growers are permitted to operate, the services of biologists should be available to them for guidance. Experiments should be planned and developed to supply some answers to their questions. In the states where public oystering is the policy, biologists and business men should team up to provide sound management divorced as far as possible from political pressures. I emphasize the combination of biologists and business men since my own experience indicates that biologists as managers are frequently quite impractical and need the assistance which good business men can give.

Oysters are cooperative subjects to work with. They spawn and the larvae set consistently if given half a chance. I am confident that every state along the Atlantic and Gulf Coasts could greatly increase its supply of oysters, if we could obtain the close liaison between science and industry. The Gulf and Caribbean Fisheries Institute can be a major factor in bringing this about.

Progress in Atlantic Coast Shad Investigations—Migration

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IN 1950, AT THE REQUEST of the Atlantic States Marine Fisheries Commission, the U. S. Fish and Wildlife Service began a study of the Atlantic Coast shad (*Alosa sapidissima*). This project was undertaken to determine causes of fluctuations in abundance of this species and methods of controlling and predicting the size of shad runs. We were remarkably successful in achieving these objectives for rivers where records of the shad catch each year and the amount of gear used each year in making that catch were available (Fredin 1954; Talbot 1954).

Much of the research depended upon estimation of the total populations of shad in the rivers being studied. The estimates were determined through tagging programs in which ratios of tagged to untagged fish sampled in catches were applied to total numbers of fish tagged so that total numbers of fish in the populations were derived. Usually between 40 and 50 per cent of the tags applied were recovered within the river of tagging. Some of those tagged fish which were not caught in the rivers and which escaped other mortalities were recaptured elsewhere, and from these, as well as recaptures from other tagging experiments, the oceanic migration pattern of shad became known.

The shad is an anadromous fish, running up coastal rivers to spawn. Its river life is rather well known. Shad begin running into the St. Johns River in Florida (which is the southern range of this species) as early as November. The runs begin in more northern streams at progressively later dates. For instance, shad enter Chesapeake Bay streams in February and March, the Hudson River in April, and the St. Lawrence River (the northern limit of the species) in June. While in the river, the females deposit an average of about 250,000 eggs. These are deposited loosely in the water and are then fertilized by the males. After absorbing water, the fertilized eggs sink to the bottom and are carried along by the current. The eggs hatch in three to ten days, depending upon

water temperature. The young shad stay in the rivers until fall and when they are three to five inches in length they migrate to the sea. After spawning, the adults, if they escape fishing and natural mortalities, migrate to sea. Where they go after leaving the rivers and where the young remain until they return as

