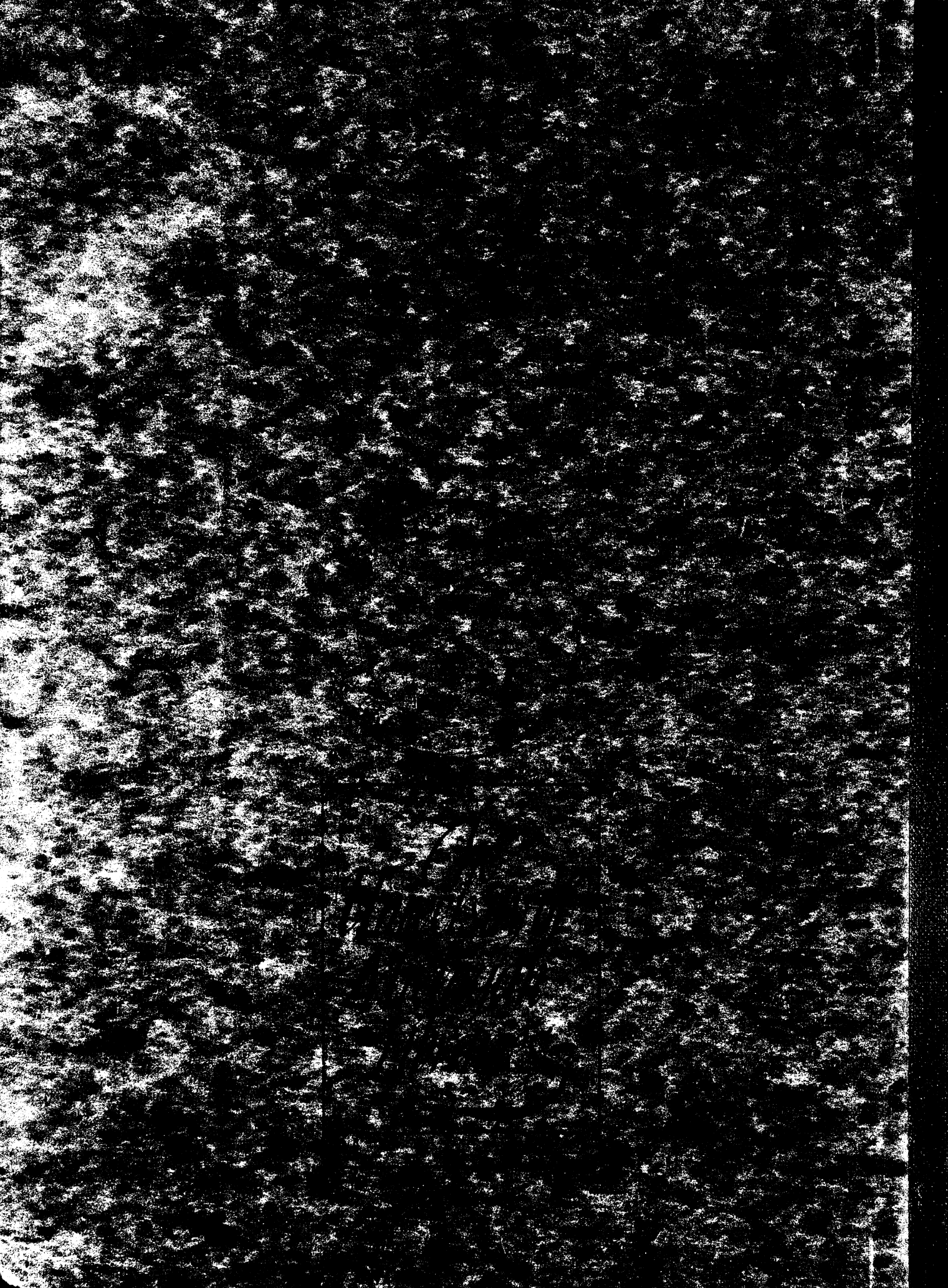
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TROUT STREAM MANAGEMENT

by

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INTRODUCTION

The primary intent of this thesis is to transmute the results of scientific investigation into an applicable design for trout stream management. The author realizes his incompetence in this matter, since I have little experience in this field. There is a certain advantage in that I have assumed the attitude of a reporter and am not bias in my judgments.

The preparation of this paper entailed a rapid survey of approximately 250 references and a careful abstraction of over 150 references. Limited time prevented a thorough survey of the existing literature, but I believe the material consulted represents an adequate sample of the whole. The major portion of this study consisted of a careful analysis of the information appearing in the following publications during the period 1936 to date: Transactions of the American Fisheries Society; Transactions of the North American Wildlife Conferences; The Progressive Fish-Culturist; Copeia; and The Journal of Wildlife Management. Additional references were also considered when their contents were believed to be especially significant.

The writer hopes that this thesis will be of value to the student by providing him with a rapid survey of the trout stream management field.

For supervision and aid in this work the writer wishes to express gratitude to Dr. Warren W. Chase and Dr. Karl F. Lagler.

The Sequence of Management

The management of trout streams in America is a very recent development. During the latter half of the nineteenth century trout management consisted entirely of the operation artificial trout hatcheries. Fish-culture was very popular and artificial stocking was believed to be the universal cure for all fishing ills. The introduction of exotic species of fish was the fad of the era. A gradual realization that artificial methods were unable to adequately restore depleted waters led to the inactment of legal restrictions. Early plantings of trout fry gradually gave way to fingerling plantings, which in turn are now being replaced by the use of legal-sized fish. The realization that stocking and laws were but a partial cure led to the rapid development of the trout stream management field to the stage as we know it today. Management is still in a primitive stage of development and continued transition will undoubtably relegate present management methods to antiquity.

THE AIMS AND THE DEGREE OF MANAGEMENT REQUIRED

Fish management may be defined as maintenance at full capacity of a sustained yield, Moore (1936). The American concept that wildlife resources are the property of the people, the benefits of which are to be distributed as equally as possible, demands that the government be responsible for its administration. According to Locke (1938) the state is the agency to direct the management and utilization of the fisheries resource to the best public advantage. The federal responsibility lies particularly in matters of broad policy and interest. It is the responsibility of the angler to practice high standards of sport

in order that the limited supply of game fish may return the greatest amount of physical and spiritual benefit. In order to obtain the necessary cooperation between the public and managerial agencies, the public must understand the primary principals and objectives of management. The primary objective of trout stream management is to provide sport rather than food, Davis (1938).

The degree to which management should be applied varies directly with the fishing pressure and with the inherent ability of a stream to produce a removable fish crop. It can readily be seen that remote areas which are rarely fished will receive little attention. Likewise streams which require a high expenditure of effort to effect an increase in productivity are justified less attention than streams which respond to a few changes.

In order to demonstrate the actual application of trout stream management methods the following example is given.

Fish Management in the Pisgah National Game Preserve-Keil (1938) and Chamberlain (1943b)

The Pisgah Project is a good example of what can be accomplished in the way of practical management, if the program is based upon known facts supplemented with research to determine the value of the management practices in force. It was set up and administered jointly by the United States Forest Service and the United States Fish and Wildlife Service. The management procedure followed four lines: (1) a preliminary stream survey of the physical and biological conditions of the waters to be considered; (2) a stream improvement project in which the physical characteristics of the streams were restored to as nearly their original conditions as possible; (3) an initial fish planting program based upon

the findings of the survey and the extent and character of the improvement work; and finally (4) a regular and systematic check-up. Through research of the results accomplished by planting marked trout so that a more permanent policy might be adopted regarding the numbers, sizes and species of fish to be planted and the amount of public angling thought justified under careful regulations.

The Pisgah System of "every fishing day an opening day" evolved to meet the management problems required by the area. This system may be described as the stream management practice whereby fishing in a given wildlife area is restricted to one stream and its tributaries on any given day, while the number and distribution of the open days on any one stream is determined by the stream's relative fishing capacity, its physical condition and the desirability of completely resting it from fishing for as long as possible after each opening day. The advantages of this system are that it is easier to administer since all the fishing is concentrated on a given area and the fish apparently react more naturally to the heavy fishing pressure since they receive a rest between opening days.

