumeration. It would not be possible to insonify the full river channel, particularly in the deep portion.

No targets were detected at Sankey Point during the sockeye season. It proved difficult to detect fish targets using vertical sonar, even during times of high passage. As a result, it was not possible to determine the behaviour of the salmon at this site. The site was abandoned as a possible enumeration site as a result of these findings. It is possible that the sockeye using this site were travelling in very shallow water and were therefore undetectable with the setup used. Boat avoidance may also be a factor in poor detection at this site. Boat avoidance was believed to occur during the chinook season as fish targets were seen on the first transect of the channel and not on subsequent transects. If the site was not transected for approximately one hour and then done again, targets would again be detected on the first transect but not on subsequent transects.

3.3 COPPER RIVER AREA

3.3.1 Site Considerations

The Copper River site showed promise for the operation of a sideways-looking split-beam system even though the site was shallow. Figure 10 shows the bottom profile from echosoundings with the horizontal axis considerably compressed relative to the vertical axis. The maximum measured depth was three metres with a width of approximately 300 metres. Operation at this site would require the use of narrow beam transducers (e.g. 4x10 degree elliptical) and would be feasible.

The downside to the Copper River site is that it is located approximately 130 km from the commercial fishing boundary. The sockeye take approximately one week to migrate this distance. Therefore, information for management purposes would be delayed by about one week. This is the closest site to the commercial fishing boundary that is suitable for shore-based split-beam acoustic enumeration. From the Copper River downstream, the Skeena is braided.

3.3.2 Mobile Downward-looking Sounding

Downward-looking sonar was used at this site for deriving the bottom profile map (Figure 10). Fish targets were not observed with the sonar in this configuration. The water was too shallow for effective detection of fish targets with a downward-looking system.

3.3.3 Stationary Sideways-looking Sounding

Salmon migrations at the site were bank oriented on both the right and left banks (Figures 11 and 12). The right bank would prove the easier bank to operate from, requiring only a small offshore weir. On the right bank the fish seemed to travel at the thalweg which was located close to the shore and had a three metre water depth. Fish passage was noted in the first 20 metres of the right bank and in the first 30 metres of the left bank (Figures 11 and 12). The left bank had a very shallow gradient for the first 30 metres and then showed a constant depth of 2 metres for about 150 metres of its width (Figure 10). Operations from the left bank would require the construction of a weir of about 30 metres in length to move the salmon offshore into deeper water for effective detection. Jumping salmon were seen in the shallow nearshore areas of the left bank.

Some targets were detected further offshore on both banks corresponding to the middle portion of the river. However, these were inconclusive fish targets as they were weak detections (Figures 11 and 12). It is likely that some fish do travel up the middle of the river at this site but they appear to be few relative to the densities observed near shore.

Hourly migration information was gathered from the right bank for a 24 hour period to look at possible diurnal or other variations. We were able to achieve an 18 metre range for gathering this data set. "Fish like" targets were passed through the beam at known depths to determine the beam's vertical coverage of the water column. The results showed that the system sampled the entire water column within this range. Therefore, fish counts were used instead of fish densities as volume corrections were not required. Peak migrations were noted in the late afternoon and early evening hours but this pattern may vary over the season (Figure 13). Fish passage through the day was fairly constant. Target counts for this same time period were highest within the first two metres of the shore-based transducer and began to drop off rapidly at about 14 metres (Figure 14). This bank oriented migration would aid in the detection of targets from a shore-based split-beam system as the cross section in which the fish are travelling could be fully insonified. Figure 15 shows the hourly passage for this same time period broken down into 2 metre distance intervals from the right bank to determine if there were changes in horizontal distribution during the day. There may be a slight tendency for the fish to move further offshore during periods of darkness but this is not strongly evident in these data.

It is likely that fish milling does not occur to any great extent at this site due to the laminar flow and straight reach characteristics of the site. Measurements of milling behaviour require the split-beam system which gives direction of travel. Further work would be required in conjunction with split-beam enumeration to determine the extent of fish passage in the middle portions of the river. The substrate at this site is good for split-beam operation, as it consists of gravel and small cobble and appears to be free of large boulders that would interfere with transducer aiming.

Entrained air from upstream disturbances did not appear to be extensive, but measurements would need to be made with the split-beam system to determine the background noise at this site. It is likely that the site would be acoustically quieter than the present site on the Fraser River. One possible source of noise that could be a problem is the jet boat traffic in the area. This source of noise is due to entrained air making its way downstream through the acoustic beam. This can likely be minimized if boaters agree to use the middle of the river. Extensive noise from boat bubbles was noted with the single-beam system when boats passed near shore or cut into shore several hundred metres upstream of the transducer. This noise can be removed from the split-beam data, however, fish detection will be affected.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 TYEE TEST FISHERY AREA

One of the most likely problems affecting the test fishery estimate of abundance is the lack of information on direction of travel. If extensive milling or passive migration with tidal flow is occurring, then migration may not be directed upstream at any particular time. Without knowing the direction of travel any form of run strength estimator will potentially have a high error. If milling behaviour is contributing to the error then this behaviour may be too variable to allow a reliable expansion factor to be applied to the test fishery data.

Data on fish migration direction is crucial for understanding Tyee. The Tyee area is not suitable for shore-based split-beam acoustic enumeration. The split-beam system could not cover the large volume of water in which the salmon are migrating. Further information may be gained on salmon milling behaviour with the use of a split-beam system, or a radio or sonic tagging programme.

An underestimate of population size may be attributable to the significant fish densities present during time periods when the test fishery is not active. Underestimation may be caused by a higher proportion of salmon migrating during times of inflowing or outflowing tides than occurred historically. In addition, large numbers of fish may be migrating during dark when the test fishery does not operate. This is inconclusive and requires further study as acoustic data are available for only one nighttime period. If these factors are affecting the population estimates, then this migration behaviour may have changed in more recent years due to environmental or behavioural factors. Historic data on fish movement does not exist for comparison.

There is no consistency between acoustic fish density estimates and the test fishery catches. Any direct comparisons are tenuous as one method cannot be used to predict the results of the other. Other studies have shown good correlation between the acoustic fish density estimates and estimates from sampling methods such as drift gillnetting (Mulligan 1995, pers. comm.). It is known that the Tyee test fishery has underestimated the population in recent years and is therefore not achieving a representative sample. It is not known if the downward-looking sonar achieved a representative sample. The acoustic fish densities encountered during this study were extremely low due to the relatively small volume of water sampled by the downward-looking sonar. A more confined river channel would provide an increase in the number of fish observed acoustically, increasing the likelihood of achieving a representative sample. Several seasons of acoustic data are needed to compare with spawning ground escapements to determine if a relationship exists. If the salmon are not directed in their migration at Tyee then both sampling methods are prone to error in estimating the size of the migrating population.

4.2 SANKEY POINT AREA

We recommend that the Sankey Point site not be considered for acoustic operations due to the low probability of detection noted during this study.

4.3 COPPER RIVER AREA

The site upriver from the mouth of the Copper River was the best suited for riverine split-beam acoustic operations. The shallow water at the site requires the use of appropriate narrow beam transducers. This site was also the closest acoustically suitable site to the commercial fishing boundary and the salmon showed bank oriented migration behaviour. The main drawback of the site is its distance from the commercial fishing boundary. The salmon travel time from the commercial boundary to the site would be approximately one week. This may be unacceptable for management purposes.

The Copper River site is unlikely to be useful for management of the commercial fishery at the mouth of the Skeena River. However, it may be useful for the management of in-river fisheries. A programme developed at this site could provide an indication of sockeye run sizes past this point and combined with a reliable sampling method, could be used for estimating the population sizes of other species such as chinook and coho. Fisheries managers would need to decide if the time and money involved in developing an acoustic system at this site is worthwhile for the information it could provide. The development period for riverine split-beam acoustic programmes is in the order of three to five years to reach a point where they can be used as a management tool.

ACKNOWLEDGEMENTS

I thank Ian Bergsma for his assistance with the field work. At times it was truly above and beyond the call of duty. I also thank the people from the Prince Rupert DFO office, especially David Southgate and Mike Jakubowski for their support and help with all the logistics. I also thank Robert Johnson and Jon Bonneschranz for their support, hospitality and willingness to share their knowledge of salmon behaviour and fishing in the Skeena River. Further thanks go to Steve Roberts of the Kitsumkalum Band and Willy MacKenzie of the Kitsalas Band for taking me on river familiarization trips below and above Terrace, for sharing their knowledge of the salmon and the area and for help during the field season. The assistance of Dr. Tim Mulligan and Norm Olsen in reviewing and commenting on this report is greatly appreciated.

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Topham, D., P. Johnston, D. Addison, 1993. Report on the WASP I trials, Kootenay Lake, Aug. 1993. Institute of Ocean Sciences, unpublished internal report. 33p.

Vroom P., 1971. An attempt to determine abundance and distribution of migrating Skeena River salmon stocks by acoustical means. Can. Technical Rep. Dep. Fish. and Forest. 1971 - 5, iii + 33p.

Fig. 1. Skeena River drainage showing the three study areas: Tyee, Sankey Point and Copper River.

