IMPROVED ROTENONE SAMPLING EQUIPMENT FOR STREAMS[1]

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ABSTRACT

Equipment and a system suitable for sampling fish populations in large streams with rotenone are described. A block net 600 × 25 feet is supported by steel wire rope and adjustable poles. Rotenone is applied by means of a high head centrifugal pump through perforated 1.5 inch discharge hoses. Potassium permanganate is constantly fed into mixing barrels and pumped into the stream below the block net through perforated 2 inch discharge hoses. Successful rotenone sampling has been done with this gear in stream flows up to 3500 cubic feet per second (cfs), and flows up to 5000-6000 cfs can be handled.

INTRODUCTION

The use of rotenone in the lotic environment to obtain quantitative fish population estimates poses problems not encountered when sampling standing water. All of the problems center about the movement of the water column through a delineated and fixed sample area. Distressed and dead fish must be kept from moving out of the sample area before they can be recovered. A sufficiently high concentration of rotenone must be maintained in the sample area long enough to achieve the desired results. At the same time undesirable fish kills downstream from the sample area must be prevented by restricting the action of rotenone to that specific site. With increasing stream flows, all of these problems are magnified.

Lawrence (1956) first reported using potassium permanganate ($KMnO_4$) to detoxify rotenone during fish sampling in small streams. Burlap bags containing $KMnO_4$ were dragged back and forth across the stream below a seine which was used to block movement of fish into or out of the sample area on the downstream side.

Lawrence (1956) did not indicate how rotenone was applied in stream sampling. One method commonly used in small stream sampling, however, was to simply hand broadcast a dilute solution of rotenone at a station upstream from the block net over a long enough time period to effect a fish kill.

There have been many refinements to the basic method of stream rotenone sampling described by Lawrence in 1956. Lennon, Schnick, and Burress (1971) reviewed techniques and results obtained by stream reclamation with rotenone.

The most widely used forms of rotenone are 5 percent emulsifiable rotenone and 2.5 percent rotenone with 2.5 percent synergist. The full strength liquid can be applied to the stream by means of gravity flow or mechanical pumps. Holder (1971) described a method of delivering a dilute solution of rotenone in a high volume of water across the full width of the stream via flexible 0.75 inch hose.

Application of potassium permanganate has taken two forms; mechanical dispersal of $KMnO_4$ crystals (Lennon et al. 1971) and pumping a solution or slurry of $KMnO_4$ in water either directly or through hoses or troughs into the stream (Holder 1971; Swan 1965; Swan, personal communication).

Block nets used to prevent movement of fish out of or into a delineated sample area have ranged from simple seines (Lawrence 1956) to hoop nets with wings extending across the complete width of the stream (Holder 1971).

Holder (1975) presented a detailed description of equipment and techniques used to take quantitative rotenone samples in Georgia's warmwater streams. This sampling method, however, was effectively limited to streams with flows not exceeding 700 cfs. Potassium permanganate could not be delivered at a high enough rate to effect a 3 parts per million (ppm) concentration in greater flows.

In order to carry out rotenone sampling in Georgia's larger streams, we modified the equipment and methods employed by Holder (1975). This paper describes the equipment and its application in quantitative rotenone sampling but does not provide a detailed description of the complete sampling operation.

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EQUIPMENT AND PROCEDURES

Block Net

A block net is used to collect fish as they drift out of the study area and to prevent movement of fish into the sample area from downstream. It is 600 feet long and 25 feet deep, long enough to sample streams 500 feet wide with maximum depths of 15 to 20 feet (Figure 1). This net allows considerable flexibility in the selection of sample sites.

The main body of the net is one inch bar mesh constructed of number 9 nylon twine (82 lb. test) and is hung on a 2/5 basis. Edges of the net have graduated selvages of 8 inches of number 12 twine (103 lb. test) and 8 inches of number 15 twine (129 lb. test) that provide extra strength in areas of high wear.

Head and foot ropes are 0.75 inch diameter twisted nylon (14,200 lb. test). Steel anchor rings 2.5 inches in diameter are positioned opposite one another at 10 foot intervals along head and foot ropes. Twisted nylon cords 0.25 inch in diameter are fastened vertically between each of the opposite anchor rings. These vertical cords are used to reef the net.

Separate float and lead lines are tied to the head and foot ropes. Plastic floats 4 inches in diameter and 3 inches in length are positioned at 1 foot intervals along the float line. Number 4 leads are positioned at 8 inch intervals along the lead line.

In order to collect a sample of fish that passes through the block net, 1 meter square sub-sample bags are attached to the net. The sub-sample bags are constructed of 0.25 inch delta mesh and are mounted on frames built of 0.5 inch diameter aluminum rod. Snap-clip fasteners mounted on the aluminum frames are used to attach the sub-sample bags to the block net.

