I.F.R. #342

Reprint from PROCEEDINGS, NORTH AMERICAN WILDLIFE CONFERENCE, Feb. 3-7, 1936. Senate Committee Print, 74th Congress, 2d Session, Washington, D. C., 1936.

LAKE AND STREAM IMPROVEMENT IN MICHIGAN

By CLARENCE M. TARZWELL, Institute of Fisheries Research, Department of Conservation and the University of Michigan

During the past 3 years lake and stream improvement has had a rapid, almost phenomenal, growth in popularity and use. As most of the work has been made possible through the use of emergency funds it has been essential to organize and carry out the work as rapidly as possible. Many streams and lakes have been worked without first being surveyed and much of the work has been carried out under an inexperienced and untrained personnel. The lack of adequate information concerning the methods of construction, the purpose of the various structures and the ecological changes brought about by them has been keenly felt and clearly shown in a great deal of the work. In view of these circumstances it is felt that the experience gained in Michigan during the past 6 years may be a help to others engaged in a similar undertaking.

Ten years ago, when discussing the decline of fishing in streams old fishermen spoke of the cleaning of the streams for log drives as the possible cause of that decline. Some advocated replacing the logs, trees, and wing jams as a means of bettering the fishing. A further development of this was the "resnagging" work carried on by Dr. Jan Metzelaar in the Pere Marquette and Little Manistee Rivers in 1928 and 1929. This "resnagging" consisted of the felling of large trees across the streams and the throwing of various materials into the streams so that they would float down and lodge against these barrier trees to form jams. It will be noted that such work takes into consideration only the formation of pools and cover and no thought was given to food or spawning conditions. As these jams continued to grow, in time they became so large that the tree could no longer hold them and they went out. As such "resnagging" work was incidental to other activities it was not extensive. It was, however, a beginning, and demonstrated that pools could be formed but that the mere throwing of material into a stream was not enough to bring about permanent results.

In 1930 with the creation of the Institute for Fisheries Research under the direction of Dr. Carl S. Hubbs the work was taken up in a more intensive manner. A program of lake and stream surveys was initiated. Mr. R. W. Eschmeyer was placed in charge of the lake surveys and the lake improvements. The speaker was given the responsibility for developing, testing, and checking the results of various methods for improving trout streams.

In the summer of this first year the Michigan Department of Conservation made an appropriation for carrying on a project on the Little Manistee River in Lake County. Since this was the first project of its kind in the State and, in fact, to the best of the speaker's knowledge, the first in the country the work was of necessity an experimental project. Many types of structures were installed in order that their action might be observed and the best ones selected. Among the more successful types the following may be listed: wing, V and I deflectors made of logs or stone, tepee and raft covers, trees, and bank covers. A number of stumps were used but about half of them were washed away due to faulty installation.

Notes were taken on the condition of the stream before the structures were installed. Type of bottom, plant beds, mucky areas, depths, cover, and size and depth of pools were all noted as well as the type and construction of the device. Each device was tagged with a numbered metal tag so that future observations could be made. In all, 500 structures were described, tagged, and located during the first season.

In 1931 a recheck was made of the previous year's work and a knowledge was gained of what each structure could be expected to do. With this information as a working basis and with a better knowledge of the requirements of the trout and the deficiencies of the streams the work was continued in a more systematic manner. Devices were installed not only for the purpose of creating pools and cover but also to improve food conditions by producing riffles uncovering gravel areas, and creating mucky areas and plant beds. Various types of deflectors, such as V's, Y's, I's and A's, were used to bring about these conditions and also to create pools. Cover was furnished by various types of raft, bank, bend and center covers. Attention was given to the prevention of bank erosion by the use of large boom covers and bend covers. As in 1930 extensive records were made of each installation and its surroundings.

While it was possible to observe the formation of pools in a stream, further and more definite information was desired as to just how the so-called improvement devices influenced the fish population and the food. In order to secure this information, fish counts and food counts were made before the devices were installed. The location of these various counts were recorded so that recounts could be made some years after improvement when conditions again became more stable.