A charge of one dollar per day is made for the fishing privilege. Fishermen are checked for permits upon entering the area, and upon leaving the area creels are checked and marked fish recorded. It is possible to regulate all fishing on the area. Anglers are allowed to fish only with artificial flies. Fifteen fish are a legal limit and a minimum length limit for brook trout is six inches and for rainbow trout eight inches. No one is permitted to fish more than ten days in a season.

Five years of experimental stream management with 150 miles of trout stream divided into six watersheds, resulted, after various management practices were tried, in an increase of approximately three hundred per cent in anglers and in numbers of fish caught. Success indicates stocking with legal-sized trout in the spring is the best means of meeting the increased fishing demand. The continued fishing success in the face of increasing fishing demand resulted in a satisfied angler and further popularity, so that the project was rapidly on the way to becoming self-supporting in 1943.

STREAM INVENTORY

The stream inventory is the basis for proper management. As mentioned previously, the intensity of management varies directly with the inherent ability of a stream to produce a removable crop and the fishing pressure to which it is subjected. The aim of management is to bring stream productivity (removable crop) and fishing pressure into balance. The stream inventory is the quantitative evaluation of these two factors.

Stream Survey

A stream survey is an investigation the aim of which is to measure those inherent qualities of a stream which determine its ability to produce a fish crop. A survey of each stream is necessary because each stream is individual in its character, so it is necessary for management to treat it as a separate entity.

The carrying capacity concept is evident in much of the present day literature. It may be defined as the extent to which given water units will support fish and fishing. The investigations of Keil

(1939), Chamberlain (1943b) and others indicate that one can only expect a certain volume of natural production from a stream, if more is demanded by a heavy fishing pressure, then artificial stocking and other improvements must be resorted to or the stream will become depleted. For this reason stream surveys plus catch evaluation are the basis for an efficient stocking program.

Various methods of rating a stream as to productivity have been used. One of the more superficial surveys is that described by Maclay (1941) as being used in Idaho. This survey classified streams as good, poor or non-producers. This type of survey leaves much to be desired, but can be used as a guide to stocking to prevent stocking in poor or non-producing streams.

Heavily fished trout streams should be treated in a much more intenstive manner. The value of an intensive stream survey is widely recognized as the basis for proper management.

Physical-Chemical Determinations

The effect of temperature as a limiting factor of trout and the many studies on the temperature tolerances of trout demonstrate the importance of temperature determinations. Other physical-chemical observations are more difficult to correlate with trout productivity although they are known to have some effects.

Hoover and Morrill (1938) found there was a rapid decline in the number of pounds of trout per acre as the stream velocity increased. They further found that an increase of velocity exerts an adverse effect upon trout populations above the two-inch class, even though food is increased.

Volume of flow is believed to have an effect upon a trout population, but this relationship is difficult to segregate from other related factors. Shetter and Hazzard (1938) found that an average stream depth of fourteen-inches or more could be definitely correlated with a greater than average population. Extreme fluctuations in volume are definitely recognized as a factor limiting high production. Tarzwell (1937) reports that floods are the major limiting factor in southwestern streams. Flood waters not only roll and grind bottom materials destroying the better food organisms, widen the streambed and destroy pools and cover, but they also sweep away the rich organic materials so essential for an abundant bottom fauna and deposite light-colored inorganic silt which is almost barren of life.

Turbidity definitely lowers stream productivity. It exerts its limiting effect upon food organisms and acts directly upon trout by smothering eggs and impairing the respiration of the trout. The fishability of the stream is lowered not only by this limitation of the trout population, but also by the fact that the remaining trout are less likely to see the fisherman's lure. Color of waters may effect trout, but is usually regarded only as an indication of relative pH or pollution.

Trout have a wide range of hydrogen ion tolerance and for this reason are rarely directly effected by this factor in natural waters. It is generally recognized that streams which are slightly alkaline are the better food producers, and therefore, are characterized by higher trout productivity. King (1942) noted this fact in a limestone water creek in Tennessee, which yielded a larger average size trout than did adjacent streams of a more acid character.

Oxygen concentration and carbon dioxide tension rarely present a problem in trout stream habitats and for this reason may be omitted in practice unless pollution is suspected.

An analysis of the physical and chemical characteristics of a stream is incomplete unless seasonal variations are taken into account. This is often impossible or neglected in routine surveys. Winter conditions may present some serious limitations upon fish life. Trout may be stranded in pools which freeze solid. Anchor ice may destroy food organisms and trout eggs. Snow may fill the stream and smother the fish. Mid-summer is also a critical period. Water temperature may rise above the limit of toleration by trout. Floods as mentioned previously may drastically reduce fish populations. The analysis of physical-chemical relations in a stream is of value in itself, but unless it is correlated with other environmental studies it is merely a partial picture of the stream environment.

Morphometry

This phase of stream management deals with the measurement of the outline of a stream. In stream survey work it should also include mapping of the stream channel and the adjacent stream banks. The bank cover shelters trout from certain predators and provides a possible source of food by attracting terrestrial insects to the stream. Logs and overhanging roots provide trout with stream cover and form natural pools. The value of bank cover is generally recognized. Average width itself seems to have an effect upon trout populations. Hoover and Morrill (1938) made a comparison of the number of trout per mile to average width and found there was a slow increase in trout from five to eight feet; from

eight to eleven feet there was a sharp increase in the trout population after which there was a steady decline.

Habitat Survey

The percentages of riffle area and pool area must be taken into account in stream survey work. In a general way it may be stated that ripples are high in food production whereas pools offer shelter and living space for the trout population. Both micro-habitats are important to stream production. The proportion which is most productive is unknown and probably is subject to considerable variation between different streams. Hoover and Morrill (1938) and Schuck (1943) found fewer trout in riffle areas than in pool areas. M'Gonigle and Smith (1938) further defined the relationship in an analysis of total trout populations between habitats in yields averaging 145.7 pounds per acre for pool sections and 69.1 pounds per acre for swifter water sections.

The value of trout shelter and cover is recognized by nearly all workers as a habitat requirement, but the amount necessary to provide adequate cover in a stream is likewise unknown Hoover and Morrill (1938) could find no correlation between trout shelter and the number and size of trout. They further found that a high percentage of shelter is not necessary and may even exert an adverse effect under certain circumstances.

Food Studies

Van Oosten (1944) came to the conclusion that the importance of quantitative food data is somewhat over-rated by fishery biologists. It is especially popular to explain that slow growth in a relatively dense population is the result of competition for food and that rapid growth in a relatively sparse population is the result of a lack of

competition. Other factors which might account for this condition in high populations are insufficient space or an unfavorable temperature. Hoover (1939) concluded that the brook trout in certain primitive streams he studied, were not stunted by food competition, since he noted the trout were fat, but by low temperature.

Hoover and Morrill (1938) in discussing quantitative food studies raise the following question: Does a large number of invertebrates indicate a good trout stream, or does it indicate some other limiting factor which precludes a large trout population to utilize the food? Their studies indicate that other things being equal, an abundance of food means few trout present and vice versa.

The usual food survey is based entirely upon a study of bottom fauna organisms. Hoover and Morrill (1938) found that 87.9 percent of the stomach contents of brook trout were of terrestrial origin, 6.3 percent aquatic invertebrates and 5.8 percent fish. Surber (1940), corraborated these results for brook trout and added that rainbow trout were also found to eat quantities of algae. Most other studies show a high percentage of the food as being bottom fauna, but this demonstrates that bottom fauna studies must be correlated with stomach analysis studies before they can assume useful quantitative values. Hess and Swartz (1941) define this correction even more broadly under the term "forage ratio" and applied it to all food organisms in the trout diet.

Available food organisms are defined as organisms which a trout is capable of eating, if he so desires. This factor is extremely difficult to determine. Ide (1942) obtained ameasure of emerging insects from a square yard of stream bottom. The number or weight of insects

emerging could be used as an availability measure, if correlated with other data. His data did show that there is variation in the rate of turn-over in bottom populations, which would further complicate the conversion of bottom fauna data into trout productivity.

Mottley, Rayner and Rainwater (1938) question the validity of the sample used in most food grade determinations. A statistically adequate sample in such a variable population as is characteristic of stream invertebrates.is nearly impossible to attain. The sampling is further complicated by the fact that bottom faunas are subject to severe fluctuations in abundance due to floods and population cycles.