The site for placing the net should be relatively free of submerged logs, large rocks, and debris that can tangle in the mesh. The net is suspended from a 0.375 inch diameter steel wire rope anchored on each side of the stream. Another wire rope of the same size is similarly anchored approximately 50 feet upstream. We have used large trees for anchoring these cables. On one occasion a 12 inch diameter tree was uprooted by the force exerted on the cables.

An electric truck winch (8000 lb. capacity) mounted in a steel frame which can be strapped to a tree is used to stretch the cables taut. The downstream cable is stretched approximately 6 feet above the water surface and the upstream cable approximately 3 feet above the water.

After the cables are suspended across the stream, the net is fastened to the downstream cable with clevices. These clevices are used to fasten each of the head rope anchor rings to the cable at 10 foot intervals. The net is positioned so that the vertical cords will be on the downstream side of the net when it is set. The net and foot rope were previously drawn up to the head rope as pictured in Figure 2. This was done by drawing the vertical cords under the foot rope and through the head rope rings on the upstream side of the net until the net was completely gathered to the head rope. Single bow knots were tied for quick release.

The net hanging procedure is completed at one bank of the stream (Figure 2). When the net has been fastened to the cable, it is pulled across the stream and secured to the opposite bank (Figure 3).

Poles constructed of 10 foot sections of 0.5 inch inside diameter pipe are used to hold the foot line of the net on the stream bottom. Both thick-wall steel conduit and thick-wall black pipe have been used. Design of these poles is presented in Figure 4. The poles can be lengthened for deeper streams by connecting 5 foot sections of conduit to them with threaded pipe nipples.

As the poles are attached to the steel anchor rings opposite one another on the head and foot ropes, the vertical cords gathering the net can be released. Also, the clevices securing the head rope rings to the net cable can be removed. Each pole is attached to the anchor ring on the foot rope by a clevice welded to the bottom of the pole and to the ring on the head rope and the net cable by a clevice welded on the adjustable handle section (Figure 4). The poles should be adjusted so that the foot rope is held just above the surface of the water. Poles are placed at 20 to 30 foot intervals across the width of the stream, depending on water velocity and the contour of the stream bottom.

Polypropylene ropes 0.25 inch in diameter are tied to the upstream cable just opposite the poles (Figure 5). The free end of each rope is allowed to float downstream and is tied to the clevice at the base of the pole. The net is set to the stream bottom by exerting downward force on the pole which is then secured at the proper length by tightening the handle section of the pole. Before the pole is completely depressed, the length of the rope from the upstream cable should be adjusted to pull the foot rope slightly upstream of the head rope.

Sub-sample bags are randomly fastened to the mesh of the block net from the downstream side by divers.

Rotenone Application

Emulsifiable rotenone is pumped into the stream by a centrifugal water pump (6,700 gph capacity) through perforated discharge hoses. Usually the rotenone application equipment is set up in a wide 14 foot boat located in the middle of the stream. In some situations, rotenone application equipment can be assembled on the bank of the stream.

Rotenone flows from 30 gallon drums through a 0.75 inch gate valve into a 19 liter carboy. The carboy is calibrated in 100 milliliter increments. Rotenone is pumped from the carboy thru a 0.75 inch hose teed into the 1.5 inch suction line (Figure 6). Water from the stream is mixed with rotenone before it enters the pump.

A 1.5 inch gate valve on the water intake line and a 0.75 inch gate valve on the rotenone suction hose allow the operator to control the rate at which rotenone is discharged into the stream.

The rotenone-water mixture is pumped into the stream through polyvinyl chloride (PVC) hoses, 1.5 inches in diameter, teed into the discharge side of the pump. These hoses, capped at their free ends, were perforated at 4 foot intervals with a 0.06 inch diameter leather punch.

Polyvinyl chloride hose is used because it can be rolled flat for storage, is chemically inert, and is durable. Quick-couples are used to connect the 150 foot sections of hose to the pump and for caps.

The rotenone hose and the boat are tied to a rope suspended across the stream. This support rope relieves some of the stress placed on the quick-couples and provides stability to the system, particularly in streams with high water velocities. Weights can be added to the rotenone hose to submerge it, however, we have not found weights necessary in the sampling we have done.

Rotenone Detoxification

Detoxification of rotenone below the study area is accomplished by constant application of $KMnO_4$ to the stream after the wave of toxicant passes the block net. The $KMnO_4$ application equipment is set up in a wide 20 foot boat that is tied to the net cable in the middle of the stream approximately 50 feet downstream from the net.