The fish counts were made by enclosing a portion of stream by barrier seines placed at the upper and lower ends of a selected section and then catching the fish in the section by the use of small seines. The barrier seines were held by means of stakes driven into the stream bed. Chicken wire was stretched across the stream in front of the stakes in order to give added support to the seines. This arrangement made it possible to hold the seines until all the fish in the section had been caught, measured and recorded.

The food counts consisted of quantitative bottom samples. These were made by collecting all the bottom organisms from a unit area. These organisms were preserved for future study. Counts were made at locations where devices were to be installed and a record of bottom type, depth, and surface current was secured. In this way it was hoped to obtain information concerning the manner and the extent to which food production was influenced or changed by the devices. Counts were made on the East Branch of Black River, Pigeon River, and Gamble Creek.

During the following year the work was continued and expended to streams in various localities. Rechecks were also made of all previous work and the ecological conditions noted. Underpass deflectors were found to be very efficient in the formation of pools. Wing deflectors proved to be most effective in the creation of muck areas and in the establishment of plant beds. Large boom covers and raft covers were found to be unstable as they were carried away by floods or they waterlogged and sank so that they became useless. Bank covers, square covers, tepee covers and wedge covers were found to be unsatisfactory in streams having a good deal of ice. In such streams it was necessary to submerge these covers below the ice level or ice forming around them would pull the stakes due to its lifting action. In constructing the submerged bank covers it was found to be well to imbed the holding legs into the bank at least as far as they projected into the stream. In general, deflectors were not affected by the ice, but it is well to keep them low and to bank them on the upstream side. V and Y deflectors were found to be especially useful for uncovering gravel by the removal of sand. This is one of the means of increasing food production. Wing deflectors, wing jams, and large bend covers were found to be effective in preventing bank erosion.

Except in certain locations stumps proved to be difficult to hold in place. In sandy bottom streams they often completely washed out the stakes holding them and in streams having a good deal of ice the stakes were pulled. A good method of holding stumps in place under such conditions is to fasten them to a stake by means of a 10- or 12-foot cable. The stake should be deeply imbedded and the cable fastened to it just above the stream bottom. In order to prevent ice from forming on the stake it should be cut off just above the stream bed. The advantage of the cable is that it allows the stump to raise and lower without exerting a direct upward thrust on the stake. Care should be used when placing stumps on a gravel bottom as the sand bar formed below the stump will often more than offset the value of the pool formed.

During the period from 1930 through 1932 the lake crew was engaged largely in survey work. They did, however, carry on some experiments in the installing of brush shelters, gravel spawning beds, and slabs as spawning places for blunt-nose minnows. Some plantings of aquatic vegetation were also made. In the fall of 1931 brush shelters, gravel beds, and slabs were placed in several lakes in Kalkaska County.

In 1931 the scope of lake and stream improvements was greatly increased due to the fact that E. C. W. and F. E. R. A. funds were available for such work. The Institute workers became associated with the supervisory personnel and put to practice their findings, experience, and training for the purpose of carrying out further projects. Work was undertaken on several lakes and a number of streams. Brush shelters were installed in 18 lakes and some 27 miles of streams were improved. In addition to the installation of brush shelters aquatic vegetation was planted and gravel spawning beds were placed in several lakes. Slabs were also introduced to improve spawning conditions for certain minnows.

While construction work was emphasized, experimental work was not neglected. Records were kept of the devices installed in lakes, and notes were taken on the ecological conditions before the work was carried out. An experiment was carried out in Tomahawk Lake to determine what devices were most suitable for encouraging the spawning of blunt-nose minnows. This lake was chosen because minnows were abundant there. Various types and sizes of devices were installed. It was found that the minnows preferred a slab or other flat object which was at least 6 inches wide and placed directly on a sandy bottom in 6 to 18 inches of water. Several will spawn on one slab and their eggs are often in one mass.