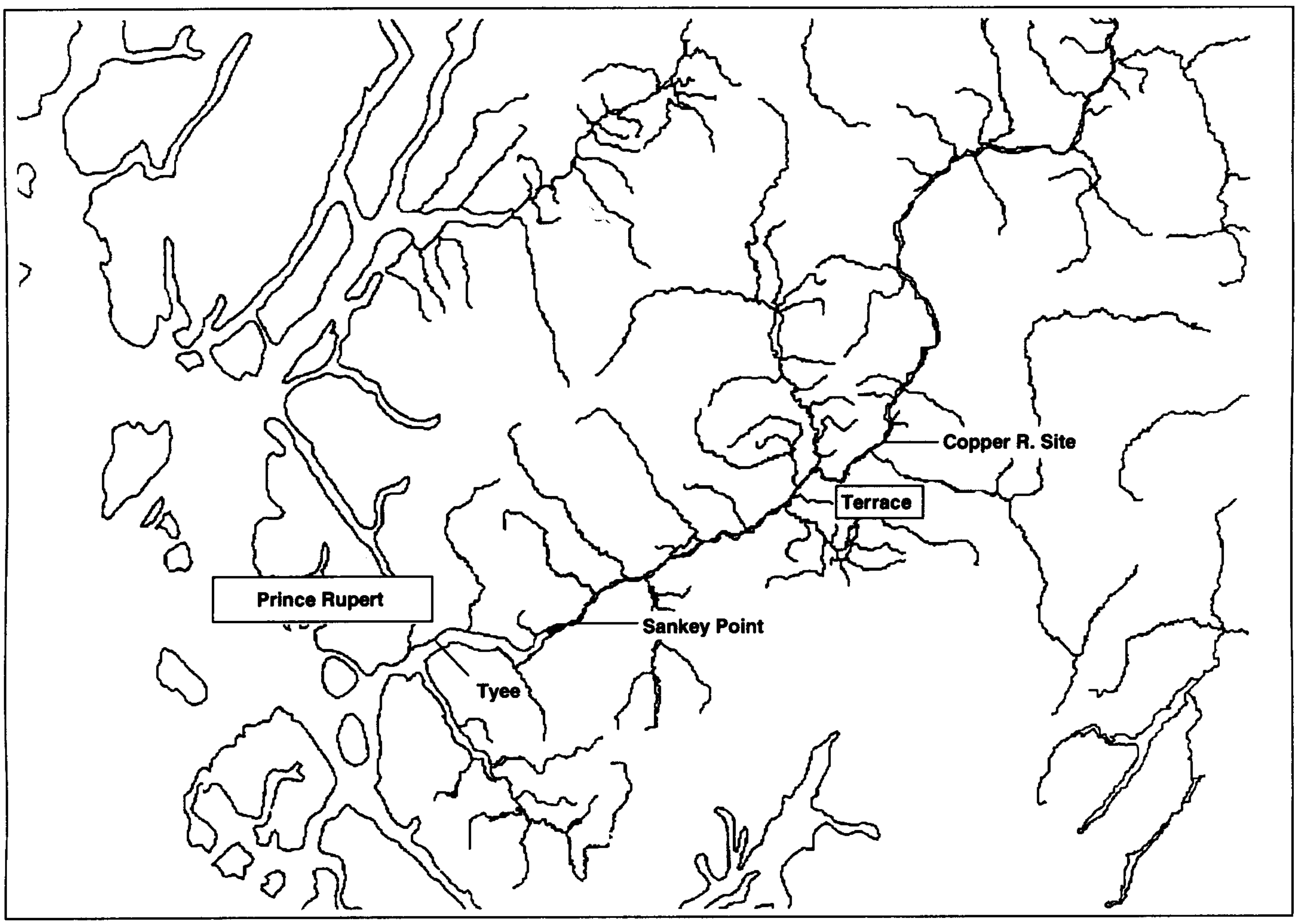


Figure 1.

Fig. 2. Copper River site bottom profile. Shaded areas represent approximate coverage of shore-based, tripod mounted 11 degree transducer.

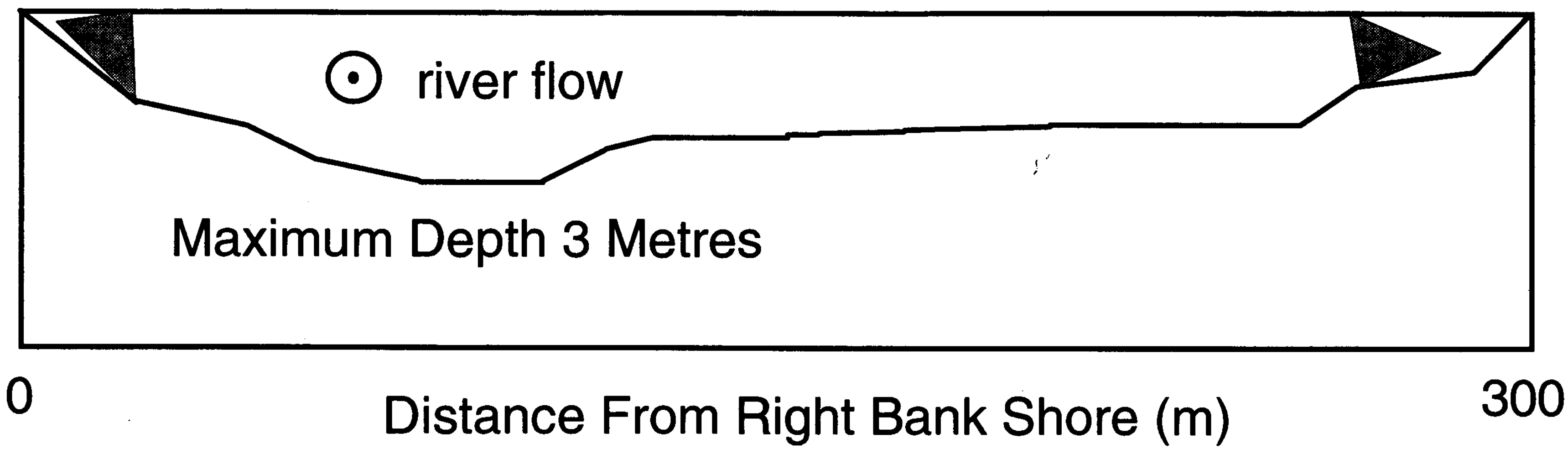

river flow
Maximum Depth 3 Metres
0
300
Distance From Right Bank Shore (m)

Figure 2.

Fig. 3. Seasonal average acoustic fish densities (fish/cubic metre) relative to the test net. The circles above the horizontal line are within the net's depth of coverage (6 metres). Circles below the line are below the net's depth of coverage. The areas of the circles represent the average acoustically measured fish densities for the season. Bin #1 represents the river cross section sampled by the test net. Bins #2 to #6 represent the river cross sections relative to the net that were not sampled by the net. Bin #3 and #4 represent densities to the right bank shore (north bank). Bin #5 and #6 represent densities to the left bank shore (south bank).

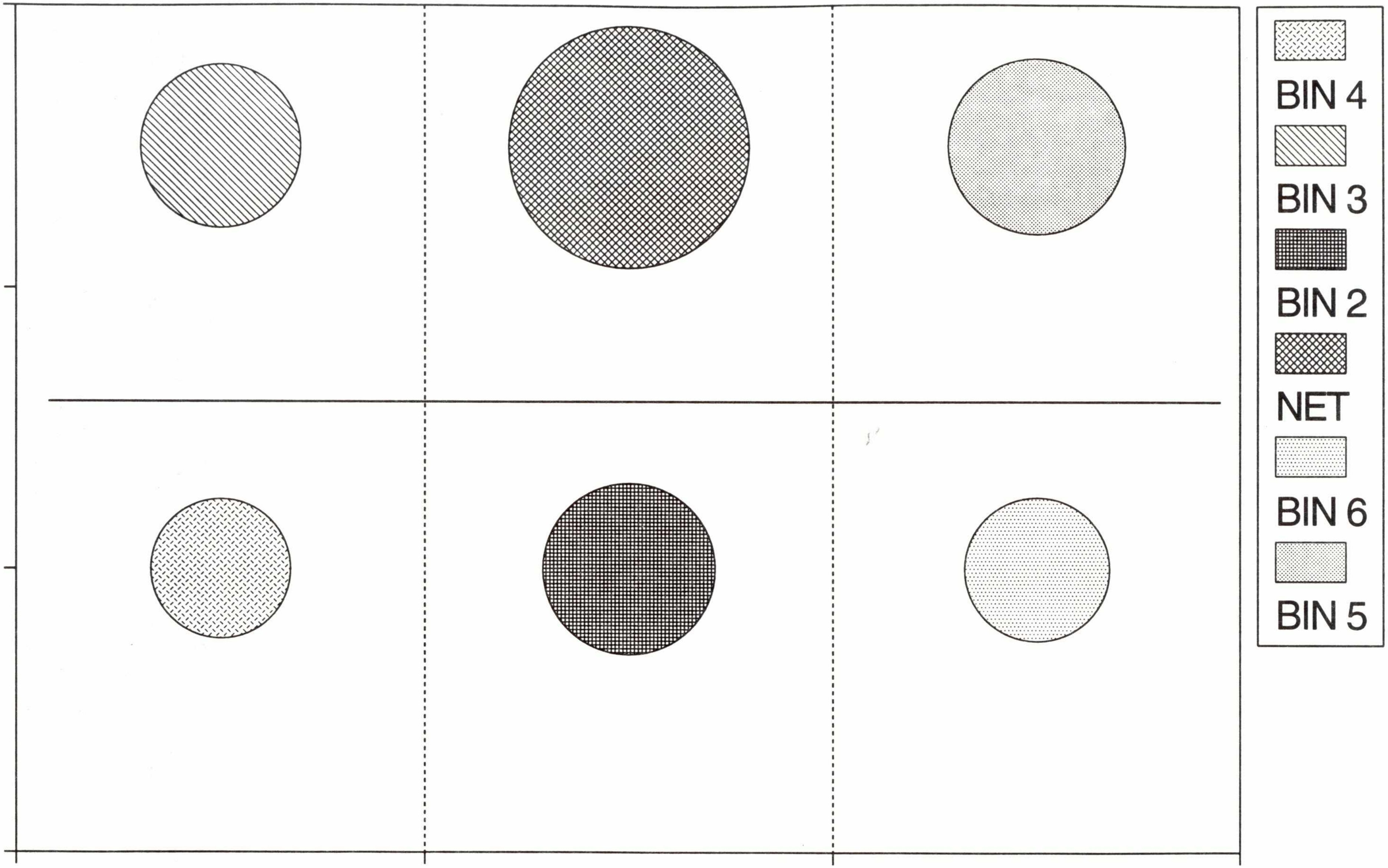
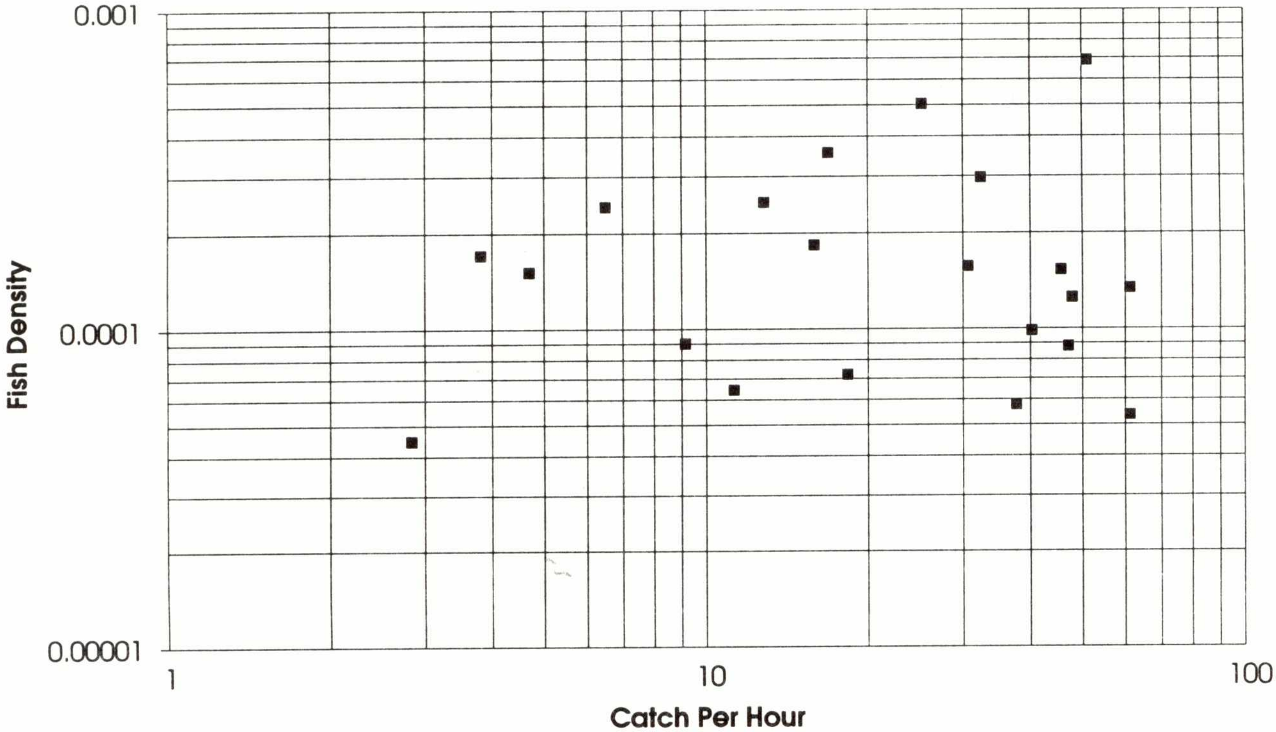


Figure 3.