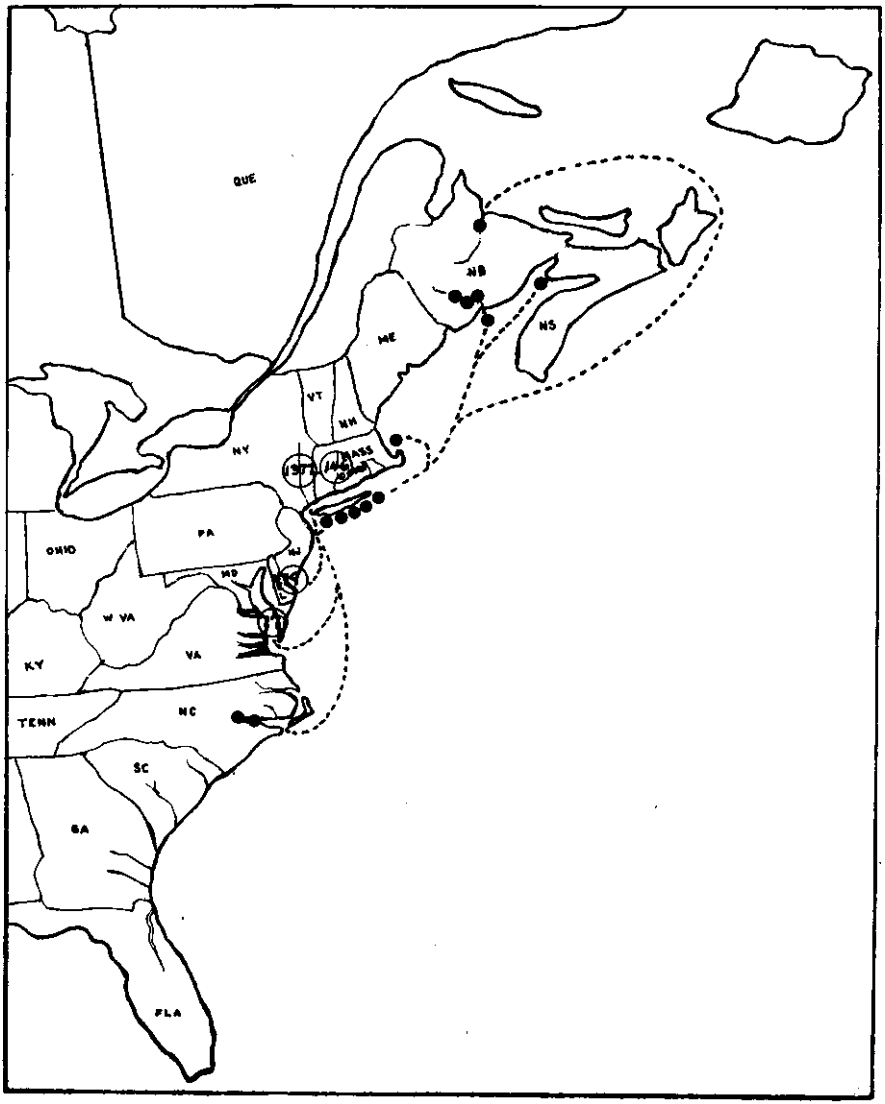

FIGURE 1. Tags recovered before or during the spawning period from tags affixed at Fire Island, Staten Island and the New Jersey Coast. Black dots indicate one tag recovery whereas numbers in circles indicate a larger number of recoveries.

adults, has always been a mystery and the subject of several hypotheses.

It was originally thought because these fish were first seen each year in the

FIGURE 2. Tags recovered before or during spawning from tags affixed in Chesapeake Bay and tributaries and from tags affixed at the mouth of the Neuse River in North Carolina. Black dots represent one recapture and numbers in circles indicate a larger number of recoveries. The dashed line indicates migration of Chesapeake Bay tagged shad while the solid line indicates migration of shad tagged at the mouth of the Neuse River.

south, that they wintered there and started northward each spring in a vast school, sending detachments into each successive stream as they passed, the last of them entering the St. Lawrence River. A later theory was that the adults, and later the young, moved out of the rivers and remained in the ocean near the mouths of the rivers where they were born and entered the rivers again when the water temperature became suitable. Tag returns, however, have shown

