the exploitation of our saltwater fisheries. Seldom, if ever, do we know whether the claims of the opposing parties are justified. The two groups are widely removed at the social, economic, educational, and philosophical level, and these differences are aggravated by emotional factors, often influenced by irresponsible journalists.

In Virginia, such controversy does not often reach serious proportions. Several reasons may be cited: a generally thoughtful and tolerant attitude on the part of the leading sportswriters, a feeling by the leading sport fishermen's organizations that the seafood supply is sufficient for all, and a personal interest by many commercial seafood operators in recreational fishing.

The ultimate solution to such controversy is facts. Pending the accumulation of knowledge, however, there is a pressing need for education, to convince the public that argument is futile unless supported by facts, that commercial and sport fishermen must cooperate with each other, and with biologists and legislators, if the facts are to be secured, and that opinions are not synonymous with reason. The conservation agency must take the lead in promoting goodwill and understanding.

Conservation of an East Coast Shad Fishery

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MOST FISHERY ADMINISTRATORS and biologists would agree that *Conservation* relating to fishes means to them something like "wise utilization of fishery resources." This, of course, implies some sort of management of the fishery. How this is to be accomplished, or indeed, even if it can be, does not seem to be so readily agreed upon.

Usually a fishery is depleted before critical management procedures are considered, and corrective measures then call for restriction of the catch, at least during the initial stages of recovery. Huntsman (1953), however, has stated, "There seems to be no good basis for restricting fishing in order to increase the long term yield." Taylor (1951) has also pointed out that although "particular species have fluctuated in abundance, the yield of the sea fisheries as a whole or of any considerable region has not only been sustained, but has generally increased . . ." Others have argued (Burkenroad, 1951) that natural fluctuations in abundance may be the cause of the declines in some fisheries and that little can be done in controlling them.

On the other hand, where serious attempts have been made to understand the dynamics of a fish population and then to manage the fishery on scientific principles, the results have been most encouraging. Outstanding examples on our west coast are the work on Pacific halibut which has been notably successful, and on Fraser River sockeye, which has been a spectacular success.

In 1950 the Atlantic States Marine Fisheries Commission sponsored legislation to provide funds to the Fish and Wildlife Service for a coast-wide study of the shad *(Alosa sapidissima)* in order to provide basic information for state shad fishery regulations along the Atlantic Coast. As part of that study the Service began its work with investigation of the Hudson River shad. Emphasis was placed on defining the dynamics of the fishery to the extent that the possibility of managing the fishery could be explored. The Hudson fishery was of particular interest, since, contrary to the general downward trend of the Atlantic shad fishery since the beginning of the century, the catch had increased between 1936 and 1946 to almost its former level of production, and then declined to a low level by 1950. The objectives of the study were to discover the factors causing the decline, to determine conditions favoring recovery, and to provide information for proper management of the fishery. This study has been completed (Talbot, 1954) and the fishery is now being managed with excellent results.

When work was begun on the Hudson River it was realized that the catch made each year by the fishermen was not necessarily a good index of the size of run since the size of the catch depends not only upon the size of run, but also upon the number of nets being fished. To establish the relationship between the catch and size of run (fishing rate) a tagging program was carried out.

In 1951, 524 shad were caught, tagged and released at the mouth of the Hudson while the shad run was in progress. These mixed with the untagged shad and continued upstream with them. They were first intercepted by the New Jersey fishermen who fish near the mouth of the river and then by the New York fishermen who fish farther upstream above the state boundary. These fishermen were contacted regularly and their total catches were recorded along with the number of tags they recovered. A total of 755,000 pounds of shad were caught along with 46 per cent of the tagged fish. Since 46 per cent of the tagged fish were caught, we could infer that 46 per cent of the shad in the river were caught and, therefore, by simple proportions the total run entering the river was calculated to be 1,641,000 pounds of shad.

A total of 1,641,000 pounds was, therefore, available to the New Jersey fishermen and, according to our records, they had caught 332,000 pounds. There was then 1,641,000 pounds minus the 332,000 pounds caught, or 1,309,000 pounds available to the New York fishermen. Of this amount the New York fishermen caught 423,000 pounds, leaving 886,000 pounds of shad to spawn.