To date the planting of aquatic vegetation in lakes has not been very successful. When plants have been placed in barren lakes they died or became gradually smaller and weaker. These results have led to a feeling that most plants have sufficient means of dispersal and they occur naturally in lakes where conditions are suitable to their growth. Thus indiscriminate planting is not thought to be of much value. Proper plantings in artificial lakes are felt to be of value.

Experiments were conducted in Howe Lake, Crawford County, to determine the results obtained from the introduction of gravel to form spawning beds for bass. One hundred and three gravel beds were placed over a sandy bottom in 1½ to 3½ feet of water. These nests were observed during the entire spawning period. All nests which were noted were made on the gravel which had been added to the lake. It was observed that even though gravel piles were placed close together nests were not made closer than 8 to 10 feet from each other. The most favorable depth was 2 to 3 feet. There is also an indication that at least a bushel of gravel is required, since when a smaller amount is used the bass dig a deep bowl-shaped nest, probably in search of more gravel. If storms occur at spawning time such nests on sandy bottoms become partially filled with sand and are thus destroyed. There is reason to believe that these artificial nests improved spawning conditions. Previous to these experiments the lake was seined each year to secure young bass. Until the time of improvement 2,500 was the greatest number secured, while after the addition of the nests 15,000 were secured.

Investigations to determine the efficiency of the brush shelters have also been conducted. Seines have been placed around many of the shelters, and then the brush has been removed so that it was possible to catch the fish which were in or around the shelter. It is apparent that some fish are attracted to the shelters more than others. The normally free-swimming fish were not attracted to any extent, while those usually favoring weed beds were found around the shelters. Suckers, which were also abundant around the shelters, were probably attracted by the abundance of algae and other types of food. Crayfish and aquatic insects were especially abundant in the shelters. A large shelter with loose rough edges attracted large fish, while small, tight, smooth shelters never attracted large fish, but were inhabited by small fish. The large fish were adult bass and suckers, while the small fish were young bass, bluegills, rock bass, suckers, and minnows.

In addition to the 27 miles of stream improvement accomplished in 1933, bank-erosion control was carried out along the Pere Marquette River. Several methods were used to hold the upper portions of the banks and protect them from erosion by wind and rain. Terraces held by stakes and poles were used on some banks, while brush or poplar pole mats were used on others. On some banks, a more expensive method was used. The banks were given a uniform slope and then large logs were stood up so that they extended from the bottom to the top of the bank. Poles were then fastened to these logs at right angles and about a foot apart. Each of these formed a small terrace. Straw or rich soil was placed on these terraces and they were sown with various grasses and trees planted at frequent intervals. Of the methods used to date, the latter has proved to be most successful.

Since 1934, the institute has not been concerned with the actual construction work, as it was felt that field had been developed to a stage where it was no longer within its province. The institute has confined its efforts to an evaluation of the work, and has acted in an advisory capacity to give aid in biological matters and in the interpretation of results.

During the past 2 years the organization has been improved, and the extent of the work has been greatly increased. Mr. Roy Johnston, who is now in direct charge of the work, has kindly furnished data on the amount of work accomplished during this period. During the past two winters, brush shelters and other improvements such as gravel spawning beds and slabs for minnows have been installed in 180 lakes. In 1934, 118 miles of stream were improved, and in 1935, 132 miles of stream were improved. In addition to this work, in 1935 some 700 miles of stream were conditioned for future improvements. This conditioning work was confined to the slower streams of the Upper Peninsula, and consisted of the cleaning out of debris left from logging operations and the improvement of springs and spring runs by cleaning and the formation of definite channels. This conditioning work will in itself greatly improve stream conditions. In addition the erosion of sand banks along 22 miles of stream was controlled. The improvement crews were also active in the improvement of environmental conditions by the removal of beaver dams, 3,786 being removed from trout streams. There were 2,306 miles of stream opened for trout migration.

In 1934 and 1935 rechecks were made on fish counts and food counts. In those sections where it was possible to obtain goods counts it was found that either the total number or the number of legal fish had been increased. The rechecks on the food counts showed an increase in food production around the deflectors. An increase of as much as 40 times has been secured. The fast riffles and the mucky areas and plant beds have been found to be productive.

