THE UNIVERSITY OF WISCONSIN—MILWAUKEE

CENTER
FOR
GREAT LAKES STUDIES

MILWAUKEE, WISCONSIN 53201 U.S.A.

POPULATION DYNAMICS OF JUVENILE ALEWIFE AND COREGONIDS OF GREEN BAY, LAKE MICHIGAN

1969

Completion Report Phase 1

Construction and Evaluation of Free-falling Net for Sampling Mesopelagic Fishes

Prepared by

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Contract number: 14-17-0004-349 Bureau of Commercial Fisheries Anadromous Fish Act

Project number: AFC 6-1 May 1, 1968 to Dec. 31, 1969

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Final Report

INTRODUCTION

Precise direct measures of fish population abundance and species ratios have not kept pace with advances in the development of theoretical methods of estimation based on characteristics of the populations. Relative changes in abundance of different species, and various measures of their population characteristics can be obtained through the use of trawls, gill nets, pound nets, hook and line, shocking, poisons, draw downs, and many more. In large and deep water bodies many of these methods are unsuitable. Furthermore, none of the methods suitable for large water can provide direct measures of population density at a position, or can do so unselectively as to size and species of fish.

This report summarizes an attempt to overcome the indirect approach to sampling fishes of large water. A new net is described which operates by straining a water column from surface to bottom. The device used to set this net is described and problems in its use are fully described. It is assumed the contents of the initial proposal of May 1968 and the 1968 progress report are available to the reader. The design of the experimental drop net (EDN) is shown in Fig. 1.

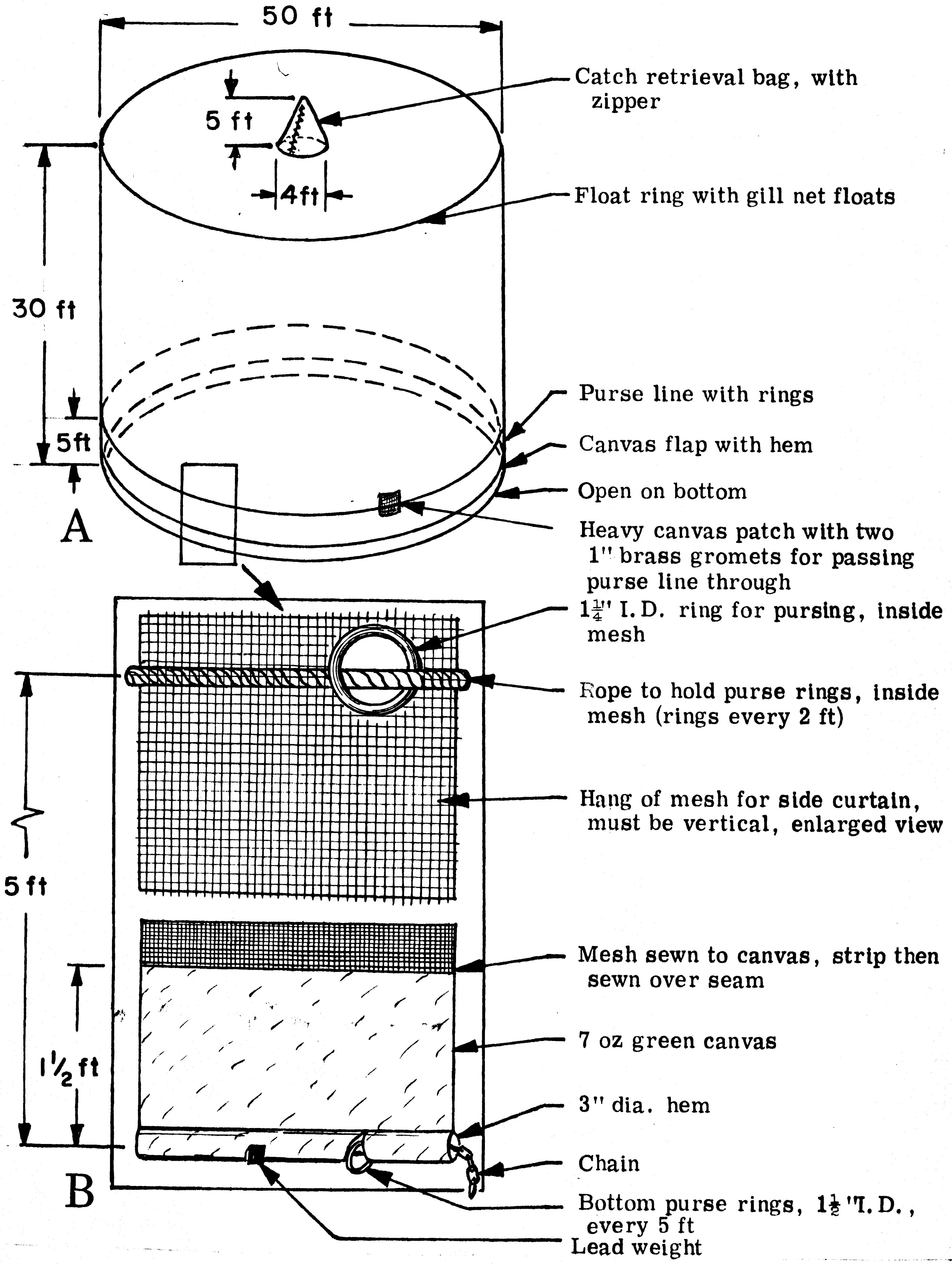

Figure 1. Experimental deep water drop net. A. Three dimensional side view showing all general features. Floats along upper circumference not shown, nor are purse rings along lower edge. Top view is exactly circular. B. Blow up of lower part of side curtain. To hang mesh vertically as shown, strips of netting must be turned 45 degrees and sewn together. Spacing of purse rings optional.