In view of the inadequacy of our present methods in quantitative food analysis, it is recommended that stream survey work be confined to the collection of qualitative information with a few comments on the relative abundance of food. Food is rightly one of the major factors to be considered in stream survey work and for this reason it must receive its proper share of attention in environmental evaluation. An understanding of the relative values of certain types of streams and certain habitats in a stream aids in this evaluation.

Trout streams possess a variety of habitats, and habitats vary as to their ability to support bottom organisms. In streams that are subject to floods the greatest limiting factor of bottom fauna populations is the scouring action of the stream. The population of bottom organisms in such a stream is constantly striving to recover from the last high-water period. A curve of bottom fauna abundance in such a stream would be characterized by an interruptive appearance. The peaks of abundance occurring just prior to each destructive deluge; followed by a vertical drop to the low population of survivors after

the flood; then a gradual recuperation until the next high water period. The higher survival in this type of stream is to be found in bottom types which are least subject to the destructive action of scouring. Needham (1927; 1928) and Pate (1931; 1932; 1933) found that the average amounts of high food organisms on the five types of riffle bottoms in New York streams were as follows: (1) rubble 176 pounds per acre, (2) coarse gravel 121 pounds per acre, (3) fine gravel 89 pounds per acre, (4) handpan 9.6 pounds per acre, and (5) bedrock 0.5 pounds per acre.

In slow moving streams not subject to floods and in large pools, the relative fertility of different bottoms generally determines their relative productivity. Needham (1927, 1928) and Pate (1931; 1932; 1933) found that the average amounts of high food organisms in the quiet water habitats of New York streams were as follows: (1) silt 333 pounds per acre (2) muck 62 pounds per acre and (3) sand 35 pounds per acre. Tarzwell (1936a; 1936b; 1937; 1938b) mentions the importance of nutrient materials in a stream bottom and the value of plant beds to bottom food production.

Needham (1938) gives the following figures for the production of bottom food by aquatic plant beds in New York: (1) Stonewort 3,553 pounds per acre, (2) watercress 1,229 pounds per acre (3) long-leaved and curley pondweeds with 566 pounds per acre each, (4) water buttercup 366 pounds per acre and (5) sage pondweed 307 pound per acre. These are figures from plant associations of slow-flowing waters. The average production for plant beds in swift water habitats were as follows: (1) a mixed growth of algae, Cladophora and moss 403 pounds per acre, (2) moss 297 pounds per acre and (3) horned pondweed 288 pounds per acre.

Evaluation of the bank cover as to the possibility of terrestrial insects adding to the food of trout must be kept in mind. As a general rule streams with a forest or brush cover contain more terrestrial insect drift than do streams in open areas.

Food evaluation in a stream survey consists largely of a habitat analysis correlated with the examination of a relatively few bottom samples to determine the species present and their relative abundance at the time of the survey.

Fish Population Survey

In order to manage any resource properly it is necessary to have some idea of the stock on hand. Fish populations can vary as to numbers or weight per acre and species, age and size composition. A study of the fish population present can give a good indication of the management required on a given stream. The ability of a stream to produce is generally reflected in its resident fish population, that is good trout waters will be found to carry more pounds of fish per acre than poor. A predominance of one species is an indication that existing environmental factors favor that species over the others present. Certain fish species are less desirable than others or are definitely noxious to the desired species, their presence and relative ability to maintain and expand their range in a stream must be recognized and counteracted by management. Abnormal size and age composition is an indication of the presence of unfavorable conditions in the environment, which management must remedy.

Fish survey data can be expressed in a quantitative manner as pounds per acre. In practical management quantitative data can not be utilized to the fullest extent, since we have little informa-

tion of a comparable nature. Needham, Moffett and Slater (1945) in studying brown trout found populations to be highly unstable as to both numbers and pounds of fish present at various times. Hazzard, Leonard and Shetter (1947) corroborated these findings in a study of a brook trout population.

Fish populations may be sampled by blocking off a section of a stream with nets and seining or anesthetizing the included population. Hoover (1938) found that seining in blocked stream sections may be classified as to its effectiveness as follows: (1) easy to seine ninety to one hundred per cent effective, (2) intermediate eighty to ninety percent effective, and (3) difficult seventy to eighty percent effective. This method is slow and cannot be applied in certain situations.

Embody (1940; 1941) describes a method of sampling fish populations by the use of a chemical called "cresol". It is used in a concentration of one part cresol to thirty thousand parts of water. If this concentration is maintained for a sufficient period of time, all the trout in the section will be anesthetized. This method requires careful calculations to insure complete anesthetization and still prevent mortality. It is slow, but it can be applied in nearly all situations.

Haskell (1940) Haskell and Zillox (1941) and Hazzard, Leonard and Shetter (1947) describe the use of an electrical shocking device, which virtually relegates to antiquity all other fish collecting methods used in fish population studies. Its operation consists of plying electrode screens through stream sections and collecting fish with scap nets as they appear. The shocker stuns the fish which then rise to the surface

belly-up. The shocker consists of two electrode screens on lead lines and a portable gasoline powered electrical generator. It is a fast and effective method of taking population samples.

Samples can be taken at random and the data collected converted into total population figures by dividing the population data collected in the area sampled by the fractional part the sample is of the whole area. Shetter (1936) describes a method of total population estimation, which can be applied when neither the area of the sample nor total area of the stream is known. The method consists of tagging fish and releasing them; then sampling the area and applying the following formula: $t(\frac{U}{R}) = X$, where X = the total population; U = the number of untagged fish in the sample; R = the number of tagged fish recaptured with the sample; and t = the total number of tagged fish originally released. The accuracy of the sample method in obtaining an estimate of total population is subject to wide variation.

Quantitative fish studies, are quite unreliable for securing accurate total population figures. They are valuable as indications of trends. Trends may be nearly as useful in guiding management practices as are total population statistics.

The Determination of Fishing Values

As previously mentioned, the intensity of the fishing pressure determines the kind and intensity of management. For this reason it is necessary to have some measure of the fishing value of the streams under management. The methods now in use are listed as follows: (1) creel census work, (2) the use of indices of fishing volume, and

(3) the system now in use by The United States Fish and Wildlife Service in their River Basin Control Work.

Creel Census

The creel census consists of the collection of such data on the angler's catch as (1) number and species of fish caught, (2) length and weight of each fish, (3) total number of hours fished, (4) remarks and (5) any other data which might be useful in a given situation. These records are taken on special creel census blanks which are designed to prevent the omission of pertinent data and to facilitate making the record. Creel census work may be carried on in an intensive or extensive manner.

Intensive Creel Census

The intensive creel census is one in which 90 to 100 percent of the angling success is recorded. This type of census is only possible on streams, which are subject to complete control, since voluntary returns are never that high. They are generally carried out as a part of an intensive program of management or on problem waters. The cost of such a census prohibits its widespread use, so that the less reliable extensive creel census is applied to extensive management programs.

Extensive Creel Census

The extensive creel census depends upon the determination of total creel data on the basis of a sample census. The voluntary creel census is a type of sample method. Lord (1936a; 1936b) explains the "Test Stream" method of voluntary creel census in the following manner. The State of Vermont set aside Furnace Brook as an experimental "Test Stream." The area was under special study by the State Conservation Department. Fishermen were required to obtain a permit to fish in the

stream. This permit was issued free, its major purpose being to impress upon the fisherman the necessity of turning in daily catch records. Red boxes were located along the "test stream", which contained forms and pencils. Lord (1937) found this method to be reliable for securing records of numbers and size of fish, but fishermen failed to cooperate in the recording of marked and unmarked trout. Pautzke and Meigs (1941) report a similar failure to secure a reliable report of marked trout returns in spite of widespread publicity. Hanson (1938) reported a return of 19 to 20 percent of all creel census forms when forms were issued with camp permits in a National Forest.

Curtis (1940) gives an account of the California state-wide creel census, which represents an attempt at a state-wide application of the voluntary creel census. The method consisted of the state requesting the angler to report the number of fish which he caught the preceding year, by species and the county in which they were caught. Over a period of three years an average return of about 27 percent was received. In order to receive some insight upon the non-reporting anglers the "second call" was inaugurated. The "second call" consisted of sending census blanks through the mail to a portion of the non-reporting anglers. Through this system it was found that a rather high percentage of the non-reporting anglers were unsuccessful the previous year. The state-wide census data is not considered reliable, since there is no way of checking the reliability of the sample. It can be used as a measure of fishing trends, if the same degree of reliability can be assumed to prevail every year.