Environmental improvement is a problem in applied ecology. Every lake and stream presents a different problem and its improvement is not so simple as some believe. If we are to improve conditions effectively we must have a knowledge of the habits and know the requirements of the various species which we wish to encourage. Further we must know what necessary factors are lacking or out of balance. We must know how to restore them or put them in their proper relation to other factors necessary for good production. It is therefore apparent that an adequate survey of the waters must be made and experimentation, investigation, and elevation carried out to determine how the needs must be met. Fall, winter, summer, and spring conditions must be known before we can efficiently improve our waters. If we are effectively to improve the fishing an effort should be made to remedy defects which manifest themselves at each season of the year. All too often the tendency is to think of conditions only during one season. An example of this is the results obtained in a Michigan stream. In most cases the ice which forms below the deflectors gives protection and cover for the fish. On the north branch of the Au Sable, which is a wide shallow stream, this is not true, as during cold periods the water behind the wings freezes solid and the fish are trapped and killed.

Flow, temperature, and the amount of ice during the winter are ecological factors which are often overlooked. The action of ice is much different than many suppose. Trout streams, which warm up most of the summer, are generally considered to be most affected by ice, freeze over early in the season, and are protected from extreme cold so that destructive anchor ice does not form. Streams which are immediately spring fed are not affected, due to their higher winter temperature. It is the intermediate streams which suffer most from anchor and slush ice, as they do not have a blanket of ice to protect them. Anchor ice, which forms on the bottom during cold nights, covers the rocks and freezes the insects. At one time during the extreme winter of 1933–34 the bottom of a stream was frozen so that the gravel could not be moved. Such conditions are certainly not beneficial to the food of fish and suggest a reason why brook trout spawn at or near springs. Such occurrences as these clearly demonstrate the need of further investigation. While some information has been gained, we have really only begun on the problems of environmental improvement and much further study is needed before it can be placed on a sound practical basis.

U. S. GOVERNMENT PRINTING OFFICE: 1937

Presented before
N. Am. Wildlife Conf.
February, 1936

Original: Fish Division
cc: C. M. Tarzwell (2)

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ANN ARBOR, MICHIGAN

February 11, 1936

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Institute for Fisheries Research

During the past three years lake and stream improvement has had a rapid, almost phenomenal growth in popularity and use. As most of the work has been made possible through the use of emergency funds, it has been essential to organize and carry out the work as rapidly as possible. Many streams and lakes have been worked without first being surveyed, and much of the work has been carried out under an inexperienced and untrained personnel. The lack of adequate information concerning the methods of construction, the purpose of the various structures and the ecological changes brought about by them has been keenly felt and clearly shown in a great deal of the work. In view of these circumstances it is felt that the experience gained in Michigan during the past six years may be a help to others engaged in a similar undertaking.

Ten years ago, when discussing the decline of fishing in streams, old fishermen spoke of the cleaning of the streams for log drives as the possible cause of that decline. Some advocated the replacing of the logs, trees and wing jams as a means of bettering the fishing. A further development of this thought was the "resnagging" work carried on by Dr. Jan Metzelaar in the Pere Marquette and Little Manistee Rivers in 1928 and 1929. This "resnagging" consisted of the falling of large trees across the stream and the throwing of various materials into the stream so they would float down stream and lodge against these barrier trees to form jams. It will be noted that such work takes into consideration only the formation of pools and cover and no thought was given to food or spawning conditions. As these jams continued to grow, in time, they became so large that the tree could no longer hold them and they went out. As such "resnagging" work was incidental to other activities it was not extensive. It was, however, a beginning and demonstrated that pools could be formed but the mere throwing of material into a stream was not enough to bring about permanent results.

In 1930 with the creation of the Institute for Fisheries Research under the directorship of Dr. Carl L. Hubbs, the work was taken up in a more intensive manner. A program of lake and stream surveys was initiated. Mr. R. W. Eschmeyer was placed in charge of the lake surveys and the lake improvements. The speaker was given the responsibility of developing, testing, and checking the results of various methods for improving trout streams.