The delivery device designed for the setting, holding and releasing of the EDN is shown in Fig. 12. The other figures show the device in detail and serve to point out features in the text. The delivery device proved to be the very key to the successful operation of the EDN.

The EDN as described herein and used as described was operationally effective for sampling a column of water from surface to bottom over various depths. Details supplied later show conclusively that a non-sprung, free-falling drop net that strains a column of water from surface to bottom, operates as first envisioned and as demonstrated with several small prototypes. The large EDN performed exactly as predicted within the limits of observation of the field testing. The method of setting and retrieval presented many unforseen problems and this represents the greatest limitation on the EDN as a practical research tool.

Negative findings have been included in this report because (1) alternative schemes can be demonstrated, thus showing at least what will not work in particular situations, and (2) the development of procedure and hardware can be traced and the various characteristics of each change explained. Discussion of procedures or hardware that were tried and discarded have been kept to a minimum. A summary of activities carried out in connection with the drop net are given in Table 1.

Table 1. Summary of activities in the development and testing of the experimental drop net during the project period.

Spring 1968	Construction and testing 3 ft. models.
Summer 1968	Testing of model and designing of large net.
Fall 1968	Ordering of large net and design of delivery device.
Winter 68-69	Construction of delivery device and ordering accessory materials for net.
Spring 1969	Construction of delivery device and rigging of net.
Summer 1969	Testing of net and delivery device in central Green Bay, near Chambers Island.
May 20-24	Trouble with delivery device, problems in loading and float ring.
May 25 +	Repair and modification of system.
June 10-14	Delivery device coming apart at junctions, air pressurized float tube scraped, old connections scrapped, problems in weight of net and loading.
June 15 +	Repair and modification of system.
July 11, 12	Pontoons flipped over, damaged.
July 18 +	Repair of delivery device.
Aug. 14-15	Everything working, two good drops made.
Sept. 10-13	Delivery device damaged in strong blow in Fish Creek harbor. Program terminated for summer. Break down and storage of all gear.
Fall 1969	Preparation of final report and reevaluation of promising alternatives to entire system.

EXPERIMENTAL DROP NET

The feasibility of a free falling net, closed at the top, was initially demonstrated with a small model. Although the model could not be scaled properly from the large size of the final EDN, the basic functional characteristics could be incorporated in models. A 3 foot diameter by 2 foot deep model was constructed with diagonal mesh for the side curtain. This model collapsed during descent. The diagonal mesh caused a scissor pulling effect to the top and bottom circumference, thus decreasing the overall size.

The second model (3 x 2 feet) was made with vertical hanging side curtain mesh. It remained open to bottom and with various adjustments was made to fall properly. The perfected model is shown falling in Figure 2, standing upright on bottom in Figure 3 and being pursed in Figure 4. The large EDN was constructed similar to this model and it is thought to behave as in Figures 2 - 4.

The 50 foot diameter EDN constructed of 1/4 inch bar, knotted nylon 210d/12, by MITSUI Fishing Net Co., Osaka, Japan, occupied approximately 30 to 40 cubic feet (Fig. 5). It weighed 270 pounds unrigged, and dry, in air. Our experience with the three foot diameter prototype indicated that an inch and a half (ID) rubber hose should be used around the upper edge of the side curtain as a float tube. A spring was inserted in the hose to prevent it from collapsing at the greater pressure in the lower waters. The purpose of the rubber hose (float ring) was twofold, (1) to allow the net to stand upright on bottom after the heavy, sinking weights, carried the net to bottom, and (2) to provide a constant upward pull that worked against the lower weights during descent, thus providing a tension that tended to counteract collapsing pressures caused by lateral forces, e.g. currents. The size of the float tube was determined by calculation of necessary buoyancy.

To sink the net and overcome the buoyancy of the float tube, weight was added to the lower edge of the side curtain in two ways. Steel chain of 0.42 pounds/foot was fed entirely around the bottom hem (Fig. 1). This chain provided slightly more than the necessary weight in water to sink the float tube. Since nylon is practically neutral in water, the weight of the net was taken as zero in water. To properly sink the net a downward force had to be exerted to overcome the upward force caused by the drag of water through the top mesh. Also, a certain speed of fall was necessary to cause sufficient "back pressure" within the upper portions so water would pass through the sides of the curtain during descent, causing the net to "bellow" out. Tests with the model verified the need for these forces. Therefore, lead weights were attached to the chain by clamping them along the lower edge (Fig. 6). Enough lead weights were added to double the buoyancy of the float ring (2.5 oz/foot). Purse rings ($1\frac{1}{2}$ inches ID) were placed on the chain every 5 feet at openings in the hem to allow for bottom pursing.