Eschmeyer (1937) reported on a method in use in Michigan. This method consists of requiring the local game warden to collect creel census data in connection with his other duties. These results are for obvious reasons unreliable, but they do indicate trends and other data in a general way.

Another sample creel census method consists of collecting data on the opening day or any other day of the regular fishing season. This type of creel census may indicate trends too, but very likely indicates only the relative quality of the fishing weather prevailing each year on the sample day. It can be seen that sample creel census records are difficult if not impossible to evaluate. They will continue to be used in spite of their short-comings, because intensive census methods are too expensive for state-wide application.

The Use of Indices

The number of license holders can be used as a reliable index to fishing pressure trends, but it is not detailed enough to be really valuable to management. Another index, which is very unreliable in most cases, might be called the "squawk index". Poor fishing is evidenced by newspaper articles, letters and general complaints. This index was used in the past to aid in the distribution of hatchery stock. The index could be useful, if there was some way to evaluate complaints. In view of its unreliability this index should not be used as a guide to stocking operations, but it can be of value in locating problem waters.

The River Basin Control System of Evaluation (Dieffenbach 1947)

The River Basin Studies of the United States Fish and Wildlife Service are attempting to place wildlife resources on a dollar value basis.

The general system of evaluation rests upon the assumption that the value of wildlife to the fisherman or sportsman is reflected in the amount of money he is willing to spend in pursuit of these sports. If one can obtain a reliable estimate of the amount of money spent in the pursuit of fishing pleasure in an area, he will then have a reliable estimate of the value fishermen place upon the fishery resources of that area. This type of evaluation would be extremely useful to a management agency, especially when it must balance the cost against the value received.

THE TOOLS OF MANAGEMENT

The tools of management fall into two general classes: (1) environmental improvements, and (2) the manipulation of populations. The unique feature of trout stream management is the fact that very little is known about the effectiveness of its tools. In this respect trout management cannot be compared to engineering or mathematics, but its application might be more comparable to music or art. The application of management to a wildlife society might be analogous to the mixing of paint, if instead of the resultant green upon blending yellow and blue pigments an infinite number of colors were possible. It must then depend upon a certain amount of trial and error, since limiting factors are generally recognized by limited observations or perhaps intuition and the tools applied may produce a wide range of effects.

Environmental Improvement

Environmental improvement has one major limitation "the point of diminishing returns." Under a given set of environmental conditions the stream has a certain fixed carrying capacity. The carry-

ing capacity is seldom achieved or maintained in a fish population, since a fish population is constantly in the process of recovering from its latest minor or major catastrophe. This dynamic quality of populations was previously discussed in relation to bottom fauna populations. The dynamics of a trout population is believed to be of a similar nature. Environmental improvement can be applied in three directions: (1) watershed improvement, (2) stream improvement, and (3) the creation of new trout waters.

Watershed Improvement

The principal limiting factor of many trout streams is correlated with violent fluctuations in the volume of the flow of water in the stream. The principal purpose of watershed improvement work is to reduce these violent fluctuations by stabilizing the water supply of the stream. In water characterized by wide fluctuations of the volume of flow, watershed protection can generally do more to increase productivity than any other tool of management. Tarzwell (1937) found that in the southwest vegetative cover is essential for the retaining of moisture and preventing severe floods. In such instances it is essential to first stabilize the watershed before stream improvement can be expected to operate effectively. It should be recognized, however, that the character of some streams is inherently that of wide fluctuations in volume, so that watershed improvements can not be expected to produce a stabilized flow in all cases.

Stream Improvement

The major objectives of stream improvement are the improvement of shelter, food and spawning conditions for trout, and to prevent excessive seasonal fluctuations in temperature and volume of flow. It

is generally recognized that the ripple areas of a stream are the high food producing areas or "trout pastures", while pools are the habitual retreats of trout. Much can be gained by producing an interspersion of these habitats thus spreading the trout population over the entire length of a stream. Smith (1938) suggests as a "rule of thumb" that a proportion of fifty percent pool to fifty percent ripple be assumed the optimism condition in most cases. In this respect it is unwise to place an improvement device where it will destroy good pool or ripple conditions just for the sake of interspersion. The place to install such structures is in the area between pool and ripple where neither good pool nor ripple conditions prevail. It has been found that stream improvement work is much better suited to operations in small size streams. In the larger streams these structures require much more effort to build, and are in general shorter lived due to the more violent fluctuation of levels.

Davis (1936) gives the following as the guiding principals in stream improvement work: (1) all structures should be as inconspicuous as possible, (2) they should be inexpensive, and (3) stream improvement is a biological problem and biological enhancement should be the primary objective of all structures. The selection of stream devices depends upon the use of structures which will effect the most reduction in the limiting factors of the given stream environment. Structures which create a pool will do the most to increase shelter. Food production can be increased to a limited extent by the use of structures which reduce the destructive action of floods or which induce an increase in the productive bottom area. Water temperature can be lowered by improvements which tend to stabilize the flow of water, restrict the

stream to a narrower and deeper channel and shade the channel from the sun.

Stream improvement should always be correlated with a need for improvement. Streams which are already good producers should be left alone. If stream improvements are properly applied they produce good results. Hazzard, Leonard and Shetter (1947) reporting on the use of pool forming deflectors found that an improvement in angling quality of 46 percent was averaged. Tarzwell (1937) studied the effect of improvement devices by improving one stream and retaining another stream as a control in a pair of very similar streams. Results based upon stream survey data and intensive creel census data show that the improved stream yielded more total food, a higher total number of fish and a greater catch per hour than did the unimproved stream.

No two stream improvement devices are alike, in that each structure must be modified to fit the particular site it is to occupy. It has been found unnecessary to use a great variety of types of improvement devices. There are many types of stream improvement structures, but those described below have been found to be the most dependable and will remedy almost any situation encountered in stream improvement work.

Dams

The type of dam referred to in this discussion is a low structure designed to withstand severe floods and yet exert sufficient resistance to the flow of water, so that a pool will be formed below the structure. The straight-log dam is a good example of such a structure. (See figures 1 and 2). A maximum fall of twelve-inches is sufficient to produce a fine pool below the dam. The pool created above

a dam is generally a detriment to stream productivity, since it is subject to silting. For this reason there is some objection to the use of dams. Dams are very effective in lowering the incidence of flood damage and for this purpose are highly recommended. Proper location of the structure will reduce to a minimum the loss occasioned by the formation of the upper pool.

Davis (1936) claims that the best dams are those made-up of large rocks, since they are inexpensive to build, very durable and have a natural appearance. In constructing such a dam the boulders are wedged together in such a manner that the force of the current acts to bind the rocks even closer together.

Deflectors

A deflector is any structure which will impede the natural flow of water to induce a local increase in the velocity of the current, which scours out a pool next to the deflector and deposites a bar behind the structure. There are many types of deflectors, but a simple wing type of deflector has been found to be the most effective. (See figure 3).

Deflectors must be properly located or their scouring action can do considerable damage. It is necessary to be certain that a deflector doesn't expend its scouring action against the opposite bank of the stream. In order to direct the scouring effect to create a pool the bank against which this deflected current impinges must be resistant to erosion. When erodable banks are encountered another deflector must be located upon the opposite bank. The second structure may be located on line with the first to produce a funnel-like constriction in the stream or it may be located below the primary structure to produce a

baffle effect upon the direction of the stream flow. Deflectors may be used as an accessory to a dam to prevent the upper pool from becoming filled with stream deposites.

Deflectors are used in connection with stream bank control work. They can be placed to protect an eroding bank or to divert water from an auxilliary channel. Large boulders may be rolled into streams to act as deflectors just as they may be used in the construction of dams.

