BULLETIN No. 274 JUNE 1950

RELATIONSHIPS and DYNAMICS of BALANCED and UNBALANCED FISH POPULATIONS

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First Printing 10M

RELATIONSHIPS and DYNAMICS of BALANCED and UNBALANCED FISH POPULATIONS

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INCREASING ATTENTION is being given in fisheries research to the determination of composition of fish populations in both natural and impounded waters in attempts to evaluate their condition and to devise more effective methods of management. There are various techniques available for use in determination of populations in various types of habitats, and improvements in these methods are being devised yearly.

Draining of ponds and subsequent counting and weighing of the entire fish population *(21)* obviously give the most accurate records, but this method is unusable in natural waters and in most impounded waters.

Haskell *(7)* described a technique of using electrical shock to sample populations in streams. The inactivated fish were collected, measured, weighed, and returned to the stream where they rapidly recovered. This method is being widely used for survey of small streams, but it apparently is largely valuable for censusing the adult fish while the young are inadequately recovered or reported.

Embody *(4)* reported success in using cresol at concentrations of 1 part to 30,000 parts of water in flowing streams for census work. The fish were rendered temporarily inactive and subsequently recovered upon being returned to the stream. This method is rarely used because more effective methods are now available.

Estimation of populations by the marking and recovery method has been investigated by a number of workers, including Shumacher and Eschmeyer *(14)*, Krumholz *(10)*, and others. It is useful mainly in estimating the adult fish in a population and is employed mainly where more accurate methods cannot be used.

Smith *(16)* used copper sulphate at a concentration of 3 p.p.m. to kill and census the populations of fishes in acid Nova Scotian lakes. This material was found to retain its toxicity to plankton and insects in the deeper waters for one year or more. As a consequence, it is now seldom, if ever, used for censusing populations.

Eschmeyer *(5)* and Thompson and Bennett *(25)* followed by numerous other workers employed powdered derris root for the purpose of killing and censusing fish populations. The use of derris root or other rotenone-containing plant products and extractions is the most satisfactory and useful of the various methods of population sampling in most natural waters and large impoundments. Historical accounts of the development of the various uses of rotenone are given by Krumholz *(11)* and Soloman *(19)*.

Tarzwell *(24)* compared the results of population studies from records obtained by rotenone poisoning, gill nets, set lines, seining, hoop nets, and sport fishing records. Poisoning with rotenone yielded the most complete population records, the other methods being highly selective for certain species within the population.

Determination of populations by rotenone poisoning has been shown by various workers to have certain inaccuracies. Thompson and Bennett *(25)* gave records showing that poisoned fish continued to come to the pond surface for 4 days following poisoning. Failure to pick up poisoned fish over an extended period, therefore, would give incomplete population records. Brown and Ball *(3)* reported that unknown numbers of small fish did not come to the surface and were not recovered or included in their population figures. It would appear that in censusing most populations by rotenone poisonings, little attempt has been made to include complete records of the small fish. This is a very serious defect in the method. Recovery of even the large fish following poisoning is apparently incomplete. Krumholz *(10)* reported recovery of 86 per cent of previously-marked fish and Ball *(1)* reported recovery of only 58.9 per cent of marked bluegills and 44.7 per cent of marked trout. Apparently the unrecovered fish decayed on the pond bottom without bloating, or were entangled in weed growths in deep water.

It is apparent that additional investigations relating to completeness of recovery of both the adult and small fish in poisoned populations under various conditions are necessary. Nevertheless, censusing or sampling populations by rotenone poisoning is still the most effective and accurate method available for most natural waters and many impoundments.

The foregoing techniques for censusing populations are being used to an increasing extent each year. There is, however, no uniformity in the methods of presenting or interpreting the information obtained because of a lack of standards for comparison of various populations. Smith *(16)* counted and weighed samples of dead fish on measured areas of shore-line and reported his results as the numbers and weights of each species per acre. Thompson and Bennett *(25)* reported the numbers, weights, and average weights of each species and the length-frequencies of more important species. They divided the species into groups of largemouth bass, "other fine fish," catfish, "rough fish," and "forage fish" and reported the percentage of the total weight that each group comprised. Bennett *(2)* in his summary of the populations in 22 Illinois ponds, reported each species and its percentage of the total weight in each population. O'Donnell *(13)* reported the numbers and weights of adult and fingerling fishes of each species and their length-frequencies. Eschmeyer *(6)* divided some species into length groups and reported the numbers and weights in each group. He also reported the number of fish small enough for bass to eat. Brown and Ball *(3)* reported the ages, sizes, numbers, weights, and percentages of the total weight of the population for each species. They also classified the fish into groups of "game fishes" and "legal game fishes." Tarzwell *(24)* listed each species with their corresponding percentages of the total weights and of the total numbers of the populations. He grouped the species under "game fish," "coarse fish," "pan fish," and "food fish" and computed their percentages of the total population weight. Swingle and Smith *(22)* grouped the various species into "forage fish (F)" and "carnivorous fish (C)." They reported F/C ratios of 1.9 to 3.5 in old ponds and suggested the use of a F/C ratio = 2 in determining the number of fish required for stocking new ponds. Meehean *(12)* from poisoned populations in Florida lakes reported ratios of "predators to supporting population" of 2.27 to 3.16. In his predator group, he included piscivorous fish plus turtles.

From the foregoing discussion, it is evident that the fisheries technician can now, with the various methods at his disposal, determine more or less accurately the species composition of a particular population. He appears, however, somewhat at a loss as to just what to do with this information, how it should be reported, and how to interpret it. It must also be kept in mind that the data he reports are more or less static figures representative of that particular population only at that instant or period of time when the census was made. The live population, however, was not static, but dynamic — constantly changing in individuals and in relative composition due to growth, predation, removal, mortality, and reproduction.

Consequently, it is not enough to merely know the species present and their relative percentages of the total population. The interrelationships between species, between groups of species and between groups within species, and the dynamics of their relationships in fish populations must be understood if fisheries biologists are to manage effectively fisheries resources.

In the experimental work on pond management at the Alabama Agricultural Experiment Station during the past 15 years, the compositions of 89 separate well-established fish populations from 2 years to 30 years old have been determined. The population censuses were determined, except for four ponds poisoned by rotenone, by draining ponds and counting, sorting, and weighing the fish. This insured relatively accurate data on the composition of each population. Various relationships within species, between species, and between groups of species in these populations were determined and compared with their ability to yield satisfactory annual crops of fish. The dynamics of certain interrelationships were determined by periodic determination of changes in selected populations over a period of several years and by experiments with various stocking procedures. It is believed that certain of these relationships will prove of value as standards for comparison of various fish populations.

BALANCED and UNBALANCED POPULATIONS

The interrelationships in fish populations are satisfactory if the populations yield, year after year, crops of harvestable fish that are satisfactory in amount when the basic fertilities of the bodies of water containing these populations are considered. Such populations are considered to be "balanced populations" and the species within such a population are "in balance."

In order to produce annual crops of harvestable fish, it is evident that the species within a balanced population must be able to reproduce periodically, usually at least annually, in order to replace the harvested individuals. Ability to reproduce within the environment, therefore, must be one criterion of a balanced population.

Due to high reproductive capacity of fishes, the ability to reproduce within a population usually results in greater numbers of individuals than can be grown to a desirable size for harvesting. To produce annual harvestable crops, the number of young fish must be controlled by predatory species *(22)*. Balance in populations, therefore, implies a combination of species, including at least one piscivorous (carnivorous) species.

Balance then denotes a condition within a population such that if 100 pounds of fish are harvested one year the correct numbers of replacements will be provided from the population so that a satisfactory poundage of fish of desirable size may be harvested in succeeding years. If the population provides too many replacements, these fish will not reach a satisfactory size for harvesting; conversely, if too few replacements are provided, the capacity of the body of water to produce will not be fully utilized and the harvestable poundage will seriously decline.

The delicacy of the balance involved may be illustrated by the results in a simple bluegill-bass combination. Where bluegills are stocked in a fertilized pond at the rate of 1,500 per acre, approximately 1,000 will survive to reach a harvestable size of 4 ounces within 1 year and will completely utilize the food available for large bluegills. Each pair of bluegills then produces an average of 5,000 young during the first summer. In successive years, 4-ounce bluegills can be caught only if the young fish are reduced by predation and natural deaths to approximately the number removed by fishing plus the number of old fish that die annually. In that case, if both the adult parents are lost from these combined causes, there is room in the pond for two replacements to grow to a 4-ounce size; the predatory fish and natural mortality must, therefore, remove 4,998 and leave 2 replacements in this family group. Actually, for various species in various aquatic environments and for different rates of harvest, from 1 to 5 or more years will be required for the reduction in numbers of a brood to the correct number of replacements for the adult fishes lost from these combined causes. This gives rise to the various "year classes" and "length-frequency" groups below the size of the harvestable fish in a population.

These smaller fishes have two primary functions in a population. They serve as food for the piscivorous species and furnish replacements for the adult stock. Consequently, from a functional standpoint, a species or a population may be said to be composed of three groups: the adult fish, or size satisfactory for harvesting; the intermediate fish or primary replacements that are too small for harvesting and too large to serve as food for the average-sized adults of the predatory species; and the small fish that are of such size that they may be eaten readily by the predatory species.

Considerable variations in total poundages harvestable occur normally in balanced populations from year to year due to the relative efficiencies with which populations supply the required numbers of replacements. Even greater variation may occur in the annual harvestable poundage of a single species in a balanced population of many species due to competition between species for a common food supply. This may cause a decrease in the total weight of one species corresponding to an increase in weight of a competing species. If this shift is to an unharvested or undesirable species, the total weight harvested from the population will show a corresponding decrease.

Unbalanced populations are those unable to produce succeeding annual crops of harvestable fish. This may be due to the inefficiency of the component species in such a combination — that is, their inability to provide sufficient replacement individuals to maintain satisfactory utilization of the potential food supply. It is more commonly due to overcrowding — the survival of so many individuals that none can grow to a size satisfactory for harvesting.

INTERRELATIONS BETWEEN GROUPS in BALANCED and UNBALANCED POPULATIONS

The separate compositions in numbers and weights of each species in 55 balanced *(Appendix Tables 1-B to 55-B)* and 34 unbalanced populations *(Appendix Tables 1-U to 34-U)* are given in the Appendix. Various relationships between species and groups of species and within species were computed for these populations in an attempt to discover those of most value in differentiating balanced and unbalanced populations and to evaluate the relative efficiencies of the various species and combinations. These various relationships, the methods for their computation, their significance, optimum values, ranges, and dynamics in balanced and unbalanced populations will be discussed in the following pages.

THE F/C RATIO

DEFINITION. This is the ratio of the total weight of all forage fishes to the total weight of all carnivorous (piscivorous) fishes in a population.

"F" AND "C" SPECIES. The carnivorous, or piscivorous, (C) species of fishes are defined as those that feed principally upon other and smaller fishes, and that cannot grow to normal average sizes of adults of those species without such food. All other fishes in a population are grouped together as forage (F) species. The "F" species feed largely upon plants, plankton, crustacea, and insects, but may occasionally eat small fish.

The largemouth black bass, *Micropterus salmoides* (Lacepede), is the principal "C" species used in pond-fish culture. Although this fish feeds to a certain extent throughout life upon insects, it seldom is able to reach a size in excess of 0.3 pound upon such a diet. To reach the normal adult size, small fish must be available for food. Even very small bass prefer the fish diet and are found feeding upon it whenever it is available. Consequently, all sizes of largemouth bass are grouped as "C" fishes.

The crappies, *Pomoxis annularis* Rafinesque, and *P. nigro-maculatus* (LeSueur), have been found in experiments to belong to either "C" or "F" groups, depending upon their sizes. Crappies up to 4 ounces in weight fed largely upon insects and competed directly with bluegills for food. They apparently, however, were unable to grow to a larger size without small fishes for food and those above 4 ounces in weight competed directly with largemouth bass. Consequently, the total weight of all crappie up to and including 4 ounces was included in the "F" group and the weight of all larger individuals in the "C" group.

All sizes of pickerel, *Esox niger* LeSueur; gar, *Lepisosteus osseus* Rafinesque; spotted bass, *Micropterus punctulatus* Rafinesque; and bowfin, *Amia calva* Linnaeus, are classed in the "C" group.

All sizes of bullheads *Ameiurus;* the channel catfish, *Ictalurus lacustris punctatus* (Walbaum), up to a size of 2 pounds; the blue cats, *I. furcatus* (Valenciennes), up to a size of 3 pounds; and the flathead cat, *Pilodictis olivaris* (Rafinesque), up to a size of 8 pounds were found in experiments to compete with bluegills and not with bass. Consequently they were all placed in the "F" group. It is quite possible that very large channels, blues, and flatheads may belong in the "C" group, but information is lacking to justify this shift in classification. It would appear improbable that a 30-pound flathead cat could support itself without resort in large measure to a fish diet. Due to its sluggish nature, it would also appear doubtful that it could capture many active fish. However, in unfished fish populations, up to 25 per cent or more of the fishes die yearly and it is possible that these dead or dying fishes form a considerable portion of the food for large flatheads and other large cats.

The principal other species in the "F" group present in natural and impounded waters reported in this investigation were bluegills, *Lepomis macrochirus* Rafinesque; stump knockers, *L. punctatus* Jordan; shellcrackers or red-ears, *L. microlophus* (Gunther); green sunfish, *L. cyanellus* Rafinesque; long-eared sunfish, *L. megalotis* Rafinesque; orange spotted sunfish, *L. humilis* (Girard); warmouth, *Chaenobryttus coronarius* (Bartram); yellow bullhead, *Ameiurus natalis* (LeSueur); speckled bullhead, *A. nebulosis marmoratus* (LeSueur); golden shiner, *Notemigonus crysoleucas* (Rafinesque); chub suckers, *Erimyzon sucetta* (Girard); gizzard shad, *Dorosoma cepedianum* (LeSueur); goldfish, *Carassius auratus* (Linnaeus); gambusia, *Gambusia affinis* (B. & G.); buffalo, *Ictiobus bubalus* (Rafinesque); spotted sucker, *Minytrema melanops* (Rafinesque); carp, *Cyprinus carpio* Linnaeus; and eel, *Anguilla bostoniensis* (LeSueur).

CALCULATION OF F/C RATIOS. To illustrate the calculation the following population is given:

		Pounds
43	large largemouth bass	53.9
68	small largemouth bass	2.8
41	large black crappie	12.6
4,196	intermediate black crappie	275.4
318	small black crappie	4.7
724	intermediate bluegills	57.8
13,860	small bluegills	219.0
	Total	626.2

The weight of "F" species, or the "F value," equals the weight of all bluegills plus the weight of small plus intermediate black crappie:

$$219.0 + 57.8 + 4.7 + 275.4 = 556.9 \text{ pounds;}$$

while the weight of "C" species, or the "C value," equals the weight of all bass plus the weight of all crappie weighing more than 4 ounces:

$$53.9 + 2.8 + 12.6 = 69.3 \text{ pounds.}$$

The F/C ratio in the above population was, therefore:

$$F/C = \frac{\text{F value}}{\text{C value}} = \frac{556.9}{69.3} = \frac{8.0}{1.0} = 8.0$$

It is quite obvious that this isolated F/C ratio is of little value until those in other known populations are available for comparison. Here it merely indicates that the predatory "C" species made up one-ninth of the total weight of the population.

The F/C ratios in the balanced and unbalanced populations given in the Appendix were computed in the manner indicated above, and their frequency distributions are given in Figure 1.

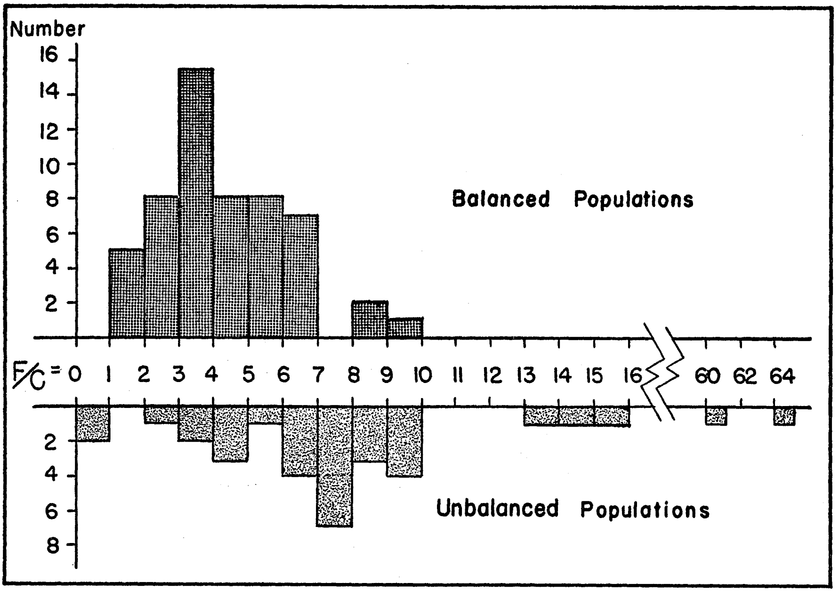

FIGURE 1. Frequency distribution of F/C ratios in balanced and unbalanced populations.

VALUES OF THE RATIO IN BALANCED AND UNBALANCED POPULATIONS. In the balanced populations, the range in F/C ratios was from 1.4 to 10.0, and 94.3 per cent were within the range of 1.4 to 6.8. In contrast to these rather tightly grouped F/C values, the corresponding range was from 0.06 to 65.1 in the unbalanced populations.