The weight of the completely rigged net with float tube (spring inside), chain, and lead weights, dry and in air was 485 pounds.

PHYSICAL ASPECTS AND THEORY OF DELIVERY DEVICE

The large net required a large floating delivery device. The delivery device needed to be (1) free floating to ride with the seas, (2) light enough and built in sections to be disconnected so they could be handled by few men and/or transported over land or on deck,

(3) strong enough to withstand the force of moderate seas, (4) operated remotely, (5) allow loading of the net by small boat, (6) relatively non-resistant to the wind, (7) a smooth surface to allow the net to fall freely from it, (8) reliable as to method of tripping and holding of the net.

This combination of characters while formidable, did not seem entirely impossible if the proper hardware could be utilized with the appropriate design. The design arrived at as the initial attempt to best satisfy the requirements is shown in Figures 7-10.

Twelve pontoons of appropriate size were constructed in the machine and instrument shop of the Center for Great Lakes Studies, to hold the folded side curtain of the EDN. The pontoons were hollow and filled with styrafoam (Fig. 7). Each pontoon weighed approximately 140 pounds, was 11 feet 8.9 inches long by 24 inches wide by 4 inches high. Each pontoon had a trough made of wire mesh that pivoted hear the outside edge of the pontoon. This trough held the folded side curtain of the EDN. The trough when tripped over (Fig. 8) by a pneumatic piston (Fig. 9) started the net on its descent.

The ends of the pontoons were initially constructed with a rubber ball and spring arrangement which allowed for all-way movement between them. The force experienced by one pontoon was only moderately transferred to the next, thus allowing each to ride semi-independently of the others.

The point of attachment between adjacent pontoons caused much trouble. The force of the waves produced tremendous pressures on the joints, and the restraining chains. Then it was discovered that the net was manufactured 9 feet too small in circumference. Because the size of the pontoons could not be easily altered, one pontoon had to be removed so the pontoon ring would fit the net. With 11 pontoons the strain between each one increased (angle went from 30 degrees to 32.7 degrees) and the inside free-play area decreased from 2 to $1\frac{1}{2}$ inches. The net used was only 47 ft 4 in instead of the 50 ft diameter shown on Figure 1, and the 11 pontoons made a ring 45 ft 3 in measured across the bodies of two opposite pontoons, or 47 ft 3 in measured across the corners of opposite pontoons. Because the diameter of the pontoon ring was almost identical to the diameter of the net, the net was difficult to adjust evenly on the pontoons so it would fall off rapidly. The delivery device should be approximately 10% smaller in diameter than the net if future models are constructed.

The original connectors were replaced by a trailer coupler and ball arrangement, with the outside strain being absorbed by a more permanent chain assembly (Fig. 10). The restraining chain later had to be replaced by a heavier chain with permanent connections (large cable clamps) to each pontoon. The hitch and ball had to be mounted as shown because of room limitations between the inside edges of the pontoons when in a circle. Rubber bumpers (shown) were mounted to absorb shock when towing the pontoons in a line.

METHOD OF OPERATION

The pontoons were towed in a line to the desired sampling area (Fig. 11). They were then drawn into a circle and tethered to the support ship (Fig. 12). The EDN was lowered over the side of the support ship. As it was going over 4 floats, each, 1 cubic foot, were attached to the upper circumference (float ring) of the net. The floats were attached at four opposite points. The net was allowed to settle down and was floated by the four floats. The only line to the net was the purse line which was held slack. The loading boat would then take one of the floats and draw the EDN to the pontoons. Then one of the floats was tied to any pontoon and the other floats drawn under and across the pontoon ring. The net in this position was directly under the pontoon ring and the side curtain hung down 30 ft.

A major difficulty was the initial forming or spreading of the net into a ring below the pontoons. The rubberhose (float tube) was only designed to hold the net erect on bottom and not float it; therefore it was pulled under by the weight of the chain and leads when at the surface. Also, it was difficult to determine in which direction to spread the net, after the rubberhose was secured at the first location, because the hose was several feet below the surface and usually twisted.

The entire float tube was sealed and an air coupling mounted to it. It was thought that if the float tube was pressurized it would automatically form a ring in the water, much as a bicycle tube with low air pressure inside. The curtain would then hang freely and properly below it, and the whole net assembly could then be maneuvered beneath and properly around the pontoons. The air pressure could be released just before tripping the net into the water to achieve the non-sprung affect again. When low air pressure of 20-30 psi was put into the hose it enlarged, stiffened against itself, began to form an automatic ring, then kinked severely. This kinking occurred at the lowest pressure possible and each kink grabbed several yards of mesh and completely bound the net. The reason for the kinking appears to be the spiral construction of the layers making up the rubber hose. It was not caused by the loose spring inside.