Fig. 4(a). Average acoustic fish density (fish/cubic metre) in the river cross section sampled by the test net (bin #1) versus the test fishery total catch per hour for same time period. Plots are on a log-log scale.

(b). Average acoustic fish density (fish/cubic metre) in the entire river cross section (all bins) versus the test fishery total catch per hour for the same time period.

(a)


0.001
0.0001
0.00001
1
10
100
Fish Density
Catch Per Hour

(b)

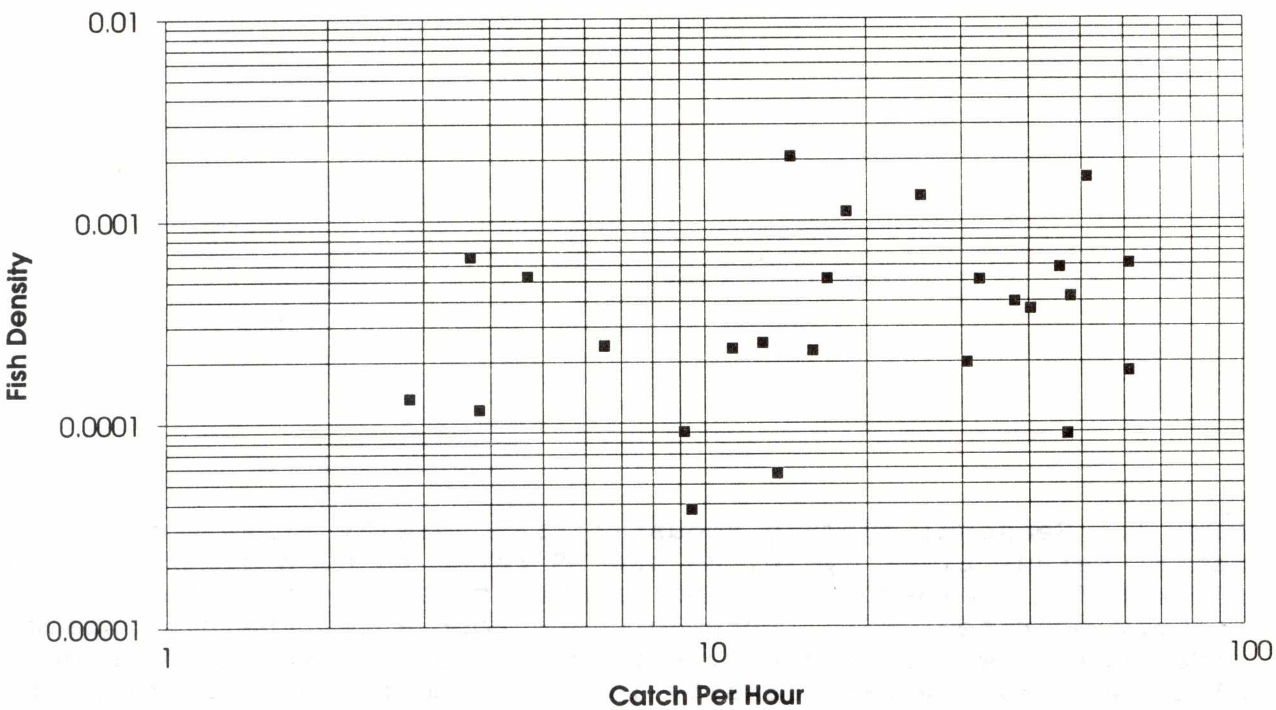

0.01
0.001
0.0001
0.00001
1
10
100
Fish Density
Catch Per Hour

Figure 4.

Fig. 5. Seasonal average acoustic fish density (fish/cubic metre) versus tidal cycle. HS and LS refer to high slack and low slack tides, respectively, and are the times at which the test fishery operated. HS+1 represents one hour after the high slack tide, HS+2, two hours after, etc., through the cycle. The high slack seasonal average density is presented twice to complete the cycle.

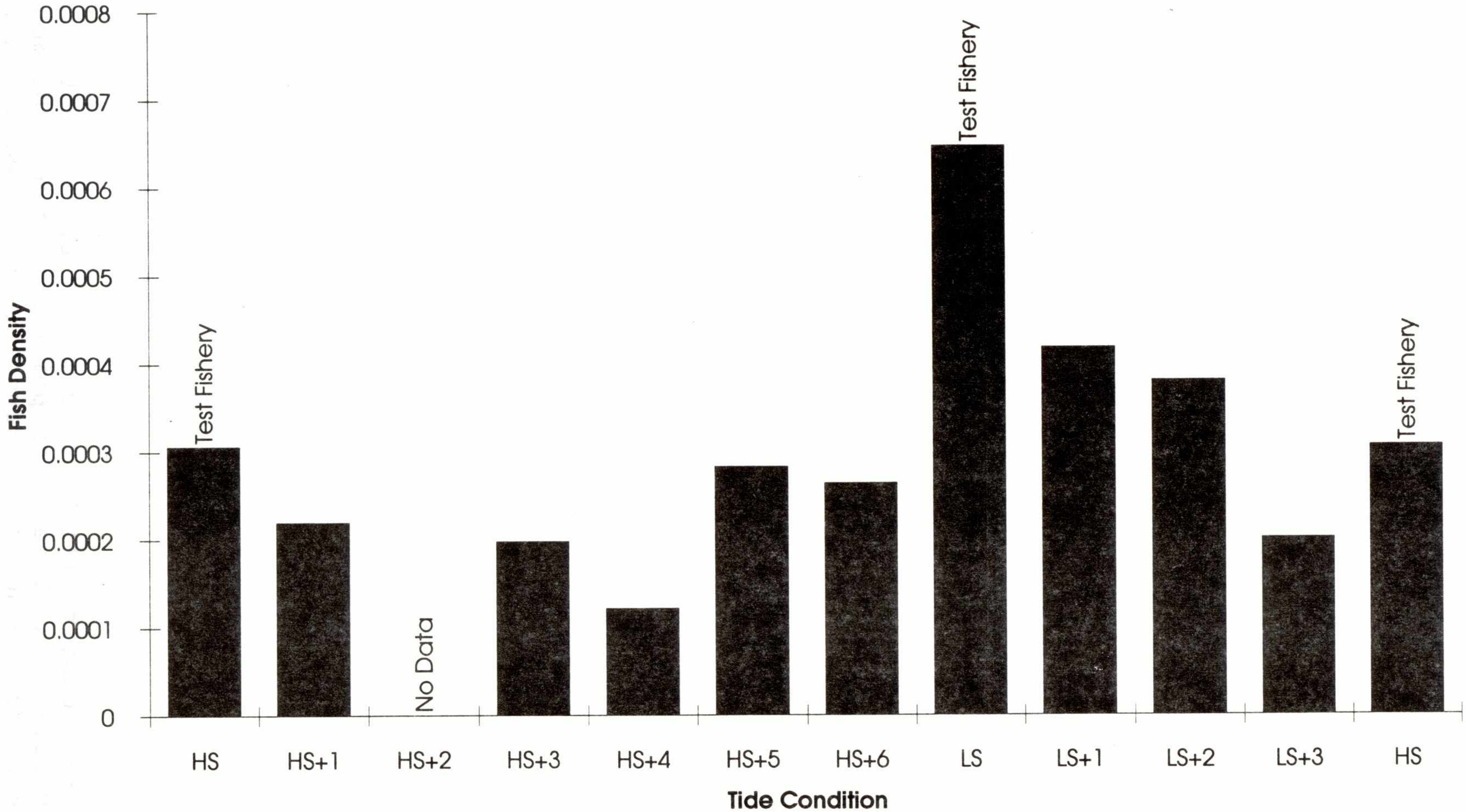

0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
Fish Density
Test Fishery
No Data
Test Fishery
Test Fishery
HS
HS+1
HS+2
HS+3
HS+4
HS+5
HS+6
LS
LS+1
LS+2
LS+3
HS
Tide Condition

Figure 5.

Fig. 6. Fish density (fish/cubic metre) by transect versus tidal cycle for July 11 at Tyee. Each point represents the acoustic fish density for consecutive transects during each tidal stage. OUT = outflow, LS = low slack, IN = inflow and HS = high slack.