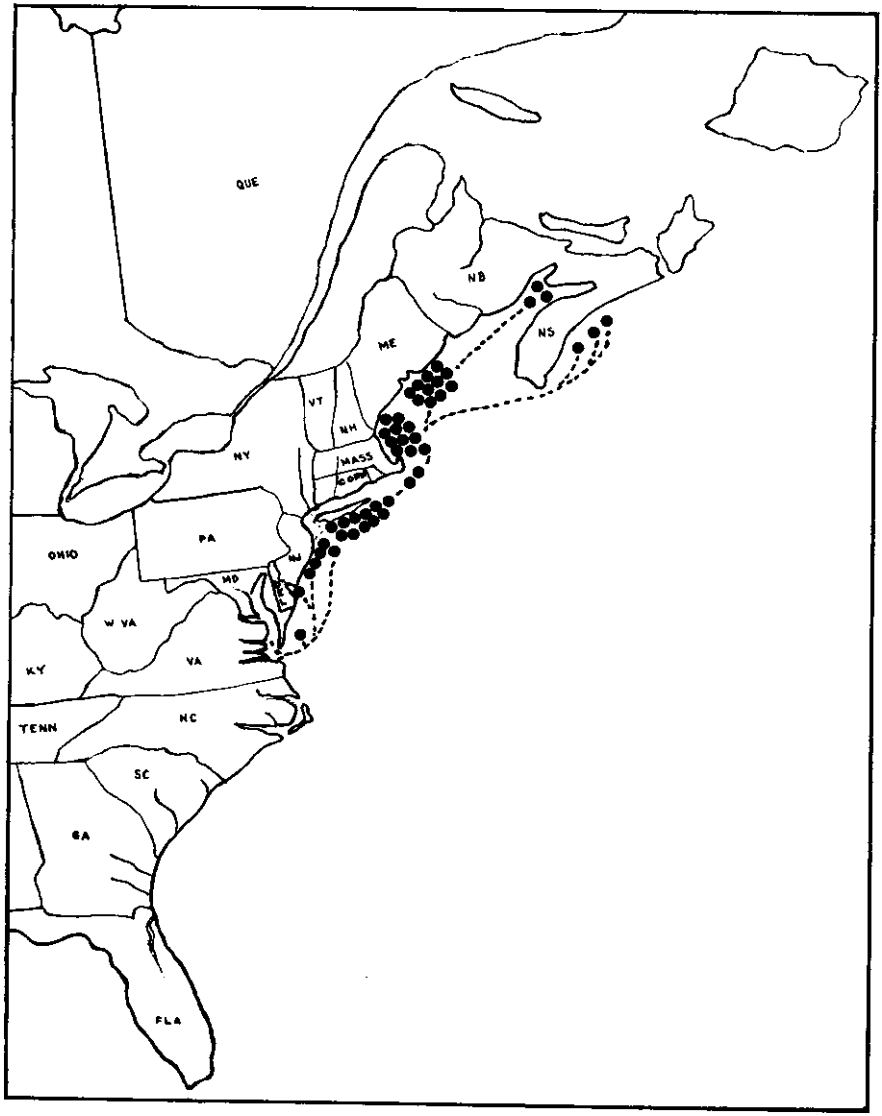

FIGURE 3. Tags recovered after the spawning period from all spring tagging programs.

that shad undertake a regular migration pattern each year which does not bear out either of these hypotheses.

The returns from a total of 17,508 tags applied to shad at many locations along the Atlantic Coast between 1938 and 1955 were used in this study. A total of 6,846 tags, or 39 per cent, of these were recovered.

Most of the tagging was carried out in the spring of the year during the

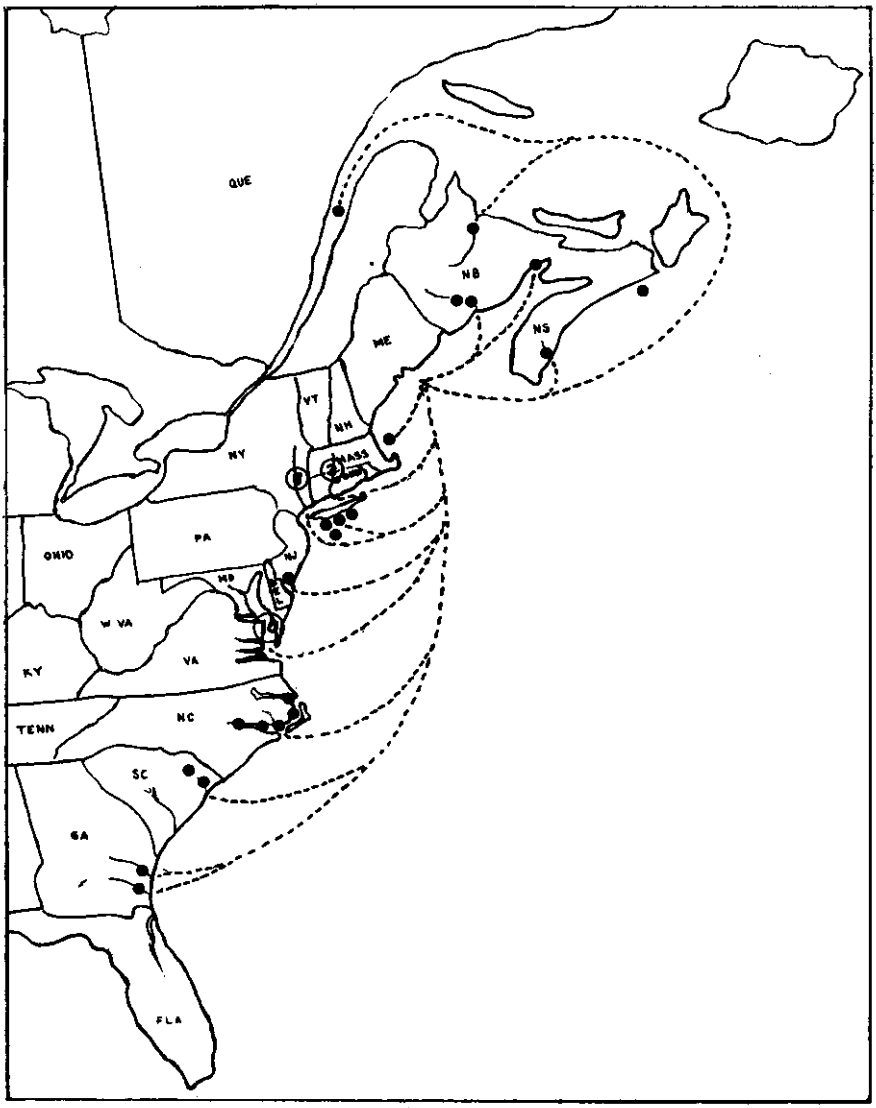

FIGURE 4. Tags recovered from tags affixed in the Gulf of Maine during the summer.

spawning run, but some were tagged off the coast of Maine during the summer months. Table 1 shows the locations where shad were tagged, the number tagged, and the number recovered. For the purpose of analyzing the tag returns from the spring tagging projects, they were separated into two categories. These are:

1. Recoveries made before or during the spawning period.
2. Recoveries after spawning.

The above separation was based on a knowledge of the spawning periods in each of the rivers. The date, May 31, was arbitrarily chosen as the latest that shad would be spawning south of Long Island and June 14 north of Long Island. The shad tagged in the Gulf of Maine were analyzed in a third category.