After the net was properly hanging below the pontoons, the loading boat with three men in it proceeded to follow the float tube around and attach it to the pontoons. The entire side curtain below a pontoon was gathered up by a man in the loading boat (two men held the boat away from the pontoon) and the roll of side curtain and canvas with weight in it was placed in the trough. This method of loading was very exhausting and fairly dangerous to the men. The boat was difficult to keep away from the pontoons and everyone was leaning over the side of the boat with hands and arms between the boat and pontoons. The pitching boat and rocking pontoons also made it difficult to hang on to the mesh of the side curtain.

During the first half of the circle the loading man was lifting practically the entire weight of the chain, lead, and much drag. A vertical pull on the hanging curtain lifted the entire lower edge, not just the weight directly below the point of pulling. This extreme weight had to be lifted all the way up and the edge of the curtain (canvas and mesh) was then placed in the pontoon trough. Because the weight was not yet distributed, there was a heavy load on the outside edge of the trough. Therefore, the troughs became overly strained and when the sea was higher than one foot, they would sometimes trip prematurely.

Even though the net was "neutral" (the nylon mesh part only) in water, its mass was felt when trying to raise the side curtain. Each several feet lifted required some acceleration, then a constant force to overcome the drag of the mesh. The actual side curtain weight of 20-30 pounds below each pontoon, was multiplied many times. Equal lifting at many points along the side curtain would overcome this difficulty. On two occasions gallon plastic jugs were attached to the lower edge to make it lighter. The jugs tangled and were impractical.

Figure 13 shows the loaded net, the float tube inside the pontoons, the restraining chain between the pontoons, and the air tubing that connected all the pistons. The side curtain is outside the outer edge of the troughs although the photograph does not show this well. The side curtain goes over the outside edge of the troughs (right side) and to the top of the net which is submerged, except for its circumference which is the float tube showing as a bent black object on the inside along the right edge of the pontoons.

When the side curtain is completely loaded, and it is not tight at any corner or caught on any edge, the air line is brought from the support ship to the pontoon ring, the connections are given a final check, then the personnel on the support ship open a valve sending 130 psi of air to the pontoons. The air first reaches a T connection at the pontoons, divides and proceeds around the ring in opposite directions. The troughs trip almost simultaneously, 2 to 4 seconds separate the first and the last. The difference in tripping depended on the static friction of each trough and piston, and on the relative weight each carried. The few seconds difference proved inconsequental to the release and fall of the net.

Because of the numerous small problems with the pontoons and net, most of the time was spent altering the hardware and procedure before a drop could be made. On one occasion an attempt was made to move the pontoons rapidly while in a ring shape. This flipped the entire ring and set the program back several weeks with repairs. The pontoons could only be towed in a ring very slowly, but they could be towed in a line up to 4 mph in a light to moderate sea. The pontoons withstood 2-5 foot seas when in a line.

After considerable trial and error, replacement of parts, and consideration of design, it was decided to remove the float tube with spring inside and replace it with something that provided lift but not weight, and was flexible. A successful drop had not been obtained although approximately 11 full working days, in three separate cruises, over a two month period, had been devoted to the testing project, Table 1, and this does not include the between cruise repair time.

Some alterations were tried on the three foot model by sewing on small pieces of wooden rod at equal intervals around the upper circumference. The small rubber float tube was removed from the model. This modification did not impair the fall and bellow characteristics of the model. Aluminum gill net floats were then attached to the upper edge of the EDN along the circumference at one foot intervals, to equal the buoyancy and replace the large float tube. The air weight of the net was decreased by 120 pounds and it was considerably more flexible.

The net and strengthened pontoons (new chain assembly) were then retested. The net was spread as before but now the corners were numbered and color coded which made it easier to form the circle. The lifting of the side curtain remained a difficult task for the same reasons as before. The loading of the net from ship to troughs was now reduced to approximately one hour. The upper float ring of gill net floats can be seen clearly in the center of the pontoon ring in Figure 14. The circumference of the upper portion did not need to be pulled under the pontoons as previously thought.

Once set the entire triggered assembly was allowed to drift slowly back behind the ship (up to 150 feet back) and 10 minutes were taken to allow the water column under the assembly to return to normal. The net was then tripped over 54 feet of water. The troughs flipped the lower, weighted edge of the EDN into the water first. The side curtain begin sinking simultaneously in a ring shape. The further it sank the more side curtain it pulled into the water and the more the entire net became cylindrical. When the side curtain had sunk 30 feet, it became taught against the upper floating part (float ring and top of net, also in a circle). At this point the entire net began to sink because of the weight overcoming the buoyancy. The upper circumference remained flat and top portion of the net rounded out. The net continued to sink slowly to bottom, straining a column of water through the top. A diver observed part of the descent and made appropriate notes.

RESULTS OF FIELD TRIALS

The EDN fell at approximately 2 ft/sec, slightly slower than the three foot model. The top rounded and the sides fell straight through the water the same as the small net. The float ring of gill net floats did not appear to come together as the net descended, indicating it tended to remain open all the way down. The diver could not follow the net to bottom. After one minute the net was pursed using the purse rings 5 feet above bottom. The net was then retrieved to the support ship bottom first (Fig 15). The catch was concentrated in the upper (now lower because the net is upside down) bag end and removed from the zippered "cod end" (Fig 16). The first drop over 54 feet of water on a bright sunny day in mid Green Bay (Secchi disc of 8 feet) caught 145 fish (Table 2). The mesopelagic living alewife made up 136 of these fish.