Covers

Stream covers have a very limited application. They consist of structures which are placed in a stream to provide sheltered situations under which trout may take refuge. Large stumps are commonly used for this purpose. They are anchored to the stream bottom with cable and stakes. Tarzwell (1936b) found in Michigan streams that stump shelters were very short-lived. Another type of cover is the raft cover, which as the name implies consists of a raft of logs staked out in a stream. These structures are not recommended, since they are very short-lived and apparently do not accomplish their purpose.

The boom cover provides trout with adequate shelter and also is useful in preventing bank erosion. It consists of a log boom constructed across a curve in a stream, in much the same manner as a chord across a segment in a circle. It is anchored to the bank at both ends and the space between the bank and the boom is filled with any bouyant material that may be available. In heavily fished streams boom covers also provide an unfishable retreat, which acts as a refuge area to help maintain a supply of brood fish for natural restocking of the stream.

The effects of the various types of covers are rather limited, so their use is rarely warranted. Some streams which possess very little natural cover may be improved by properly installed covers.

California Check Dams

As the name implies these structures were designed to meet the needs of certain California streams. They can be profitably applied to streams which are characterized by a low water period during which the normal flow of water is so slight as to exert a limiting effect upon the fish population.

Needham (1936) explains their construction and operation in the following manner. These dams are constructed to retain the rain and snow waters in the spring of the year and to release this reserve in a steady flow throughout the dry low water summer period. The dams are constructed with an eight-inch iron pipe placed in the bottom of the dam. This pipe is equipped with a valve, which permits regulation of the flow. Once the valve is regulated according to the capacity of the dams impounded water reserve, it is permitted to flow at that rate the year around. During high water the impoundment is filled and excess water spills over the top. During low water periods the dam continues to flow at a constant rate by drawing upon the impounded water.

By this means many miles of trout stream increased in productive capacity and natural spawning conditions were greatly improved.

Stream Bank Improvement

Stream banks may be stabilized by planting bank holding plants, such as willows, or by a combination of plantings and deflectors. Other very expensive methods of bank stabilization are required in some very

difficult situations, but expensive constructions are rarely justified in trout stream improvement work.

Willow plantings are made almost to the exclusion of other species. The particular advantage of the use of willows lies in the fact that they are not only successful in holding stream banks, but they also can be readily propogated by means of cuttings. Many stream banks have been successfully stabilized, merely by inserting willow cuttings into the eroding bank. The problem is usually not as simple as this, and demands that bank improvement work be correlated with watershed protection and stream improvement activities.

Stabilized banks furnish a trout stream with trout cover. They induce a lower stream temperature by providing shade and restricting and deepening the stream channel.

Special Improvements.

In almost any stream situation special conditions may be encountered which will require special consideration. A marshy spring run, which is so spread out over a marsh meadow, as to considerably warm the water before releasing it to a stream, is an example of a special case. This situation may be corrected by constructing a ditch from the spring source to the stream.

Gilmore (1937) recommends the use of small dams ten or twenty feet high in certain cold mountain streams to raise water temperatures and provide a fish habitat when the streams are frozen solid.

The use of regular check dams in the intermittent drainages of a trout stream is recommended in the southwest. They lower the crest of flood waters and provide a reserve water supply which is gradually released to the stream. These structures differ from the California check dam in that they are smaller and are located in the dry washes tributary to a stream.

Creation of New Trout Water

There are in effect many ways to create new trout waters. The lowering of water temperatures, as mentioned previously, is an effective way to increase trout stream mileage. Besides these intentional trout stream improvement methods an increase in trout water might result as an incidental by-product of some large project. Tarzwell (1938a) reports upon an example of such a situation. The construction and operation of the Norris Dam changed about twenty miles of the Clinch River from a warm-water stream to a cold-water stream. This transition is due to the fact that the water which is released from the dam usually has a temperature below fifty degrees Fahrenheit. This is clear water from below the thermocline of the impoundment. It becomes good trout water once it has had an opportunity to become aerated.

The diversion of large trout streams into several channels in an effective way to raise total trout water productivity. As previously discussed, trout streams with a large volume of water are generally less productive per unit volume than smaller streams. The diversion of water into several channels may also reduce the destructive action of flood waters.

The Manipulation of Populations

The purpose of population manipulations is to effect a control upon the kind, number and size composition of fish populations. The optimum population would be one in which the favored trout species predominated with a high percentage of the population consisting of large size trout and in such numbers as to offer successful angling to the majority of the fishermen using the stream. Management attempts to fulfill this aim by exerting the following controls.

Predatory Animal Control

Fish have many enemies, especially during their early stages of development. From predaceous invertebrates to man is a long gauntlet of natural enemies which must be run before trout reach sufficient size to enter the fisherman's creel. Normal predation in streams is generally recognized to be beneficial to a fish population, since predators act as a natural control to overstocking. The whole predatory animal control problem is one that requires a thorough study of the predator-prey relationship before action is justified. Every situation must be judged upon its own merit with the effects of the predator upon the angler's creel properly evaluated and rated against the cost of control. In many of the trout predator problems there are two values to consider. The value of the prey being one and the value of the predator constituting the other.

Salyer and Lagler (1939; 1940) in a study on the predaceous activities of fish-eating ducks in Michigan found that losses from this source were not serious in normal situations, but when American Mergansers formed concentrations of over twenty-five birds per mile of trout stream control measures were recommended. In Europe predatory fish are controlled by seining and spearing. Predator control in America is rarely justified, since we have so little information on the predator-prey relationship that it is not worthwhile to risk upsetting the "balance of nature". There are specific situations where high concentrations of predators are producing a local decimation of the fish population and in such instances control action should be taken to restore a more normal "balance of nature".

The Control of Competitors

Under certain conditions less desirable species of fish offer serious competition to the trout population. In such situations measures to control the obnoxious species should be initiated. These problems usually occur in the marginal trout waters, which are not entirely suited to the production of trout.

Greeley (1945) reports that barrier dams have been used in several New York streams to prevent bass, suckers and other fish from running up into trout sections. He further reports that in Scholarie Creek, New York, the state-wide bass law was liberalized in this stream to reduce the conflict between bass and trout.

Competition within natural trout waters as a general rule, is of minor importance, although less desirable exotic species of trout often crowd out the more desirable native forms. Where competition is so severe that poisoning the entire population is justified, the use of rotenone is recommended. A concentration of one part powdered derris root (warranted rotenone content five percent) to two-million parts of water is sufficient to kill all fish. Before restocking is attempted measures should be taken to insure that the noxious species will not be reintroduced.

Manipulation of the Stream Stock

Every stream has certain micro-habitats and is characterized by certain environmental conditions. In most streams the native species are the species best adapted to their particular stream conditions. This condition would undoubtably be universally true, but for the fact that the activities of man and sometimes other agencies have very definitely altered primoidal stream conditions. Adjustments to change no doubt occur

in any natural community, but such adjustments may not be to the advantage of man and the native species may not be the species best adapted to present stream conditions. In such situations management should introduce more suitable strains or species of trout. It should be emphasized that before any introductions are made the situation should be thoroughly studied to make certain that the introduction will be successful and that the new species will not become a nuisance. Other streams in the vicinity, which might be unintentionally stocked with the introduced species through their normal dispersal, should be studied to determine the effects of the exotic upon them.

The use of rainbow trout, which is more tolerant under certain conditions than brook trout, has undoubtably resulted in an improved sport fishery in most places where it has been introduced. Indications are that the introduction of brown trout has in most cases been unwise. In using the more tolerant trout their introduction is generally most successful in the main streams and lower trout waters, whereas the native species continues to maintain dominance in the tributaries. In many cases it is wise to confine introductions by means of barriers to prevent them from occupying certain waters.

The use of trout which are adapted to the environment assures management of a greater total yield, than when streams are populated by species not entirely suited to the prevailing conditions. The use of several species of trout may lead to a greater total production, when compared to that of a single species population. The competition which two species give might result in a more efficient utilization of the stream due to the wider range of adaptability and selectivity which two species would exhibit. It can be seen that much may be gained

by considering the stream stock in a critical manner and questioning whether the present stock is making the most efficient use of the stream.