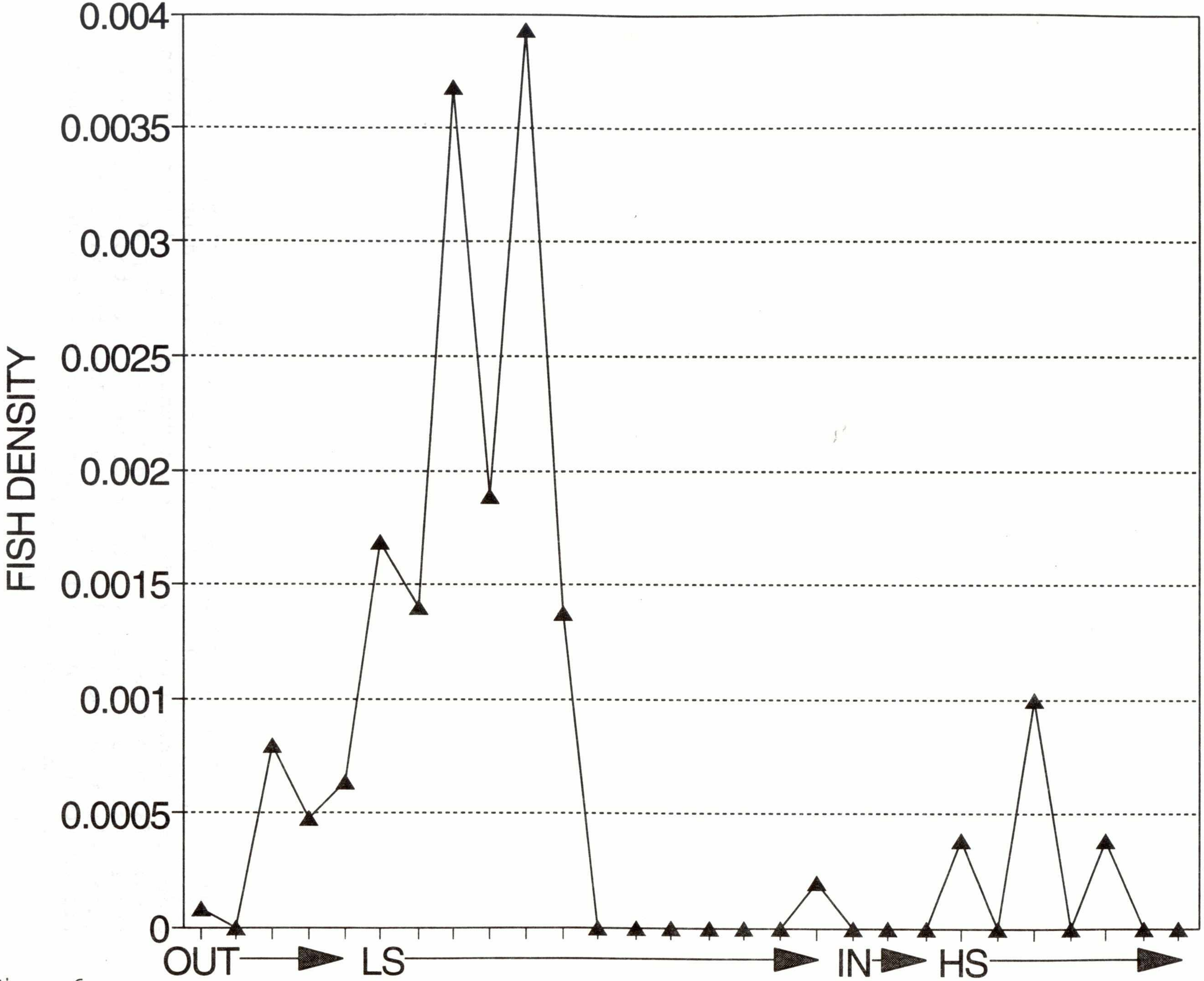

0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
FISH DENSITY
OUT
LS
IN
HS

Figure 6.

Fig. 7(a). Low slack tide mean acoustic fish density (fish/cubic metre) versus high slack tide mean acoustic fish density. Each point represents the low slack mean density for all transects in a calendar day versus the high slack mean density for all transects in the same day. The plot shows only those days where data exists for both tidal conditions. The straight line represents the points where the two measurements would be equal.

(b) Low slack versus outflow.

(c) Low slack versus inflow.

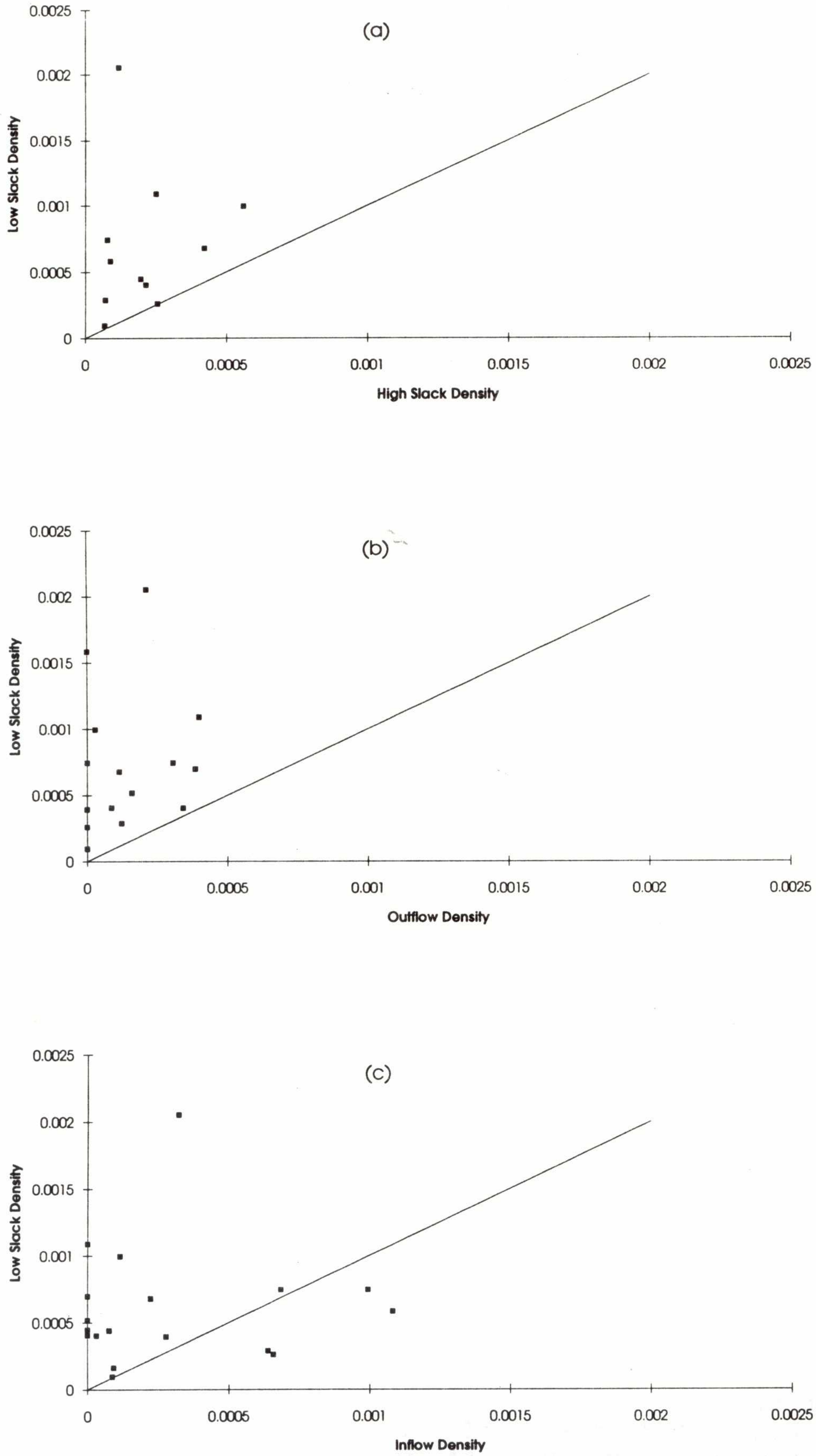
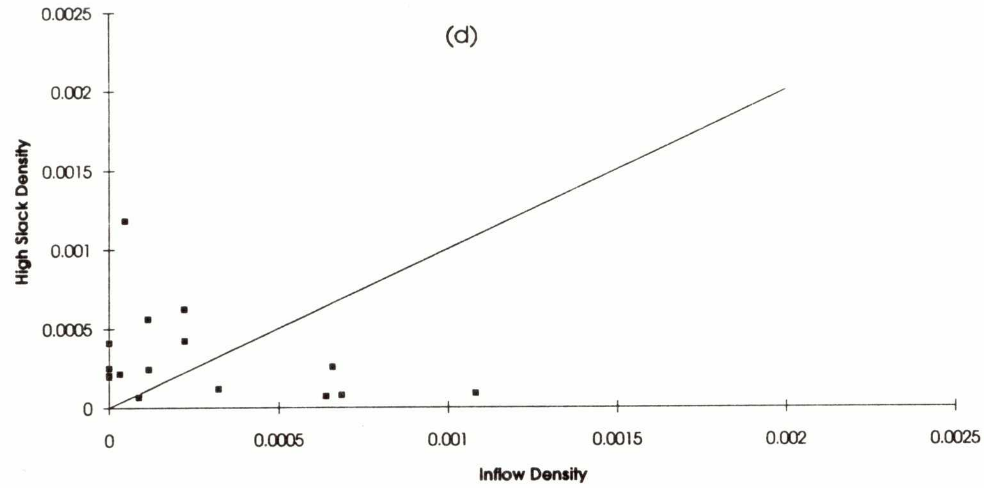
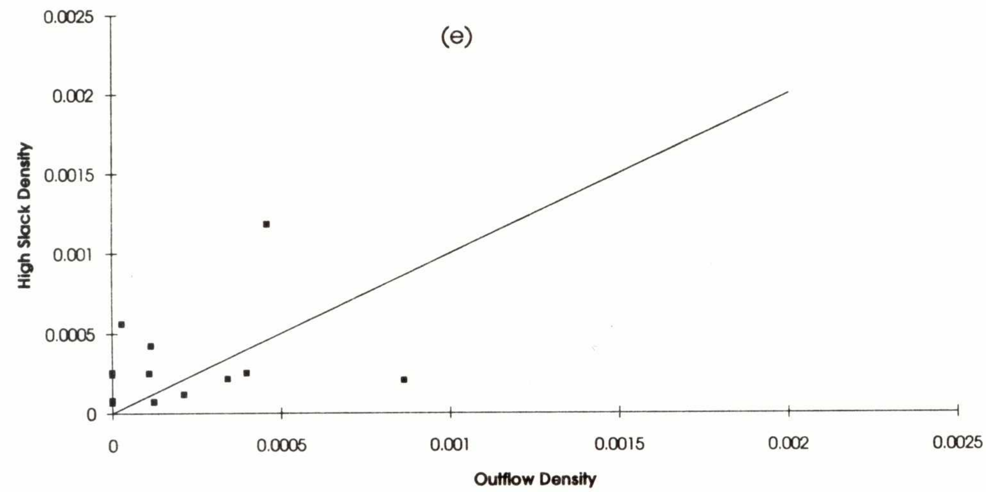

(a)
Low Slack Density
High Slack Density
0.0025
0.002
0.0015
0.001
0.0005
0
(b)
Low Slack Density
Outflow Density
(c)
Low Slack Density
Inflow Density

Figure 7.

Fig. 7 (Con't)
(d) High slack versus inflow.
(e) High slack versus outflow.
(f) Outflow versus inflow.