In the balanced populations, all F/C ratios were not equally desirable. Within the range 1.4 to 2.0, there occurred only populations in which bass were overcrowded, or from which no bass had been harvested over a period of 2 years, or in which a large golden shiner population had been largely eliminated by the "C" species during the summer preceding draining.

Within the range F/C = 2.0 to 3.0, approximately 50 per cent of the populations were somewhat overcrowded by the "C" species. In this range also was found a population (Table 44-B) where following 8 years of fertilization no fertilizer was applied for 1 year prior to draining. As is usual in such cases, reduction in fertility reduced production of the "F" species more rapidly than it affected the "C" species. Reduction in food prevented the movement from the group of small fishes into the intermediate group and the movement of the intermediates into the group of large fishes, thus subjecting them to predation for a longer than normal period of time. This combined with the harvesting of adult "F" species has tended to produce low F/C ratios in fish populations when fertilization has been discontinued.

The F/C ratios from 3.0 to 6.0 appear to be the most desirable in the balanced range, and 77 per cent of the best producing populations fell within this group. However, 66 per cent of the poorest of the balanced ponds also was in the same range. It is, therefore, apparent that other relationships within a population, in addition to the F/C ratio, must be known in order to adequately describe the capacity of a population to produce yearly crops of harvestable fish.

It is also evident in Figure 1 that the F/C ratios for balanced and unbalanced ponds overlapped to a considerable extent. However, in the range from F/C = 0.06 to 2.7, all unbalanced populations (Tables 12-U, 17-U, and 21-U) were unbalanced because the F species (green sunfish or shellcrackers) were disappearing under bass predation. Also, all populations with F/C ratios in excess of 10 were unbalanced. There was, in addition, a noticeable difference in the modes of the two types of populations; in balanced populations ratios between F/C = 3 to 4 occurred most frequently, while in unbalanced populations the peak occurred in the interval F/C = 7 to 8.

It would appear, therefore, that, in fish populations capable of producing yearly crops of harvestable fish, there is a relatively narrow range in the ratio of the weight of F species to the weight of C species. In effect, the weight of F species present would appear to be a function primarily of the fertility of the body of water in which it exists; the weight of C species, within limits, is apparently dependent in turn upon the weight of the "F" species upon which it is dependent for food.

Values between F/C = 1 to 3 apparently indicated, in general, populations somewhat overcrowded with "C" species. This is an undesirable condition because overcrowded C species eventually result in reduced total production, as indicated by the following results of three experiments on rates of stocking bass (Table 1).

TABLE 1. EFFECT OF RATES OF STOCKING LARGEMOUTH BASS ON FISH PRODUCTION

Rates of stocking per acre		1-year experiment		2-year experiments	
Bluegill fingerlings	Bass	Total lb. fish per acre	F/C	Total lb. fish per acre	F/C
1,500	100 Fry	383.2	12.8	386.0	10.0
1,500	150 Fry	371.6	8.8	303.4	6.2
1,500	200 Fry	394.4	5.8	216.2	2.2
1,500	100 Fingerlings			350.0	5.5
1,500	200 Fingerlings			224.2	3.2
1,500	400 Fingerlings			207.0	2.5

These experiments indicate no reduced production at the end of 1 year, but there was a sharp decline in total production and low F/C values resulted during the second year with increased rates of stocking bass. Apparently overcrowded bass allowed the survival of insufficient bluegills to replace the adults lost by natural mortality, and as a result there were insufficient individuals to utilize the food efficiently.

STABILITY OF RATIOS. The F/C ratio gives considerable information concerning a population. The problem then arises as to whether it is a fluctuating or a relatively stable value for a particular population over a period of years. In order to answer this question, a 1.3-acre pond was stocked with 1,500 bluegill fingerlings + 100 bass fingerlings + 4 white crappie fingerlings per acre. After 1 year, the pond was drained and the F/C ratio determined. All fish were returned to the water and the pond was fished the subsequent season for both bluegills and bass. At the end of the next year, the pond was again drained, the F/C ratio determined, and the fish returned to the pond. It was again fished and at the end of the third year it was drained and the experiment terminated. The results were as follows:

Age of population years	*F/C Ratios in catch*	*F/C ratios in population on draining in December*
First	—	5.1
Second	2.0	4.6
Third	5.7	4.7

Since it appeared possible that draining annually may have upset the natural balance and resulted in abnormal values, it was decided to restock the same pond with 1,500 bluegill fingerlings + 100 bass fingerlings, fish annually for 4 years, and then drain and determine the F/C value of the population. These results were as follows.

Age of population years	*F/C Ratios in catch*	*F/C Ratio in population on draining in December*
First	2.8	—
Second	2.9	—
Third	3.2	—
Fourth	1.8	4.4

It is apparent that in these experiments, where the fertility remained relatively constant due to uniform fertilization and the cover remained constant, the F/C ratios in the populations remained relatively constant in spite of great variations in the ratios between harvested F and C species. It must be remembered that the F/C ratio is a ratio between weights and not between numbers of fishes. With the harvest of 10 pounds of F or C species, food is released that enables the remaining individuals in these groups to increase their total weight by a similar poundage. It would appear necessary for the ratio to change immediately following a heavy withdrawal from the population, but indications are that it will tend to approach closely the original value within an indefinite subsequent period.

Insufficient experiments are available to determine the effect of time, cover, relative areas of shallow and deep waters, and other possible factors upon the F/C ratios in fish populations.

The effect of age of a population upon the F/C ratio is especially worthy of further investigation. In numerous experiments, it was found that populations seldom reached a relatively stable F/C ratio until the "C" species had been in the pond for approximately 1 year and had reproduced. Possibly further changes with age may occur under certain conditions. One pond, stocked with 1,500 bluegills + 100 bass per acre, had a F/C ratio = 4.5 at the end of 6 years. In ponds with unknown rates of stocking, one had a F/C ratio = 3.2 when 9 years old; one a F/C ratio = 2.2 when 13 years old; one a F/C ratio = 5.1 when 25 years old; one a F/C ratio = 2.7 when 25 years old; and another, a F/C ratio = 2.2 when 30 years old. The majority of these older ponds, therefore, had low F/C ratios in the range where populations are inefficient and had been drained or poisoned because they were giving unsatisfactory fishing. If there were a shift with age of balanced populations toward a F/C ratio of 2.0 or lower, this might in part explain the decrease in catch correlated with increase in age of many inpoundments that contain only desirable sport fishes. However, the low F/C values reported for these old ponds may be the result of the unknown methods of stocking or other factors and not the result of age.

Meehean *(12)* reported ratios of "predators to supporting population" in poisoned Florida lakes to range from 2.27 to 3.16. This would appear at first glance to indicate F/C ratios of low values. However, turtles were included in the "predator population," while the F/C ratio is confined to the weights of various species of fishes. The calculated F/C ratios for these fish populations were 4.0, 5.8, 6.0, 3.3, and 6.4. His results, therefore, do not show low F/C ratios in old populations. The computed F/C ratio of the fish population in Michigan's Third Sister Lake reported by Brown and Ball *(3)* was 5.3, also a relatively high value.

The presence or absence of heavy cover, and the relative areas of extremely shallow water influence the efficiency of predation and may be expected to influence the F/C ratios in various bodies of water. No information regarding these problems is available.

USES OF F/C RATIO. A knowledge of the distribution of F/C ratios for entire populations under various conditions of balance and unbalance provides standards for comparison and analysis of samples from various other populations. Since this adds to the understanding of the condition of a population, it should also aid in the determination of correct management practices. Conditions in populations indicated by various F/C ratios are summarized in Figure 2.

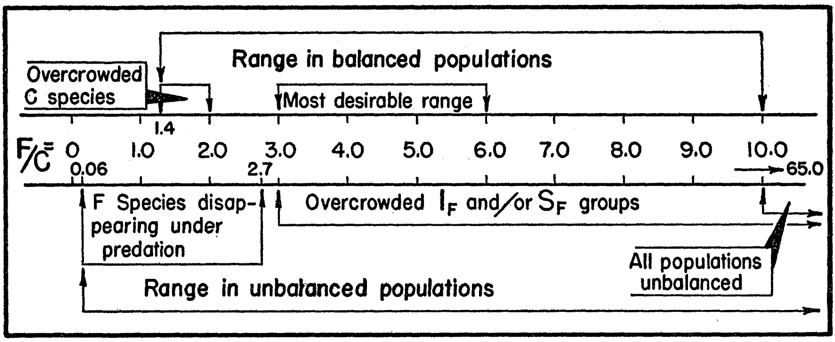

FIGURE 2. Conditions in populations indicated by F/C ratios.

Use of the F/C ratio for determination of methods for stocking new waters has been suggested previously *(22)*. Because of the lack of sufficient information, a F/C ratio of 2 was arbitrarily accepted and only 50 per cent of the calculated number of bass was used in stocking. Additional information in this report allows the use of more accurate F/C values, and information from other experiments on annual mortality of bass allows a more accurate estimate of the rate of stocking of new waters for production of balanced populations where the approximate carrying capacity in pounds of fish per acre is known. Where this is not known, it can be determined by poisoning and weighing established populations or by stocking new waters with 1,000 or more bluegills only per acre and determining the total production per acre at the end of one year.

If it is found that ponds in a certain area will support 100 pounds of bluegills or similar fish per acre, the number of bluegills and bass required for stocking may be figured as follows:

A F/C ratio = 4 is in the desirable range. If this ratio is achieved, the weight of bluegills in a balanced bluegill-bass population in the above pond after 1 year will be:

$$4/5 \times 100 = 80 \text{ pounds}$$

Since bluegills will reach a size of 4 ounces in one year, the number required for stocking to give the above weight one year later is:

$$80 \times 4 = 320 \text{ bluegills}$$

Actually, only 75 per cent of the bluegills used in stocking, will, on the average, be alive one year later. No correction for this mortality is necessary in the case of bluegills, because they will spawn during the first summer and the loss due to mortality is replaced by the weight of young fish. Similarly, the weight of largemouth bass in the above population after 1 year will be:

$$1/5 \times 100 = 20 \text{ pounds}$$

Since largemouth bass will reach a size of 1 pound in one year, the number of calculated bass required is:

$$20 \times 1 = 20 \text{ bass}$$

However, it has been found that on an average only 70 per cent of the bass used in stocking will be alive one year later, and no young will be produced normally until the second summer. Consequently, it is necessary to stock such a number that 20 bass may be expected to be alive when the pond is one year old, or:

$$70\% = 20 \text{ bass}$$

$$100\% = \frac{100}{70} \times 20 = 29$$ advanced fry or fingerling bass should be added.

If the pond will support 400 pounds of fish per acre, the number of bluegill fingerlings desirable for stocking to achieve a F/C ratio = 4 will be:

$$4/5 \times 400 = 320 \text{ pounds}$$

$$320 \times 4 = 1{,}280 \text{ bluegill fingerlings}$$

The number of bass will be:

$$1/5 \times 400 = 80 \text{ pounds of bass or 80 1-pound bass}$$

$$70\% = 80 \text{ bass}$$

$$100\% = \frac{100}{70} \times 80 = 114 \text{ advanced fry or fingerlings.}$$

If the above numbers of each species are used, balanced populations will usually result, barring excessive mortality among the stocked fish.

The Y/C Ratio

Definition. The Y/C ratio equals the Y value, or the total weight in pounds of all those individuals in the "F" group that are small enough to be eaten by the average-sized adult in the "C" group, divided by the C value, or total weight in pounds of the "C" group. In other words, it is the pounds of small fish of the "F" species available as food for each pound of "C" species in a population.

Calculation of Y/C Ratios. For the populations given in the Appendix, each "F" species was divided into groups of small, intermediate, and large fishes at the time the population was being sorted and weighed. The group of "small" fish included all small fish of a species up to the maximum size that could be swallowed readily by the average-sized "C" fishes in the "large" groups. The Y/C ratio then equaled:

$$\frac{\text{Y Value}}{\text{C Value}} = \frac{\text{Total pounds of all "small" fishes in the "F" group}}{\text{Total pounds of "C" species}}$$

In a population with the following composition:

		Pounds
43	large largemouth bass	53.9
68	small largemouth bass	2.8
41	large black crappie	12.6
4,196	intermediate black crappie	275.4
318	small black crappie	4.7
724	intermediate bluegills	57.8
13,860	small bluegills	219.0
	Total	626.2

Y = 4.7 pounds small black crappie + 219.0 pounds small bluegills = 223.7 pounds

C = 53.9 pounds large bass + 2.8 pounds small bass + 12.6 pounds large crappie = 69.3 pounds

$$\text{Therefore, } Y/C = \frac{223.7}{69.3} = 3.2$$

REASONS FOR ITS CALCULATION. It has been shown that there is a relationship between total weights of forage and carnivorous species in a population. However, only that portion of the total "F" weight that exists in small enough units to be gulped by the "C" species is actually available as food for the latter. It would appear that the Y/C ratio should express the condition within a population affecting the growth of the "C" species and might be useful as a measure of balance. At least, a knowledge of its limits in balanced and unbalanced populations should add to an understanding of population composition and dynamics. Unfortunately, the Y/C ratio could only be determined as a static value – true for the population at the time at which draining or poisoning occurred.

Y/C RATIOS IN BALANCED AND UNBALANCED POPULATIONS. The Y/C ratios for the populations given in the Appendix were calculated; their frequencies of occurence in balanced and unbalanced populations are shown in Figue 3.

The range of these values was relatively narrow in balanced populations – from 0.02 to 4.8. Within the range 0.02 to 0.5, all populations were so severely overcrowded with "C" species that they probably should be considered "temporarily balanced" because the bass were unable to gain weight and in fact will lose weight, while insufficient numbers of bluegills were surviving to adequately utilize available food. Consequently, populations with these values were inefficient.

In the range 0.5 to 0.9, the "C" species apparently lacked sufficient food for good growth. The most desirable range appeared to be 1.0 to 3.0. Above 3.0, the small fishes apparently reduced the average sizes of the large forage fishes.

All populations with Y/C ratios in excess of 4.8 were unbalanced and were incapable of producing yearly crops of harvestable fish. These populations were composed largely of overcrowded forage fishes.

It will be noted also that some unbalanced populations had Y/C ratios overlapping in range with those in balanced populations. In the range 0.06 to 3.0, occurred populations unbalanced because the "F" species (green sunfish, Tables 12-U and 21-U, or shellcrackers,

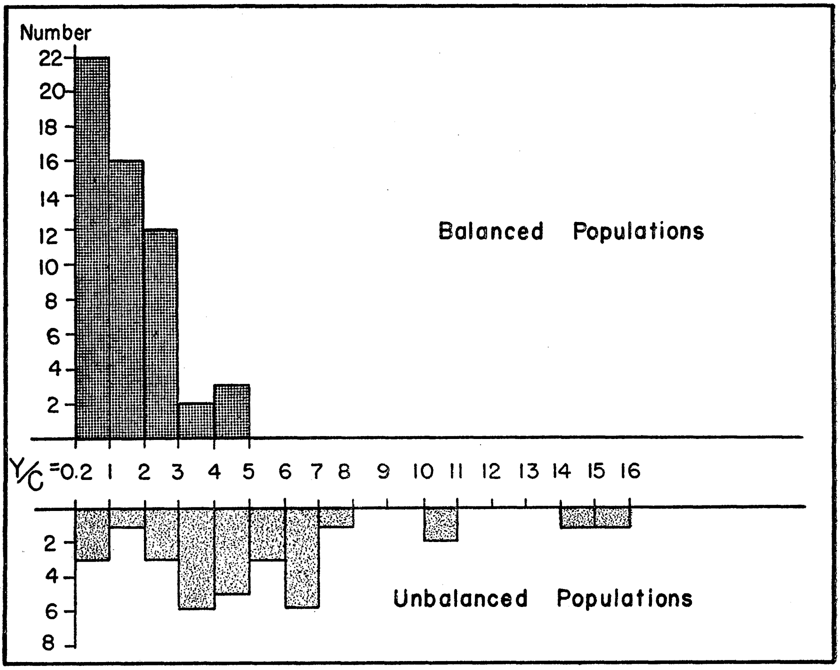

FIGURE 3. Frequency distribution of Y/C ratios in balanced and unbalanced populations.

Table 17-U) were disappearing under predation, or those unbalanced because of the accumulation of large weights of stunted fishes in the "intermediate" groups as a result of insufficient predation.

Uses of Ratio. In the range of Y/C ratios above 5.0, the Y/C ratio alone is sufficient to indicate the extent of unbalance. However, in the lower ranges it is apparent that other factors in addition to the Y/C ratios must be known in order to differentiate balanced from unbalanced populations. However, the Y/C ratio is very useful in determining the desirability of the balance within a population and in indicating future trends in species interrelationships.

This ratio emphasizes the importance of small fishes in those populations that are capable of producing yearly crops of harvestable fish. In populations censused by poisoning, too little attention has been given to their recovery or their estimation. An estimate of their abundance and the calculation of the Y/C ratio gives information of great value concerning a population. The conditions in populations indicated by various Y/C ratios is summarized in Figure 4.

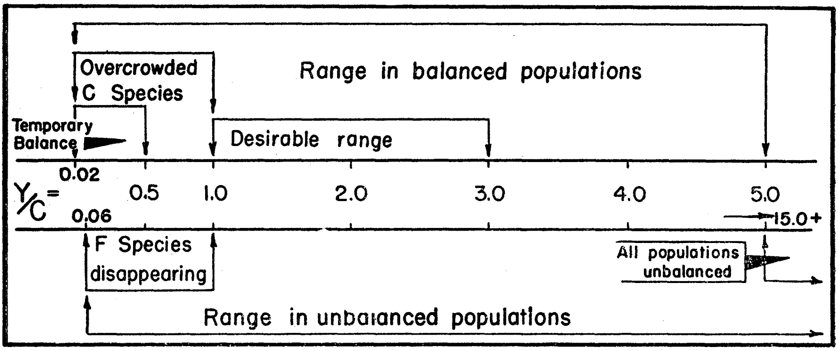

FIGURE 4. Conditions in populations indicated by Y/C ratios.