Legal Control

In the majority of trout streams the angler is by far the greatest predator, and in many cases the chief limiting factor to natural trout productivity. To control the activities of man is of primary importance in the management of trout streams. As stated previously the primary value of trout lies in the sport they provide. Laws must, therefore, limit the methods of taking trout to to the type of tackle that will provide the greatest amount of sport for each pound of trout taken. Lord (1936) recommends that where shorter seasons are necessary, the season be shortened at the spring of the year. At this time fish are in their poorest fighting condition and the weather is not conducive to the full enjoyment of the sport.

Management must strive to create laws which will assure the greatest total sport. Where trout streams can withstand additional fishing pressure laws should be liberalized to increase the catch. Laws which increase the number of fishing days provide a greater total sport than those which decrease length limits or increase creel limits. The usual creel limits and length limits are liberal enough. Most fishermen wouldn't keep smaller fish if they were allowed to and they would be very satisfied if they could fill the present creel limits.

In streams subject to an excessively heavy fishing pressure it is desirable to drastically lower the creel limit. A limit as low as one or two fish is justified, so that the legal fish population will last longer and provide more sport. Westerman (1941) reported

on an experiment to determine the losses resulting from the capture and release of trout by anglers as follows according to gear used: (1) artificial flies 2.75 percent, (2) barbless hooks and bait 5.6 percent, and (3) barbed hooks and bait 8.75 percent. A combined total loss of only 5.7 percent in fifteen hundred fish captured and released. It can be seen from these results that a fish captured and released could provide sport for an average of twelve to fifty times depending upon the tackle used before injuries resulting from capture and release would prove fatal.

In setting legal length limits it is the general rule to allow a fish to attain a sufficient length, so that it will have spawned at least once before it becomes legal game. This length limit can be lowered in overstocked streams to reduce the number of spawning trout. It can likewise be raised in streams which do not have sufficient natural spawners due to an over-depletion of the brood stock.

Legal controls alone cannot greatly increase trout productivity, but they can insure a more equitable distribution and result in a greater amount of total sport from a given trout crop.

Fish Stocking

Trout stocking is one of the most useful tools of management, but like all tools of management it has some very definite limitations. The basic principal behind stocking is obviously that of "put and take". The State of New Jersey has been successfully following this policy of "put and take" for many years. In spite of this seemingly simple process there is more to successful stocking

operations than most fish culturists care to admit. It has been found that hatchery reared trout suffer a high mortality after release into a trout stream, so add little to the residual population. For this reason stocking is justified only where it will provide a direct return to the angler of sufficient value to balance the cost of the stocking program.

The Zero Margin Return.

When a given planting provides a return to the angler, which just balances the cost of stocking that is produces neither a profit nor a loss, the planting may be said to provide a zero margin return. If the return is less than the zero margin, a loss is incurred. If the return is greater, a profit is obtained. The zero margin may then be used to classify streams for stocking.

The zero margin stream may be calculated, if the following values are known: (1) the cost of producing and distributing hatchery trout, that is the total cost of stocking, and (2) the total value of trout to the angler. It can be expressed as the recovery in percent of the total plant. In order to demonstrate the calculation and the use of the zero margin the following values are used. Actually the zero margin should be calculated for each management area on the basis of values and costs prevailing in that area.

French (1939) calculated the average cost for producing legal-length hatchery trout in Pennsylvania from 1933 to 1938 at 0.578 dollars per pound. Olman (1947) reported that the River Basin Control Studies of the United States Fish and Wildlife Service were using an estimated value of 2.00 dollars per pound, as the value of trout to the fisherman. If we accept these figures as a basis for our determinations, we find upon dividing 0.578 by 2.00 and multiplying

this quotient by 100, that our zero margin return is 28.9 percent. This is a very conservative minimum recovery for the following reasons: (1) The cost of producing trout has undoubtably risen since 1938, while the 2.00 dollar value is a recent estimate based upon current prices, (2) the costs given by French (1939) do not include interest upon the capital investment in hatchery and equipment, this estimate includes only the cost of maintenance and operating costs, (3) the cost of planting was not included, and (4) the cost of administering the stocking operation was omitted. In view of these additional costs it would be safe to assume that the zero margin requires at least a thirty-five percent recovery. We now can classify for stocking all the streams of a given state on this basis.

The Classification of Streams

The zero margin throws streams into two general classes for stocking: (1) these which have a positive margin, so are profitable to stock, and (2) those exhibiting a negative margin in which stocking would be carried on at a loss. This system can be carried on farther to classify streams as to their relative response to stocking. For example, if we have two streams producing a recovery to the angler's creel in total planted trout of ten percent and sixty-five percent respectively, we may say that the ten percent recovery represents a margin of profit of minus twenty-five percent, and the sixty-five percent recovery represents a margin of profit of plus thirty percent, as based upon the zero margin of thirty-five percent. In this manner we can rate any stream in the state. A certain margin of safety should be allowed in stocking operations just as in business to take care of unseen costs. This method readily classifies all streams not only as

to whether stocking would pay for itself, but it also shows which streams should be stocked first in the event that adequate funds for a complete stocking operation are not available.

The system of stocking evaluation given above shows that stocking depends upon the attainment of a certain minimum rate of return to the angler. This rate of return is influenced directly by the fishing pressure to which a stream is subjected. Fishing pressure in turn depends upon the proximity of the stream to population centers and the availability of every section of the stream. In order to develop high margin streams, the trout waters near population centers should be utilized to their fullest capacity. This can be accomplished by securing public fishing sites and eliminating unfishable retreats. These improvements will raise the stocking margin and make stocking operations more efficient. In addition stocked waters should be correlated with other management tools to further increase the effectiveness of stocking.

Those waters which exhibit a negative margin should not be stocked even if depletion is occurring. Hazzard and Shetter (1938) concluded that although planting of legal trout during the season temporarily increased the catch, it may deplete a stream of wild adults. The universal failure of hatchery trout to carry over from one season to the next indicates the failure of hatchery stock to replace a depleted natural population. The use of hatchery stock as a buffer for a natural trout is not well enough understood to recommend its application to general management. To solve the problem of depletion in these waters, it is necessary to apply other tools of management or to raise the margin of return before stocking should be considered.

Methods of Stocking

Stocking is an artificial process. It is carried out under the artificial condition of heavy fishing pressure. Then why base stocking upon the natural capacity of a stream to produce trout? The intensity of stocking should be determined by the difference between the amount of residual stock present and the amount of trout per mile necessary to produce the optimum amount of angling pleasure in catch per hour? If anyone could catch a full creel every time he went fishing, the sport would lose much of its appeal. The very fact that success fluctuates makes fishing all the more interesting. Likewise repeated failures make the sport tedious. Schuck (1942) suggests that an average angling success of one legal fish per hour be assumed the optimum catch. He found that with a fishing pressure of 11.4 hours per day, it was necessary to have a brook trout population of 396 legal-sized trout per mile to realize an average return of one fish per hour. His results show that brook trout respond as population increases with an increase in catch per hour. Densities of 346 and 244 fish per mile would produce yields of 0.8 and 0.5 fish per hour, respectively. Brown trout did not respond with such increases, so stocking to increase brown trout catch is not justified.

The optimum angling success should be the aim of a stocking project, but it must be recognized that such a success in many streams would be produced only under a condition of severe overstocking with the resultant low survival of planted trout. For this reason this aim cannot be realized in many streams, but a certain amount of overstocking is justified to produce the results desired. Frequent restocking during the season to replace losses to fishermen and other factors will

not only increase catch returns, but also reduce the strain of over-stocking. The number of fish to plant in a given stream section should depend upon the following: (1) the angling success desired, (2) the carrying capacity of the stream, and (3) the rate of loss in relation to the time interval between plantings.

It is well established that plantings of fingerling trout give poor returns in most situations. Surber (1940) received a return to the anglers creel of 2.4 percent in a planting of 11,104 large fingerling trout. It must be emphasized that a stream possesses a certain limited carrying capacity. The addition of fingerling trout is likely to overbalance the normal size range of a trout population and result in a population made up predominantly of small-size trout with a retarded growth rate. This situation cannot be relieved by fishing since only a small percentage of the trout are of legal-size. For these reasons fingerling plantings are not recommended in most situations.

The planting of fingerlings, fry or even eyed-eggs is justified under certain conditions. Their use is especially important in the west where inaccessibility prohibits the use of legal-size fish. Streams which do not possess adequate spawning facilities or which present excessive hazzards to a certain life history stage may be maintained by this type of planting. The use of eyed-eggs in very inaccessible areas is recommended by West (1940). He reports an average total loss of only 3.2 percent in transit and during the hatching period for plantings of eyed-eggs in planting trays.