(d)
High Slack Density
Inflow Density
0.0025
0.002
0.0015
0.001
0.0005
0


(e)
High Slack Density
Outflow Density
0.0025
0.002
0.0015
0.001
0.0005
0

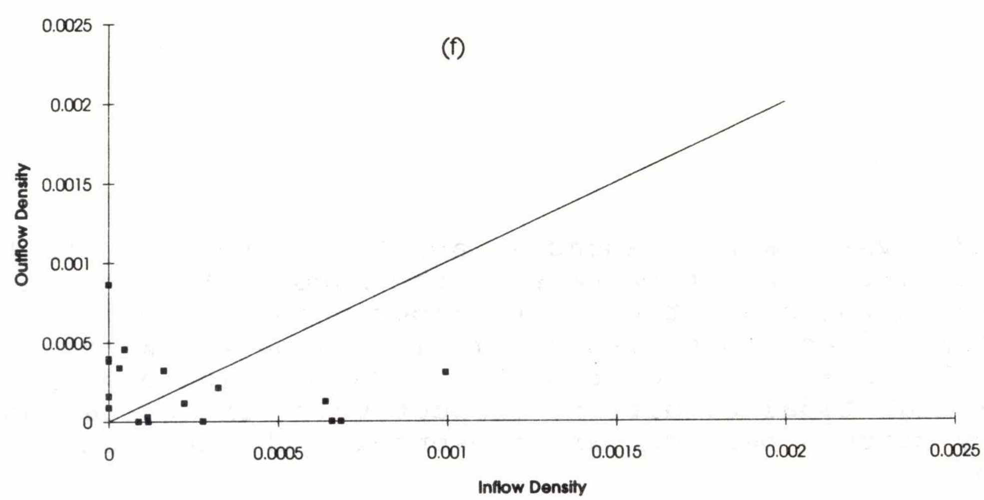

(f)
Outflow Density
Inflow Density
0.0025
0.002
0.0015
0.001
0.0005
0

Figure 7.

Fig. 8. Sideways-looking transducer acoustic target counts for July 14 and 15. Each point represents the number of fish counted per hour versus the start time of the hour sample. The hours in which the test fishery operated are indicated on the X-axis. LL, HH, HL and LH annotations refer to the low-low, high-high, high-low and low-high tidal conditions respectively. The corresponding test fishery catches per hour are presented with the tide information.

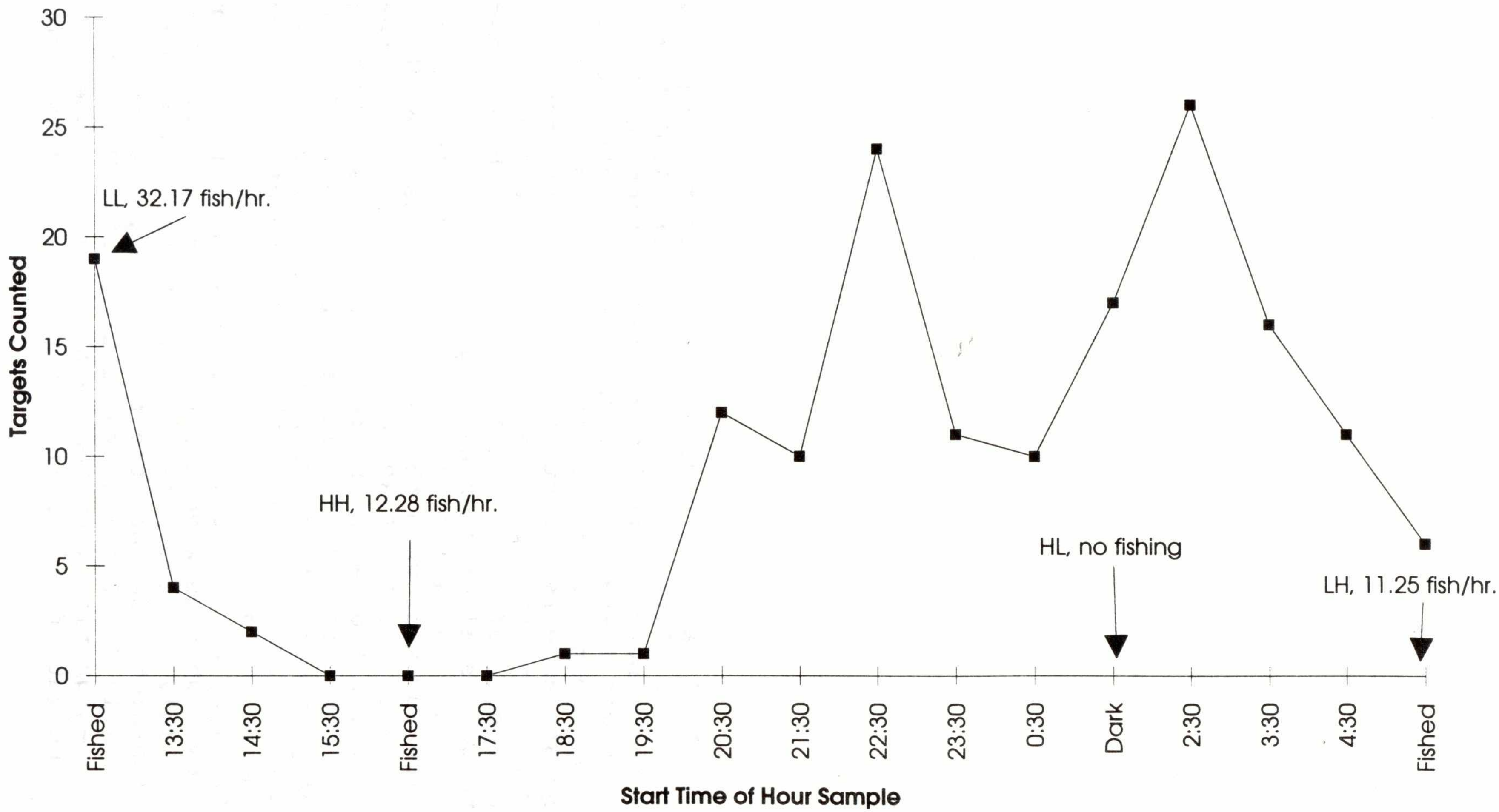

30
25
20
15
10
5
0
Targets Counted
LL, 32.17 fish/hr.
HH, 12.28 fish/hr.
HL, no fishing
LH, 11.25 fish/hr.
Fished
13:30
14:30
15:30
Fished
17:30
18:30
19:30
20:30
21:30
22:30
23:30
0:30
Dark
2:30
3:30
4:30
Fished
Start Time of Hour Sample

Figure 8.

Fig. 9. WASP II data for time periods corresponding to various tidal conditions. Figure 9(a) is for July 08, 4:53:47 to 5:03:44 GMT. This ten minute interval was during a high-low tide when the test fishery was operating. For the range in metres on the Y-axis, the 0.0 point represents the bottom of the river. The thick black line at range represents the surface. The range to the surface varies in other plots according to the tidal stage. Except for Figure 9(i), all WASP II plots are thresholded to exclude targets smaller than herring size.

(b) July 09, 18:14:53 to 18:24:50 GMT. This interval was during a low-low tide when the test fishery was operating.

(c) July 09, 18:45:30 to 18:55:27 GMT. This interval was during a low-low tide when the test fishery was operating. This interval is close in time to Figure 9(b) and was included as it was the only echogram found with numerous surface targets. The surface targets are unusual in that they are of such a high density and may be debris.

(d) July 08, 22:08:43 to 22:18:40 GMT. This interval was during a low-high tide when the test fishery was operating.

(e) July 09, 22:56:44 to 23:06:41 GMT. This interval was during a low-high tide when the test fishery was operating.

(f) July 07, 21:21:19 to 21:31:16 GMT. This interval was during a low-high tide when the test fishery was operating. Note increasing height of unidentified bottom targets as incoming flow increases.

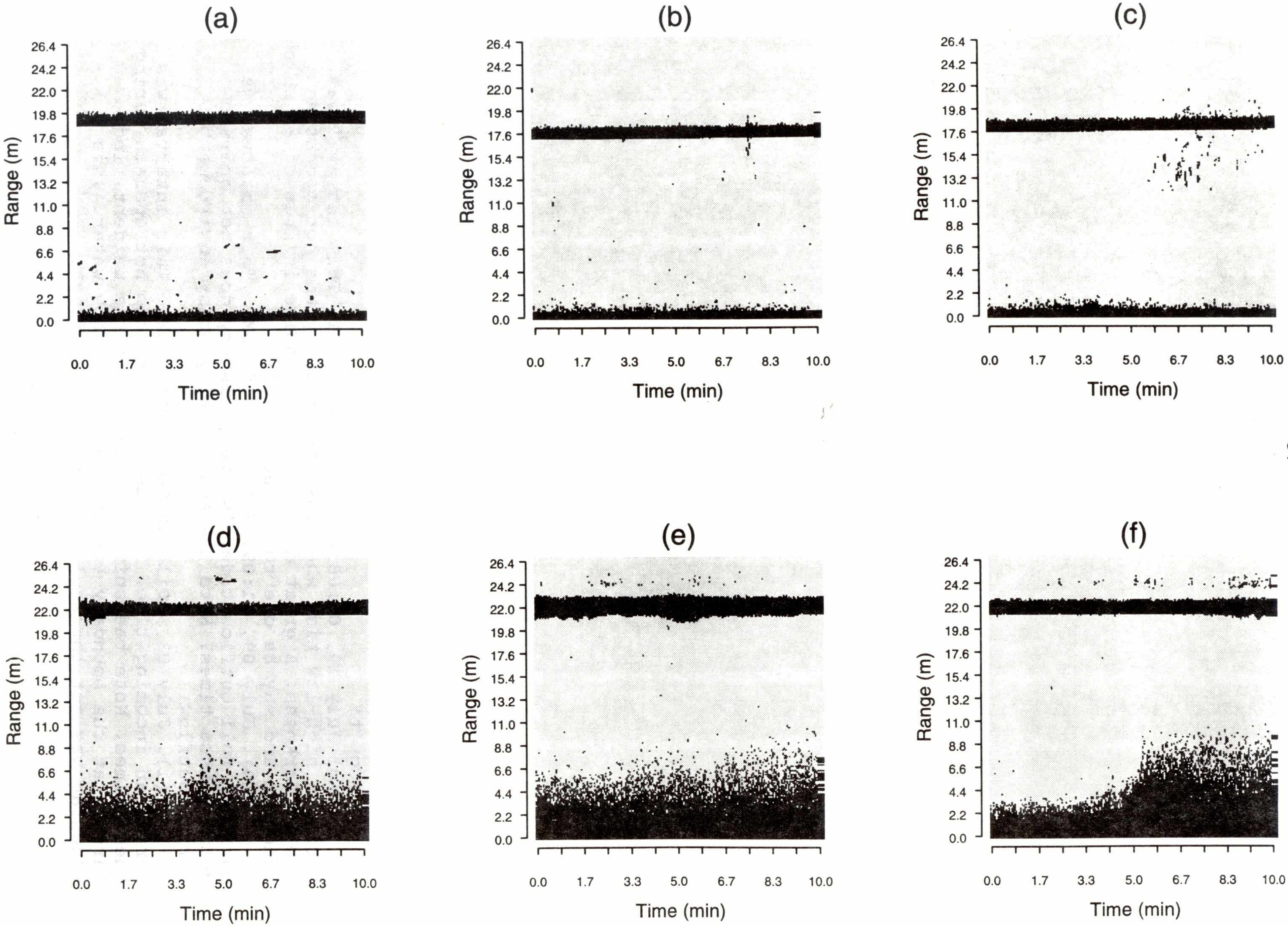

(a)
(b)
(c)
(d)
(e)
(f)
Range (m)
26.4
24.2
22.0
19.8
17.6
15.4
13.2
11.0
8.8
6.6
4.4
2.2
0.0
0.0
1.7
3.3
5.0
6.7
8.3
10.0
Time (min)

Figure 9.