STABILITY OF Y/C RATIOS. As has been indicated, the Y/C ratio is an expression of a condition in a population at the time of censusing. The various populations reported in this bulletin were censused in June, July, August, September, October, November, December, or January, the great majority being in the period of September to December. No difference in Y/C ratios appeared correlated to the time at which these records were obtained. However, it would appear that the values for this ratio should be least in the spring just prior to spawning of the "F" species, and should increase subsequent to this period. The ratio also should be affected to some extent by day to day predation and by the rates of harvest of adult fishes. However, since the ratio is a weight ratio, it does not fluctuate as greatly as might be expected.

In some populations it was found possible to determine the Y/C ratios each year for 2 to 3 years by draining the ponds and returning the entire population upon refilling. In one pond where no "C" species were removed over a 3-year period, the successive annual Y/C values were 6.9, 3.1, and 1.1. In another pond, where no "C" species were removed for 2 years, the Y/C ratios at the end of each year were 3.5 and 1.9; and, in a similar pond under the same conditions, the Y/C ratio dropped from 1.6 at the end of the first year to 0.7 at the end of the second. In another pond where very light fishing occurred for 2 years with resulting Y/C ratios of 0.8 and 0.6 at the end of each year, heavy fishing the third year for both "F" and "C" species resulted in an increase by the end of that year to Y/C = 2.0 – a much healthier condition in the population.

It is evident, therefore, that the Y/C ratio is a dynamic value – changing with changes in predation pressure and varying rates of harvest, yet remaining within a rather narrow range in balanced populations. Since it is a constant within limits, each rise in pounds of small fishes must be accompanied by a subsequent corresponding rise in pounds of "C" species or the population is not balanced.

As the degrees of success of many natural waters and large impoundments are judged solely by their ability to produce "C" species, the Y/C value and the factors affecting the value of Y are of utmost importance in management. The latter will be discussed further in a subsequent section.

THE A_T VALUE

DEFINITION. The A_T value (total availability value) is the percentage of the total weight of a fish population composed of fish of harvestable size.

HARVESTABLE SIZE. In order to calculate the available yield from a population, it is necessary to set standards of the minimum sizes suitable for harvest. For certain fishes in certain areas, these sizes are set by law. However, they vary from place to place and from year to year and are usually given as length limits that are unusable for population studies. Consequently, minimum weights for harvestable fishes of the species used in these studies were adopted as follows:

	Pounds
Bluegills, shellcrackers and similar sunfishes	0.1
Crappies	0.26
Largemouth bass	0.4
Bullheads	0.3
Gizzard shad	0.5
Channel cats	0.5
Gar	1.0
Buffalo	1.0
Carp	1.0

The above figures are admittedly arbitrary, but some line of separation was necessary, and they were adopted in this study because, in fishing experiments where no size limits were placed on the catch, they were found to be the smallest sizes that the public would utilize. All fishes of the above sizes or larger were grouped under "large fish" in the populations given in the Appendix. It will be noted that such species as the gar and shad, which are normally not harvested, are included. If they were produced by the population and were available for use, they were included in the A_T value. In order to differentiate used and unused portions of the population available for harvest, it is suggested that:

A_T^H represent that portion of the A_T value composed of species that are normally harvested, and

A_T^N represent the portion composed of unharvested species, and consequently,

$$A_T = A_T^H + A_T^N$$

From the standpoint of population studies, this would appear much more logical than separation of the population into artificial groups, such as game fish, pan fish, food fish, and rough fish. Large groups of unharvested adult fishes, regardless of whether they are bluegills or gizzard shad or another species, have a depressing effect upon the "C" groups in a population, which could be dissipated if harvesting were practiced.

CALCULATION OF A_T VALUES. In one experiment, a pond was stocked with 140 gizzard shad, 1,500 bluegill fingerlings, and 100 bass advanced fry per acre. Two years later, the pond was drained and the following fishes recovered per acre:

		Pounds
356	large bluegills	56.4
19,546	small bluegills	248.4
92	large gizzard shad	81.2
8,124	intermediate gizzard shad	677.2
0	small gizzard shad	0.0
8	large largemouth bass	16.4
0	small largemouth bass	0.0
	Total	1,079.6

The total weight of large fish is 56.4 pounds large bluegills + 81.2 pounds gizzerd shad + 16.4 pounds bass = 154.0 pounds. The A_T value is then:

$$A_T = \frac{154.0}{1079.6} \times 100 = 14.2$$

If it is wished to subdivide this value:

$$A_T^H = \frac{54.4 \text{ lbs. (large bluegills)} + 16.4 \text{ lbs. (large bass)}}{1079.6} \times 100 = 6.7$$

$$\text{and } A_T^N = \frac{81.2 \text{ pounds (large shad)}}{1079.6} \times 100 = 7.5$$

$$\text{and } A_T = A_T^H + A_T^N = 6.7 + 7.5 = 14.2$$

In order to interpret these values, it is necessary to know the distribution of A_T values in balanced and unbalanced populations.

A_T VALUES IN BALANCED AND UNBALANCED POPULATIONS. Frequency distributions of A_T values in the various populations studied are shown graphically in Figure 5. The range of values for balanced populations

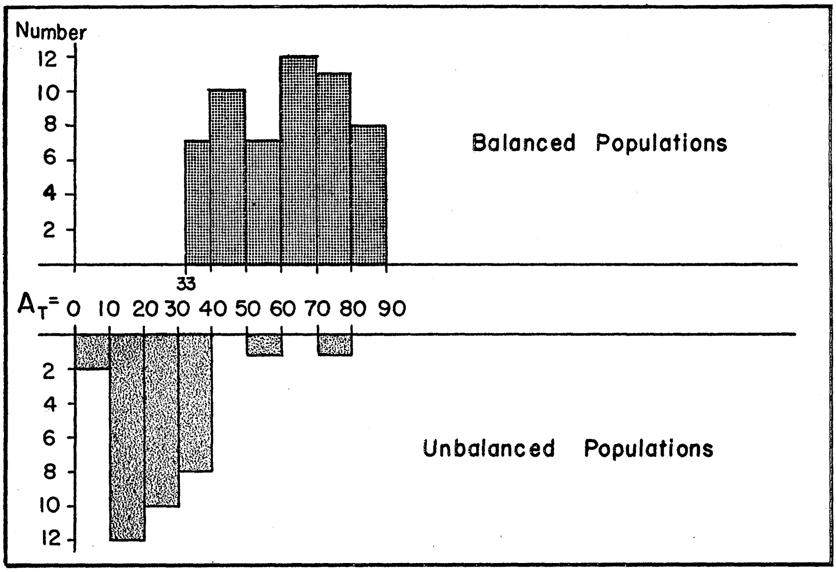

FIGURE 5. Frequency distribution of A_T values in balanced and unbalanced populations.

was 33 to 90, while in unbalanced populations it was 0 to 40, except for two cases. These two cases were populations 2 years old containing two species—largemouth bass and green sunfish (Tables 12-U and 21-U). The latter species proved unable to maintain itself under bass predation and had practically disappeared from the populations. The A_T values of 58.4 and 72.7 for these populations were temporary values that could not be maintained over a longer period of time. This condition could not occur in older established populations and would seldom be encountered in fisheries investigations.

The A_T values of balanced and unbalanced populations overlapped in the range from 33 to 40. The unbalanced populations in this range bordered upon balance and the balanced populations bordered upon unbalance. Outside of this narrow overlapping range, the A_T values alone appeared to differentiate fairly definitely balanced and unbalanced populations.

Within the range of balanced populations, the most desirable portion of the range appeared to be between 60 and 85. Populations with A_T values above 85 had too few intermediates for replacements and too few small fishes to furnish adequate food for the "C" species; in other words, this was the range containing populations having overcrowded "C" fishes. Even in the range from 80 to 85, growth of the "C" groups was unsatisfactory due to slight overcrowding.

In the range from 33 to 40, the "C" groups in balanced populations grew at a rapid rate, but the populations were less efficient in that relatively large percentages of their weights were of small and intermediate fishes.

STABILITY OF A_T VALUES. During the process of harvesting large fish in a population, the A_T value must necessarily decrease and in a balanced population it must subsequently increase in order to provide a harvestable crop for the following year. The rapidity and extent of this replacement is a measure of the satisfactory nature of the balance in the population.

While the A_T values fluctuate, these results indicate that they must fluctuate within the limits of 33 to 90 if the pond is to remain in balance. Normally, the processes of depletion by harvest and replacement by growth are going on concurrently, and fluctuation in the A_T values does not reach these extremes. In one experiment where the crop was removed in approximately equal weekly amounts for a period of 1 year, the results were as follows:

	December 1939 initial population	*Removed by fishing 1940*	*December 1940 remaining population*
Total weight (pounds)	616.4	339.5	369.6
A_T value	81.7	———	88.9

With a slow rate of harvest, the A_T value remained relatively constant and the depletion was in the total weight of the population.

In other experiments, the application of heavy fishing pressure removed 70 per cent of the harvestable crop within 2 weeks, with a correspondingly rapid decline in A_T value. However, hook-and-line fishing alone has not reduced the A_T value in any experiment below the 40 per cent required for good balance in a population. On the other hand, where the crops were removed in part by seining and the A_T values were reduced to 23.6 and to 20.7 in two ponds (Tables 10-U and 11-U), both populations became unbalanced and no fish of harvestable size could be caught the following year.

USES OF A_T VALUE. This value is the most useful indicator of balance and is a measure of the efficiency of a population in production of harvestable fish. The conditions in populations indicated by various A_T values are summarized in Figure 6. As has been indicated, these should be of value in the study of the effect of rates of harvest upon a population.

The range of this value in balanced populations also limits the methods that may be used in stocking new waters to obtain balanced populations. It is obvious that, if balanced populations are to be

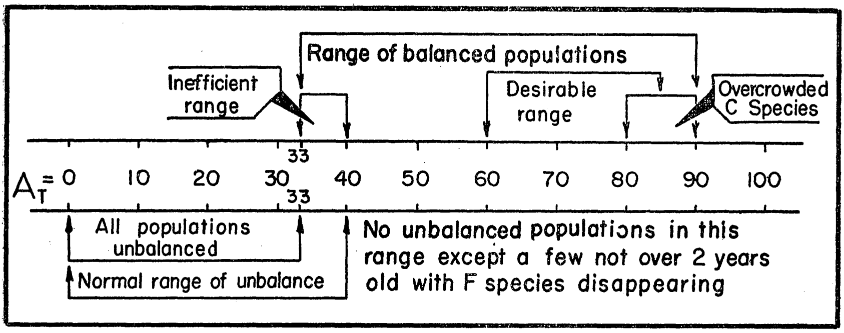

FIGURE 6. Conditions in fish populations indicated by various A_T values.

expected within a minimum period, enough fish must be stocked so that 1 year later their weight will make up more than 33 per cent of the total weight of the population.

For instance, if a body of impounded water is capable of producing 400 pounds of fish and is stocked with only 100 bass fingerlings plus 100 bluegill fingerlings, the following population may be expected 1 year later:

70% survival of 100 stocked bass........70 bass
75% survival of 100 stocked bluegills........75 bluegills.

The population composition at the age of 1 year would be:

	Pounds
70 large bass	70
75 large bluegills	25
Total small and intermediate fishes	305
Total	400

In this population, the A_T value would be:

$$\frac{70 + 25}{400} \times 100 = 23.8$$

The result is, therefore, an unbalanced population at the end of 1 year. It can come into balance only if the bass are able to reproduce during the second summer, and no large fishes are removed until their combined weight exceeds 132 pounds. If bass were unable to reproduce because of the overcrowded small bluegills *(23)*, the population would probably never come into a balance because natural mortality of the large bass during the second summer might prevent attainment of an A_T value in the balanced range.

The *minimum* rate of stocking with bluegills + bass to achieve the minimum desirable $A_T = 40$, could be calculated as follows:

$$400 \times 40\% = 160 \text{ pounds of large fish in population.}$$

Stocking 100 bass yields 70 pounds of large bass (70% survival), as calculated, and,

$$160 - 70 = 90 \text{ pounds of large bluegills in population.}$$

Since bluegills may be expected to grow to 4 ounces in the first year,

$$90 \times 4 = 360 \text{ large bluegills in population 1 year after stocking.}$$

Since the average mortality among the stocked bluegills is approximately 25%, the number to be used in stocking would be:

$$\frac{100}{75} \times 360 = 480 \text{ bluegill fingerlings}$$

Similarly, if a more desirable $A_T = 70$ is wanted, the calculated rate of stocking that may be expected on the average to achieve this condition would be 100 bass plus 1,120 bluegills.

It will be noted that in these calculations, the number of bass was kept constant. This was done because experiments have shown that approximately 100 bass per acre is the maximum number that will reach approximately a 1-pound average size in 1 year. It should also be noted that the A_T value relates methods of stocking to total productivity; consequently, the number of fish necessary in stocking to achieve balance is dependent upon the fertility of the water to be stocked.

E Values

Definition. The E value of a species or group is the percentage of weight of the entire population composed of that species or group.

Reasons for Calculation. The ability of various species of fish to maintain their abundance in populations under the pressures of predation, cropping, and competition with other species determines largely their relative importance as food or game fishes. This ability will be called the survival efficiency or E value of a species for convenience of discussion. It is affected by such factors as reproductive habits, reproductive capacity, food habits, adult size, rapidity of growth, and adaptation to various environments. Since each species within a population is in a sense a competitor with the others, the percentages of total weight of the population due to each species should be a measure of its relative survival efficiency under those environmental conditions. Many authors including Tarzwell *(24)*, Bennett *(3)*, and Ball *(1)* have reported results of population studies in this form.

It must be remembered that survival efficiency or E value of a species is of importance only if a large percentage of the individuals that survive reach a desirable size year after year and thus produce a harvestable annual crop. This condition can occur only in balanced populations. Consequently, the E values of species is of interest principally in various balanced combinations of species.

E VALUES IN BALANCED POPULATIONS. For simple populations composed of only 1 "F" species and 1 "C" species (e.g. bluegills and largemouth bass), the range of E values for the two species can be calculated from the range of F/C ratios in balanced populations (Figure 2), as follows:

$$F/C = 1.4 = \frac{1.4}{1}$$

$$E_{\textit{Largemouth bass}} = \frac{1}{2.4} \times 100 = 41.6$$

Similarly in the upper range of $F/C = 10 = \frac{10}{1}$,

$$E_{\textit{Largemouth bass}} = 9.1$$

Therefore, the range in E values for this species in balanced populations is from 9.1 to 41.6 per cent of the population. Similarly it can be calculated that the desirable range is between 14 and 25 per cent. The averages in 26 balanced populations composed of only bluegills plus largemouth bass were:

$$E_{\textit{Largemouth}} = 22.8$$
$$E_{\textit{Bluegills}} = 77.2$$
$$\text{Total} = 100.0$$

The E values for various species in balanced populations are given in Appendix Tables 1, 2, and 3.

USES OF E VALUE. If additional "F" species are added to this simple combination, the $E_{\textit{Bluegill}}$ value should decrease and the addition of other C species should reduce the $E_{\textit{Largemouth}}$ value. Due to the range for E_F and E_C in balanced populations, the effect of additional species can be determined only in rigidly controlled experiments or from the averages of many populations. The E values, therefore, are significant only when the combination of species in which they occur and the condition of the population, whether balanced or unbalanced, are given. For instance, in a balanced population containing bluegills, largemouth bass, and white crappie, $E_{Largemouth} = 6.1$ gives considerable information. It is evident that if this is a balanced population, the E value for this species was low because of competition with another "C" species, the white crappie. In this population, $E_{White\ crappie} = 5.8$ substantiated the statement that these two species were competitors, (Table 37-B).

Consistently low E values for a species in various combinations of species would indicate that the species was of relatively little importance from the standpoint of sport fishing or commercial fishing.

RELATIONSHIPS WITHIN SPECIES

The relationships discussed thus far have been between the various groups and species within the population. This has yielded information under conditions of balance and unbalance on the relationships between "F" and "C" groups of species, between the weights of the large fishes and the entire populations, between total weights of "C" groups and the small fishes upon which they feed, and also on the relative efficiencies of species in various combinations.

A study of relationships between various groups within each species is also necessary to more fully understand the dynamics involved in balanced populations. The conventional methods used in the study of a species include the division of the individuals into various age or length-frequency groups and the determination of their length-weight relationships and coefficients of condition *(9, 8, 26)*. While such studies yield information of value, they in reality are an attempt to study growth and abundance of a species as though it were an isolated group and not a part of a dynamic population. Consequently, these methods were considered of little value for the present studies and the division into groups within a species was based upon their function within the population.

A, I, and S Values

The division in this work of a species into three groups — large, intermediate, and small — has already been discussed and each group has been defined under previous sections. Briefly, the "large" fish are those of suitable size for harvest, and minimum sizes for this group are given under the discussion of the A_T value. The "intermediates" are those between the sizes in the "large" and "small" groups.

The "small" fishes are those that are sufficiently small to be eaten readily by the average-size "C" fishes in the "large" group. This, then divides a species into functional groups – those ready for harvest, the primary replacements, and those available to the "C" group as food.