In the summer of this first year the Michigan Department of Conservation made an appropriation for carrying on a project on the Little Manistee River in Lake County. Since this was the first project of its kind in the state and, in fact, to the best of the speaker's knowledge the first in the country, the work was of necessity an experimental project. Many types of structures were installed in order that their action might be observed and the best ones selected. Among the more successful types the following may be listed: wing, V, and I deflectors, made of logs or stone; tepee and raft covers; trees; and bank covers. A number of stumps were used but about half of them were washed away due to faulty installation.

Notes were taken on the condition of the stream before the structures were installed. Type of bottom, plant beds, mucky areas, depths, cover and size and depth of pools were all noted as well as the type and construction of the device. Each device was tagged with a numbered metal tag so future observations could be made. In all 500 structures were described, tagged and located during the first season.

In 1931 a recheck was made of the previous year's work and a knowledge was gained of what each structure could be expected to do. With this information as a working basis and with a better knowledge of the requirements of the trout and the deficiencies of our streams, the work was taken up in a more systematic manner. Devices were installed not only for the purpose of creating pools and cover, but also to improve food conditions by producing riffles, uncovering gravel areas, and creating mucky areas and plant beds. Various types of deflectors such as wings, V's, Y's, I's, and A's were used to bring about these conditions and also to create pools. Cover was furnished by various types of raft, bank, bend and center covers. Attention was also given to the preventing of bank erosion by the use of large boom covers and bend covers. As in 1930 extensive records were made of each installation and its surroundings.

While it was possible to observe the formation of pools in a stream,further and more definite information was desired as to just how the so-called improvement devices influenced the fish population and the food. In order to secure this information fish counts and food counts were made before the devices were installed. The location of these various counts were recorded so recounts could be made some years after improvement, when conditions again became more stable.

The fish counts were made by enclosing a portion of stream by barrier seines placed at the upper and lower ends of the selected section and then catching the fish in the section by the use of small seines. The barrier seines were held in place by means of stakes driven into the stream bed. Chicken wire was stretched across in front of the stakes first in order to give added support to the seines. This arrangement made it possible to hold the seines until all the fish had been caught, measured and recorded.

The food counts consisted of quantitative bottom counts. These were made by collecting all the bottom organisms from a unit area. These organisms were preserved for future study. Counts were made at locations where devices were to be installed and a record of bottom type, depth, and surface current was secured. In this way it was hoped to obtain information as to the manner and the extent which food production was influenced or changed by the devices. Counts were made on the East Branch of the Black River, Pigeon River, and Gamble Creek.

During the following year the improvement work was continued and expanded to streams in various localities. Rechecks were also made on all previous work and the ecological changes noted. Underpass deflectors were found to be very efficient in the formation of pools. Wing deflectors proved to be most effective in creation of mucky areas and the establishment of plant beds. Large boom covers and raft covers were found to be unstable as they were carried away by floods or they waterlogged and sank so they became useless. Bank covers, square covers, tepee covers and wedge covers when placed at the surface were found to be unsatisfactory for streams having a good deal of ice. In such streams it is necessary to submerge these covers below the ice level or the ice which forms around them will pull the stakes due to its lifting action. In constructing the submerged bank covers, it is well to embed the holding logs into the bank at least as far as they project into the stream. In general deflectors are not affected by ice, but it is well to keep them low and to bank them on the upstream side. V and Y deflectors were found to be especially useful for uncovering gravel by the removal of sand. This is one of the means on increasing food production. Wing deflectors, wing jams and large bend covers were found to be effective in preventing bank erosion.

Except in certain locations stumps proved to be difficult to hold in place. In sand bottom streams they often completely wash out the stakes holding them and in streams having a good deal of ice the stakes were pulled. A good method of holding stumps under such conditions is to fasten them to a stake by means of a 10 or 12 foot cable. The stake should be deeply embeded and the cable fastened to it just above the stream bottom. In order to prevent ice from forming on the stake, it should be cut off just above the stream bed. The advantage of the cable is that it allows the stump to raise and lower without exerting a direct upward thrust on the stake. Care should be used when placing stumps on a gravel bottom, as often the sand bar formed below the stump will more than offset the value of the pool formed.