Statistics showing the catch of shad in the Hudson River by New York and New Jersey fishermen, and also the number of nets used each year, were available for each year since 1915. The New Jersey gear appeared to be much more efficient than the New York gear—probably because the river is narrower than in the New York section. It was, therefore, necessary to determine the fishing power of the gear of each state so that they could be combined to determine the total fishing effort for each year. To do this the following calculations were used: We let p equal the fishing power of a single unit of gear, and defined "fishing power" to mean the ability of one unit of gear to capture a certain fraction of the fish present in the river in one day's fishing. We let q equal the fraction of the fish that were not captured so that $p + q = 1$. Now, if we consider the run as a whole and denote its size by N, the number of pounds of shad removed in one net-day of fishing would equal pN, and the number remaining would equal qN. The fish not caught by the first net-day of fishing are susceptible of being captured by the second net-day of fishing during which pqN are removed. The number of pounds removed and the number of pounds remaining after successive net-days of fishing would then be as follows:

	No. of pounds removed	No. of pounds remaining
1st net-day	pN	qN
2nd net-day	pqN	q^2N
3rd net-day	pq^2N	q^3N
4th net-day	pq^3N	q^4N
*	*	*
*	*	*
*	*	*
n-1 net-day	$pq^{n-2}N$	$q^{n-1}N$
nth net-day	$pq^{n-1}N$	q^nN

After the nth net-day of fishing there remains q^nN pounds of shad in the river. In this case n equals the fishing effort, or in other words, the number of nets fished multiplied by the number of days they fished which was available; and N, the total run, and the number of pounds of fish remaining (spawning escapement) were determined from the tagging program. The only unknown, therefore, is q which can be calculated for the gear fishing in each state. From the calculated q's, the p's were determined easily, since $p = 1-q$. We then had a measure of the fishing power for the gear of each state and found that the New Jersey gill-nets had about five times the fishing power of the New York nets. A New York net was taken as the standard unit of fishing effort and the total net-days fished each year between 1915 and 1951 by the New York fishermen were combined with net-days fished each year by the New Jersey fishermen, increased five-fold. This gave us the total fishing effort exerted by the shad fishermen of the Hudson River for each year since 1915 in standard fishing unit days.

Now, as previously shown, pN is the number of pounds of shad removed the first standard fishing unit day, pqN is the number of pounds removed the second fishing unit day, and so forth. It can be seen that in any season the total catch is as follows:

$$C = pN + pqN + pq^2N + pq^3N + \dots\dots\dots\dots + pq^{n-1}N$$

Factoring,

$$C = pN\,(1 + q + q^2 + q^3 + \dots\dots + q^{n-1})$$

Since the expression in the parenthesis is a geometric progression, its sum can be expressed by the formula $\frac{1-q^n}{1-q}$

Substituting, we have:

$$C = pN\,\frac{(1-q^n)}{(1-q\ )} \quad \text{and transposing}$$

$$N = \frac{C}{p\,\frac{(1-q^n)}{(1-q\ )}} \quad \text{or, since } p = 1-q,\ N = \frac{C}{1-q^n}$$

Since we knew the total catch (C) made in the river each year since 1915, and had the total fishing effort, n, for each year and also had the value, q, it was now possible to calculate the total run of shad, N, for each year since 1915. Since we also had the catch for each year we could, by subtraction, find the amount of shad escaping the fishery and spawning each year. With this information it was possible to compare fluctuations in size of run with factors suspected of influencing the size of run. It was not possible to do this with only the catches of shad made each year because they are influenced by the amount of gear used in catching the fish.

Many factors were suggested by persons connected with the Hudson shad fishery as being responsible for the recent decline. These were: changes in stream flow, changes in water temperature, dredging to improve the ship channel, increase in ship traffic, curtailment of hatchery operations, pollution, natural cycles of abundance and scarcity, catches made outside the river, and overfishing. All these things were considered during our investigations.

However, before we could determine cause and effect relationship with any of these factors, additional information was needed concerning the biology of the shad. We knew that the adults return to the river of their origin in the spring of the year for the purpose of spawning, and it is at this time that the commercial fishery takes the harvest. Those that escape the fishery and do not die from natural causes, spawn and return to the ocean, and if they do not die of natural causes or are not caught elsewhere, they come back again the following spring to spawn. The eggs of the shad hatch in five or six days, and the young live in the river until the fall when, at a length of three or four inches, they leave for the ocean. It was vitally necessary, however, to know at what age these fish return as adults to spawn for the first time, since any factor adversely affecting the young, for instance, would not become evident in the fishery until the time they would normally return as adults.