Potassium permanganate is fed from a 55 gallon hopper through a hydraulically driven grain auger (12 feet long, 4 inch diameter) and deposited into a 55 gallon mixing drum (Figure 7). The auger is driven through a 3-speed lawn mower transmission by a Char-Lynn hydraulic orbit motor (Model A5A). A self-contained Gresen hydraulic pump, driven by a 10 hp gasoline engine powers the orbit motor. This hydraulic system provides constant, non-slip torque to drive the auger through a wide range of rpm's. By changing the speed range of the transmission and regulating oil flow through the hydraulic valve, $KMnO_4$ can be delivered at controlled rates from 0.5 to 110 pounds per minute.

Potassium permanganate is fed into one of two 55 gallon mixing drums, connected by a 6 inch quick-couple fitting. Water is constantly pumped into the drum receiving $KMnO_4$ by a 2 inch centrifugal pump (9000 gph capacity) through a quick-couple connection in the bottom of the drum and into the top of the second drum by a similar pump (Figure 7). The mixture of water and potassium permanganate is then pumped from the bottom of the second drum through rigid PVC suction pipes by two additional 2 inch pumps and into the stream through perforated hoses. The amount of water being added to the mixing drums is balanced to the volume of solution being pumped into the stream by regulating gate valves on the water pumps.

We are using centrifugal water pumps built with cast iron impeller housings and impellers because they are capable of pumping sand and crystals of $KMnO_4$ without being damaged. Potassium permanganate is quite soluble in water, 64 grams per liter at 20 C. In most cases, however, the solubility of $KMnO_4$ is exceeded in the mixing drums when conducting a study. This system will successfully pump the undissolved $KMnO_4$ and water through the perforations in the hoses without a significant build up of $KMnO_4$ crystals. Two intake and 2 discharge pumps are used to minimize the danger resulting from engine failure.

Potassium permanganate dispensing hoses are constructed of 2 inch diameter PVC discharge hoses. The hoses were perforated with a 0.17 inch diameter leather punch at 10 foot intervals. We are currently using 300 feet of hose which is divided into 50 foot sections. Quick-couple connections are used on each section of hose so that the total length of the hose can be adjusted.

Ropes about 50 feet long are fastened from the block net cable to the hoses at approximately 30 foot intervals (Figure 5). These support ropes relieve some of the stress placed on the fittings and provide stability. Weights can be added to submerge the hose, however, we have not found them necessary.

Sampling

With the manpower at our disposal, three consecutive days have been required to conduct rotenone sampling with the equipment described here. On the first day, all chemicals and equipment

are transported to the sample site. Both cables are suspended across the stream and marked with flagging ribbon and safety lights. The block net can be attached to the cable and secured at one of the stream banks if no drastic changes in stream flow are expected to occur over night (Figure 2). If marked fish are to be used for estimates of recovery, they should be collected at this time.

On the second day one team of men set the block net, another the sub-sample bags, while two additional teams set up and calibrate the rotenone and $KMnO_4$ application equipment. The stream flow should be determined to assure that chemicals will be applied at the proper rates. For guidance in determining chemical application rates, refer to Holder (1975).

Potassium permanganate is collected from the auger in a bucket over a timed interval and weighed to set the delivery rate. After the delivery rate of $KMnO_4$ has been set, water flow through the mixing barrels is balanced, and the station is ready to operate.

To calibrate the delivery rate of rotenone to the stream flow, the carboy is filled with water rather than rotenone. Water is pumped from the stream through the perforated hoses while the 1.5 inch and 0.75 inch valves on the intake side of the pump are adjusted to achieve the desired rate of water removal from the calibarated carboy. When the system has been calibrated, rotenone is gravity fed into the carboy at a rate equal to that being pumped out.

Generally 2 people run the rotenone application system while 3 operate the $KMnO_4$ system. Due to noise and distance, hand held two-way citizens band radios are used to communicate between application stations and the biologists in charge. Should a problem arise, swift corrective action can be taken by either station.

When rotenone application begins, all available personnel should be ready to recover fish as they become distressed and surface. The area below the block net should be observed for a downstream fish kill so that corrective action, if needed, can be carried out promptly.

After the kill has been completed and sub-sample bags collected, fish can be removed from the net before it is detached from the support cable. To accomplish this, the foot rope of the net is pulled above the surface of the water using the adjustable poles. Starting from one of the banks and working across the stream, fish are emptied from the net by pulling the mesh of the net toward the head rope and allowing the fish to dump over the foot rope into the boat. After all the fish have been taken from the net, the poles should be removed and the net fully reefed by tying the vertical ropes to opposite anchor rings. The remainder of the net removal procedure is the reverse of the net hanging phase outlined previously.