The sizes to be placed in the "small" group were determined for each species in a population by arbitrary selection of the largest forage fish that the average-size adult "C" fishes in that population could easily gulp. This size was then used as the dividing line between "small" and "intermediate" fish. The length frequencies were determined for each group in some of the populations. However, after consideration it was decided that length measurements among these groups were worthless. Since the "C" species can eat only sizes that they are able to gulp and swallow, the maximum depth or girth of "F" species would appear to be the only dimension of importance to the fishes in a population. Unfortunately, this conclusion was reached too late for such measurements and correlation with the requirements of "C" species of various sizes to be made for the populations studied.

The numbers of fish and weights in each group of the various species are reported in the appendix tables. In order to facilitate comparisons, the relative weights of each group are expressed as the A, I, and S values of a species.

DEFINITION. A_S is the percentage of total weight of a species composed of fish in the "large" group.

I_S is the percentage of total weight of a species composed of fish in the "intermediate" group.

S_S is the percentage of total weight of a species composed of fish in the "small" group.

METHOD OF CALCULATION. The following population is given:

	Pounds
392 large bluegills	68.4
151 intermediate bluegills	10.3
81 small bluegills	1.6
53 large largemouth bass	36.1
225 small largemouth bass	20.6
Total	137.0

In order to determine the A, I, and S values for bluegills, the total weight of bluegills is first determined:

68.4 + 10.3 + 1.6 = 80.3 pounds. Then,

$$A_{Bluegill} = \frac{68.4}{80.3} \times 100 = 85.2$$

$$I_{Bluegill} = \frac{10.3}{80.3} \times 100 = 12.8$$

$$S_{Bluegill} = \frac{1.6}{80.3} \times 100 = 2.0$$

$$A + I + S = 100.0$$

Distribution of A, I, and S Values for Bluegill in a Bluegill-Bass Combination. In order to determine the significance of these values in a population, their ranges, averages, frequency distributions, and interactions will be considered in a simple population containing one "C" (largemouth bass) and one "F" (bluegill) species. To facilitate the discussion, these values for bluegills will be designated A_B, I_B, and S_B.

Frequency distributions of A_B values for balanced and unbalanced populations are shown graphically in Figure 7. The range was from

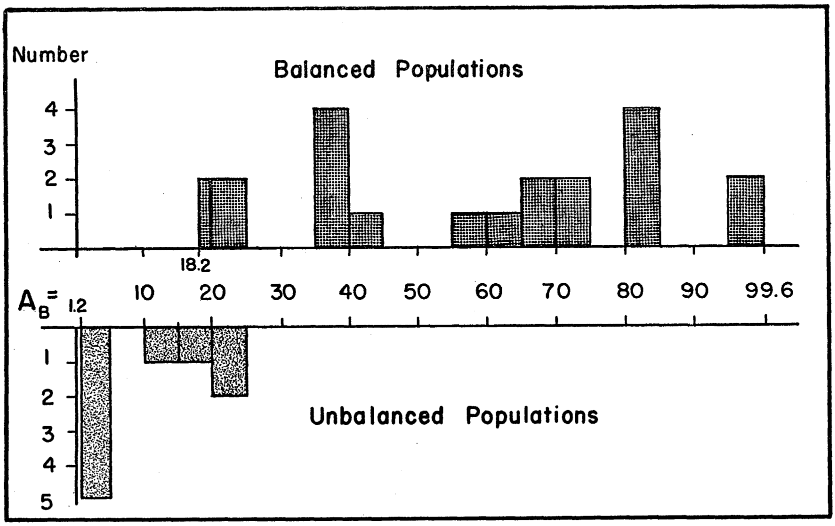

FIGURE 7. Distribution of A_B values in balanced and unbalanced populations composed only of bluegills and largemouth bass.

18.2 to 99.6 in balanced populations, with an average of A_B = 58.9. The unbalanced range was from 1.2 to 25.7, with an average of A_B = 10.6. Within the balanced range, A_B values below 35 were found only in populations verging on unbalance and values above 85 occurred only in populations overcrowded with the "C" species. The most desirable part of the range was from 60 to 80 and the minimum A_B value in a satisfactory population was 35.5. It is probable, therefore, that A_B = 35 represents approximately the maximum allowable depletion of the stock of large fish of the "F" group if satisfactory balance and consequently satisfactory production is to be maintained in a population.

Frequency distributions of I_B values for balanced and unbalanced populations are shown in Figure 8. It will be noted that the range and frequency distributions were approximately the same in both groups. In the balanced group, the range was 0 to 20.2 with an average of I_B = 6.6. In the unbalanced group, the range was 0 to 13.2, with an average of I_B = 5.4. It is apparent that the intermediate group of the "F" species normally made up less than 7 per cent of the total weight.

Frequency distributions of the S_B values in balanced and unbalanced populations are shown in Figure 9. The range in balanced populations was 0.4 to 80.9, with an average of S_B = 34.5. The range in the unbalanced group was 64.4 to 95.5, with an average of S_B = 84.2.

While the two ranges overlap, it is apparent that S_B values of 81 or higher indicate unbalance. Within the balanced range, populations with S_B values in excess of 60 were relatively unsatisfactory. Those with values less than 10 were overcrowded with the C species and the most desirable range was between 15 and 40.

A, I, AND S VALUES FOR COMBINED F SPECIES. These values represent the respective percentages of total weights of the "F" species composed of large, intermediate, and small fishes. They will be designated by A_F, I_F, and S_F for convenience in discussion. An examination of all populations showed that where the population contained more that one "F" species, the A_F, I_F, and S_F values correspond almost exactly in range, distribution, and significance with the A_B, I_B, and S_B values in the simple bluegill-bass population previously discussed above and shown in Figures 7, 8, and 9.

The summarized information on conditions in populations indicated by A_F values given in Figure 10 is based on the results from all populations. No summarization is given for the I_F values, since the values in balanced (0.0 to 41.4) and unbalanced groups (0.0 to 100.0) overlap to such an extent as to render them relatively useless. Information on the conditions indicated by S_F values is given in Figure 11.

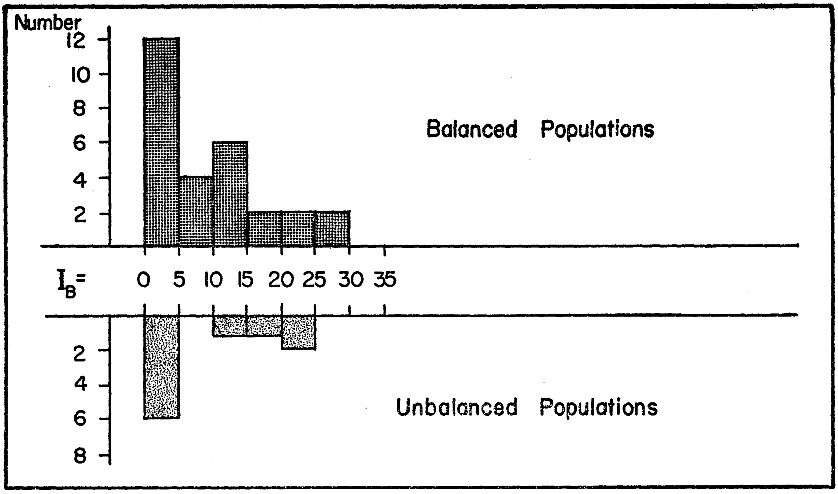

FIGURE 8. Frequency distribution of I_B values in balanced and unbalanced populations composed only of bluegills and largemouth bass.

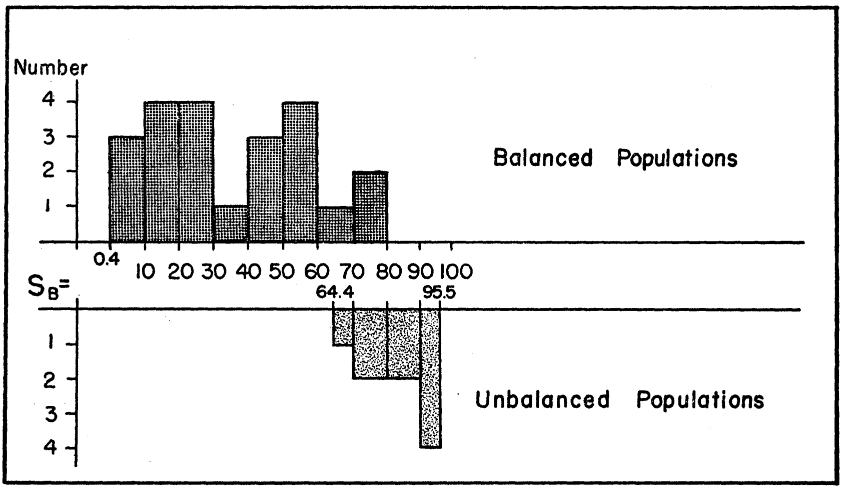

FIGURE 9. Frequency distribution of S_B values in balanced and unbalanced populations composed only of bluegills and largemouth bass.

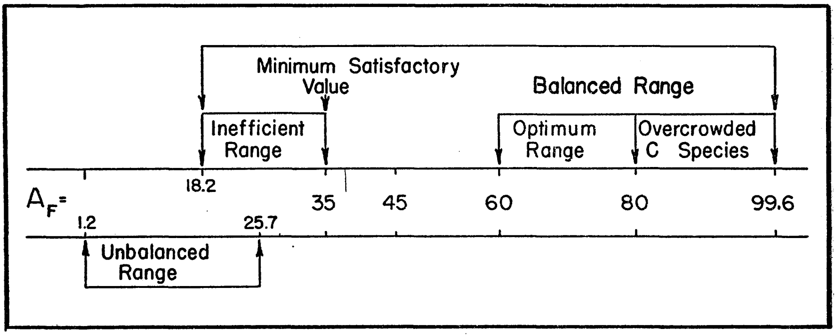

FIGURE 10. Conditions in populations indicated by various A_F values.

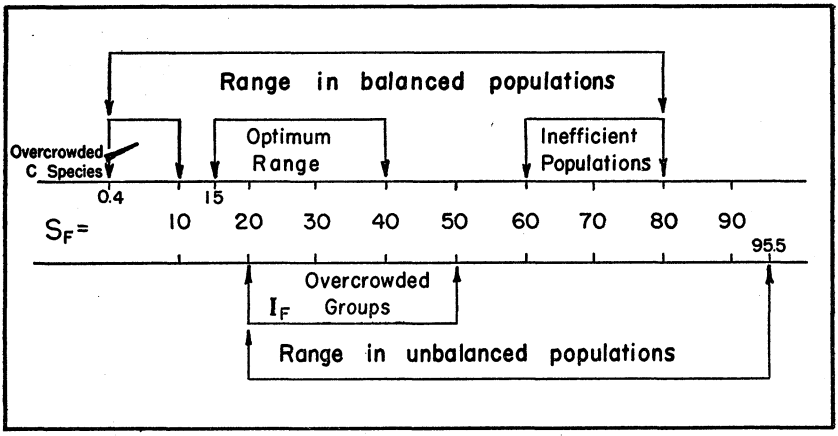

FIGURE 11. Conditions in populations indicated by various S_F values.

Here, consideration of all populations increased the range of S_F values in unbalanced populations to from 20 to 95.5, which included populations unbalanced due to overcrowded I_F groups. It is probable that the same range would have been found for simple bluegill-bass combinations if sufficient unbalanced populations had been examined.

It must be pointed out that, with the presence of additional "F" species, the A_B, I_B, and S_B values in such populations will no longer have the same distribution as the A_F, I_F, and S_F values. For example in the complex population given in Table 52-B, the I_B value is 75.3, far higher than the distribution in balanced populations containing only bluegills and bass given in Figure 8. However, if the I_F value is calculated, it is found to be 18.9 and falls within the balanced range.

As another example, in the population given in Table 24-U, the A_B

value is 61.8. In the distribution given in Figure 7 for the A_B values in simple bluegill-bass combinations, this would indicate a balanced population. However, in the population in question, a second "F" species, the gizzard shad, occurs. Consequently, the A_F value must be used. This value is 15.5, indicating the unbalanced population that it actually is.

The foregoing results illustrate the erroneous conclusions that are likely to result if a species within a population is considered as a separate and distinct unit.

It was apparent from these studies that a simple bluegill-bass combination could be used to represent other and much more complex "F"-"C" combinations.

STABILITY OF A_F, I_F, AND S_F VALUES. These values are obviously not static values but subject to change due to harvest, predation, and growth. Since, however, they are percentages of the "F" population, the rate of change is not as rapid as might be expected. For instance, in a population subjected to very heavy fishing, it was found possible to reduce the large "F" fishes by 38.2 per cent in 5 days of hook-and-line fishing. Since in this period the change in weights of intermediate and small fishes would be practically nil, it was possible to calculate the approximate changes in A_F, I_F, and S_F values resulting from this heavy rate of fishing (Table 2).

It will be noted that the reduction of 38.2 per cent in the weight of large "F" fishes reduced the A_F value by only 7.7 due to the simultaneous reduction in total weight of the "F" population. It should also be noted that the reduction of 7.7 in the A_F value increased the I_F value by 0.6 and the S_F value by 7.1. The reduction in total weight of the "F" population had the effect of increasing the food available for each pound of the fish remaining. Also, the shifts in A_F, I_F, and S_F

TABLE 2. CHANGES IN A_F, I_F, AND S_F VALUES DURING 5 DAYS OF FISHING

Groups of "F" fishes	Dates			
	6/18	6/19	6/21	6/23
	Lb.	*Lb.*	*Lb.*	*Lb.*
Amount caught	0.0	36.4	26.4	49.3
Large "F" fishes remaining	294.0	257.6	231.2	181.9
Intermediate "F" fishes remaining	4.0	4.0	4.0	4.0
Small "F" fishes remaining	53.0	53.0	53.0	53.0
Total amount "F" species	351.0	314.6	288.2	238.9
A_F values	83.8	81.9	80.2	76.1
I_F values	1.1	1.3	1.4	1.7
S_F values	15.1	16.8	18.4	22.2

values correspond to shifts in the relative percentages of the food supply available to each group.

The increased food available to the I_F group normally results in the subsequent movement of individuals from the intermediate into the group of large fishes. As a result of the interaction of increased growth and predation in the S group, replacements move up into the I group. Insufficient records are available to render at this time a more detailed study of these changes.

As a result of harvest of part of the "F" species and accompanying increase in food available for the A_F group, more rapid growth and increased reproduction will result. Since the small "F" fishes will subsequently increase in numbers and since they have available a larger percentage of the food supply, the weight of this group will tend to increase. However, these small fishes function as the food supply for the "C" group, and the increase should be largely passed on to the latter, since it has been shown that the Y/C ratio is a constant within limits.

INTERRELATIONSHIPS BETWEEN A_F, S_F, AND C VALUES. It is apparent from the foregoing discussion that interrelationships exist between the A_F and S_F values and the total weight of "C" species (or C value) in a population. In order to more fully understand their nature and the extent of their importance, a series of 12 balanced populations containing principally bluegills as the "F" species and only largemouth bass as the "C" species were selected for further analysis. The ponds containing these populations were fertilized at a uniform rate to give relatively uniform productivity. They were fished at various rates for 1 to 6 years, thus insuring dynamic populations. They were then

TABLE 3. THE A_F, S_F, AND C VALUES OF BALANCED DYNAMIC POPULATIONS IN WATERS WITH APPROXIMATELY EQUAL PRODUCTION CAPACITY

Population[1]	"C" value[2] in pounds per acre	Correction[3] factor	A_F	S_F
1 B	56.7	0.3	85.2	2.0
9 B	60.2	25.3	44.1	40.5
10 B	102.3	37.3	24.9	62.2
11 B	37.7	8.7	67.8	26.1
12 B	56.0	29.6	38.0	54.6
13 B	60.1	27.6	19.0	53.4
24 B	48.1	8.6	74.6	20.4
26 B	88.2	38.9	40.4	59.6
27 B	57.6	41.4	50.7	44.5
29 B	34.2	5.9	65.4	25.4
32 B	57.8	9.9	72.2	27.8
55 B	37.4	7.8	87.2	12.8

[1]Population numbers refer to table numbers in Appendix.
[2]Total pounds of largemouth bass per acre.
[3]Total pounds of small "F" fishes per acre divided by five. This gives the approximate additional "C" value still present as small fishes.

drained and the numbers and weights of the various groups determined. The summarized results are given in Table 3.

The weights of "C" fishes in these populations were obviously not the result of the small fishes present in the populations at the time both were censused but were the result of the small fishes previously present. However, both groups present concurrently were the result of previous conditions in the population. It would, therefore, appear possible to establish in a general way some relationship between the S_F value and the pounds of "C" species in dynamic populations; that is, those that are in the process of replacing harvested "F" and "C" groups.

In Figure 12, the S_F values were plotted against the pounds of "C" fish per acre taken from Table 3. The coefficient of correlation *(18)* between these values, with significance indicated at the 1.2 per cent level, was +0.701, indicating that an increase in the S_F value in a population is accompanied by an increase in the total pounds "C" species per acre. In static populations, there would probably be a reverse relationship because high concentrations of "C" species would eventually result in reduction in the S_F value and increase in the A_F value.

It would be much more important from a management standpoint to establish some relationship between the A_F and the "C" values because of the great interest of the fishing public in "C" species and also because it is possible to change the A_F value by harvest of adult fishes. It must be remembered that the degree of success of a majority of natural waters and most of the large impoundments is measured largely by their ability to produce "C" species.

Consequently, the dynamic populations in Table 3 were examined for possible relationship between the A_F values and the pounds per acre of the "C" species. A graph with A_F values plotted against the actual weight per acre of the "C" group is given in Figure 13. The coefficient of correlation between these two values, with significance indicated at the 2.5 per cent level, was —0.646. In general, this indicated that as the A_F value decreased, the pounds of "C" species per acre increased.