To determine this, scales from a sample of shad were taken throughout the runs of 1950 and 1951 from the catches made by the fishermen. A method was found to read these for total age as well as for the number of times they had previously spawned. It was found that the majority of shad returned to the river as adults for the first time at four and five years of age. Therefore, it could be expected that any factor affecting the young of any one year would not show until four and five years later. It was also found from the scale readings that about 50 per cent of those captured had spawned in previous years.

With the age-composition of the shad known, it was possible to make valid comparisons between factors suspected of affecting the run and the size of run each year.

No effects from variations in stream flow or water temperatures could be found. Dredging in the river had no measurable effect on size of shad run, but deepening the river increased the number of ships running up the river to Albany. Shipping appeared to have no effect on the size of shad run, but did increase the hazards of fishing and caused loss of fishing gear and damage to boats.

Production of shad hatcheries had no measurable effect on subsequent size of the shad runs and no evidence of natural cycles of abundance was found. Evidence of gross pollution of the river was found, but this condition has apparently been serious since the beginning of the century. Pollution abatement probably would increase the productivity of the river and certainly would result in a higher quality fish, but there was not enough evidence available to compare fluctuations in the size of run with changes in pollution. Catches outside the river undoubtedly influenced the run, but there was no way to distinguish the Hudson River fish from the other shad caught outside the river and so this effect could not be determined.

In analyzing the effect of fishing on the size of the run, or in other words, to determine if overfishing caused the recent decline, a comparison was