The second test over 75 feet, one mile from the first site, was made the following day. The loading was as before but this time there were 3 foot seas with a strong current. The purse line was moved from the rings 5 feet up to the rings along the lower hem, in an attempt to catch more bottom fishes. This time there were apparently no alewife in the column of water strained but 31 fishes were captured that normally occupy the hypolimnion of Green Bay (Fig 16) and Table 2). It is interesting to note that sculpin were captured because these fish seldom live more than several inches off the bottom. The bottom pursing therefore must be somewhat effective in capturing these demersal fishes.

The smallest fish captured were the sculpins (48 mm) and sticklebacks (63 mm). The largest fish were the alewife (201 mm) and the smelt (189 mm).

The drop that was pursed five feet above bottom in 54 feet would not be expected to catch anything much different than what it did in central Green Bay at that time of year (August 14). Forty six to 54 feet is within the upper edge of the thermocline (Table 3) at that date near the test area.

Table 2. Fishes caught with deep water drop net on east side of Chambers Island, Green Bay. August 14 and 15, 1969

Species	54 foot drop, pursed five feet off bottom	75 foot drop, pursed on bottom
Alewife *Aloso pseudoharengus*	136	--
Smelt *Osmerus mordax*	6	19
Ninespine stickleback *Pungitius pungitius*	2	4
Slimy sculpin *Cottus cognatus*	--	8
Spottail shiner *Notropis hudsonius*	1	--
Total	145	31

Table 3. Water temperatures near experimental drop net test sites, Aug 15, 1969

Depth, meters	Temperature (°C)	Depth, nearest foot
S	21.2	S
2	20.5	7
4	20.1	13
6	20.2	20
8	20.0	26
10	19.8	33
12	19.0	39
15	15.7	49
18	13.4	59
20	11.1	66
24	10.0	79
26	9.7	85

Gill net catches made with gill nets of all sizes ($\frac{1}{2}$, 1, $1\frac{1}{2}$, 2, 3, and 4 inch stretch) in the same area all summer, have shown the following. Most smelt were deeper since mid-June and the whitefish and lake trout were scattered and/or deeper. Sucker, mostly long nose, are found in shallower water and even if they were there would have probably been missed because the net was pursed above bottom. Perch are practically non-existent near the drop area. The ninespine stickleback indicates that there must have been at least a narrow band of cool water (less than 17° C) above the bottom, and this may explain the few smelt. Table 3 shows the 3-9 feet just above bottom were cooler than the upper waters. The troutperch and spottail shiner normally occur in shallower water (warmer too) than the sticklebacks and this may explain why they were not caught in numbers.

If the drop would have been pursed on bottom it is likely more fishes other than alewives would have been caught, but perhaps not in different ratios.

The dropping, pursing, and retrieving of the net took approximately 20 minutes. An efficient crew could thus make one drop every $1\frac{1}{2}$ to 2 hours with our design and method. The time could proably be reduced to near one hour per drop.

As with the shallow drop, the deep drop apparently caught what was beneath it. Why no alewife were below it in the deep water the second day is impossible to say. The lake herring are "gone" from Green Bay so it could not make up a part of the mesopelagic catch over any depth.

Gill net data indicate that the summer fish fauna of mid Green Bay in the thermocline(1) and above consists almost entirely of alewife. Smelt were the most abundant species below the thermocline in water 50 feet or deeper. Other fairly numerous species were the slimy sculpin and the stickleback. Lake trout occurred but they were few and widely scattered, as are rainbow and brown trout. Most whitefish had apparently moved out of this part of the bay by this time and the burbot was uncommon in summer. The suckers were confined to the warmer shallower water. Therefore the bottom pursing of the second drop seems to have sampled effectively the hypolimnetic fish fauna and the upper waters, under the 50 foot circle on that date.

For both drops no measure or estimate is available of the fish that may have escaped the net during descent, or escaped during pursing. The depth of cool water sampled by the deep drop was 3-4 times greater than the shallower drop, and the catch of smelt by the deep drop was 3 times greater.

DISCUSSION AND CONCLUSIONS

The deep water drop net appears theoretically sound. Its ability to catch fish has been demonstrated. Its sampling efficiency is unknown. Further testing should adequately demonstrate this.

The pontoon design incorporated to initially test the net proved inadequate for large water use. The numerous difficulties of loading the delivery device from a boat, using a boat to spread the net under the pontoons, etc. make the pontoons we utilized seem impractical for long term sampling in large water bodies. The entire process of setting

(1) Numerous oblique and horizontal canned gill net sets were made with small mesh nets in the same area all summer.

seems to be the major drawback to repeated effective use. The task is difficult, depends on the sea conditions, takes one hour or more per drop, and there were many difficulties.