In these populations at the time the censuses were made, there were certain weights of "C" species representing small fishes previously consumed, plus a certain weight of small fishes yet to be utilized. The latter are represented in column three of Table 3 as a correction factor or the "C" equivalent of these small fishes. This was computed, assuming that 5 pounds of small fishes was equal to 1 pound of "C" species. If now the A_F values are plotted against the actual weights per acre plus the correction factors per acre for the "C" species, the

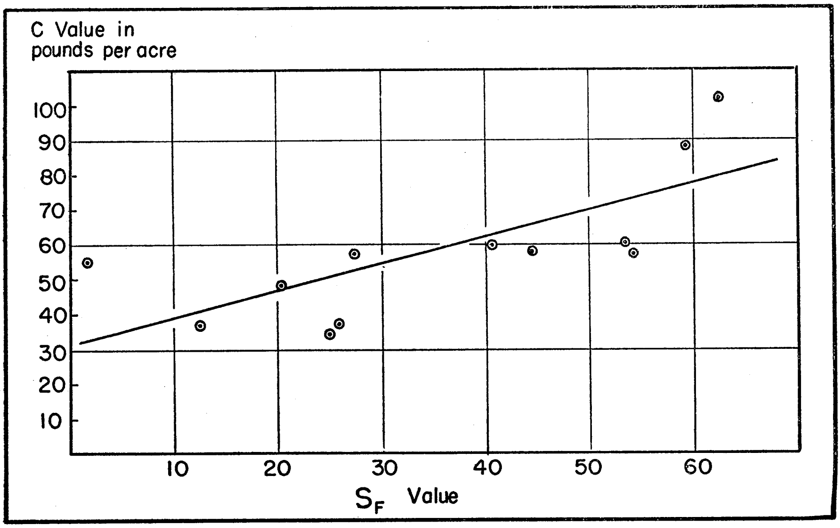

FIGURE 12. Relationship of S_F values to pounds per acre of "C" species in dynamic balanced populations from waters of approximately equal productivity. Coefficient of correlation $r = +0.701$, $t = 3.108$, d.f. $= 10$.

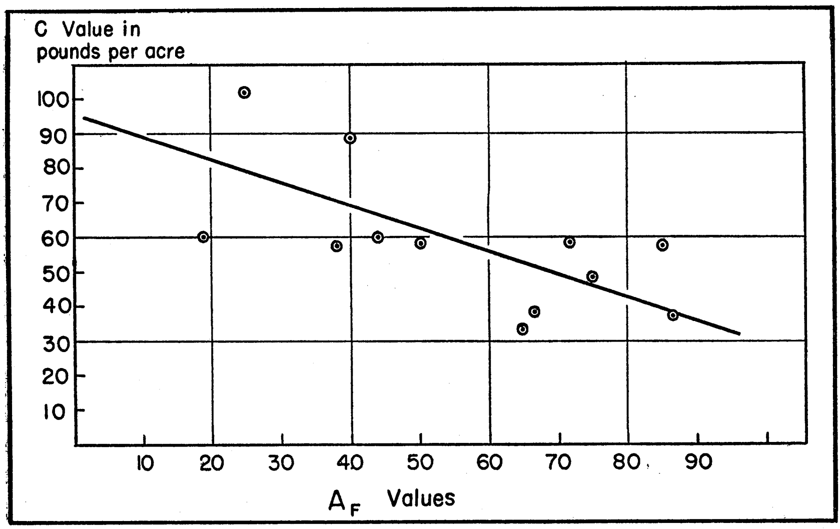

FIGURE 13. Relationship of A_F values to pounds per acre of "C" species in dynamic balanced populations from waters of approximately equal productivity. Coefficient of correlation $r = -0.646$, $t = 2.6764$, d.f. $= 10$.

coefficient of correlation is found to be —0.740, with significance indicated at less than the 1 per cent level.

Since the $A_F + I_F + S_F$ values = 100, and since the I_F value is normally low, a relatively high degree of negative correlation may be expected between the A_F and S_F values. In the above populations, the coefficient of correlation between the two was —0.782, and t = 3.968 with 10 d.f., indicating significance at less than the 1 per cent level. The fiducial limits of the coefficient in the population from which the samples were drawn were —0.212 to —0.959. This indicates that decreasing A_F values are accompanied by increasing S_F values in dynamic balanced populations.

CHANGES DUE to RATES of HARVEST in BALANCED POPULATIONS

The relationships in fish populations previously discussed throw considerable light upon the effect of rates of harvest upon various parts of the population. These have been discussed in part under the sections dealing with the various ratios and values. In order to systematize and integrate this miscellaneous information, the effects of rates of harvest of the "F" and "C" groups will be discussed separately. In this discussion it will be assumed that the harvest of large fishes means their removal from their aquatic environment by fishing or otherwise. In the absence of harvest, natural mortality alone is assumed to regulate the rate at which the stocks of large fishes are dissipated. Since harvest of adult fishes may be expected to reduce losses due to natural mortality, low rates of harvest tend in part to replace as well as supplement such losses.

Effects Due to Harvest of "F" Species. The negative correlation established between A_F and S_F values indicated that harvest of the adult "F" species was accompanied by an increase in the relative abundance of and in the food supply for the "S" group. The positive correlation between the S_F and C values demonstrated that the weight of "C" species per acre increased with increase in the S_F value. The negative correlation between A_F and C values substantiated the foregoing conclusions that harvest of the adults in the "F" group increased the weight of the "C" group in the population.

It is evident from these relationships that the abundance of small "F" fishes in a population where the food supply remains a constant is regulated by two factors — the A_F value and the C value. Consequently, if the A_F group is not harvested, the pressure of predation reduces the S_F value and part of this group passes into the intermediates and into the A group, thus increasing the A_F value. This results in reduction of the weight of "C" fishes in the population.

These results have been corroborated in pond management experiments. Failure to harvest the adult bluegills in bluegill-largemouth bass combinations repeatedly has been found to reduce greatly the production of young bluegills and subsequently reduced the production of bass. Heavy fishing in such ponds was normally followed with heavy reproduction of young bluegills within 1 month and subsequent improvement in the condition of the bass population.

Therefore, if maximum increase in the piscivorous sport fishes, such as bass, pickerel, pike, crappie, and others, is desired, it is necessary to harvest the large forage fishes in the population. Failure to harvest this group adequately results in a static population with high A_F and low S_F values and subsequent decline in the "C" species. This problem is especially acute in populations with relatively high A_T^N values due to the presence of gizzard shad or other undesirable fishes that are entirely unharvested. In such cases the production of small fishes is dependent upon the rates of nautral mortality of these species.

In populations in Tables 23-U, 24-U, and 25-U, the presence of unharvested large and intermediate gizzard shad prevented the production of young bluegills and young gizzard shad during the entire summer before the ponds were drained and consequently prevented the survival of any young bass. In the balanced population given in Table 52-B, unharvested gizzard shad, carp, buffalo, and suckers reduced reproduction in the "F" group so that the Y/C ratio was 0.3. This resulted in the bass being divided into rapid- and slow-growing groups. The large bass, with average weights above 2.43 pounds, were growing well because they could eat the fishes in the I_F group. The small bass of the current year were thin and starved because of the low reproduction of the "F" group. In the population in Table 54-B, the same unharvested species reduced the spawning of the "F" group so severely that the Y/C ratio was 0.07 and all "C" species were unable to grow at a satisfactory rate.

Effects Due to Harvest of C Species. Slow annual rates of harvest of the adult "C" group or losses such as those normally occurring due only to natural mortality in this group have been shown to result in a reduction in the Y/C ratio. Since under such conditions, the "C" value tends to change very slowly, the reduction is largely in the value of Y. Reduction in the Y value has the result of reducing the S_F and increasing the A_F values. This has been shown to result in a reduction in the weight of "C" fishes in the population. It is thus evident that failure to adequately harvest "C" species results in less pounds of "C" species for future harvest.

Long-continued slow rates of harvest or failure to harvest the "C" species also affects the "F" species in the following manner: The resulting reduction of the Y/C ratio tends to move the ratio into the inefficient or overcrowded "C" range (Figure 4). Under these conditions, too few small "F" fishes survive predation to move in adequate numbers into the I and A groups. As a result of insufficient numbers, the food supply is inadequately utilized and the total weight of the "F" species declines. Evidence is accumulating that the F/C ratios in such populations shift also toward the inefficient range of 1.4 to 2.0 (Figure 2). Failure to harvest adequately "C" species is thus shown to temporarily increase the A_F value and improve fishing for these species, but when continued over a long period (more than 1 year), it eventually reduces the pounds of "F" species available for harvest.

Severe reductions in the Y/C ratio as a result of long-continued low rates of harvest of the "C" species has one other effect that has been observed in seining ponds in controlled fishing experiments. It has greatly reduced the rate of growth and greatly reduced or entirely prevented survival of young-of-the-year "C" species. It also has caused loss in weight or condition of the large individuals in the "C" group and this eventually has had the curious effect of making these fishes very hard to catch by either pole-fishing or casting.

More rapid rates of harvest of the adults in the "C" group tends to maintain or increase the Y/C ratio and consequently maintain or increase the weight of the "C" species available for harvest. This also results in more rapid growth and higher survival of the young "C" fishes and in adequate survival in the "F" group for maintenance of high production.

It has also been shown possible to deplete the "C" group too rapidly. Where seining was used to harvest largemouth bass in two populations (Table 10-U and 11-U), so many were removed that the A_T values fell below the minimum of 33 required for balance and the F/C ratios moved up into the unbalanced range. Heavy mortality in the "C" group from low oxygen or other causes has had similar effects.

SUMMARY

Various relationships between groups and species and the dynamics of various interrelationships were determined for 55 balanced and 34 unbalanced fish populations.

Balanced populations were defined as those capable of producing satisfactory annual crops of harvestable fish. They were characterized by having (1) a definite range in ratios of the weights of forage and piscivorous groups, (2) a narrow range in the ratios of weights of small forage fishes to the weights of piscivorous groups, and (3) more than 33 per cent of the total population weight in the form of fishes of harvestable size.

A fish population may be divided into two classes – the "C" class, composed of species that feed principally upon other fishes and that cannot attain normal adult size without such food; and the "F" class, composed of all other species in the population that feed principally upon plants, plankton, water insects, and other small aquatic invertebrates.

The "C" value is the weight in pounds of the "C" class and the "F" value is the weight in pounds of the "F" class. The F/C ratio equals the "F" value divided by the "C" value. The range of F/C ratios in balanced populations was from 1.4 to 10.0. Populations with F/C = 1.4 to 2.0 were overcrowded with "C" species.

The most desirable populations were those with F/C ratios between 3.0 and 6.0. Unbalanced populations with disappearing "F" species had F/C ratios from 0.06 to 2.7. All populations with F/C ratios above 10.0 were unbalanced. Balanced populations with F/C ratios below 3.0 were inefficient due to overcrowding of the "C" species. This was found to reduce the total weight of the population.

The F/C ratio was a relatively stable value, remaining almost constant despite variations in the rates of fishing for "F" and "C" species. This ratio is useful in comparing and in determining the condition of populations. It may also be used to determine the rates of stocking new ponds with bluegills and bass and it relates rates of stocking to the productivity of pond waters.

The Y value in a population is the total weight in pounds of all fishes in the "F" class which are small enough to be readily gulped by the average-size adult in the "C" class. The Y/C ratio is an expression of the food available to the "C" class. In balanced populations, the range in Y/C ratios was from 0.02 to 4.8. All populations with Y/C = 0.02 to 0.5 were severely overcrowded with "C" species. The most desirable populations were in the range Y/C = 1.0 to 3.0. All populations with Y/C ratios in excess of 4.8 were unbalanced and in-

capable of producing yearly crops of harvestable fish. This ratio was found to be a dynamic ratio, changing with changes in predation pressure and rates of harvest, yet remaining a constant within limits in balanced populations.

The A_T value is the percentage of the total weight of a population composed of fish of harvestable size. In balanced populations, the range of this value was from 33 to 90. The most desirable populations had values between $A_T = 60$ to 85. Values in excess of 85 indicated populations overcrowded with "C" species. Unbalanced populations occurred in the range $A_T = 0.0$ to 40. The A_T value fluctuated with rapid rates of harvest, but remained relatively constant under slow rates. The limits of the value in balanced populations indicated that $A_T = 40$ was the maximum allowable depletion of adult fish stocks for the maintenance of satisfactory annual production and that depletion below $A_T = 33$ caused an unbalanced condition. The A_T value is useful in determination of balance and comparison of the efficiencies of populations. Its range in balanced populations limits the methods that can be used in stocking new waters to obtain balanced populations. These values can be used to determine numbers of fish necessary for stocking new waters and to determine the probable results of various stocking methods.

The E value of a species is the percentage of weight of a population composed of that species. The ranges of E values for "F" and "C" groups were calculated from the F/C ratios and found to agree with those in the populations studied. They are useful in determining the extent of competition between species.

The "F" class and also the "F" species were subdivided into groups of "large", i.e. fishes of harvestable size; "intermediates," i.e. those too large to be eaten by the average "C" species and too small for harvest; and "small", i.e. the fishes small enough to be eaten by the average-sized individual in the "large" group of "C" species in the population.

The A_F value is the percentage of the total weight of the "F" class composed of "large" fishes. The I_F and S_F values are the percentages of the total weight of the "F" class composed respectively of the "intermediate" and "small" fishes.

The range in A_F values in balanced populations was 18.2 to 99.6. Within this range $A_F = 35$ appeared to be the minimum value found in desirable populations and apparently expresses the maximum allowable depletion of the adult "F" species if satisfactory production is to be maintained. Values above 85 occurred only in populations with overcrowded "C" species. The most desirable populations were in the range $A_F = 60$ to 80. The unbalanced populations had A_F values from 1.2 to 25.7.

I_F values overlapped in balanced and unbalanced populations. The range in the former was 0 to 41.4 and in the latter from 0 to 100.0.

The S_F values in balanced populations ranged from 0.4 to 80.9. Satisfactory populations occurred in the range 15 to 40. Values in excess of 60 indicated inefficient populations.

The A_F, I_F, and S_F values were found to be dynamic values shifting with changes due to harvest, predation, natural mortality, and growth. The coefficient of correlation between the A_F and S_F values in dynamic populations was $r = -0.782$; that between A_F and pounds of "C" species per acre (C value) was $r = -0.646$; and that between the S_F and C values was $r = +0.701$.

These results indicated that harvest of adult "F" species increased the pounds of "C" species per acre and that failure to adequately harvest the former group resulted in a decrease in the pounds of "C" species in the population.

Failure to harvest adequately the "C" species was shown to reduce subsequently the pounds of "C" species available for harvest. This was also found to increase temporarily but eventually to decrease the adult F species available for harvest. When seining was used to harvest the "C" class, it was found possible to deplete them so rapidly that the populations became unbalanced.

The ratios and values used in this study and the interrelationships established in 55 balanced and 34 unbalanced populations establish standards for comparison of other populations if the compositions of adequate samples from these populations are determined.

The dynamic interrelationships in these populations provide a better understanding of the mechanism of balance and the effects of harvest. Consequently, they provide a basis for improved management practices.

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APPENDIX

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TABLE 1. E VALUES IN BALANCED POPULATIONS

Total pounds fish per acre	Largemouth bass E	Bluegills E
137.0	41.4	58.6
463.5	28.3	71.7
387.5	20.6	79.4
393.6	22.2	77.8
411.0	21.7	78.3
350.5	25.1	74.9
379.4	40.8	59.2
326.8	39.3	60.7
373.5	16.1	83.9
401.6	25.5	74.5
327.0	17.1	82.8
319.3	18.8	81.1
306.3	12.8	87.2
230.1	12.8	87.2
279.2	37.3	62.7
350.0	15.4	84.6
224.2	24.1	75.9
207.0	29.0	71.0
386.0	9.1	90.9
303.4	13.8	86.2
216.2	31.0	69.0
299.8	16.0	84.0
259.1	18.6	81.4

TABLE 2. E VALUES OF SPECIES IN BALANCED POPULATIONS

Total lb. fish	E values for									
per acre	L.B.	B	S	W.C.	W	G.S.	C.S.	Y.B.	F.C.	G.S.
452.7	20.0	80.0								
319.3	18.8	81.1								
327.0	17.1	82.8								
525.5	11.0	71.5	17.5							
440.1	10.3	70.0	17.4		2.3					
146.6	23.3	76.1*								
197.3	19.0	76.7*				1.0				
371.3	16.6	82.0				1.1				
236.2	24.5	71.0				4.5				
408.0	13.2	81.9				4.9				
404.0	12.9	64.9				22.2				
611.0	20.8	62.8				16.4				
302.0	21.2	76.8				2.0				
301.8	6.1	88.1		5.8						
474.1	15.8	77.8		6.4						
284.3	10.1	82.3		7.6						
311.6	11.7	82.4		5.9						
147.2	14.4	52.2					23.6	9.8		
108.0	22.9	75.3					0.0	1.8		
104.1	23.0	72.5						4.5		
199.8	21.7	65.8*		12.4				0.1		
515.8	13.5	49.6		7.4				0.3	17.9	11.3
515.4	12.4	75.3		12.2				0.1		

L.B. = largemouth bass; B = bluegill; S = shellcracker; W. C. = white crappie; W = warmouth; G.S. = golden shiners; C.S. = chub suckers; Y.B. = yellow bullheads; F.C. = flathead cats; and G.S. = gizzard shad.

* Plus shellcrackers.