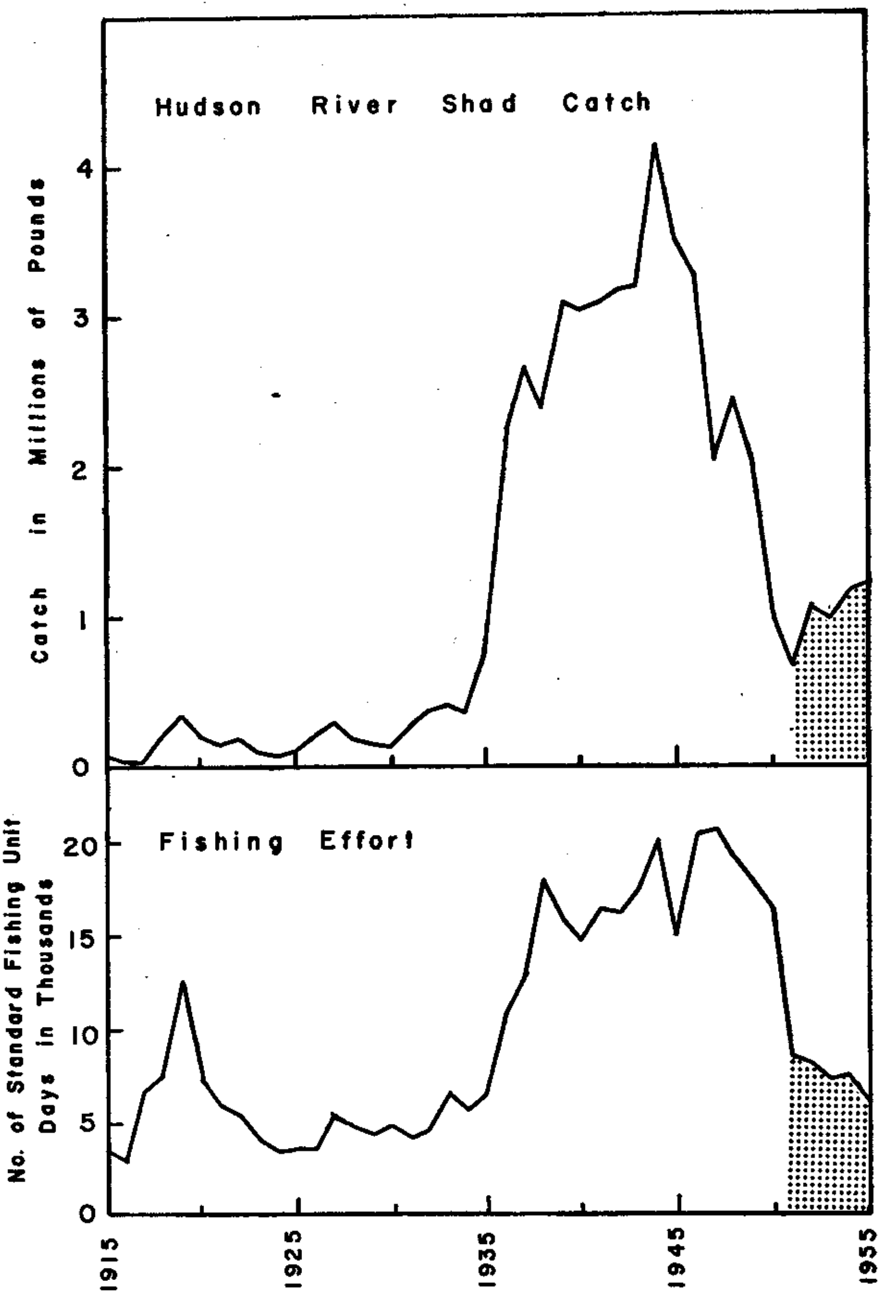

FIGURE 1.—Hudson River shad catches and fishing effort from 1951 through 1955. Data to 1951 from Talbot (1954). Data after 1951 from New York and New Jersey statistics.

made between the size of run in any year and the size of the spawning escapement the year previous and four and five years previous. This was done because it had been shown from the scale readings that about 50 per cent of the catch

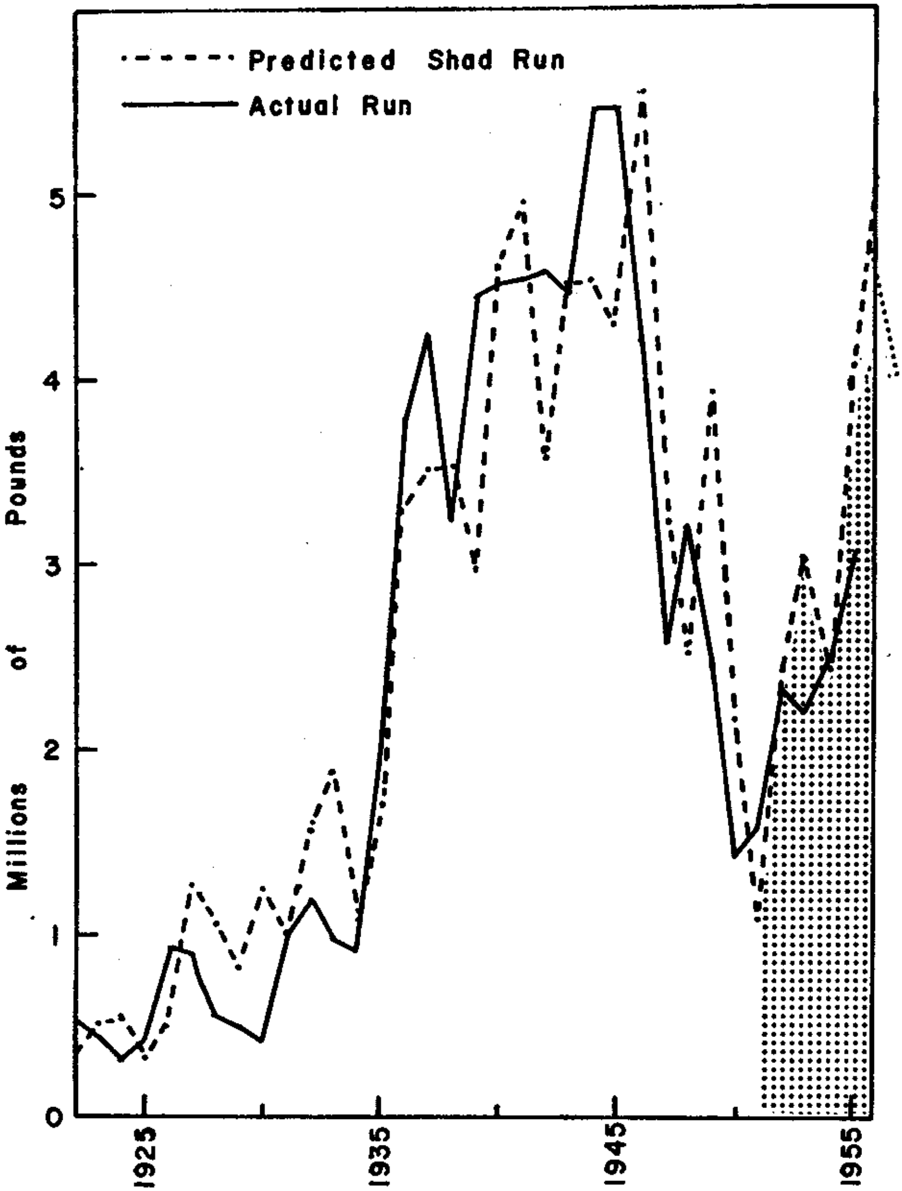

FIGURE 2.—Predicted and calculated actual shad runs, in pounds for Hudson River, 1922 through 1956.