During the period from 1930 through 1932 the lake crew was engaged largely in survey work. They did however carry on some experiments on the installing of brush shelters, gravel spawning beds, and slabs as spawning places for blunt-nose minnows. Some plantings of aquatic vegetation were also made. In the fall of 1931 brush shelters, gravel beds and slabs were placed in several lakes in Kalkaska County.

In 1933 the scope of lake and stream improvement was greatly increased due to the fact that E.C.W. and F.E.R.A. funds were made available for such work. The

Institute workers became associated with the supervisory personnel and put to use their findings, experience and training for the purpose of carrying out further projects. Work was undertaken on several lakes and a number of streams. Brush shelters were installed in 18 lakes and some 27 miles of streams were improved. In addition to the installation of brush shelters, aquatic vegetation was planted and gravel spawning beds were placed in several lakes. Slabs were also introduced to improve spawning conditions for certain minnows.

While construction work was emphasized, experimental work was not neglected. Records were kept of the devices which were installed in streams and notes were taken on the ecological conditions before the work was carried out. An experiment was carried out in Tomahawk Lake to determine what devices were most suitable for encouraging the spawning of blunt-nose minnows. This lake was chosen because these minnows were abundant in it. Various types and sizes of devices were installed. It was found that the minnows preferred a slab or other flat object which was at least six inches wide and placed directly on a sandy bottom in 6 to 18 inches of water. Several will spawn on the same slab and the eggs are often in one mass.

To date the planting of aquatic vegetation in lakes has not been very successful. When plants have been placed in barren lakes they have died or they are gradually becoming smaller and weaker. These results have lead to a feeling that most plants have sufficient means of dispersal and they occur naturally in lakes where conditions are suitable for their growth. Thus indiscriminate planting is not thought to be of much value. Proper plantings in artificial lakes are felt to be of value.

Experiments were conducted in Howe Lake, Crawford County to determine the results obtained from the introduction of gravel to form spawning beds for bass. 103 gravel beds were placed on sandy bottom in $1\frac{1}{2}$ to $3\frac{1}{2}$ feet of water. These nests were observed during the entire spawning period. All nests which were noted were made on the gravel which had been added to the lake. It was observed that even though gravel piles were placed close together, nests were not made closer than 8 to 10 feet. The most favorable depth was 2 to 3 feet. There is also an indication that at least a bushel of gravel is required,as when a smaller amount is used the bass dig a deep bowl-shaped nest,

~~They are~~ probably in searchi~~ng~~ ~~for~~ of more gravel. If storms occur at spawning time, such nests on sandy bottoms become partially filled with sand and thus destroyed. There is reason to believe these artificial nests improve spawning conditions. Previous to these experiments the lake was seined each year to secure young bass. Until the time of improvement 2500 was the greatest number secured, while after the addition of the nests 15,000 were secured.

Investigations to determine the efficiency of the brush shelters have also been conducted. Seines have been placed around many of the shelters and then the brush has been removed so it was possible to catch the fish which were in or around the shelter. It is apparent that some fish are attracted to the shelters more than others. The normally free swimming fish were not attracted to any extent, while those normally found in the weed beds were found around the shelters. Suckers which were also abundant around the shelters were probably attracted by the abundance of algae and other types of food. Crayfish and aquatic insects were especially abundant in the shelters. A large shelter with loose, rough edges attracted large fish, while small tight smooth shelters never attracted large fish, but were inhabited by small fish. The large fish were adult bass and suckers, while the small fish were young bass, bluegills, rock bass, suckers and minnows.