Generally, the removal of fish from the block net begins approximately 1 hour after the end of the fish kill. This allows time for dead fish to drift into the net. After all of the fish have been recovered they can be transported to the landing and covered with ice to preserve them in good condition until the following day or processed immediately, depending on available manpower.

Teams of men should begin dismantling and transporting the block net and rotenone and $KMnO_4$ dispensing equipment as soon as possible so that these operations do not have to be completed after dark. We have used a minimum of 16 people to complete the second day's work.

DISCUSSION

Four samples have been collected with this equipment. Limnological conditions under which these samples were collected, chemical application rates and time, and standing crops of fish recovered in the samples are presented in Table 1. During the rotenone sampling done on 23 June 1974, an insufficient amount of rotenone was applied to achieve a total kill of fish in the area, therefore, the quantitative data calculated for this study are probably low and not indicative of the actual standing crop.

The sample collected 26 October 1973 above Plant Mitchell was taken from one arm of a bifurcated section of the stream. This area is enriched and has yielded high standing crops when sampled with other gear.

The percentage recovery of marked fish 9 and 23 Octover 1974 (Table 1) is within the range found in reservoir samples for which such data were collected (Reservoir Committee, Southern Division, Amer. Fish. Soc.; unpublished data).

The largest stream flow in which we have successfully collected a sample has been 3500 cfs. Rotenone was applied at a rate of 5.94 liters per minute and $KMnO_4$ at 39 pounds per minute. The average water velocity at the net during this study was 2.49 feet per second. We feel that successful sampling could be done using the equipment described here in stream flows of 5000 to 6000 cfs, if water velocity at the net were no greater than 3 feet per second.

Normally, stream rotenone sampling should be done during periods of low flow because less chemical is required and cost will be reduced. Rotenone sampling planned for the fall should be accomplished before large numbers of leaves have fallen. Leaves and other stream detritus will accumulate in the block net adding resistance to the flow of water and complicating fish removal.

We recommend setting the block net in a area of the stream where water velocity is between 0.5 and 2.5 feet per second, if possible. Water velocity must be high enough to carry dead and distressed fish into the net but not so great that working around and with the net is too difficult.

Successful detoxification of rotenone by $KMnO_4$ may be influenced in streams possessing large amounts of organic material or tannic acid. Holder (1975) outlines a procedure for determining the amount of $KMnO_4$ required to neutralize rotenone in such streams. We have not experienced difficulty in detoxifying rotenone with a 3 ppm $KMnO_4$ concentration in any of the sampling we have done. No downstream fish kills have been observed.

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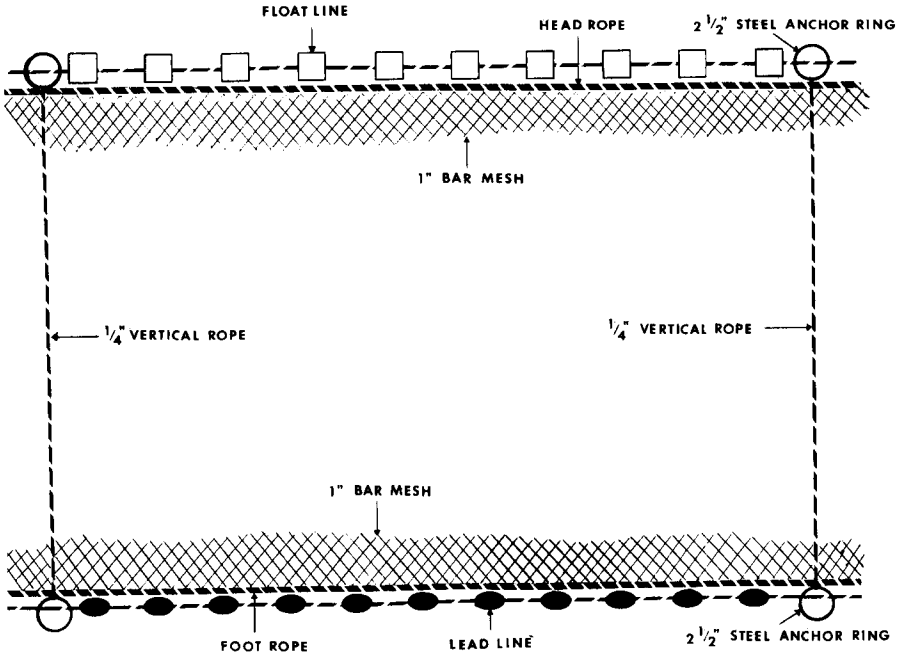


Figure 1. Block net detail.