A large ship with a substantial winch and boom can most effectively operate the net. The two successful drops, however, were made using only a 32 foot pound-net boat as the support ship, with no boom or winch. The loading boat pursed the net with a line running through a pully on the anchored pound-net boat. The net was then hauled in (after being drawn to the pound boat) by hand over the side of the pound-net boat. Catch removal was fairly difficult with this method however. This point demonstrates that the entire assembly as described can be used by small boats (or a boat and a large raft) if necessary, as long as manpower is available. The pontoons were left at anchor overnight near the sampling area.

It would be most instructive to attempt a drop in water several hundred feet deep and observe the characteristics of the net during descent. This would require either a calm day on the open water or a different design for the pontoons.

The mesh size of $\frac{1}{4}$ inch bar knotted nylon performed as designed by resisting the flow of water as the net descended, thus creating a parachute effect to the net. Larger meshes may do the same but the proper combination of size of net, size of mesh, weight of lower hem, and length of side curtain would have to be worked out, if only larger fishes were wanted. The entire net could be made 130 pounds lighter (approximately 250-300 total rigged weight, dry and in air) simply by using 1/2 inch bar mesh. One inch bar mesh would provide a gross air weight of approximately 140 to 180 pounds. The total weight would then be more manageable. By increasing the mesh size the drag would be reduced. Therefore the weight needed to cause a particular rate of fall could be lessened. Appropriate adjustments would need to be made in the float ring.

The length of the side curtain in the 50 foot diameter model EDN is 30 feet. If a faster falling net were designed, the length may be able to be shortened, for example to 20 feet. This would speed loading, reduce disturbing the water column, reduce drag when moving the net to the delivery device, reduce cost of the net, and reduce weight. The size we tested might be able to be scaled down to 40 by 24, or 30 by 20 feet and still capture a representative sample of what is beneath it. The smaller the net the smaller the delivery device needed and this further reduces all costs and some difficulties of operation. For very large waters with large ships and adequate mechanical lifting aids, the size of a net as described could be constructed of immense proportions to take advantage of the low densities of some species.

A further consideration is that in water equal to the depth of the side curtain, or shallower, the EDN most certainly would capture all of the fishes beneath its area; assuming the delivery device did not appreciably disturb the water column of course. The converse of making an extremely long (deep) side curtain so it fell completely to bottom in a ring before the top started down, would be equivalent to setting a purse seine as a cylinder, with the seine having a closed top. This latter aspect may have enough promise to warrant testing thoroughly.

With the design described in this report, the best place for its utilization is in smaller lakes that are not so prone to heavy seas.

The depth of the lake that can best utilize the EDN and pontoons as described csnnot be stated. It is thought the EDN will operate through any depth but difinitive proof is yet lacking. In turbid, shallow water bodies (e.g. some reservoirs) the EDN would give an immediate figure for pounds per acre by species. With true ratios of species abundance in hand and actual biomasses per acre, much valuable information is provided for many aspects of fishery monitoring and management.

This project has demonstrated the feasibility of the deep water drop net within the limited testing carried out. An adequate delivery device can no doubt be perfected for use on large water bodies. The device should be practically self-sufficient, and capable of allowing men to work directly from it. If the retrieving were also done directly to the delivery device, the resetting would be simplified. The ideal delivery device would have a boom and winch, be rigid, have a working platform, have the troughs operate mechanically, be capable of being towed, and large enough to be stable. A single small or medium support boat would be all that would be necessary to tow the platform to the desired area and purse the net.

The present model can be used on smaller water bodies. Here, it can provide information obtainable by no other direct sampling means. The drop nets' potential to fishery research remains apparent, and efforts should be made to continue development so its primary unique capability of being able to sample mesopelagic fishes in deep waters, can be fully realized.

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Acknowledgments

Thanks are extended to L. P. Levine for many suggestions concerning delivery device design, and Robert Scott who constructed and made many useful suggestions on the delivery devices. The Bureau of Commercial Fisheries is gratefully acknowledged for providing support through the Dept of Natural Resources, Wisconsin, to construct and test the deep water drop net and delivery devices. Anthony Kegel assisted closely with many phases of the modification and testing program.