In addition to the 27 miles of stream improvement accomplished in 1933, bank erosion control was carried out along the Pere Marquette River. Several methods were used to hold the upper portions of the banks and protect them from erosion by wind and rain. Terraces held by stakes and poles were used on some banks, while brush or poplar pole mats were used on others. On some banks a more expensive method was used. The banks were given a uniform slope and then large logs were stood up so they extended from the bottom to the top of the bank. Poles were then fastened to these logs at right angles and spaced about a foot apart. Each of these formed a small terrace. Straw or rich soil was placed on these terraces and they were sown with various grasses and trees were planted at frequent intervals. One other method used was to place chicken wire on frames and place these frames on the bank.

The base of the bank which is the critical point, due to the fact that it is at that point where erosion actually takes place, was usually protected by a wall of logs held in place by stakes. Sand bags were placed behind this wall and in some cases sod was placed on the filled area behind the wall. Willows were usually planted on the lower portion of the bank. A few deflectors and covers were also used to deflect the current away from the base of the bank.

While on the whole this work has been quite successful, a few improvements can be made. The work on the upper portions of the banks has been more successful than that at the bases of the banks. Slipping has been stopped for the time being and wind and water erosion is almost non-active. Many of the trees which have been planted are growing very well and if the base of the bank holds they will certainly recapture the slope and hold it. Among the various plants which were sown, sweet clover appears to be the most successful. Among the trees, the black locust is outstanding for its growth. The willows did not do so well as a large percentage of them died.

Among the various methods used for stabilizing the slopes, the one where large logs were placed on the slope of the bank and cross pieces fastened to them has been the most successful. The chicken wire has been a complete failure. It is of use however in that it gives an idea of how much erosion the other work has prevented. The bank in the chicken wire section has eroded back at least three feet in the last year and a half. This gives an idea of the enormous amounts of sand which are added to the stream. Such addition of sand fills pools, covers food producing areas, and destroys spawning beds.

While the work on the slopes of the banks has been relatively permanent, that at the base of the banks has not been so. The sand bags quickly decayed and most of the fill has been washed from behind the protecting walls. In some cases the walls themselves were destroyed. If this work is to be successful, erosion at the waterline must be stopped, since if it is allowed to continue the upper slopes will start slipping in spite of the vegetative covering, as the sand will come to its stable slope. Wing deflectors, wing jams, large covers along the base of the banks and stone riprap are other methods which are more successful for holding the base of the banks. When deflectors are used, their inner ends must be built high and slanted up into the slope of the bank, otherwise when flood waters go over them they will increase rather than decrease erosion.

If the critical area, the base of the bank, is effectively protected the work on the slope need not be so elaborate or expensive. A covering of brush held in place by a pole placed across the butt ends and fastened down with stakes will give ample protection to the slope. Revegetation can be hastened by the planting of desirable species. It is judged that this method of bank erosion control is feasible and practical.

Since 1934 the Institute has not been concerned with the actual construction work, as it was felt that field had developed to a stage where it was no longer within its province. The Institute has confined its efforts to an evaluation of the work and has acted in an advisory capacity to give aid in biological matters and in the interpretation of results.

During the past two years the organization has been improved and the extent of the work has been greatly increased. Mr. Roy Johnstone, who is now in direct charge of the work, has kindly furnished data on the amount of work accomplished during this period. During the past two winters brush shelters and other improvements such as gravel spawning beds and slabs for minnows have been installed in 180 lakes. In 1934 118 miles of stream were improved, and in 1935 one hundred thrity-two miles of stream were improved. In addition to this work, in 1935 some 700 miles of stream were conditioned for future improvements. This conditioning work was confined to the slower streams of the upper peninsula and consisted of the cleaning out of debris left from logging operations and the improvement of springs and spring runs by cleaning and the formation of definite channels. This condition work will in itself greatly improve stream conditions. In addition the erosion of sand banks along 22 miles of stream was controled. The improvement crews were also active in the improvement of environmental conditions by the removal of beaver dams. 3786 beaver dams were removed from trout streams and 2306 miles of stream were opened for trout migration.

In 1934 and 1935 rechecks were made on the fish counts and food counts. In those sections where it was possible to get good counts, it was found that either the total number or the number of legal fish had been increased. The rechecks on the food counts have clearly shown an increase in food production around the deflectors. An increase of as much as 40 times has been secured. The fast riffles and the mucky areas and plant beds have been found to be very productive.