TABLE 3. E VALUES OF SPECIES IN BALANCED POPULATIONS

Species	E values							
Largemouth bass	12.6	34.6	31.0	31.2	21.4	8.6	3.1	14.7
Bluegills	80.1	41.2	54.0*	68.1	59.9	12.5	11.9	22.4
Shellcrackers						4.2	0.1	12.2
White crappie	1.6				3.6	12.7**	1.9	4.3
Warmouth			0.8	0.1	4.1		0.5	5.7
Golden shiners		23.2			2.3		0.0	0.1
Chub sucker					3.9			
Yellow bullheads		0.9		0.3	0.2	0.4		
Flathead cats							1.2	
Gizzard shad						44.0		21.1
Buffalo	4.3					5.5		
Goldfish	1.4							
Gambusia		0.1						
Spotted suckers			8.9	0.2		2.4	37.6	1.8
Speckled bullheads			5.3	0.1	4.6			5.4
Carp						8.4	4.1	2.4
Gar						1.1		4.2
Spotted bass							21.6	
Channel cats							13.6	
Green sunfish							1.0	0.2
Eel								1.3
Bowfin								4.1
Miscellaneous							3.4	
Total lb. per acre	313.9	386.7	48.0	77.9	100.8	426.0	31.4	216.3

* Bluegills plus shellcrackers.
** Black crappie.

TABLE 1-B. RECOVERED PER ACRE ON DRAINING, OCTOBER 25, 1948

Number	Species	Pounds
392	Large bluegills	68.4
151	Intermediate bluegills	10.3
81	Small bluegills	1.6
53	Large largemouth bass	36.1
225	Small largemouth bass	20.6
	Total	137.0

$F/C = 1.4$, $Y/C = 0.03$, $A_T = 76.3$, $A_F = 85.2$, $I_F = 12.8$, $S_F = 2.0$

TABLE 2-B. RECOVERED PER ACRE ON DRAINING, SEPTEMBER 29, 1949

Number	Species	Pounds
352	Large bluegills	60.5
92	Intermediate bluegills	3.0
48,360	Small bluegills	269.0
80	Large largemouth bass	124.0
48	Small largemouth bass	7.0
	Total	463.5

$F/C = 2.5$, $Y/C = 2.1$, $A_T = 39.8$, $A_F = 18.2$, $I_F = 0.9$, $S_F = 80.9$

TABLE 3-B. RECOVERED PER ACRE ON DRAINING, OCTOBER 4, 1949

Number	Species	Pounds
219	Large bluegills	63.3
276	Intermediate bluegills	16.0
26,468	Small bluegills	228.2
60	Large largemouth bass	75.5
196	Small largemouth bass	4.5
	Total	387.5

$F/C = 3.8$, $Y/C = 2.9$, $A_T = 35.8$, $A_F = 20.6$, $I_F = 5.2$, $S_F = 74.2$

TABLE 4-B. RECOVERED PER ACRE ON DRAINING, OCTOBER 5, 1949

Number	Species	Pounds
752	Large bluegills	197.2
280	Intermediate bluegills	22.0
9,972	Small bluegills	87.2
68	Large largemouth bass	76.0
556	Small largemouth bass	11.2
	Total	393.6

$F/C = 3.5$, $Y/C = 1.0$, $A_T = 69.4$, $A_F = 64.4$, $I_F = 7.2$, $S_F = 28.4$

TABLE 5-B. RECOVERED PER ACRE ON DRAINING, OCTOBER 6, 1949

Number	Species	Pounds
448	Large bluegills	127.0
364	Intermediate bluegills	24.8
36,480	Small bluegills	170.2
48	Large largemouth bass	70.5
116	Small largemouth bass	18.5
	Total	411.0

$F/C = 3.6$, $Y/C = 1.9$, $A_T = 48.1$, $A_F = 39.4$, $I_F = 7.7$, $S_F = 52.9$

TABLE 6-B. RECOVERED PER ACRE ON DRAINING, OCTOBER 6, 1949

Number	Species	Pounds
1,176	Large bluegills	179.0
440	Intermediate bluegills	30.0
6,760	Small bluegills	53.5
64	Large largemouth bass	65.0
196	Small largemouth bass	23.0
	Total	350.5

$F/C = 3.0$, $Y/C = 0.6$, $A_T = 69.6$, $A_F = 68.2$, $I_F = 11.4$, $S_F = 20.4$

TABLE 7-B. RECOVERED PER ACRE ON DRAINING, OCTOBER 4, 1949

Number	Species	Pounds
1,016	Large bluegills	125.5
172	Intermediate bluegills	8.0
13,036	Small bluegills	91.2
84	Large largemouth bass	123.5
116	Intermediate largemouth bass	31.0
24	Small largemouth bass	0.2
	Total	379.4

$F/C = 1.5$, $Y/C = 0.6$, $A_T = 65.6$, $A_F = 55.9$, $I_F = 3.6$, $S_F = 40.5$

TABLE 8-B. RECOVERED PER ACRE ON DRAINING, OCTOBER 6, 1949

Number	Species	Pounds
660	Large bluegills	76.0
96	Intermediate bluegills	6.5
18,144	Small bluegills	115.8
72	Large largemouth bass	120.0
64	Intermediate largemouth bass	8.0
20	Small largemouth bass	0.5
	Total	326.8

$F/C = 1.5$, $Y/C = 0.9$, $A_T = 60.0$, $A_F = 38.3$, $I_F = 3.3$, $S_F = 58.4$

TABLE 9-B. RECOVERED PER ACRE ON DRAINING, OCTOBER 4, 1949

Number	Species	Pounds
748	Large bluegills	138.3
880	Intermediate bluegills	48.2
27,260	Small bluegills	126.8
56	Large largemouth bass	50.0
300	Small largemouth bass	10.2
	Total	373.5

$F/C = 5.2$, $Y/C = 2.1$, $A_T = 50.4$, $A_F = 44.1$, $I_F = 15.4$, $S_F = 40.5$

TABLE 10-B. RECOVERED PER ACRE ON DRAINING, OCTOBER 5, 1949

Number	Species	Pounds
588	Large bluegills	74.5
540	Intermediate bluegills	38.5
29,048	Small bluegills	186.3
72	Large largemouth bass	98.5
184	Small largemouth bass	3.8
	Total	401.6

$F/C = 2.9$, $Y/C = 1.8$, $A_T = 43.1$, $A_F = 24.9$, $I_F = 12.9$, $S_F = 62.2$

TABLE 11-B. RECOVERED FROM 3.5 ACRES ON DRAINING, OCTOBER, 1949

Number	Species	Pounds
1,134	Large bluegills	389.9
588	Intermediate bluegills	36.3
88,186	Small bluegills	151.7
56	Small green sunfish	2.3
4	Large speckled bullheads	8.5
2	Chub suckers, large	1.6
114	Large largemouth bass	89.5
216	Small largemouth bass	42.5
	Total	722.3

$F/C = 4.5$, $Y/C = 1.2$, $A_T = 67.5$, $A_F = 67.8$, $I_F = 6.1$, $S_F = 26.1$

TABLE 12-B. RECOVERED PER ACRE ON DRAINING, OCTOBER, 1948

Number	Species	Pounds
594	Large bluegills	102.8
337	Intermediate bluegills	19.9
26,740	Small bluegills	147.9
1	Shellcracker, large	0.4
49	Large largemouth bass	51.3
97	Small largemouth bass	4.7
	Total	327.0

$F/C = 4.8$, $Y/C = 2.6$, $A_T = 47.2$, $A_F = 38.1$, $I_F = 7.3$, $S_F = 54.6$

TABLE 13-B. RECOVERED PER ACRE ON DRAINING, OCTOBER 25, 1948

Number	Species	Pounds
360	Large bluegills	49.3
1,565	Intermediate bluegills	71.5
5,228	Small bluegills	138.1
23	Warmouth, small	0.3
75	Large largemouth bass	60.0
13	Small largemouth bass	0.1
	Total	319.3

$F/C = 4.3$, $Y/C = 2.3$, $A_T = 34.2$, $A_F = 19.0$, $I_F = 27.6$, $S_F = 53.4$

TABLE 14-B. RECOVERED FROM 1.5 ACRES ON DRAINING, NOVEMBER, 1940

Number	Species	Pounds
1,724	Large bluegills	188.2
46,630	Small bluegills	212.7
135	Large largemouth bass	58.6
	Total	459.5

$F/C = 6.8$, $Y/C = 3.6$, $A_T = 53.7$, $A_F = 46.9$, $S_F = 53.1$

TABLE 15-B. RECOVERED FROM 1.5 ACRES ON DRAINING, NOVEMBER, 1941

Number	Species	Pounds
801	Large bluegills	89.3
14,155	Small bluegills	211.5
27	Large largemouth bass	31.0
263	Small largemouth bass	13.3
	Total	345.1

$F/C = 6.8$, $Y/C = 4.8$, $A_T = 34.9$, $A_F = 29.7$, $S_F = 70.3$

TABLE 16-B. RECOVERED PER ACRE ON DRAINING, AUGUST 18, 1943

Number	Species	Pounds
688	Large bluegills	128.0
62,652	Small bluegills	47.0
44	Large largemouth bass, 3 yr.	39.2
156	Large largemouth bass, 2 yr.	65.0
	Total	279.2

$F/C = 1.7$, $Y/C = 0.5$, $A_T = 83.2$, $A_F = 73.1$, $S_F = 26.9$

TABLE 17-B. RECOVERED PER ACRE ON DRAINING, AUGUST 18, 1943

Number	Species	Pounds
612	Large bluegills	193.0
41,200	Intermediate + small bluegills	103.0
88	Large largemouth bass	47.0
36	Small largemouth bass	7.0
	Total	350.0

$F/C = 5.5$, $Y/C = 1.9$, $A_T = 68.6$, $A_F = 65.2$, $I_F + S_F = 34.8$

TABLE 18-B. RECOVERED PER ACRE ON DRAINING, AUGUST 18, 1943

Number	Species	Pounds
436	Large bluegills	143.2
27,000	Small bluegills	27.0
144	Intermediate largemouth bass	54.0
0	Small largemouth bass	0.0
	Total	224.2

$F/C = 3.2$, $Y/C = 0.5$, $A_T = 63.9$, $A_F = 84.1$, $S_F = 15.9$

TABLE 19-B. RECOVERED PER ACRE ON DRAINING, AUGUST 18, 1943

Number	Species	Pounds
680	Large bluegills	143.0
4,000	Small bluegills	4.0
288	Intermediate largemouth bass	60.0
0	Small largemouth bass	0.0
	Total	207.0

$F/C = 2.5$, $Y/C = 0.07$, $A_T = 69.1$, $A_F = 97.3$, $S_F = 2.7$

TABLE 20-B. RECOVERED PER ACRE ON DRAINING NOVEMBER 7, 1944

Number	Species	Pounds
940	Large bluegills	294.0
68	Intermediate bluegills	4.0
25,911	Small bluegills	53.0
44	Large largemouth bass	28.0
80	Small largemouth bass	7.0
	Total	386.0

$F/C = 10.0$, $Y/C = 1.5$, $A_T = 83.4$, $A_F = 83.8$, $I_F = 1.1$, $S_F = 15.1$

TABLE 21-B. RECOVERED PER ACRE ON DRAINING, NOVEMBER 7, 1944

Number	Species	Pounds
792	Large bluegills	214.4
48	Intermediate bluegills	3.0
29,333	Small bluegills	44.0
92	Large largemouth bass	40.0
16	Small largemouth bass	2.0
	Total	303.4

$F/C = 6.2$, $Y/C = 1.0$, $A_T = 83.8$, $A_F = 82.0$, $I_F = 1.1$, $S_F = 16.9$

TABLE 22-B. RECOVERED PER ACRE ON DRAINING, NOVEMBER 7, 1944

Number	Species	Pounds
452	Large bluegills	126.2
40	Intermediate bluegills	3.0
16,000	Small bluegills	20.0
112	Large largemouth bass	67.0
0	Small largemouth bass	0.0
	Total	216.2

$F/C = 2.2$, $Y/C = 0.3$, $A_T = 89.4$, $A_F = 84.6$, $I_F = 2.0$, $S_F = 13.4$

TABLE 23-B. RECOVERED PER ACRE ON DRAINING, NOVEMBER 7, 1944

Number	Species	Pounds
1,368	Large bluegills	250.8
0	Intermediate bluegills	0.0
280	Small bluegills	1.0
256	Intermediate largemouth bass	48.0
0	Small largemouth bass	0.0
	Total	299.8

$F/C = 5.2$, $Y/C = 0.02$, $A_T = 83.7$, $A_F = 99.6$, $S_F = 0.4$

TABLE 24-B. RECOVERED FROM 1.3 ACRES ON DRAINING, DECEMBER, 1945

Number	Species	Pounds
777	Large bluegills	204.5
1,950	Intermediate bluegills	13.8
28,000	Small bluegills	56.0
115	Large largemouth bass	53.0
70	Small largemouth bass	9.5
	Total	336.8

$F/C = 4.4$, $Y/C = 0.9$, $A_T = 76.5$, $A_F = 74.6$, $I_F = 5.0$, $S_F = 20.4$

TABLE 25-B. RECOVERED PER ACRE ON DRAINING, JUNE 27, 1947

Number	Species	Pounds
991	Large bluegills	128.5
9,446	Intermediate bluegills	73.1
42,828	Small bluegills	160.6
105	Large largemouth bass	66.2
2,634	Small largemouth bass	24.3
	Total	452.7

$F/C = 4.0$, $Y/C = 1.8$, $A_T = 43.0$, $A_F = 35.5$, $I_F = 20.2$, $S_F = 44.3$

TABLE 26-B. RECOVERED FROM 2 ACRES ON DRAINING, OCTOBER 22, 1947

Number	Species	Pounds
501	Large bluegills	162.0
51,297	Intermediate + small bluegills and shellcrackers	389.0
271	Large shellcrackers	102.0
107	Large largemouth bass	150.0
601	Small largemouth bass	26.3
	Total	829.3

$F/C = 3.7$, $A_T = 49.9$, $A_F = 40.4$, $I_F + S_F = 59.6$

TABLE 27-B. RECOVERED PER ACRE ON DRAINING, NOVEMBER, 1946

Number	Species	Pounds
770	Large bluegills	144.3
1,188	Intermediate bluegills	22.3
37,215	Small bluegills	206.8
380	Large shellcrackers	91.5
32	Large largemouth bass	57.5
4	Small largemouth bass	0.1
	Total	522.5

$F/C = 8.1$, $Y/C = 3.6$, $A_T = 56.1$, $A_F = 50.7$, $I_F = 4.8$, $S_F = 44.5$

TABLE 28-B. RECOVERED PER ACRE ON DRAINING, OCTOBER 25, 1948

Number	Species	Pounds
601	Large bluegills	74.1
258	Intermediate bluegills	21.0
58,708	Small bluegills	213.1
210	Large shellcrackers	36.2
553	Intermediate shellcrackers	38.3
200	Small shellcrackers	2.0
109	Intermediate warmouth	9.9
30	Large largemouth bass	35.6
240	Small largemouth bass	9.9
	Total	440.1

$F/C = 8.7$, $Y/C = 4.7$, $A_T = 33.2$, $A_F = 28.0$, $I_F = 17.5$, $S_F = 54.5$

TABLE 29-B. RECOVERED PER ACRE ON DRAINING, OCTOBER 26, 1948

Number	Species	Pounds
182	Large bluegills	58.7
33	Large shellcrackers	14.8
173	Intermediate bluegills and shellcrackers	9.5
43,603	Small bluegills and shellcrackers	28.6
21	Large largemouth bass	30.1
28	Small largemouth bass	4.1
11	Golden shiners	0.8
	Total	146.6

$F/C = 3.3$, $Y/C = 0.9$, $A_T = 70.7$, $A_F = 65.4$, $I_F = 8.4$, $S_F = 26.2$

TABLE 30-B. RECOVERED PER ACRE ON DRAINING, DECEMBER 6, 1945

Number	Species	Pounds
145	Large bluegills	30.5
58	Large shellcrackers	21.0
49,875	Intermediate and small bluegills and shellcrackers	99.8
24	Large largemouth bass	29.5
28	Small largemouth bass	8.0
35	Golden shiners	2.0
3	Goldfish, large	6.5
	Total	197.3

$F/C = 4.3$, $Y/C = 2.7$, $A_T = 44.3$, $A_F = 36.3$, $I_F + S_F = 63.7$

TABLE 31-B. RECOVERED PER ACRE ON DRAINING, DECEMBER 6, 1945

Number	Species	Pounds
593	Large bluegills	113.5
1,478	Intermediate bluegills	84.0
5,704	Small bluegills	107.0
2	Large shellcrackers	1.0
27	Large largemouth bass	41.0
85	Small largemouth bass	20.5
40	Golden shiners	4.0
20	Small green sunfish	0.3
	Total	371.3

$F/C = 5.0$, $Y/C = 1.8$, $A_T = 41.9$, $A_F = 37.0$, $I_F = 27.1$, $S_F = 35.9$

TABLE 32-B. RECOVERED PER ACRE ON DRAINING, OCTORER 30, 1946

Number	Species	Pounds
877	Large bluegills	128.8
19,440	Small bluegills	38.8
124	Large largemouth bass	52.3
25	Small largemouth bass	5.5
80	Golden shiners	10.8
	Total	236.2

$F/C = 3.1$, $Y/C = 0.9$, $A_T = 76.7$, $A_F = 72.2$, $S_F = 27.8$

TABLE 33-B. RECOVERED PER ACRE ON DRAINING, OCTOBER 29, 1943

Number	Species	Pounds
776	Large bluegills	152.0
45,500	Intermediate and small bluegills	182.0
285	Golden shiners	20.0
54	Large largemouth bass	54.0
0	Small largemouth bass	0.0
	Total	408.0