Fig. 9 (Con't)

(g) July 10, 06:08:40 to 06:18:37 GMT. This interval was during a high-low tide when the test fishery was not operating due to darkness. A great deal of surface noise is present in this echogram and may be due to surface waves.

(h). July 09, 01:09:57 to 01:19:54 GMT. This interval was during a full outflow tide. The test fishery does not operate during these times. Note the acoustically noisy environment during outflow.

(i). July 08, 10:15:38 to 10:25:35 GMT. This interval was during an incoming tide. The test fishery does not operate during these times. Note the spiralling nature of the unidentified targets at the boundary between salt and fresh water. This echogram was not thresholded to show this effect.

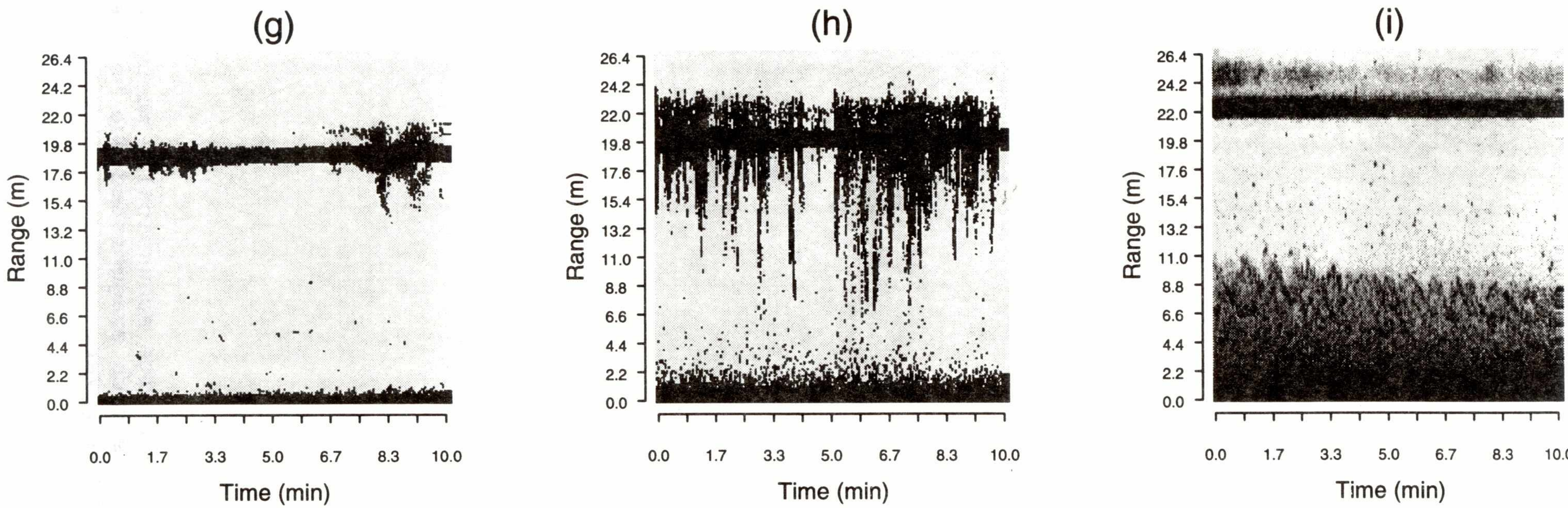
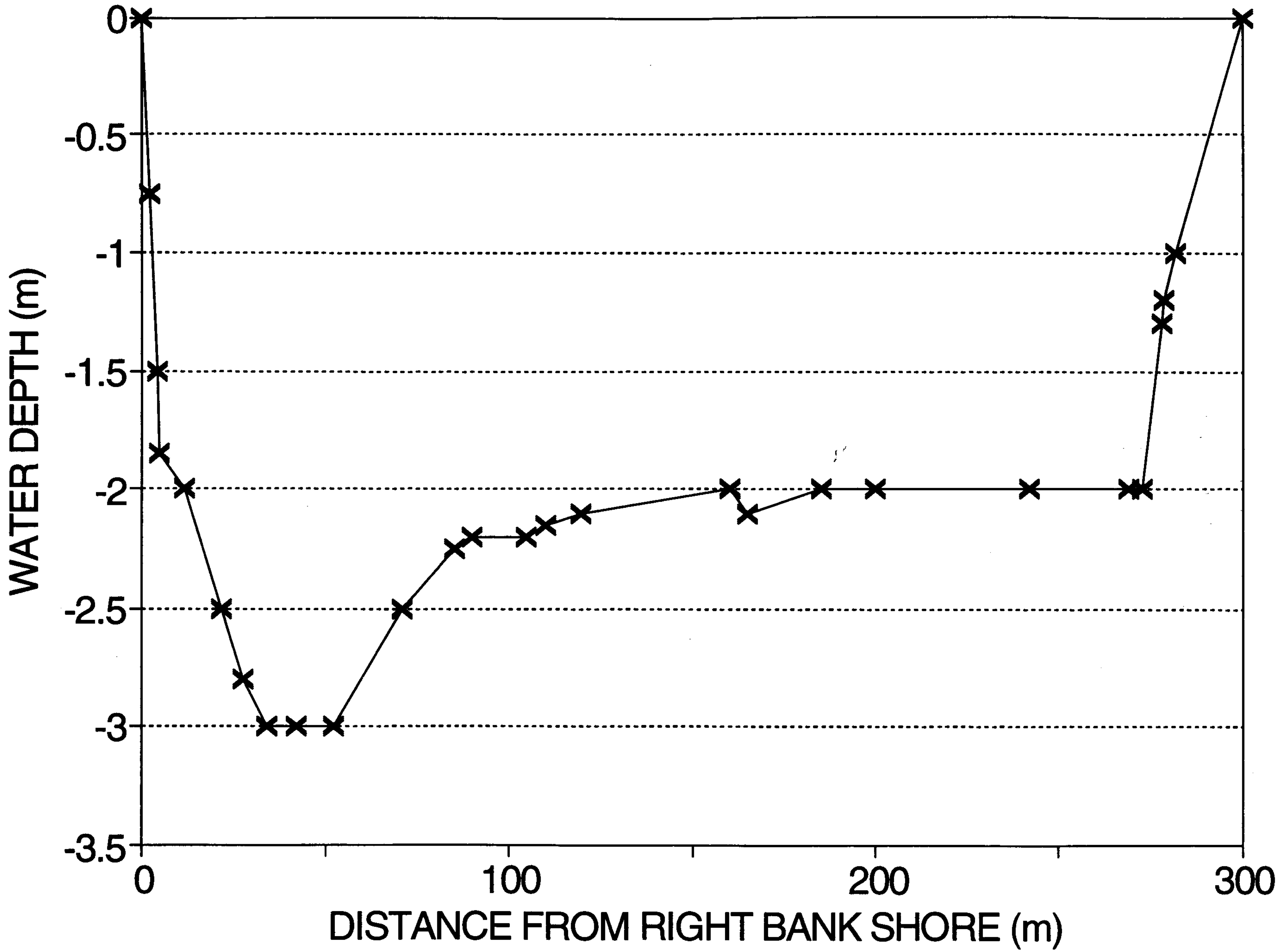

(g)
(h)
(i)
Range (m)
26.4
24.2
22.0
19.8
17.6
15.4
13.2
11.0
8.8
6.6
4.4
2.2
0.0
0.0
1.7
3.3
5.0
6.7
8.3
10.0
Time (min)

Figure 9.

Fig. 10. Copper River site acoustically measured bottom profile. The vertical scale is much exaggerated due to the wide and shallow nature of the river.



0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
WATER DEPTH (m)
0
100
200
300
DISTANCE FROM RIGHT BANK SHORE (m)

Figure 10.

Fig. 11. Copper River average count per hour versus distance from right bank shore. Targets further offshore were weak detections and may or may not be fish targets.