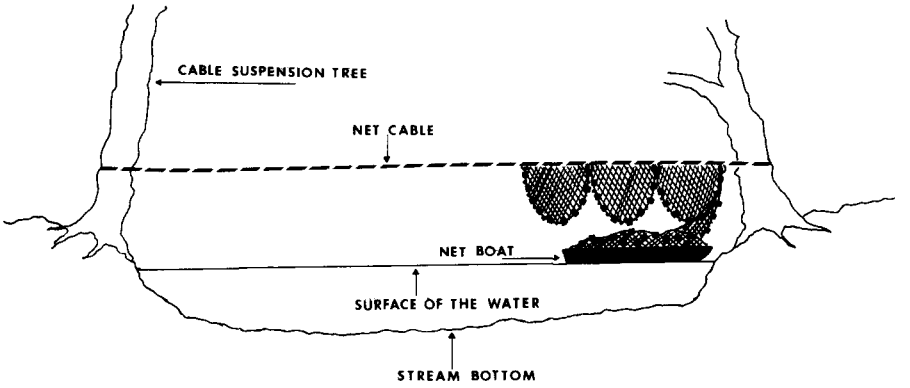


Figure 2. Cross-sectional view of attaching the net to the suspension cable.

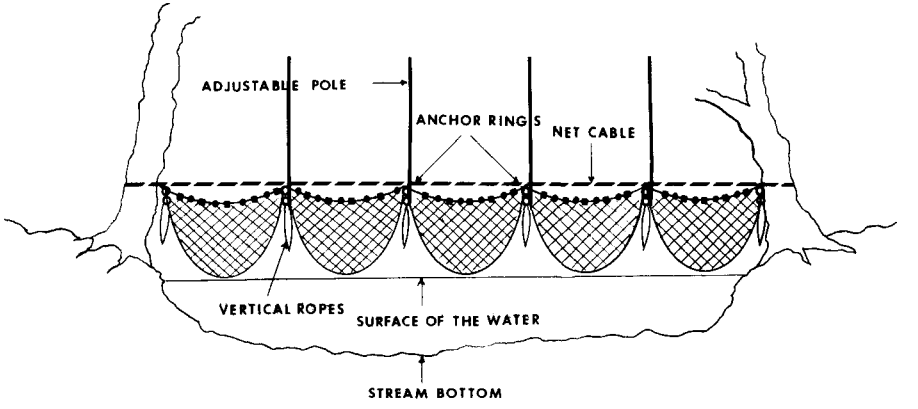
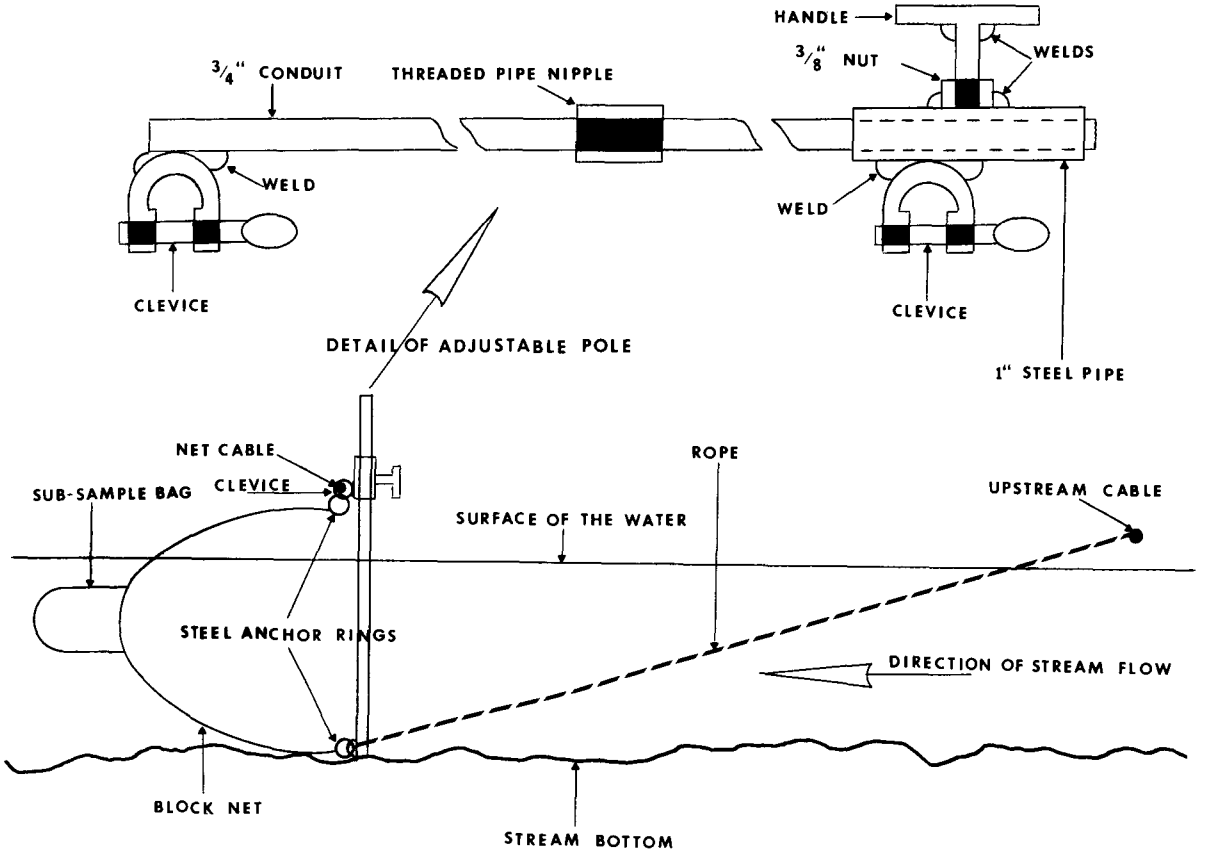