Lord (1936a) and Chamberlain (1943) found plantings were

much more successful if the trout were distributed along the stream. The "Pisgah System" of planting trout consisted of back-packing trout to every pool on the stream and releasing not more than three or four fish in each pool at any one time. On navigable streams trout may be scattered quickly and effectively by means of a boat.

Recent investigations using marked hatchery trout have shown very definitely that spring plantings and during the season plantings are far superior to fall or winter plants. (See table I.) Chamberlain (1943a) gives the full history of a certain fall plant made in 1937 as follows: 2.3 percent were taken in 1938; 1.1 percent in 1939; 1.4 percent in 1940, when fishing effort increased; and 0.7 percent in 1941. The total recovery in four seasons of 5.5 percent indicates a substantial loss. Nesbit and Kitson (1937) expressed the results of fall to spring plants in the form of a ratio as follows: (1) rainbow trout with a ratio--in percent of recovery of spring plants to the percent of recovery of fall plants--of 9.9 to 1, and (2) brown trout with a ratio of 5.1 to 1. These findings conclusively show that all stocking operations should be carried on during the fishing season or in the spring.

There are many problems in stocking operations, which would allow wider use of hatchery stock if we were able to answer their needs. Mortality is known to be high in hatchery reared trout following their release. If the exact nature of these losses were known, then we could introduce measures to reduce this post planting loss. The ability to produce hatchery trout that would successfully adapt themselves to natural conditions to become a part of the residual population

Table I -- A table summarizing the results of recent investigations upon the recovery of legal-sized hatchery trout by the angler.

Trout Species	Percentage of Survival to Creel Fall and Winter plantings	Spring and during the season plantings	Locality	Reference
Rainbow	12	60 good	North Carolina	Chamberlain (1943a)
"	18	---	" "	
"	7.7	58.8	New Mexico	Gee (1942)
"	2.2	28.2	" "	" "
"	---	72.0	" "	" "
"	---	57.5	" "	" "
"	---	40	" "	" "
"	---	17.5	Michigan	Hazzard & Shetter (1938)
"	2.8	42.3	North Carolina	Holloway & Chamberlain (1942)
"	15.7	---	" "	
"	27.9 (plus)	---	Vermont	Lord (1936a)
Brook	---	83	North Carolina	Chamberlain (1943a)
"	---	19.8	Michigan	Hazzard & Shetter (1938)
"	2.2	55.1	North Carolina	Holloway & Chamberlain (1942)
"	---	92.0	" "	
"	---	72.0	" "	
"	1.0	19.6	Upper Penn. Mich.	Smith (1941)
Brown	10.6	14.4	North Carolina	Holloway & Chamberlain (1942)
New Mexico	---	57.5	New Mexico	Gee (1942)
Native	---	37.3	" "	" "
"	---	54.6	" "	" "
"	---	42.0	" "	" "

would permit the use of such trout in low margin streams, which are being depleted of natural stream stock. Greater development and increased trout fishing will no doubt permit a wider application of hatchery trout in future trout stream management work.

TROUT CULTURE

The fish used in stream stocking work are almost entirely made up of trout of hatchery origin. For this reason fish-culture is an integral part of management. The application of science to stream stocking operations has resulted in an increased demand for legal-sized trout with a commensurate reduction in demand for fry and fingerling stock. As compelled by this change trout rearing stations, which formerly concentrated upon the production of large numbers of small-sized fish are now more concerned with the production of a smaller number of large-size trout.

The principal factors which prevent a wider use of hatchery trout in scientific management are: (1) the high cost of producing hatchery fish to a legal-size, and (2) the rather poor quality of the hatchery product. Scientific investigations are being conducted in the hope that a reduction in the effect of these factors will result. Research is being directed along three major lines as follows: (1) nutrition, (2) disease and (3) selective breeding.

Nutrition

Present studies are being directed along two major lines: (1) balancing the trout diet to produce vigorous fish and (2) producing a reduction in the cost of feeding trout. McCay (1937) worked on experiments designed to reduce the cost of feeding by the use of dried milk

and cottonseed meal. He found that food conversion by trout varied from 1.5 to 15 pounds of food to produce 1 pound of trout depending upon the nature of the food itself. Hewitt (1936; 1937a; 1937b) concentrated his attention upon balancing the diet to prevent hatchery trout from acquiring a "fatty liver" which is indicative of an unhealthy condition. Much remains to be accomplished in the production of a low cost balanced diet for trout.

Disease

Fish (1940) in an evaluation of the efficiency of trout-culture by an analysis of hatchery records found that an accumulative loss of approximately fifty percent is sustained from the egg stage to the number four fingerling stage. The importance of disease control is very evident. Preventative measures include: (1) a suitable water supply, which is free of all wild trout, (2) cessation of all inter-hatchery exchange, if a transfer of stock is necessary it should be combined to a transfer of eggs and all eggs and egg trays should be carefully disinfected and (3) avoid spreading disease in the hatchery itself by keeping all lots segregated and carrying on a continuous policy for the sterilization of equipment.

The control of diseases once they become evident consists in a strict quarantine of infected lots and an attempt at treatment. All treatments, with the exception of salting, require the administration of disinfectants in such a concentration that it operates within the narrow margin between killing the parasite and killing the fish. Gutsell (1947) reports that the use of sulfamerazine will effectively stop mortality from Furunculosis. The treatment of trout diseases in general remains a very uncertain and only partially effective cure.

Selective Breeding

The development of an improved brood stock to provide eggs for artificial propagation could be evidenced in an increased efficiency of the hatchery operation and in the development of strains of trout which are better adapted to fit specific stream conditions. Davis (1940) reported that brook trout experiments in selective breeding resulted in a doubling of the rate of growth and the production of eggs in two generations. Lewis (1944) found that selection increased the growth rate to produce an increase in weight of from five ounces to eight ounces for yearling rainbow trout. The development of trout strains, which exhibit certain desirable characteristics such as non-migratory habits or disease resistance, would be of real benefit to trout managment. In consideration of the possible benefits which might result from the selection of brood stock a record of trout pedigrees might well be justified as a feature of future management.

CONTROVERSIAL ISSUES

The productive ability of a trout stream is sometimes impaired or eliminated by certain other interests which are in direct competition with trout or which inadvertently destroy stream productivity. In dealing with such conflicts all efforts should be made to eliminate this strife so that the interests may become compatable. If the situation by nature is impossible to remedy then both interests must be properly evaluated and the asset with the greater value allowed domination in a given situation. These conflicts are many and varied. They are in evidence in almost every stream. For this reason only a few of the major conflicts will be mentioned in this paper.

Interspecific Wildlife Conflicts

Sportsmen and nature lovers are the two groups of people most interested in the wildlife resource. Sportsmen are primarily interested in wildlife as a crop, while nature lovers maintain a preservationist attitude. These somewhat divergent aims are certain to create friction between the groups when such problems as fish predator and beaver trout relations demand attention. The conflict is generally amplified by a somewhat fanatical attitude on the part of each group. The fish predator problem was discussed earlier. The beaver trout problem warrants a brief discussion.

The beaver by nature dams up streams to create an impoundment. These impounded waters in nearly all situations lower the productivity of a trout stream. In many situations beaver literally take a stream away from the trout. Beaver ponds act to the detriment of trout in the following manner: (1) they warm the water, (2) lower food productivity and (3) hamper the normal migration of trout. These ponds are also of value to trout as they retard flood waters, temporarily provide good conditions for trout production and under certain conditions provide wintering places in streams which normally freeze solid during the winter. In dealing with beaver it can be seen that each situation should be evaluated upon its own merit and control applied where necessary. Some measure of control is necessary in most situations. The fact that beaver themselves represent a valuable resource indicates that in some situations they should be given dominance over trout and allowed to completely take over a stream so that a maximum beaver crop can be attained. The usual situation indicates that beaver should be controlled sufficiently to be maintained at a rather low population level.