During the past six years the ~~writer~~ speaker has had the opportunity to construct stream improvements in seven states and to observe and check the results of improvement in several other states throughout the country. Studies have been carried on throughout the year and are thus not confined to any one season. From this continual study and observation, certain ideas and conclusions have been gradually built up and a better concept gained of the place of environmental control in a fisheries management program. Contrary to the opinion of some, lake and stream improvement, that is environmental control or habitat improvement, is not a "cure all" for all our fisheries troubles. It is only one of the important and necessary parts of a fisheries management plan. This tendency to regard environmental control as a "cure all" may place lake and stream improvement in disrepute, as a few structures placed in a stream at random can never overcome all deficiencies. Such a reaction would be regrettable, since it is felt that environmental control has real value and a definite place in fisheries management.

The need for such work is apparent when we note the deficiencies in our lakes and streams. These deficiencies are of two types, inherent or intrinsic deficiencies and those brought about by the actions of man. Contrary to the opinion of some, inherent or natural deficiencies can be wholly or partially overcome if we are properly informed and apply our knowledge to good advantage. Since our lakes and streams are the result of geological processes, they were not created especially for fish life. For this reason it is maintained that it is possible to improve on nature. An example of this is the case of a dam to create shallows in a lake where they did not occur before.

Unfavorable conditions brought about by the activities of man are numerous and of great importance. Some of the works and unwise actions of man which are producing unfavorable conditions for fish life are: deforestation, timber drives, fires, overgrazing, drainage, removal of grass cover for agriculture, erosion, removal of stream side shade and stream bottom vegetation, pollution power dams which form barriers to migration and cause harmful fluctuations in level, lowering of the water table, hydraulic mining and other types of mining which add wastes to the stream, unwise road building, and unwise recreational developments and use. When one considers the effects of these activities, it is apparent that fish like game is an orphan which receives little or no consideration under our present economic system. Unless these forces of destruction are controlled or managed, our puny efforts to improve environmental conditions cannot restore or maintain favorable environmental conditions. Much can be accomplished however in regions where these forces are not so active.

Environmental improvement is a problem in applied ecology. Every lake and stream presents a different problem and their improvement is not so simple as some believe. If we are to effectively improve conditions, we must have a knowledge of the habits and know the requirements of the various species which we wish to encourage. Further, we must know what necessary factors are lacking or out of balance, and we must know how to restore them or put them into their proper relation to other factors necessary for good production. It is therefore apparent that an adequate survey of the waters must be made and experimentation, investigation and evaluation carried on to determine how the needs may be met. Fall, winter, summer and spring conditions must be known before we can efficiently improve our waters. If we are to effectively improve the fishing, an effort should be made to remedy the defects which manifest themselves at each season. All too often the tendency is to think only of conditions during one season. An example of this is the results obtained on a stream in Michigan. In most streams the ice which forms below the deflectors gives protection and cover for the fish. On the North Branch of the AuSable, which is a wide, shallow stream, this is not true, as during cold periods the water behind the wings freezes solid and the fish are trapped and killed.

Flow, temperatures, and the amount of ice during the winter are ecological factors which are often overlooked. The action of ice is much different than many would suppose. Our warmer streams which are generally considered to be most affected by ice freeze over early in the season and are protected from extreme cold, such that destructive anchor ice does not form. It is the intermediate to cold streams which suffer most from anchor and slush ice, as they do not have a blanket of ice to protect them. Anchor ice which forms on the bottom during cold nights covers the rocks and freezes the insects. At one time during the extreme winter of 1933-1934, the bottom of a stream was frozen so the gravel could not be moved. Such conditions are certainly not beneficial to the food of fish and suggest the reason why brook trout prefer to spawn at or near springs. Such occurrences as these clearly demonstrate the need of further investigation. While some information has been gained, we have really only begun on the problems of environmental improvement, and much further study is needed before it can be placed on a sound and practical basis.

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