Figure 3. Cross-sectional view of the net suspended across the stream with poles attached, prior to setting the net to the stream bottom.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3/8" NUT
WELDS
3/4" CONDUIT
THREADED PIPE NIPPLE
WELD
WELD
CLEVICE
CLEVICE
1" STEEL PIPE
DETAIL OF ADJUSTABLE POLE
NET CABLE
CLEVICE
SUB-SAMPLE BAG
ROPE
UPSTREAM CABLE
SURFACE OF THE WATER
STEEL ANCHOR RINGS
DIRECTION OF STREAM FLOW
BLOCK NET
STREAM BOTTOM

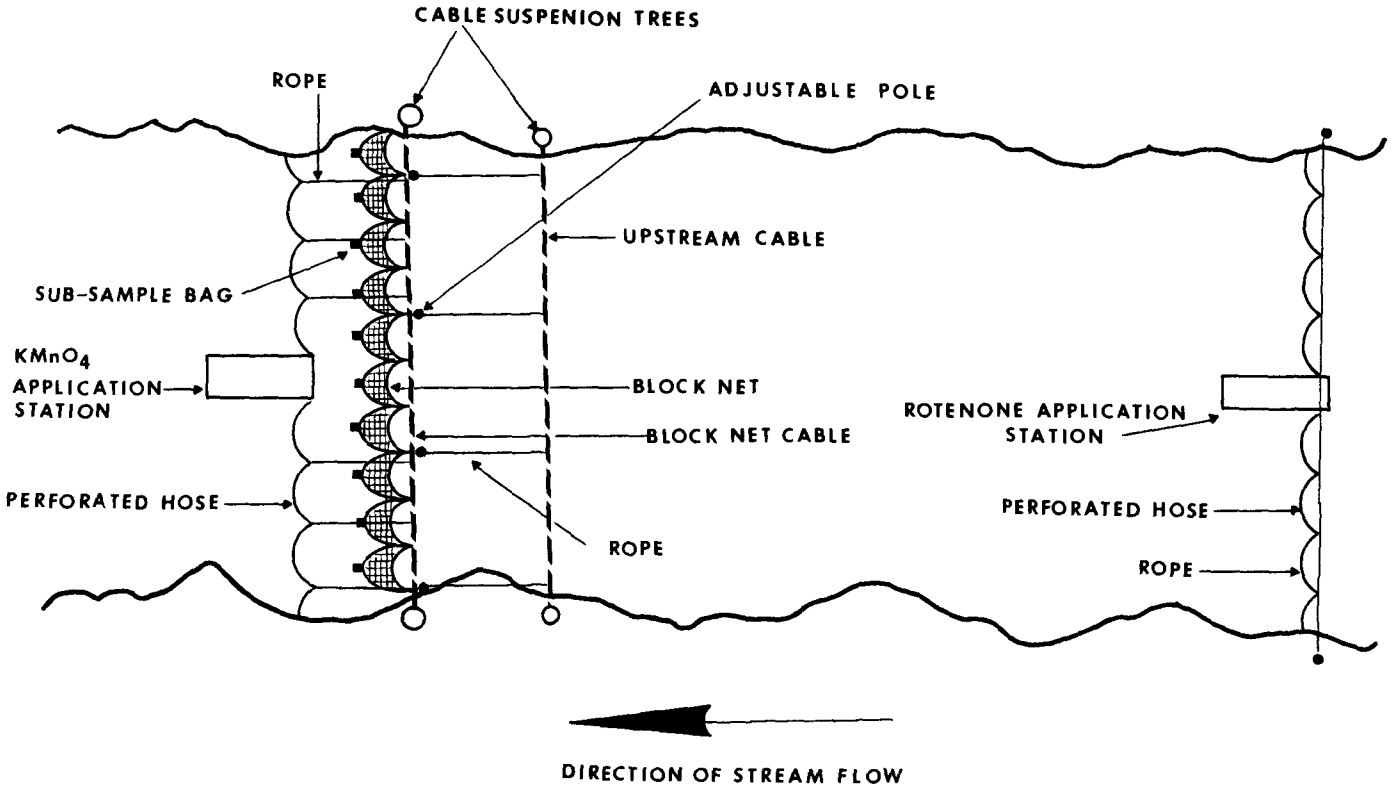

Figure 5. Aerial view of the improved sampling equipment set up on a stream.

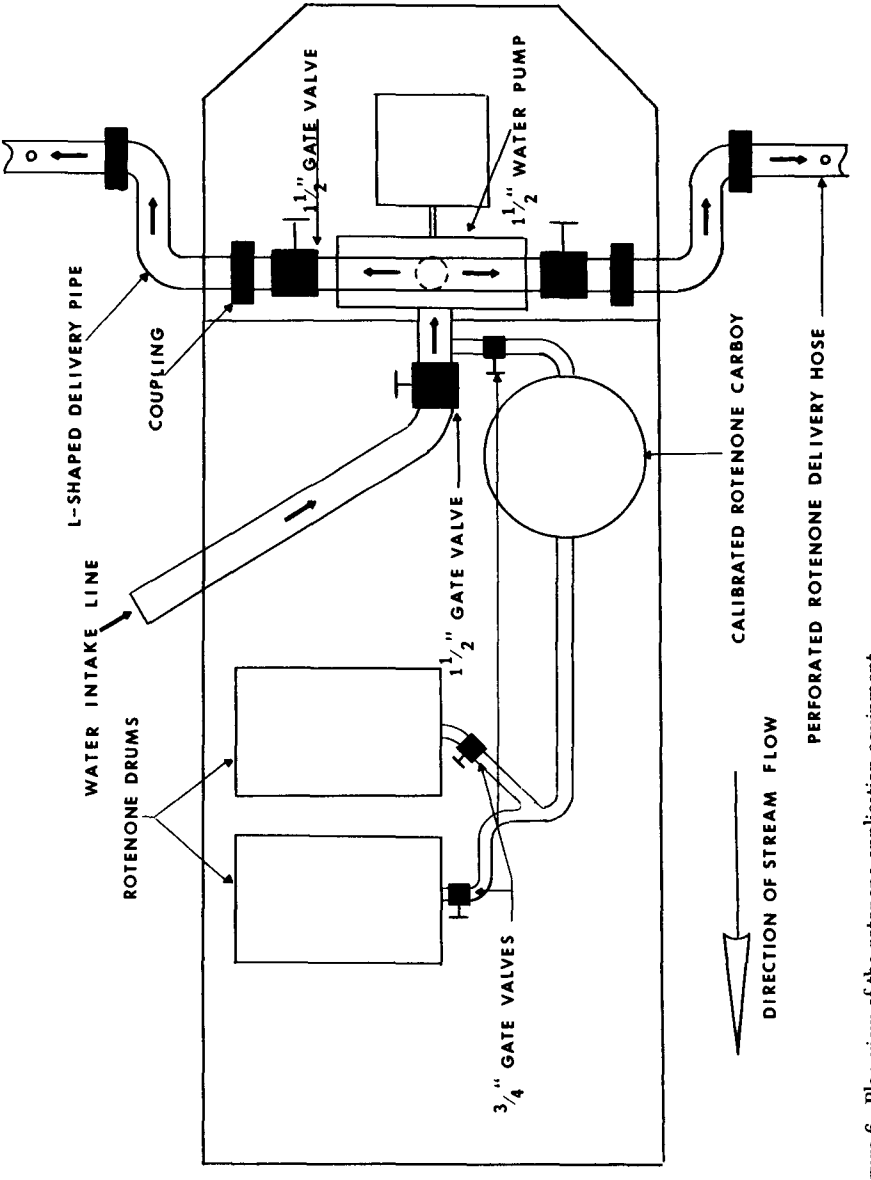

Figure 6. Plan view of the rotenone application equipment.