was made up of shad which has escaped the fishery the year previous, and that the majority of the fish caught were four and five years old. Those allowed to escape the fishery and spawn would return the next year in the fishery and their progeny would return and enter the fishery mostly four and five years later. This comparison was made using a mathematical analysis termed a multiple regression analysis. This disclosed that there was a very significant correlation between the amount of shad allowed to spawn each year and subsequent shad runs. In fact, 85 per cent of the fluctuations in size of run could be accounted for by changes in the escapement. Since the size of run is determined by the amount of fish allowed to spawn, it was possible to predict by the use of an equation, using the calculated escapements what the total run should be one year in advance. This was done for each year for which statistics were available and the predicted populations agreed closely with the actual calculated populations. It could be seen from these comparisons that the amount of fish allowed to escape the fishery each year was responsible not only for the recent decline, but also for the great increase in size of run between 1936 and 1946. The equation, plus the statistics of the catch and effort, were the tools needed to regulate the fishery to produce maximum yields each year. Since the size of run could be predicted one year in advance, fishery regulations could be formulated to allow a predetermined escapement which would give the desired size of run four and five years later.

In 1951 it was realized that the fishing intensity was too great for the size of shad runs, and concurrent restrictive regulations of the fishery were imposed by both New York and New Jersey as a means of conserving the fishery. The fishing intensity was decreased to about one half that which had been in effect for the past several years and in 1951 only 755,000 pounds were caught. The small sacrifice in catch, however, has paid off. The lower catch resulted in an increased spawning escapement that year and the following year the shad run began to increase because of the increased "repeaters" from the year before. The fishing effort has continued to decline, but in spite of less fishing being done, the total catch of shad has increased from 755,000 pounds in 1951 to over 1,200,000 pounds in 1955 (Fig. 1), and in 1955 the total run was over 3 million pounds as compared to half that amount in 1950 and 1951 (Fig. 2). As a result of the facts developed by the intensive study of the Hudson River shad and the prompt action of the States of New York and New Jersey in amending their regulations, this fishery is now well on its way toward being restored to its former level of abundance.

The results of this study appear to add weight to the theory that at least some of our fishery resources can be scientifically managed so as to produce maximum sustained yields year after year. In many cases the problems involved in doing this are not great. The most important tools necessary are adequate catch and effort statistics compiled over a series of years. These, in combination with a comprehensive research program, can point the way to sound conservation programs.

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Principles of Shrimp Fishery Management

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Introduction

THERE ARE TWELVE OR MORE SPECIES of shrimp of the family Penaeidae living in the waters of the Gulf of Mexico at depths of forty fathoms or less. The flesh of all of these is edible, but small size and rarity exclude the majority from the commercial catch. Possibly the tastiest shrimp in this area are two species of the genus *Sicyonia,* commonly known as stone shrimp because of their hard shells. They are also rather small and are not very numerous. A night's dragging may yield ten to fifty pounds. They are consumed only by the fishermen themselves and perhaps a gourmet here and there. They have been marketed sporadically and rarely at Brownsville, but we are not concerned with them here.

On the Louisiana coast the "six barbes" of the French fishermen, *Xiphopeneus kroyeri,* or sea bob of the other fishermen is sometimes used on the drying platforms. It is also a very delectable shrimp, but it is just barely large enough to eat, at least for the American taste which is now well accustomed to larger shrimp. Production may be a million pounds a year or even less and in the following remarks we shall not be concerned with them either.

The 200,000,000 pound annual shrimp production of the Gulf of Mexico is based on three species of shrimp. Ranked in order of catch, the first is the brown shrimp, *Penaeus aztecus* Ives, followed by the white shrimp, *Penaeus setiferus* (Linnaeus), and last is the pink shrimp, *Penaeus duorarum* Burkenroad. Roughly, each succeeding shrimp in this short series yields about half as much as the preceding one.

The brown shrimp production is greatest in the western Gulf, especially along the lower half of the Texas coast and Mexico as far south as Obregon, at the very southernmost part of the Gulf of Campeche. Thus, part of brown shrimp grounds lie south of the Campeche pink shrimp area, a fact not commonly appreciated. There is also a small ground for white shrimp lying closer inshore, and farther south, in the same area. It should be noted, however, that the brown shrimp is also becoming increasingly important east of the Mississippi, at least into Alabama waters.

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