Related Land-Use and Fishing Interests

The conflict between land use and trout production is generally such that it can be remedied to a very great extent by the application of proper land use practices. Farming, grazing and logging all effect trout stream productivity. The proper use of these resources is of primary importance to stream management, since watershed protection is of such vital importance to a trout stream. Land management is the responsibility of other agencies. For this reason there should be a correlation of the activities of land and stream management agencies.

Mining operations pollute streams with mine tailings and other pollutants. Erosion from spoil banks and settling basins, as well as the activities of placer and hydraulic mining all fill streams with silt. In such cases little can be done to remedy the situation, so trout must sustain the loss. In other cases where drainage from mines is polluting the stream such situations can be remedied by rendering the pollutant innocuous before releasing it to the stream. These problems can rarely be solved by stream management agencies alone, but require the concerted efforts of the land-owner and the agencies directing proper land-use practices.

Related Stream-Use and Fishing Interests

Navigation, flood control, sewage disposal, log-driving and irrigation are all stream-uses which conflict with trout interests. The multiple use of streams can in many cases be achieved with little loss to each constituent, if the activities of the individual users are properly correlated. Navigation, sewage disposal and flood control are not generally problems in trout waters, so will not be discussed.

Log-driving

The use of streams in transporting logs to a mill, generally results in a drastic reduction of stream productivity. This reduction is occasioned by the accumulation of debris in the stream, a disturbance of the stream bed and the direct action of logs upon stream life. As in mining operations, little can be done to minimize this type of damage. Measures can be taken following cessation of these logging practices which will return the stream to productivity. These measures include the removal of debris and stream barriers and the use of stream improvement devices to restore the stream to its pre-logging condition.

Irrigation

The use of streams for irrigation can present many problems, but by far the major proglem is that of stranding trout in irrigated fields. Trout, especially fry and fingerlings, drift with the current. This habit accounts for the loss of many trout which enter irrigation canals to be stranded when the flow is shut down. The screening of irrigation canals is the universal method to prevent such losses. Screens must be maintained or they clog and fail to function properly. To obviate this difficulty self-cleaning screens have been devised. These screens consist of a slowly revolving screen cylinder which is cleaned by the change in the direction of the water pressure as the screen revolves. The cost of this device has prevented its wide-spread use, so that many canals remain unscreened. The solution of this problem according to Gardner (1941) requires that the responsibility of the water-user with respect to screening be established and that the conservation agency assist in the construction of the screening diversions.

SUMMARY

The principal feature of trout stream management lies in its extremely variable nature. Proper management is based upon two distinct variables: (1) the inherent factors of the stream and (2) fishing pressure. These major variables can be broken down into a multitude of minor variables. Each habitat will then possess a different combination in the amount of influence each environmental factor exerts to fashion it into a separate entity. Management is further complicated by the fact that it is dealing with dynamic forces which produce wide fluctuations with the passage of time. Proper management must be administered through a system of individual management units each with its particular management plan which is in a continuous process of modification in order to remain up to date.

Stream inventory work gives us the information which describes the limits of each management unit, and prescribes the respective plan. This extreme variability does not allow the use of a single classification of streams for management purposes, but it does lend itself to the classification of streams in relation to single management features. We can, for instance, classify streams as to food productivity, accessibility, stocking margin, etc., and in this manner base each managerial operation upon a given rating system. The problem is to correlate each operation, so that the most efficient plan is evolved. This problem does not lend itself to a standard solution, but requires the manager to properly integrate the various tools of management into an effective plan.

K DAM

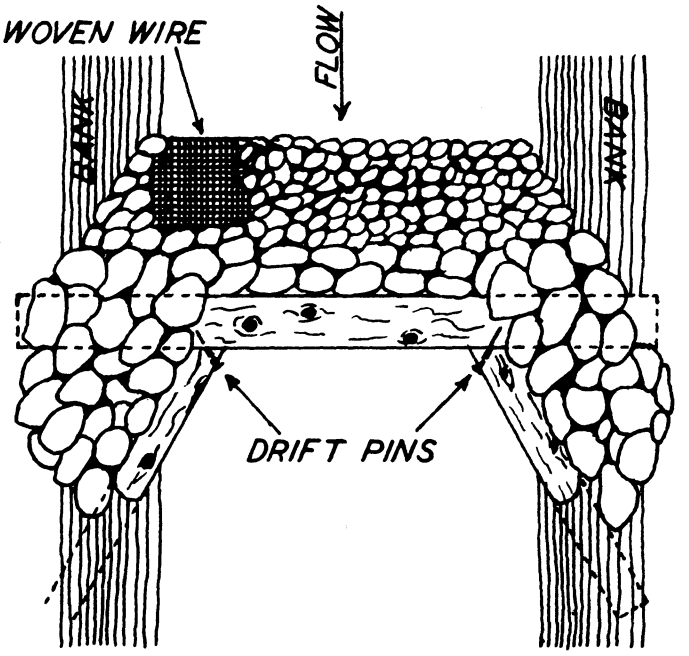


FIGURE 1

CROSS SECTION OF LOG DAM AT SPILLWAY

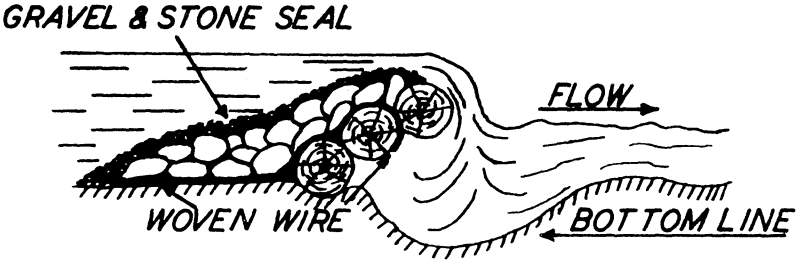


FIGURE 2

TARZWELL (1938)

TRIANGULAR CRIB-WING DEFLECTOR

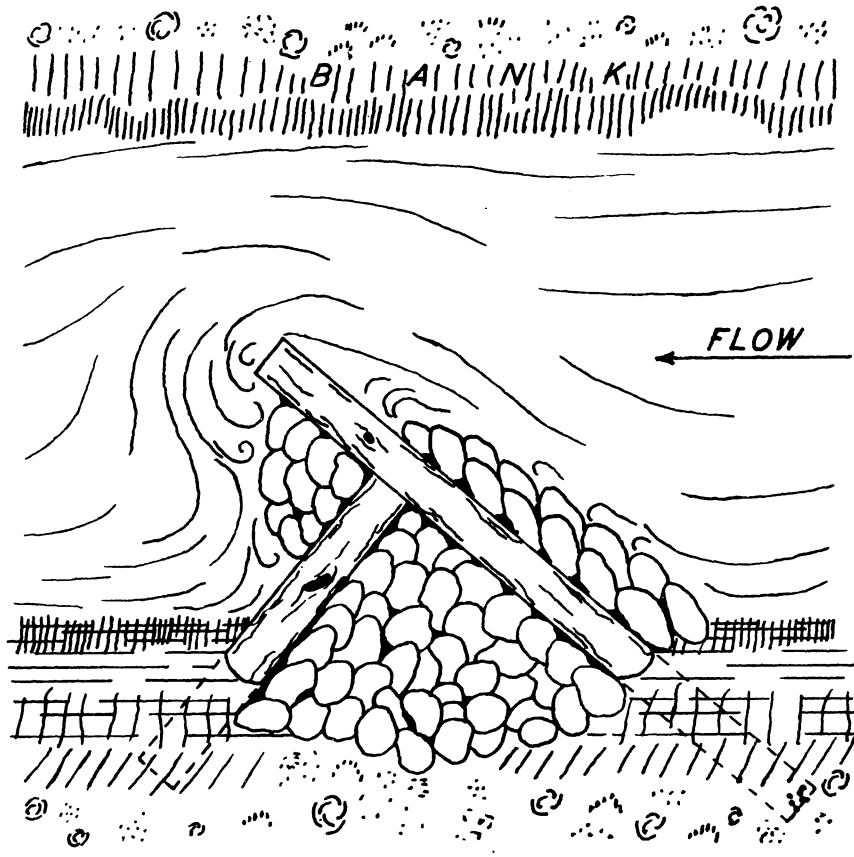


FIGURE 3

TARZWELL (1938)

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