$F/C = 6.6$, $A_T = 50.5$, $A_F = 42.9$, $I_F + S_F = 57.1$

TABLE 34-B. RECOVERED PER ACRE ON DRAINING, OCTOBER 30, 1943

Number	Species	Pounds
548	Large bluegills	126.0
13,600	Small bluegills	136.0
2,126	Golden shiners	90.0
40	Large largemouth bass	52.0
	Total	404.0

$F/C = 6.8$, $Y/C = 4.3$, $A_T = 44.1$, $A_F = 35.8$, $S_F = 64.2$

TABLE 35-B. RECOVERED PER ACRE ON DRAINING, NOVEMBER, 1, 1943

Number	Species	Pounds
708	Large bluegills	146.0
23,800	Small bluegills	238.0
625	Golden shiners	100.0
92	Large largemouth bass	127.0
	Total	611.0

$F/C = 3.8$, $Y/C = 2.7$, $A_T = 44.7$, $A_F = 30.2$, $S_F = 69.8$

TABLE 36-B. RECOVERED PER ACRE ON DRAINING, NOVEMBER, 1942

Number	Species	Pounds
476	Large bluegills	121.0
36,963	Small bluegills	111.0
90	Golden shiners	6.0
88	Large largemouth bass	64.0
	Total	302.0

$F/C = 3.7$, $Y/C = 1.8$, $A_T = 61.3$, $A_F = 50.8$, $S_F = 49.2$

TABLE 37-B. RECOVERED PER ACRE ON DRAINING, DECEMBER 6, 1945

Number	Species	Pounds
1,170	Large bluegills	186.0
600	Intermediate bluegills	34.0
15,250	Small bluegills	45.8
39	Large white crappie	14.5
15	Small white crappie	3.0
23	Large largemouth bass	18.5
0	Small largemouth bass	0.0
	Total	301.8

$F/C = 8.1$, $Y/C = 1.5$, $A_T = 72.6$, $A_F = 69.2$, $I_F = 12.6$, $S_F = 18.2$

TABLE 38-B. RECOVERED FROM 1.3 ACRES ON DRAINING, DECEMBER, 1939

Number	Species	Pounds
1,657	Large bluegills	430.6
8,200	Small bluegills	49.0
88	Large largemouth bass	68.8
188	Small largemouth bass	28.5
4	Large white crappie	4.5
235	Small white crappie	35.0
	Total	616.4

$F/C = 5.1$, $Y/C = 0.8$, $A_T = 81.7$, $A_F = 83.7$, $S_F = 16.3$

TABLE 39-B. RECOVERED FROM 1.3 ACRES ON DRAINING, DECEMBER, 1940

Number	Species	Pounds
1,066	Large bluegills	265.0
7,494	Small bluegills	39.0
93	Large largemouth bass	35.3
26	Small largemouth bass	2.1
83	Large white crappie	28.1
1	Small white crappie	0.1
	Total	369.6

$F/C = 4.6$, $Y/C = 0.6$, $A_T = 88.9$, $A_F = 87.1$, $S_F = 12.9$

TABLE 40-B. RECOVERED FROM 1.3 ACRES ON DRAINING, DECEMBER, 1941

Number	Species	Pounds
716	Large bluegills	191.5
59,887	Small bluegills	142.3
57	Large largemouth bass	36.8
83	Small largemouth bass	10.5
40	Large white crappie	24.0
0	Small white crappie	0.0
	Total	405.1

$F/C = 4.7$, $Y/C = 2.0$, $A_T = 62.3$, $A_F = 57.4$, $S_F = 42.6$

TABLE 41-B. RECOVERED FROM 1.8 ACRES ON DRAINING, NOVEMBER, 1940

Number	Species	Pounds
601	Large bluegills	68.2
356,809	Small bluegills	70.1
41	Large largemouth bass	38.1
2	Small largemouth bass	0.1
579	Chub suckers	62.5
451	Yellow bullheads, intermediate	25.9
	Total	264.9

$F/C = 5.9$, $Y/C = 3.5$, $A_T = 40.1$, $A_F = 30.1$, $I_F = 11.4$, $S_F = 58.5$

TABLE 42-B. RECOVERED FROM 1.8 ACRES ON DRAINING, NOVEMBER, 1943

Number	Species	Pounds
126	Large bluegills	20.3
668	Intermediate bluegills	42.0
13,919	Small bluegills	83.9
55	Large largemouth bass	43.5
21	Small largemouth bass	1.0
8	Yellow bullheads, large	3.5
	Total	194.2

$F/C = 3.4$, $Y/C = 1.9$, $A_T = 34.7$, $A_F = 15.9$, $I_F = 28.1$, $S_F = 56.0$

TABLE 43-B. RECOVERED PER ACRE ON DRAINING, DECEMBER 8, 1945

Number	Species	Pounds
245	Large bluegills	53.8
351	Intermediate bluegills	18.1
14,032	Small bluegills	49.0
26	Large largemouth bass	25.3
72	Small largemouth bass	13.1
17	Large yellow bullheads	7.5
	Total	166.6

$F/C = 3.3$, $Y/C = 1.3$, $A_T = 52.0$, $A_F = 47.8$, $I_F = 14.1$, $S_F = 38.1$

TABLE 44-B. RECOVERED FROM 12.5 ACRES ON DRAINING, SEPTEMBER 27, 1949

Number	Species	Pounds
195	Large largemouth bass	491.45
649	Small largemouth bass	49.50
845	Large crappie (white)	245.40
3,664	Small crappie (white)	63.50
3,034	Large bluegills	437.45
9,118	Intermediate bluegills + shellcrackers	644.15
69,286	Small bluegills + shellcrackers	470.45
183	Large shellcrackers	93.30
7	Small yellow bullheads	0.20
3	Large yellow bullheads	2.50
	Total	2,497.90

$F/C = 2.1$, $Y/C = 0.7$, $A_T = 50.8$, $A_F = 31.2$, $I_F = 37.6$, $S_F = 31.2$

TABLE 45-B. RECOVERED PER ACRE ON DRAINING, NOVEMBER, 1940

Number	Species	Pounds
1,574	Intermediate bluegills	144.8
3,100	Small bluegills	111.2
76	Large largemouth bass	67.6
24	Small largemouth bass	1.8
16	Large flathead cats	92.4
112	Large gizzard shad	58.2
160	Intermediate white crappie	38.2
6	Intermediate yellow bullheads	1.6
	Total	515.8

$F/C = 6.4$, $Y/C = 1.6$, $A_T = 42.3$, $A_F = 33.7$, $I_F = 41.4$, $S_F = 24.9$

TABLE 46-B. RECOVERED PER ACRE ON DRAINING, NOVEMBER, 1941

Number	Species	Pounds
1,394	Large bluegills	308.0
2,550	Intermediate and small bluegills	80.0
30	Large largemouth bass	46.0
323	Small largemouth bass	18.0
118	Large white crappie	60.0
10	Small white crappie	3.0
10	Yellow bullheads, small	0.4
	Total	515.4

$F/C = 3.2$, $Y/C = 0.7$, $A_T = 80.3$, $A_F = 78.7$, $I_F + S_F = 21.3$

TABLE 47-B. RECOVERED PER ACRE ON DRAINING, OCTOBER 26, 1948

Number	Species	Pounds
780	Large bluegills	132.4
643	Intermediate bluegills	34.1
46,299	Small bluegills	84.9
1	Buffalo, large	13.5
2	Goldfish, large	4.4
3	Golden shiners	0.2
8	Large white crappie	4.9
19	Large largemouth bass	34.4
39	Small largemouth bass	5.1
	Total	313.9

$F/C = 6.1$, $Y/C = 1.9$, $A_T = 60.4$, $A_F = 55.8$, $I_F = 12.6$, $S_F = 31.6$

TABLE 48-B. RECOVERED FROM 1.5 ACRES ON DRAINING, JANUARY, 1939

Number	Species	Pounds
263	Large bluegills	65.4
7,880	Small bluegills	173.6
76	Large largemouth bass	124.2
346	Small largemouth bass	76.6
2,353	Golden shiners	134.7
8	Yellow bullheads, large	5.3
22	Gambusia	0.3
	Total	580.1

$F/C = 1.9$, $Y/C = 1.5$, $A_T = 33.6$, $A_F = 18.6$, $S_F = 81.4$

TABLE 49-B. RECOVERED FROM 29 ACRES ON DRAINING, OCTOBER, 1940

Number	Species	Pounds
2,215	Large bluegills	471.0
826	Large shellcrackers	255.4
3,434	Small bluegills + shellcrackers	25.0
22	Large largemouth bass	140.5
71	Large largemouth bass	71.0
2,282	Small largemouth bass	220.0
95	Warmouth, large	11.0
83	Suckers (spotted), large	124.4
59	Speckled bullheads, large	73.7
	Total	1,392.0

$F/C = 2.2$, $Y/C = 0.06$, $A_T = 82.4$, $A_F = 97.4$, $S_F = 2.6$

TABLE 50-B. RECOVERED FROM 25 ACRES ON DRAINING, NOVEMBER, 1939

Number	Species	Pounds
1,697	Large bluegills	447.1
1,500	Intermediate bluegills	300.0
388,350	Small bluegills	579.6
810	Large largemouth bass	598.4
3,500	Small largemouth bass	8.8
9	Warmouth, large	2.0
27	Yellow bullheads, intermediate	5.6
1	Speckled bullhead, large	2.6
1	Spotted sucker, large	4.2
	Total	1,948.3

$F/C = 2.2$, $Y/C = 1.0$, $A_T = 54.1$, $A_F = 34.0$, $I_F = 22.8$, $S_F = 43.2$

TABLE 51-B. RECOVERED EROM 4.75 ACRES ON DRAINING, JULY, 1940

Number	Species	Pounds
303	Large bluegills	76.6
12,245	Intermediate and small bluegills	210.5
93	Large largemouth bass	86.8
139	Small largemouth bass	15.9
23	Large white crappie	11.8
106	Small white crappie	5.5
28	Large warmouth	7.8
644	Small warmouth	11.8
14	Large speckled bullheads	18.9
34	Small speckled bullheads	3.1
3	Yellow bullheads, large	1.0
85	Chub suckers	18.5
148	Golden shiners	11.0
	Total	479.2

$F/C = 3.2$, $Y/C = 2.3$, $A_T = 42.3$, $A_F = 28.3$, $I_F + S_F = 71.7$

TABLE 52-B. RECOVERED FROM 2.3 ACRES ON POISONING, SEPTEMBER 4, 1948

Number	Species	Pounds
199	Large bluegills	28.3
2,312	Intermediate bluegills	92.5
1,052	Small bluegills	2.0
237	Large shellcrackers	36.1
62	Intermediate shellcrackers	5.0
4	Small green sunfish	0.4
5	Small stump knockers	0.3
2	Large speckled bullheads	3.8
5	Small speckled bullheads	0.1
6	Large carp	82.0
5	Large buffalo	54.0
11	Large spotted suckers	23.5
4	Large long-nose gar	10.4
5	Large eels	1.4
80	Large gizzard shad	180.0
2,223	Intermediate gizzard shad	211.5
3,947	Small gizzard shad	39.9
306	Large black crappie	66.6
481	Intermediate black crappie	57.0
41	Small black crappie	0.4
34	Large largemouth bass	82.6
62	Small largemouth bass	2.1
	Total	979.9

$F/C = 5.1$, $Y/C = 0.3$, $A_T = 57.9$, $A_T^H = 22.2$, $A_T^N = 35.7$, $A_F = 75.8$, $I_F = 18.9$, $S_F = 5.3$

TABLE 53-B. RECOVERED FROM 3 ACRES ON POISONING, OCTOBER 21, 1949

Number	Species	Pounds
40	Large spotted bass	15.19
124	Small spotted bass	5.19
3	Large largemouth bass	1.61
8	Small largemouth bass	1.25
26	Large bluegills	3.94
475	Small bluegills	7.25
1	Large warmouth	0.38
26	Small warmouth	0.13
126	Small green sunfish	1.00
45	Large spotted sucker	35.50
4	Small long-ear sunfish	0.31
26	Orange-spot sunfish, small	0.13
1	Small shellcrackers	0.06
178	Log perch, small	0.75
73	Small white crappie	1.75
18	Large channel cats	5.38
125	Inetrmediate and small channel cats	7.50
1	Large flathead cat	1.00
2	Small flathead cats	0.13
1	Carp, large	3.88
379	Minnows	2.07
	Total	94.40

$F/C = 3.1$, $Y/C = 0.6$, $A_T = 70.4$, $A_F = 70.4$, $I_F = 11.5$, $S_F = 19.1$

TABLE 54-B. RECOVERED FROM 5 ACRES ON POISONING, SEPTEMBER 3, 1949

Number	Species	Pounds
188	Large largemouth bass	146.8
624	Small largemouth bass	12.5
105	Large white crappie	41.4
81	Small white crappie	5.0
584	Large bluegills	102.9
3,053	Intermediate bluegills	136.6
23,450	Small bluegills and shellcrackers (1″)	2.4
712	Large shellcrackers	83.1
900	Intermediate shellcrackers	49.1
21	Intermediate green sunfish	2.0
266	Large warmouth	49.0
139	Intermediate warmouth	11.9
336	Small warmouth	1.0
59	Large speckled bullheads	56.0
40	Small speckled bullheads	2.4
1	Round flier, large	0.1
186	Large gizzard shad	223.0
134	Small gizzard shad	5.5
3	Carp, large	26.0
20	Suckers (spotted), large	19.5
29	Eels, large	14.5
20	Bowfin, large	44.8
21	Gar, large	45.0
43	Golden shiners	1.2
	Total	1,081.7

$F/C = 2.7$, $Y/C = 0.07$, $A_T = 78.8$, $A_T^H = 44.3$, $A_T^N = 34.5$, $A_F = 72.5$, $I_F = 25.3$, $S_F = 2.2$

TABLE 55-B. RECOVERED PER ACRE ON DRAINING, NOVEMBER, 1939

Number	Species	Pounds
986	Large bluegills	265.0
0	Intermediate bluegills	0.0
15,222	Small bluegills	39.0
20	Large largemouth bass	35.2
65	Small largemouth bass	2.2
	Total	341.4

$F/C = 8.1$, $Y/C = 1.0$, $A_T = 87.9$, $A_F = 87.2$, $S_F = 12.8$

TABLE 1-U. RECOVERED PER ACRE ON DRAINING, SEPTEMBER 29, 1949

Number	Species	Pounds
304	Large bluegills	55.0
420	Intermediate bluegills	18.0
51,028	Small bluegills	312.4
56	Large largemouth bass	91.0
124	Small largemouth bass	3.8
	Total	480.2

F/C = 4.1, Y/C = 3.3, A_T = 30.4, A_F = 14.3, I_F = 4.7, S_F = 81.0

TABLE 2-U. RECOVERED PER ACRE ON DRAINING, OCTOBER 5, 1949

Number	Species	Pounds
48	Large bluegills	9.0
212	Intermediate bluegills	7.2
60,864	Small bluegills	350.0
28	Large largemouth bass	52.0
8	Small largemouth bass	0.2
	Total	418.4

F/C = 7.0, Y/C = 6.7, A_T = 14.6, A_F = 2.5, I_F = 2.0, S_F = 95.5

TABLE 3-U. RECOVERED PER ACRE ON DRAINING, OCTOBER 6, 1949

Number	Species	Pounds
56	Large bluegills	12.2
256	Intermediate bluegills	8.2
142,740	Small bluegills	285.5
20	Large largemouth bass	39.0
0	Small largemouth bass	0.0
	Total	344.9

F/C = 7.8, Y/C = 7.3, A_T = 14.8, A_F = 4.0, I_F = 2.7, S_F = 93.3

TABLE 4-U. RECOVERED PER ACRE ON DRAINING, OCTOBER 6, 1949

Number	Species	Pounds
8	Large bluegills	5.0
176	Intermediate bluegills	8.8
44,480	Small bluegills	216.8
24	Large largemouth bass	45.0
328	Small largemouth bass	26.2
	Total	301.8

F/C = 3.2, Y/C = 3.0, A_T = 16.6, A_F = 2.2, I_F = 3.8, S_F = 94.0

TABLE 5-U. RECOVERED PER ACRE ON DRAINING, OCTOBER 3, 1949

Number	Species	Pounds
8	Large bluegills	4.2
748	Intermediate bluegills	28.8
108,820	Small bluegills	308.8
44	Large largemouth bass	84.0
0	Small largemouth bass	0.0
	Total	425.8

$F/C = 4.1$, $Y/C = 3.7$, $A_T = 20.7$, $A_F = 1.2$, $I_F = 8.4$, $S_F = 90.4$

TABLE 6-U. RECOVERED PER ACRE ON DRAINING, OCTOBER 6, 1949

Number	Species	Pounds
532	Large bluegills	119.2
788	Intermediate bluegills	46.2
31,928	Small bluegills	299.3
32	Large largemouth bass	45.0
168	Small largemouth bass	4.3
	Total	514.0

$F/C = 9.4$, $Y/C = 6.1$, $A_T = 31.9$, $A_F = 25.7$, $I_F = 9.9$, $S_F = 64.4$

TABLE 7-U. RECOVERED PER ACRE ON DRAINING, OCTOBER 3, 1949

Number	Species	Pounds
24	Large bluegills	8.0
1,184	Intermediate bluegills	55.0
102,980	Small bluegills	354.2
32	Large largemouth bass	54.5
0	Small largemouth bass	0.0
	Total	471.7

$F/C = 7.7$, $Y/C = 6.5$, $A_T = 13.2$, $A_F = 1.9$, $I_F = 13.2$, $S_F = 84.9$

TABLE 8-U. RECOVERED PER ACRE ON DRAINING, OCTOBER 4, 1949

Number	Species	Pounds
236	Large bluegills	69.5
556	Intermediate bluegills	16.2
51,740	Small bluegills	301.8
56	Large largemouth bass	62.0
0	Small largemouth bass	0.0
	Total	449.5