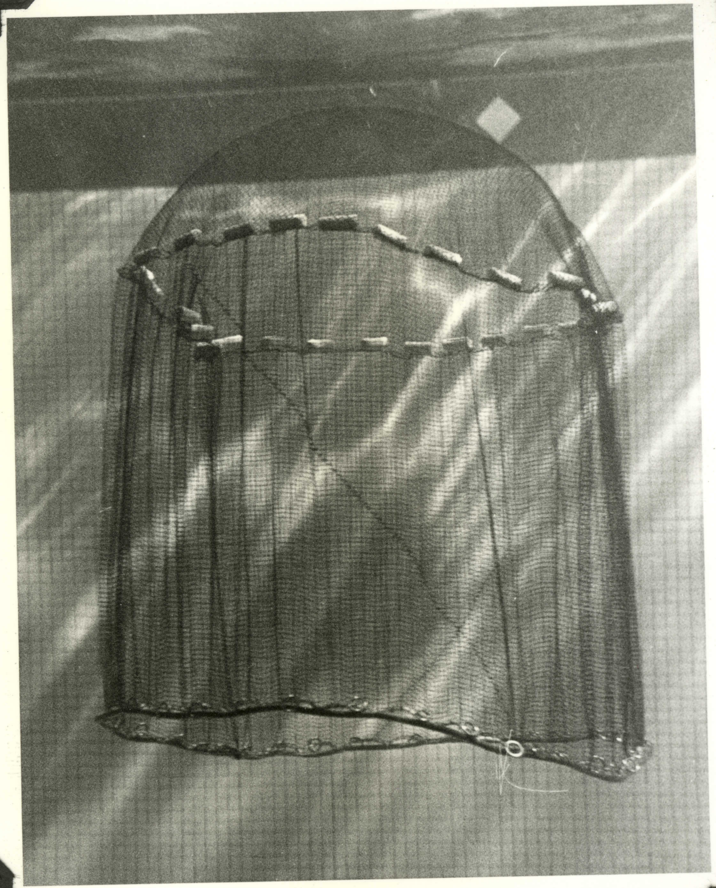


Figure 2. Prototype of experimental drop net being tested in pool. Rounded top indicates parachute effect as the net descends to bottom

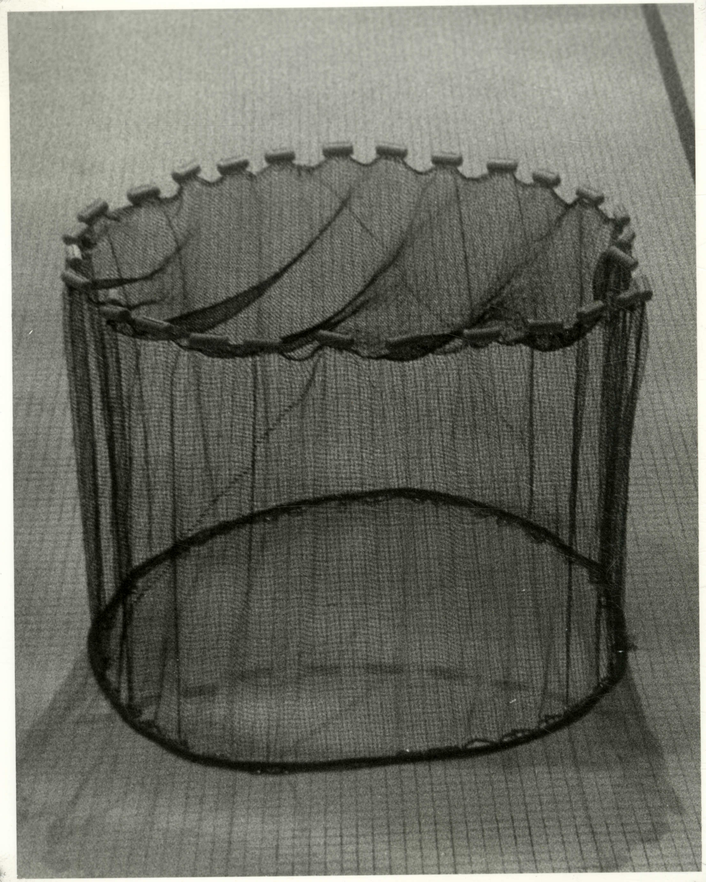


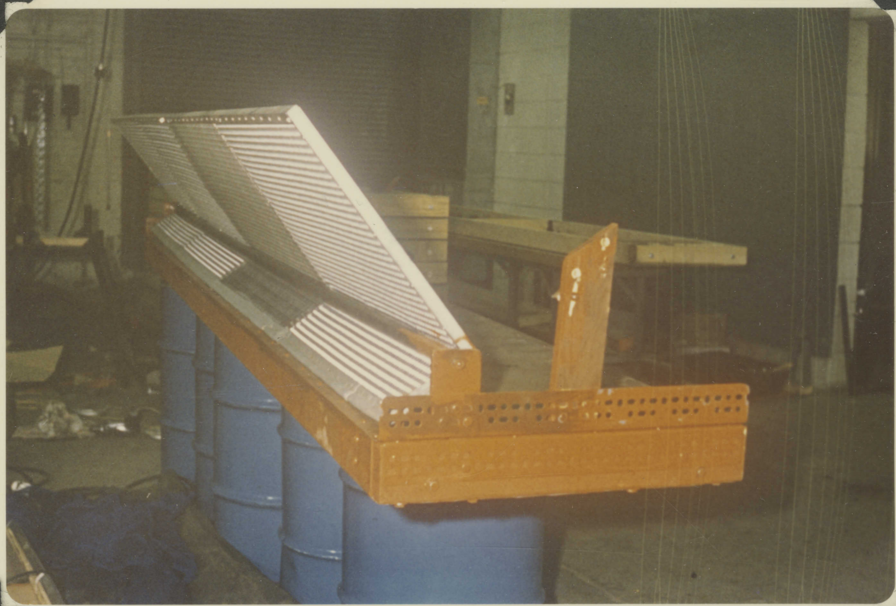
Figure 3. Prototype resting on bottom of pool after falling through 10 feet of water. Note that bottom of net is still fully open and the upper floats are supporting net upright.