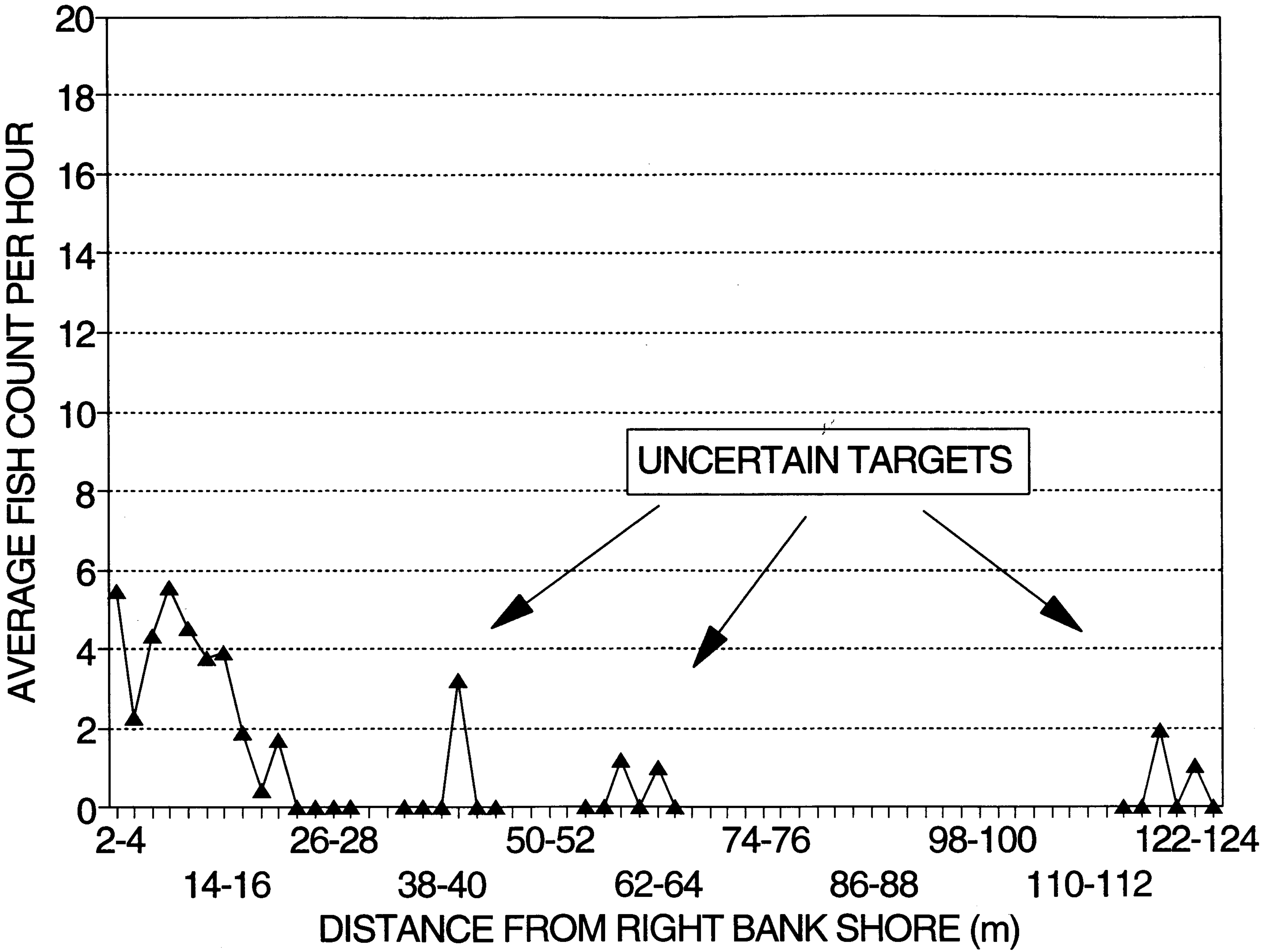
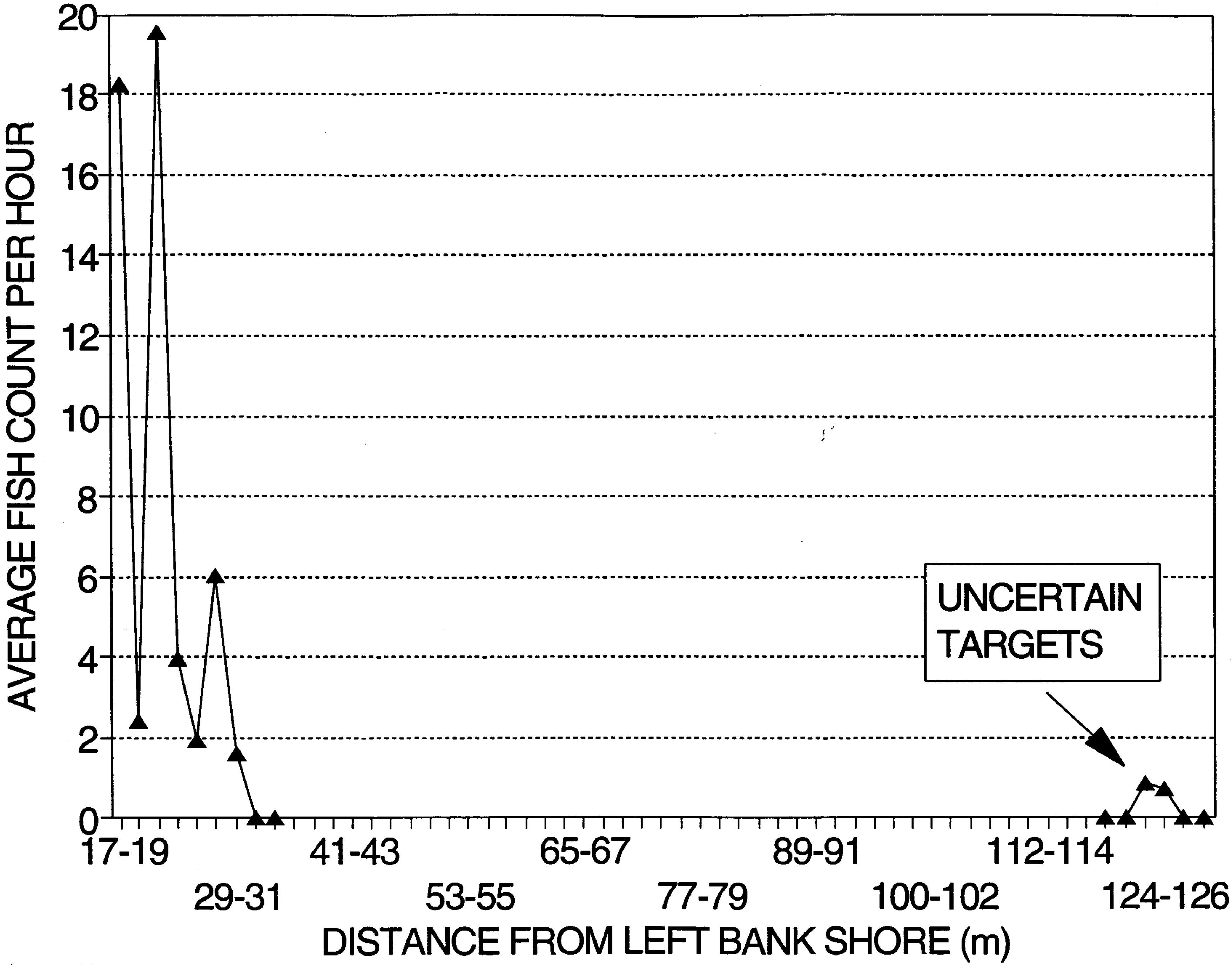

AVERAGE FISH COUNT PER HOUR
20
18
16
14
12
10
8
6
4
2
0
UNCERTAIN TARGETS
2-4
26-28
50-52
74-76
98-100
122-124
14-16
38-40
62-64
86-88
110-112
DISTANCE FROM RIGHT BANK SHORE (m)
Figure 11.

Fig. 12. Copper River average count per hour versus distance from left bank shore. Targets further offshore were weak detections and may or may not be fish targets.



20
18
16
14
12
10
8
6
4
2
0
AVERAGE FISH COUNT PER HOUR
17-19
29-31
41-43
53-55
65-67
77-79
89-91
100-102
112-114
124-126
DISTANCE FROM LEFT BANK SHORE (m)
UNCERTAIN TARGETS

Figure 12.

Fig. 13. Copper River right bank hourly fish passage for August 7 and August 8. Each point represents the number of fish targets counted in the hourly period starting at the time noted on the X-axis. The transducer was located approximately 2 metres from shore.

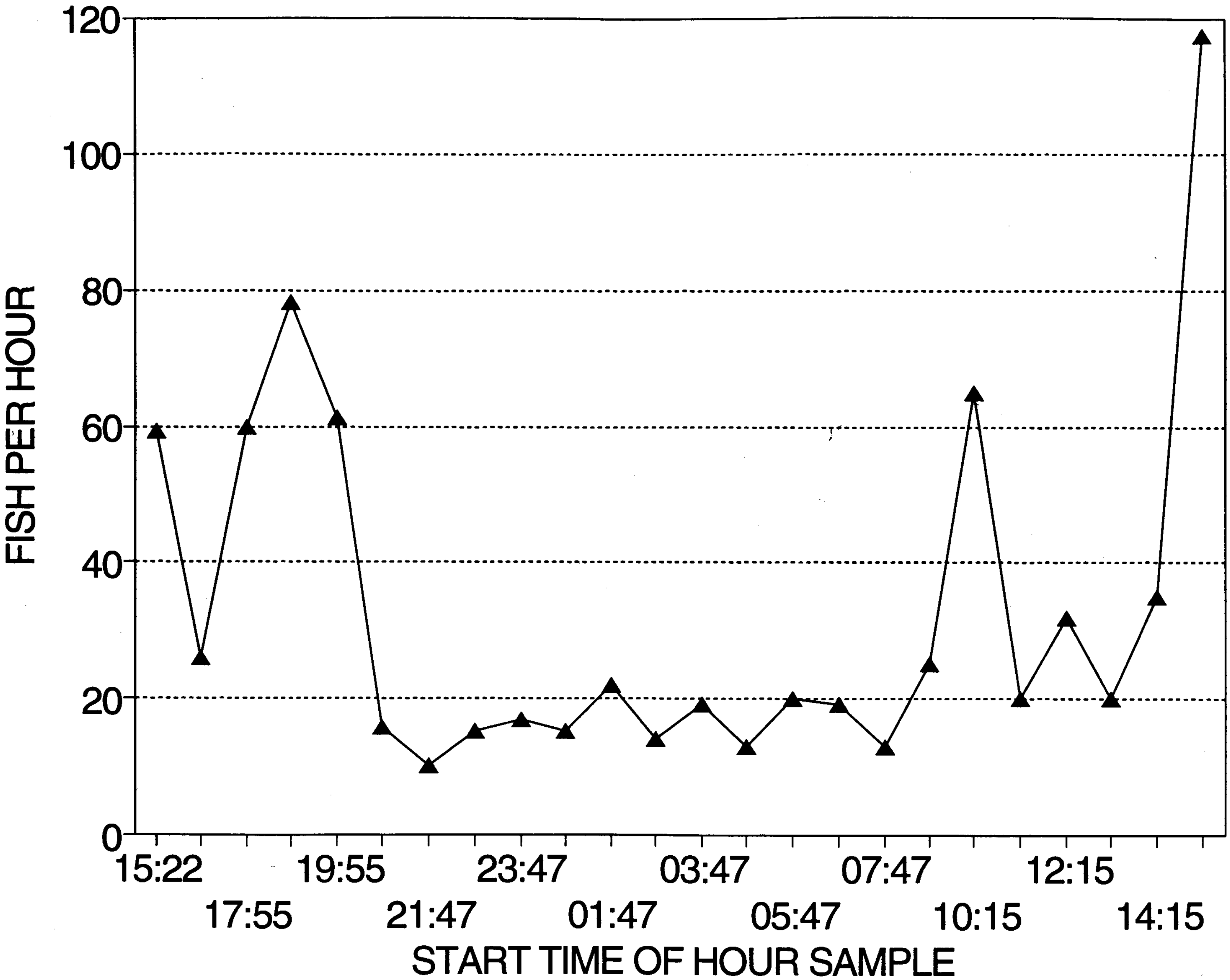

120
100
80
60
40
20
0
FISH PER HOUR
15:22
17:55
19:55
21:47
23:47
01:47
03:47
05:47
07:47
10:15
12:15
14:15
START TIME OF HOUR SAMPLE

Figure 13.

Fig. 14. Copper River 24 hour fish passage versus distance from right bank transducer. The transducer was located approximately 2 metres from the shore.