$F/C = 6.3$, $Y/C = 4.9$, $A_T = 29.3$, $A_F = 17.9$, $I_F = 4.2$, $S_F = 77.9$

TABLE 9-U. RECOVERED PER ACRE ON DRAINING, AUGUST 18, 1943

Number	Species	Pounds
760	Large bluegills	92.0
37,600	Small bluegills	300.0
20	Large largemouth bass	38.0
36	Large largemouth bass	36.0
	Total	466.0

$F/C = 5.3$, $Y/C = 4.1$, $A_T = 35.6$, $A_F = 23.5$, $S_F = 76.5$

TABLE 10-U. RECOVERED PER ACRE ON DRAINING, OCTOBER 30, 1946

Number	Species	Pounds
305	Large bluegills	39.8
17,400	Intermediate and small bluegills	235.3
27	Large largemouth bass	33.3
40	Small largemouth bass	1.5
	Total	309.9

$F/C = 7.9$, $A_T = 23.6$, $A_F = 14.5$, $I_F + S_F = 85.5$

TABLE 11-U. RECOVERED PER ACRE ON DRAINING, OCTOBER 30, 1946

Number	Species	Pounds
415	Large bluegills	61.8
15,981	Intermediate and small bluegills	293.0
15	Large largemouth bass	16.5
100	Small largemouth bass	7.0
	Total	378.3

$F/C = 15.1$, $A_T = 20.7$, $A_F = 17.4$, $I_F + S_F = 82.6$

TABLE 12-U. RECOVERED PER ACRE ON DRAINING, NOVEMBER 11, 1944

Number	Species	Pounds
0	Large green sunfish	0.0
11	Intermediate green sunfish	1.0
0	Small green sunfish	0.0
13	Large largemouth bass	12.8
35	Small largemouth bass	3.8
	Total	17.6

$F/C = 0.06$, $Y/C = 0.0$, $A_T = 72.7$, $A_F = 0$, $I_F = 100.0$, $S_F = 0$

TABLE 13-U. RECOVERED PER ACRE ON DRAINING, OCTOBER 25, 1948

Number	Species	Pounds
601	Large bluegills	74.1
258	Intermediate bluegills	21.0
58,708	Small bluegills	213.1
210	Large shellcrackers	36.2
553	Intermediate shellcrackers	38.3
200	Small shellcrackers	2.0
109	Warmouth, intermediate	9.9
30	Large largemouth bass	35.6
240	Small largemouth bass	9.9
	Total	440.1

$F/C = 8.7$, $Y/C = 4.7$, $A_T = 33.2$, $A_F = 28.0$, $I_F = 7.5$, $S_F = 54.5$

TABLE 14-U. RECOVERED FROM 2.6 ACRES ON DRAINING, OCTOBER 28, 1948

Number	Species	Pounds
641	Large bluegills	76.9
6,977	Intermediate bluegills	402.4
219	Large shellcrackers	30.4
80,725	Small bluegills + shellcrackers	220.4
2,432	Intermediate green sunfish	128.3
241	Large speckled bullheads	130.6
113	Small speckled bullheads	7.0
2	Large largemouth bass	4.3
21	Large smallmouth bass	11.0
	Total	1,011.3

$F/C = 65.1$, $Y/C = 14.9$, $A_T = 25.0$, $A_F = 23.9$, $I_F = 53.3$, $S_F = 22.8$

TABLE 15-U. RECOVERED FROM 1.3 ACRES ON DRAINING, OCTOBER 24, 1947

Number	Species	Pounds
764	Intermediate bluegills	57.8
13,860	Small bluegills	219.0
41	Large black crappie	12.6
4,196	Intermediate black crappie	275.4
318	Small black crappie	4.7
43	Large largemouth bass	53.9
68	Small largemouth bass	2.8
	Total	626.2

$F/C = 8.0$, $Y/C = 3.2$, $A_T = 10.6$, $A_F = 0.0$, $I_F = 59.8$, $S_F = 40.2$

TABLE 16-U. RECOVERED PER ACRE ON DRAINING, OCTOBER 26, 1948

Number	Species	Pounds
73	Large shellcrackers	20.4
154	Intermediate shellcrackers	12.1
661	Small shellcrackers	12.4
56	Large bluegills	15.4
275	Intermediate bluegills	18.8
11,559	Small bluegills	158.5
11	Large largemouth bass	19.8
50	Small largemouth bass	0.9
1,202	Golden shiners	50.3
	Total	308.6

$F/C = 13.9$, $Y/C = 10.7$, $A_T = 18.0$, $A_F = 12.5$, $I_F = 10.7$, $S_F = 76.8$

TABLE 17-U. RECOVERED PER ACRE ON DRAINING, DECEMBER 6, 1945

Number	Species	Pounds
11	Large shellcrackers	8.1
14	Intermediate shellcrackers	0.8
8,187	Small shellcrackers	35.7
30	Large bluegills	11.4
7	Intermediate bluegills	1.7
3,691	Small bluegills	58.6
31	Large largemouth bass	31.0
51	Small largemouth bass	15.3
104	Golden shiners	8.5
	Total	171.1

$F/C = 2.7$, $Y/C = 2.2$, $A_T = 29.5$, $A_F = 15.6$, $I_F = 2.0$, $S_F = 82.4$

TABLE 18-U. RECOVERED PER ACRE ON DRAINING, NOVEMBER, 1943

Number	Species	Pounds
380	Large bluegills	62.0
1,720	Intermediate bluegills	52.0
12,500	Small bluegills and shellcrackers	254.0
112	Large shellcrackers	28.0
512	Intermediate shellcrackers	22.0
48	Large largemouth bass	56.0
372	Small largemouth bass	43.0
4	Large yellow bullheads	4.0
Total		521.0

$F/C = 4.3$, $Y/C = 2.6$, $A_T = 28.8$, $A_F = 22.3$, $I_F = 17.5$, $S_F = 60.2$

TABLE 19-U. RECOVERED PER ACRE ON DRAINING, OCTOBER 26, 1948

Number	Species	Pounds
200	Large bluegills	63.1
1,859	Intermediate bluegills	81.5
4,284	Small bluegills	84.7
10	Large largemouth bass	14.4
22	Small largemouth bass	0.5
1	White crappie, large	1.0
	Total	245.2

$F/C = 14.4$, $Y/C = 5.3$, $A_T = 32.0$, $A_F = 27.5$, $I_F = 35.5$, $S_F = 37.0$

TABLE 20-U. RECOVERED FROM 2.2 ACRES ON DRAINING, NOVEMBER 5, 1948

Number	Species	Pounds
501	Large bluegills	61.4
149	Intermediate bluegills	8.9
175,024	Small bluegills	229.7
3,522	Small green sunfish	45.6
4,537	Intermediate speckled bullheads	435.5
20	Small speckled bullheads	0.1
1	Large goldfish	0.5
69	Large largemouth bass	74.7
43	Small largemouth bass	8.3
	Total	864.7

$F/C = 9.4$, $Y/C = 3.3$, $A_T = 15.8$, $A_F = 7.9$, $I_F = 56.9$, $S_F = 35.2$

TABLE 21-U. RECOVERED PER ACRE ON DRAINING, NOVEMBER, 1948

Number	Species	Pounds
38	Large bluegills	17.1
3,689	Small bluegills	4.1
27	Large green sunfish	4.4
134	Small green sunfish	2.4
31	Large largemouth bass	31.6
1,085	Small largemouth bass	31.4
	Total	91.0

$F/C = 0.4$, $Y/C = 0.08$, $A_T = 58.4$, $A_F = 76.8$, $I_F = 0.0$, $S_F = 23.2$

TABLE 22-U. RECOVERED FROM 2.1 ACRES ON DRAINING, NOVEMBER 10, 1948

Number	Species	Pounds
232	Large bluegills	44.6
298	Intermediate bluegills	23.0
45,797	Small bluegills	540.0
15	Large green sunfish	3.3
7	Intermediate green sunfish	0.5
1,764	Small green sunfish	21.0
49	Large largemouth bass	87.8
20	Intermediate largemouth bass	6.0
71	Small largemouth bass	2.7
	Total	728.9

$F/C = 6.6$, $Y/C = 5.8$, $A_T = 18.6$, $A_F = 7.6$, $I_F = 3.7$, $S_F = 88.7$

TABLE 23-U. RECOVERED PER ACRE ON DRAINING, OCTOBER, 1948

Number	Species	Pounds
356	Large bluegills	56.4
19,546	Small bluegills	248.4
92	Large gizzard shad	81.2
8,124	Intermediate gizzard shad	677.2
8	Large largemouth bass	16.4
	Total	1,079.6

F/C = 64.8, Y/C = 15.2, A_T = 14.2, A^H_T = 6.7, A^N_T = 7.5, A_F = 12.9, I_F = 63.7, S_F = 23.4

TABLE 24-U. RECOVERED PER ACRE ON DRAINING, NOVEMBER 16, 1943

Number	Species	Pounds
620	Large bluegills	107.0
16,500	Small bluegills	66.0
136	Large largemouth bass	101.0
2,360	Intermediate gizzard shad	516.0
	Total	790.0

F/C = 6.8, Y/C = 0.7, A_T = 26.3, A_F = 15.5, I_F = 74.9, S_F = 9.6

TABLE 25-U. RECOVERED PER ACRE ON DRAINING, OCTOBER 22, 1948

Number	Species	Pounds
288	Large bluegills	41.2
29,224	Small bluegills	196.8
24	Large gizzard shad	16.0
1,672	Intermediate gizzard shad	494.0
16	Large largemouth bass	40.0
	Total	788.0

F/C = 18.7, Y/C = 4.9, A_T = 12.3, A_F = 7.6, I_F = 66.1, S_F = 26.3

TABLE 26-U. RECOVERED FROM 2.2 ACRES ON DRAINING, NOVEMBER 18, 1949

Number	Species	Pounds
982	Large bluegills	269.8
625	Intermediate bluegills	51.7
30,336	Small bluegills	509.3
98	Large warmouth	21.4
113	Intermediate warmouth	13.2
7,784	Small warmouth	88.0
132	Large Eastern pickerel	128.7
6	Small Eastern pickerel	1.0
	Total	1,083.1

F/C = 7.4, Y/C = 4.6, A_T = 38.8, A_F = 30.5, I_F = 6.8, S_F = 62.7

TABLE 27-U. RECOVERED PER ACRE ON DRAINING, SEPTEMBER 29, 1949

Number	Species	Pounds
160	Large bluegills	34.5
692	Intermediate bluegills	29.0
49,060	Small bluegills	276.0
116	Small warmouth	4.5
64	Large largemouth bass	95.2
0	Small largemouth bass	0.0
	Total	439.2

$F/C = 3.6$, $Y/C = 2.9$, $A_T = 29.5$, $A_F = 10.0$, $I_F = 8.4$, $S_F = 81.6$

TABLE 28-U. RECOVERED PER ACRE ON DRAINING, NOVEMBER, 1938

Number	Species	Pounds
2,278	Intermediate bluegills	108.8
2,368	Small bluegills	3.2
184	Intermediate white crappie	16.8
12,472	Gambusia	38.4
	Total	167.2

$F/C = \infty$ $A_T = 0.0$

TABLE 29-U. RECOVERED PER ACRE ON DRAINING, NOVEMBER, 1939

Number	Species	Pounds
0	Large bluegills	0.0
2,016	Intermediate bluegills	156.8
23,816	Small bluegills	152.8
144	Large white crappie	58.4
16,968	Small white crappie	72.0
8,320	Gambusia	11.2
16	Chub suckers, large	4.8
8	Yellow bullheads, large	2.4
	Total	458.4

$F/C = 6.8$, $Y/C = 4.0$, $A_T = 14.3$, $A_F = 1.8$, $I_F = 39.2$, $S_F = 59.0$

TABLE 30-U. RECOVERED FROM 1.2 ACRES ON DRAINING, DECEMBER, 1938

Number	Species	Pounds
287	Large bluegills	44.5
29,778	Intermediate + small bluegills	124.5
53	Large white crappie	24.9
240	Small white crappie	19.0
5,023	Gambusia	16.8
	Total	229.7

$F/C = 8.2$, $Y/C = 6.4$, $A_T = 30.2$, $A_F = 21.7$, $I_F + S_F = 78.3$

TABLE 31-U. RECOVERED FROM 1.2 ACRES ON DRAINING, DECEMBER, 1939

Number	Species	Pounds
0	Large bluegills	0.0
2,462	Intermediate bluegills	114.6
15,554	Small bluegills	229.6
17	Large white crappie	22.4
118	Intermediate white crappie	13.4
2,368	Small white crappie	52.6
10,397	Gambusia	14.7
	Total	447.3

F/C = 19.0, Y/C = 13.2, A_T = 5.0, A_F = 0.0, I_F = 30.1, S_F = 69.9

TABLE 32-U. RECOVERED FROM 1.8 ACRES ON DRAINING, DECEMBER, 1937

Number	Species	Pounds
4	Large largemouth bass	12.4
0	Small largemouth bass	0.0
8	Large bluegills	3.4
20,696	Small bluegills	79.2
8	Large white crappie	10.6
3,849	Intermediate white crappie	32.2
10	Large yellow bullheads	8.8
668	Small yellow bullheads	62.3
4	Large blue cats	13.1
277	Chub Suckers	15.5
3	Goldfish, large	2.5
630	Gambusia	2.0
	Total	242.0

F/C = 9.5, Y/C = 6.9, A_T = 21.0, A_F = 12.7, I_F = 14.7, S_F = 72.6

TABLE 33-U. RECOVERED FROM 1.8 ACRES ON DRAINING, DECEMBER, 1938

Number	Species	Pounds
13	Large largemouth bass	43.7
11	Large bluegills	3.8
5,661	Intermediate bluegills	125.9
21,670	Small bluegills	58.4
5	Large white crappie	4.1
1,392	Intermediate white crappie	42.8
0	Small white crappie	0.0
493	Small yellow bullheads	82.0
4	Large blue cats	14.6
50	Chub suckers, small	4.3
2	Goldfish, large	2.8
3,017	Gambusia	2.8
	Total	385.2

F/C = 7.1, Y/C = 3.1, A_T = 17.9, A_F = 6.3, I_F = 50.0, S_F = 43.7

TABLE 34-U. RECOVERED FROM 1.8 ACRES ON DRAINING, DECEMBER, 1939

Number	Species	Pounds
9	Large largemouth bass	43.5
1	Small largemouth bass	0.2
28	Large bluegills	7.8
4,093	Intermediate bluegills	188.9
25,620	Small bluegills	49.9
8	Large white crappie	10.4
1,707	Intermediate white crappie	66.3
0	Small white crappie	0.0
212	Large yellow bullheads	100.1
141	Small yellow bullheads	8.9
4	Chub suckers	0.1
0	Goldfish	0.0
956	Gambusia	1.8
	Total	477.9

$F/C = 7.8$, $Y/C = 1.1$, $A_T = 33.9$, $A_F = 25.5$, $I_F = 60.2$, $S_F = 14.3$

OTHER AVAILABLE PUBLICATIONS

BULLETIN No. 254. *Management of Farm Ponds.* H. S. Swingle and E. V. Smith; 32 pages illustrated.

One of the chief reasons for failure of ponds to yield good fishing is the lack of understanding of the principles underlying management of water areas. Based on their research, the authors explain the principles of good management, proper stocking, managing old ponds, fertilizing, fishing, and controlling weeds and mosquitoes.

BULLETIN No. 264. *Experiments on Pond Fertilization.* H. S. Swingle; 36 pages.

This is a technical bulletin that reports results from many experiments, and includes: variations of plankton growth, factors determining algal production, surface scum and dispursed growth of plankton algae, phytoplankton pulses, delayed algal growth, carbon dioxide as limiting factor in fish production, fertilizer treatments involving organic and inorganic materials, and clearance of muddy waters.

CIRCULAR No. 87. *Factors Affecting the Reproduction of Bluegill Bream and Largemouth Bass in Ponds.* H. S. Swingle and E. V. Smith; 8 pages.

One of the principal problems involved in raising fish in ponds is management of population, so that a maximum number reaches desirable size each year. Some of the factors that were found in experiments conducted by this Station to affect the reproduction of bluegills and black bass are summarized in this circular.

CIRCULAR No. 95. *Construction of Farm Ponds.* John Lawrence; 56 pages illustrated.

This publication gives the step-by-step methods for building a farm pond, including: water supply, depth requirements, determination of pond area, construction details of dam, how to protect dam from breaks, filling the pond, and measures for mosquito control.

LEAFLET No. 20. *Ponds for Improving Stream Fishing.* E. V. Smith and H. S. Swingle; 8 pages illustrated.

Construction and proper management of ponds on small streams appear to offer the best method of immediately improving stream fishing. The authors tell how ponds restock streams, increase food supply of streams, reduce fishing pressure on streams, and prevent silting of stream channel.

LEAFLET No. 22. *Raising Crickets for Bait.* H. S. Swingle; 4 pages illustrated.

The necessary equipment and methods for raising crickets in the garage, basement, or vacant room are given in detail in this publication.

PROGRESS REPORT SERIES No. 5. *Raising Fishworms for Bait.* H. S. Swingle and D. G. Sturkie; 4 pages.

The authors tell how a supply of fishworms can be maintained in the garage, basement, or outdoor worm bed.

Free copies of the above publications may be obtained by writing the DIRECTOR, ALABAMA AGRICULTURAL EXPERIMENT STATION, *Auburn, Ala.* Order by number or title.