Figure 4. Prototype being pursed with purse line up from weighted lower edge. Large experimental drop net has flexible chain along lower edge and thus does not resist bending as much.

Figure 5. Unrigged 50 ft. experimental drop net and weight chain. Green canvas is actually bottom of net. Total weight 270 pounds.

Figure 6. Lead weights being clamped to lower curtain. Note purse ring in slot in hem.

Figure 7. Basic construction of pontoon body showing pits for floatation and false ends. Sheeting is 18 ga. galvanized sheet steel.



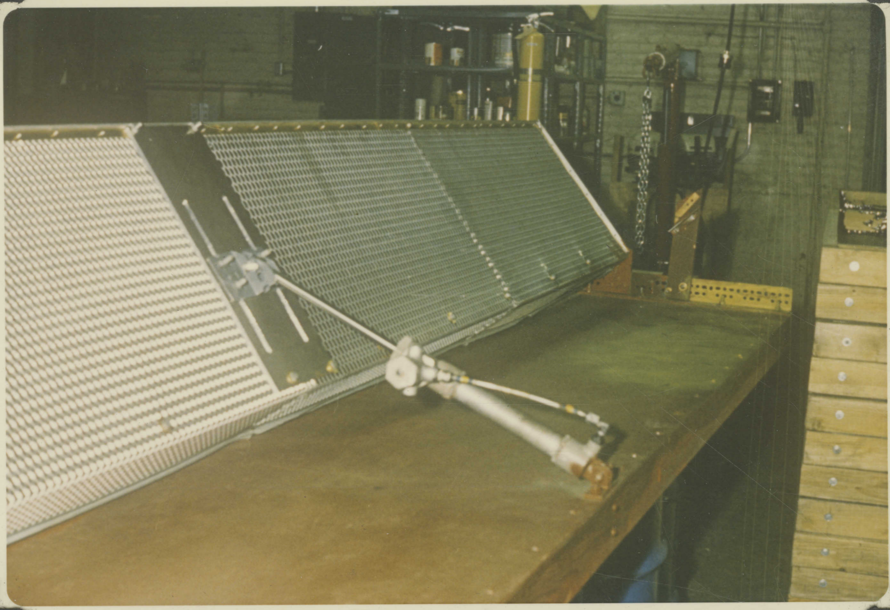


Figure 9. Pneumatic piston that pushed trough over. Air hoses not connected.

Figure 10. Modified pontoon end. Fulcrum for trough later moved to very edge of pontoon. Note rubber bumpers.

Figure 11. Towing pontoons to station and testing riding capabilities with 18 inch waves.

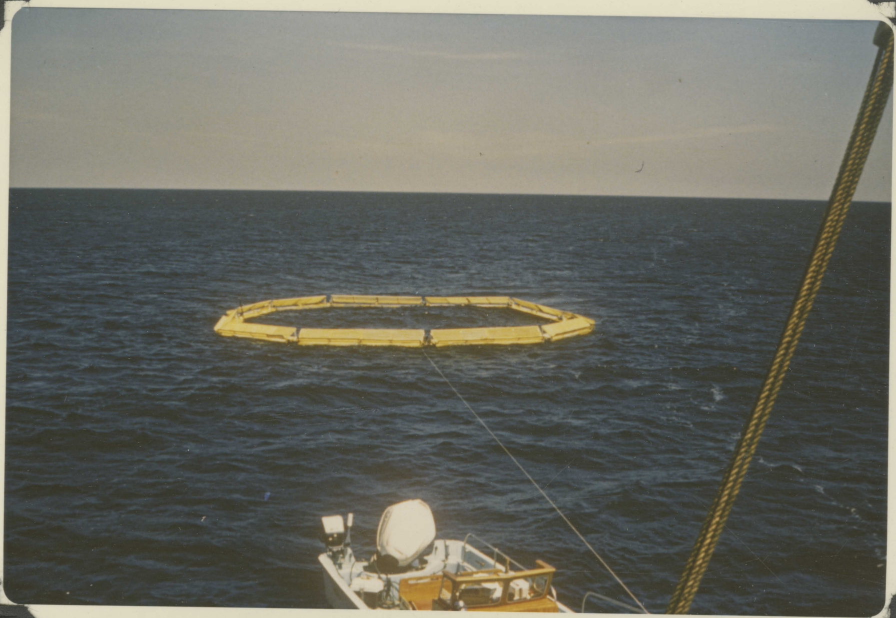


Figure 12. Pontoons moored to support ship on 100 foot line. The EDN was drawn back to the ring with the small boat. Note how pontoons are riding independently in sea of one foot.

Figure 13. Loaded pontoons with EDN before changing float tube. Mesh is outside pontoons and over edge. Note float tube in center and restraining chain between pontoons.

Figure 14. EDN loaded on pontoons just prior to dropping in 54 feet. Note circle of gill net floats on inside of pontoons. As before the entire 30 ft. of side curtain and lower canvas is in each trough.

Figure 15. Lower curtain of EDN pursed together and coming aboard support ship. The net is pursed 5 feet up in this shot. Note lower purse rings used on second drop.