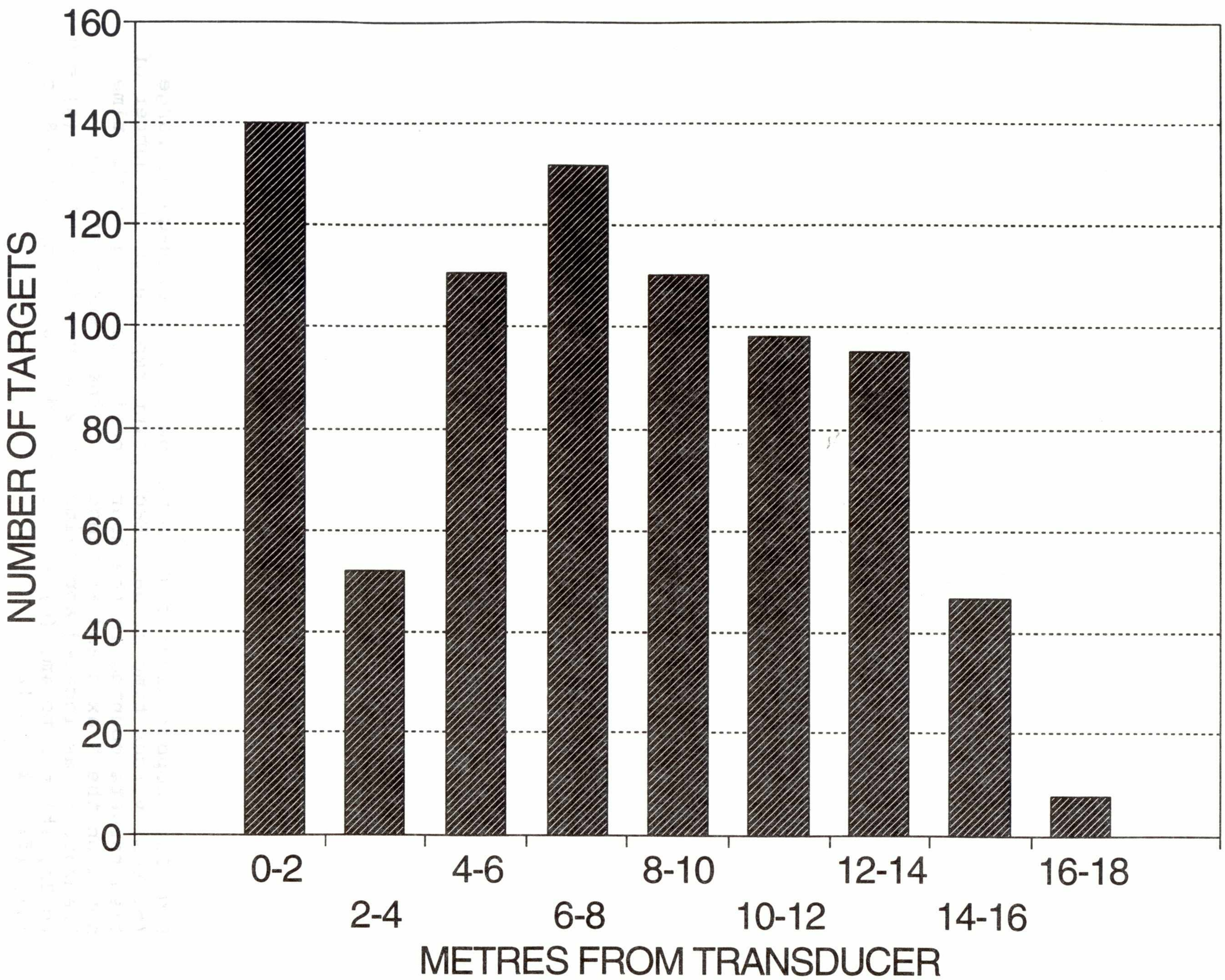

160
140
120
100
80
60
40
20
0
NUMBER OF TARGETS
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
METRES FROM TRANSDUCER

Figure 14.

Fig. 15. Copper River right bank hourly fish passage at range (metres) versus time of day. Each point represents the number of fish targets counted in the hourly period starting at the time noted on the X-axis and at range from the transducer. The transducer was located approximately 2 metres from shore. (a) = 0 to 2m, (b) = 2 to 4m, (c) = 4 to 6m, (d) = 6 to 8m, (e) = 8 to 10m, (f) = 10 to 12m

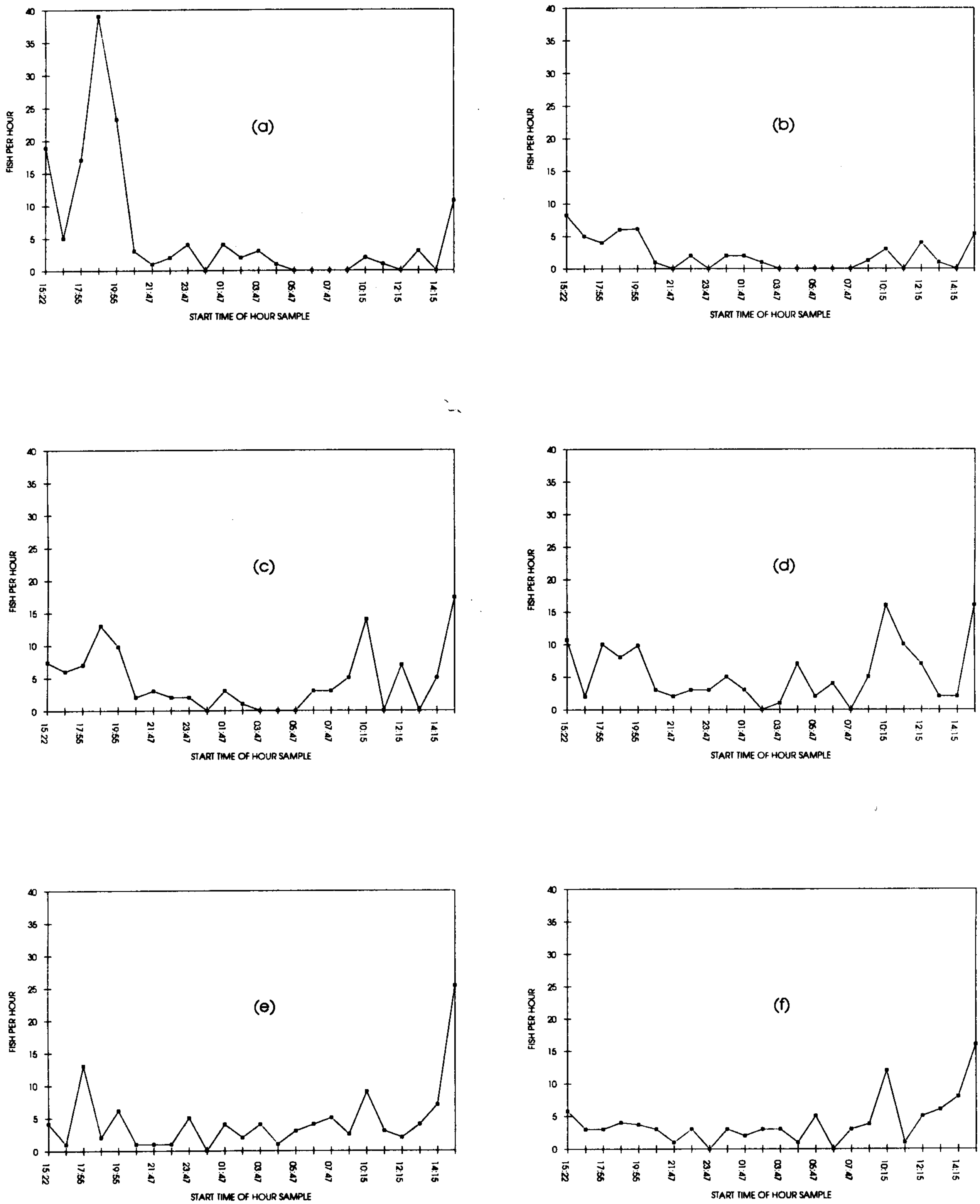

(a)
(b)
(c)
(d)
(e)
(f)
FISH PER HOUR
START TIME OF HOUR SAMPLE
0
5
10
15
20
25
30
35
40
15:22
17:55
19:55
21:47
23:47
01:47
03:47
05:47
07:47
10:15
12:15
14:15

Figure 15.

Fig. 15 (Con't). (g) = 12 to 14m, (h) = 14 to 16m and (i) = 16 to 18m.

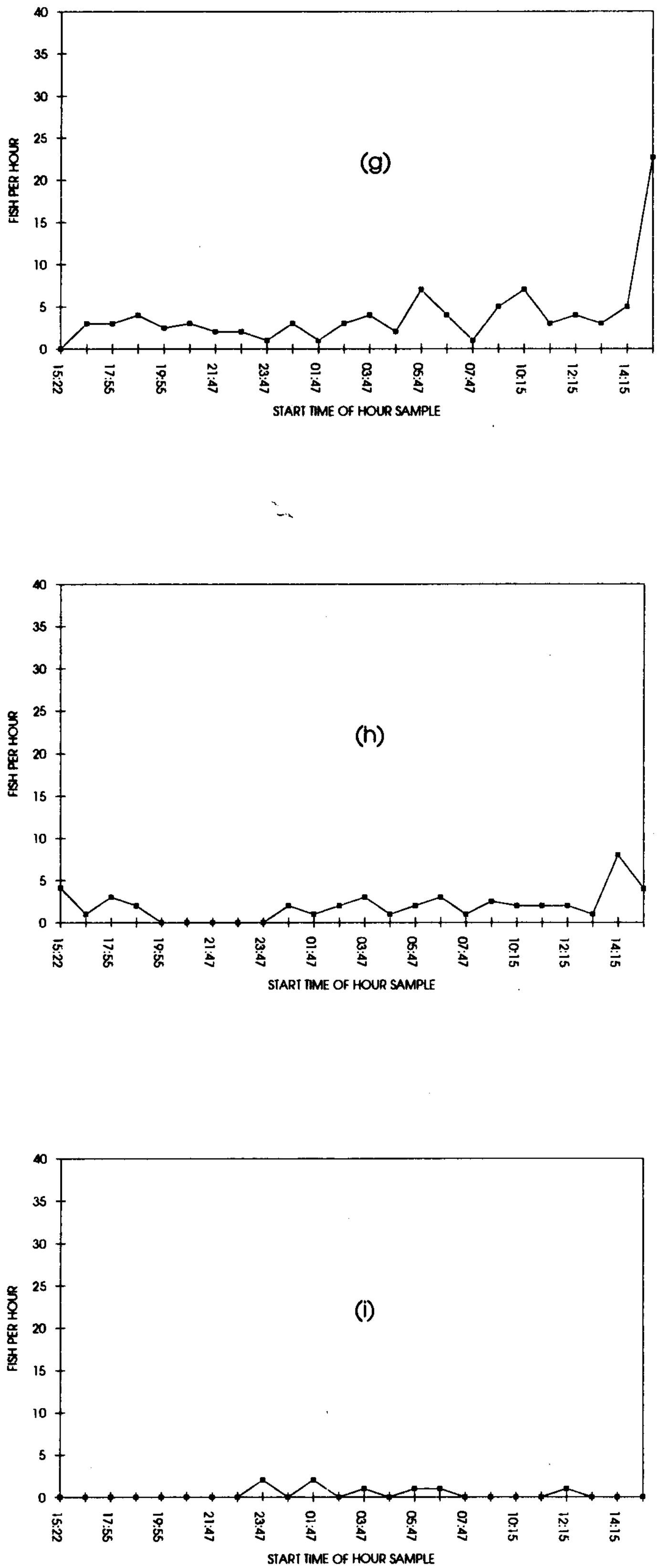

40
35
30
25
20
15
10
5
0
FISH PER HOUR
(g)
15:22
17:55
19:55
21:47
23:47
01:47
03:47
05:47
07:47
10:15
12:15
14:15
START TIME OF HOUR SAMPLE
(h)
(i)

Figure 15.