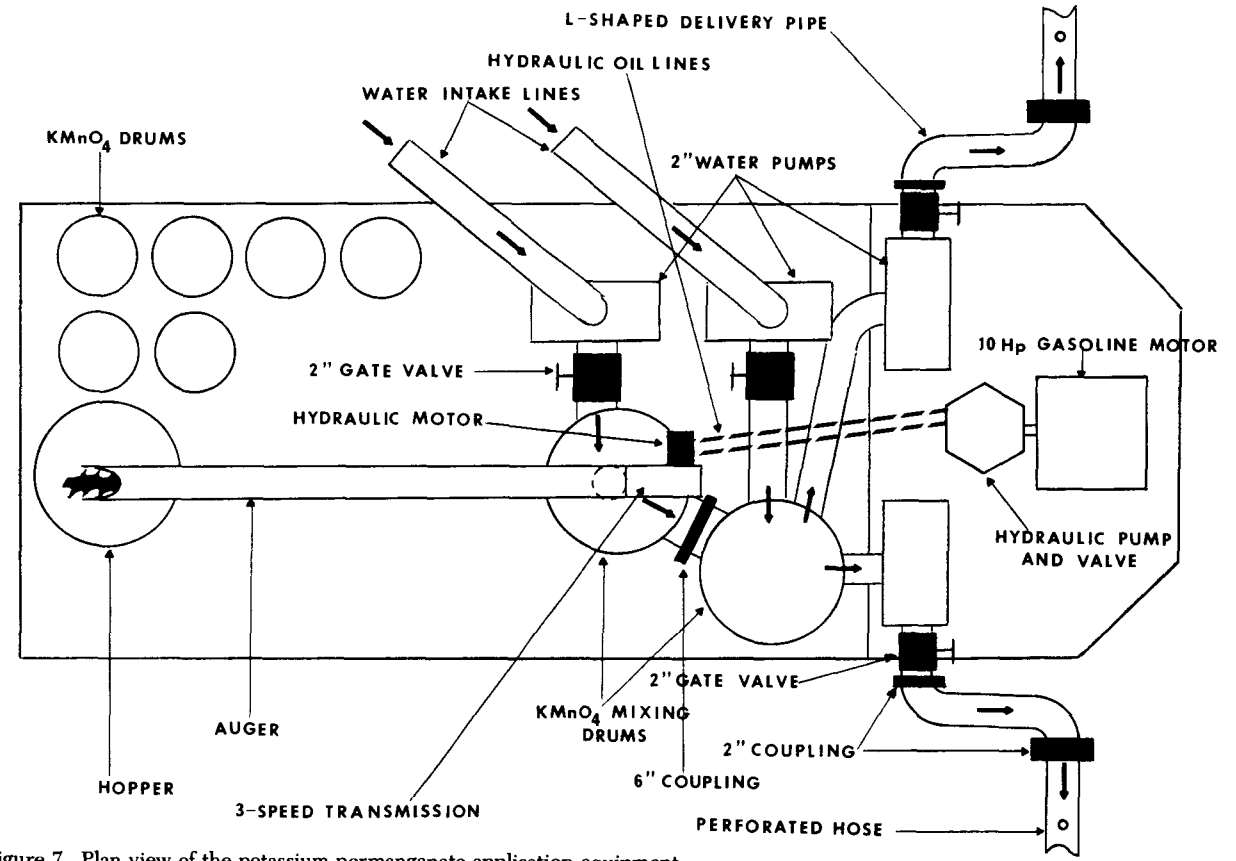

Figure 7. Plan view of the potassium permanganate application equipment.

Table 1. Limnological conditions, chemical application rates, chemical application times, and results of four rotenone samples taken with improved rotenone sampling gear.

Date and Location	*26 October 1973 Flint River above Plant Mitchell*	*23 June 1974 Flint River Ga. Highway 32 Bridge*	*9 October 1974 Flint River Below Plant Mitchell*	*23 October 1974 Flint River Harmons Landing*
Stream Flow (cfs)	500	1700	3500	1400
Avg. Water Velocity (ft/sec)	1.14	1.38	2.49	1.90
Area Sampled (acres)	3.0	12.4	5.7	2.2
Average Depth (ft)	4.5	5.6	5.1	7.7
Max. Depth (ft)	8.0	6.9	7.0	14.0
Avg. Stream Width (ft)	137	267	275	97
Stream Width at the Net (ft)	127	278	275	226
Water Temperature (F)	65	70	68	62
Total Standing Crop (lbs/acre)	310.5	4.6	66.0	98.1
Percentage Marked Fish Recovered			40	68
Chemical Application Time (min.)				
Rotenone	45	45	45	75
$KMnO_4$	60	60	75	105
Rotenone Application Rates at 1 ppm (l/min)	.085	2.9	5.94	2.3
$KMnO_4$ Application Rates at 3 ppm (lbs/min)	5.6	19.1	39	11