Figure 1 shows the pattern of migration of shad tagged at Fire Island and Staten Island, New York, and the New Jersey coast from March through June and recovered before or during the spawning period. The bulk of the shad caught and tagged in this area were heading for the Hudson River where 1,377 returns were made and to the Connecticut River where 146 were recaptured. Some, however, were recaptured south of New Jersey—nineteen in Delaware Bay and tributaries, seventeen in Chesapeake Bay and tributaries, two in North Carolina waters, and several north of New Jersey as far as the Bay of Fundy and Mirimichi River in Canada.

Figure 2 shows the recoveries of shad tagged in the spring in Chesapeake Bay and recaptured elsewhere before June 1. Those recovered in Chesapeake Bay and tributaries were of course in the majority—some 1,700—but are not shown since they show no migration. Those migrating out of the Bay and recaptured before or during spawning were recovered in the ocean and streams from South Carolina to New Brunswick, Canada. Also shown in this figure is the migration of a shad tagged at the mouth of the Neuse River, North Carolina, and recovered in the Altamaha River in Georgia. Here too, the bulk of the Neuse River tagged fish were recaptured in the river of tagging.

TABLE 1

SHAD TAGGED AND TAGS RECOVERED

Place tagged	No. tagged	No. recovered
Gulf of Maine	601	44
Connecticut River	2,542	612
Fire Island, New York	198	49
Staten Island, New York	1,054	478
Hudson River	3,295	1,321
New Jersey Coast	3,421	1,263
Chesapeake Bay and tributaries	4,775	2,514
Neuse River, North Carolina	377	226
Edisto River, South Carolina	128	16
Ogeechee River, Georgia	235	133
St. Johns River, Florida	882	190
Totals	17,508	6,846

The tag recoveries shown in these two figures indicate that, in general, most of the shad caught in the spring of the year at each location are heading toward the nearest spawning streams in the area, but with them are shad bound for other places along almost the entire range of the species.

Figure 3 shows recoveries from all tagging programs made after the spawning period—that is, after May 31 at Long Island and southward, and after June 14 north of Long Island. All recaptures were made north of the tagging sites from shad which were either in the Gulf of Maine or apparently on their way there. The recaptures near Long Island were made between June 5 and 26. Those captured off Massachusetts were made between June 22 and November 3, but none was recaptured during September. In Maine and Canadian waters the recoveries were made only during July, August, and September. This indicates that shad are caught during June, July, and August as they migrate past Massachusetts on their way north into the Gulf of Maine region, and again during October and November on a southern migration. Vladykov (1950, 1957) has reported that shad tagged in the St. Lawrence River during the spawning run also migrated to the Gulf of Maine during July and August. Not a single tag affixed to shad in streams south of the Chesapeake Bay area was recovered after the spawning period.

Recoveries of tags affixed in the Gulf of Maine are shown in Figure 4. These were tagged during August and September, and all recoveries were made the following spring except the one in Massachusetts which was recaptured in the fall approximately two months after tagging. As can be seen, shad tagged in the Gulf of Maine area were later recaptured throughout the entire range of the species except for the St. Johns River in Florida. Since the number of fish tagged was small and the recapture spread along the entire coast, we believe the lack of recaptures in the St. Johns River is probably the result of chance rather than an exception to the general pattern.

Since none of the adult shad tagged in streams south of Chesapeake Bay was ever recovered outside the rivers, the shad tagged in Maine which entered the southern rivers must have been immature when tagged. This leads to the conclusion that young shad migrate to the Gulf of Maine for the summer as well as adult fish. Atkins (1887) and Bigelow and Welsh (1925) reported large numbers of both large and small shad in the Gulf of Maine, but these writers at the time thought they were shad from Maine streams. In recent years, however, there have been few shad in Maine streams because of dams and pollution (Taylor, 1951), but still large numbers of shad are found in the Gulf of Maine each year. The migration to this area by shad from all other Atlantic Coast shad streams undoubtedly accounts for the large numbers found in the Gulf of Maine during the summer months.

Not much is known about where these fish spend the winter months since only one tag has been recovered during December and January. This was recovered in the ocean off New Jersey. Shad appear in abundance, however, along the middle and south Atlantic Coasts beginning in February, and it is assumed that they spend the winter here, probably in deep water. Some evidence of this was found when shad were caught in forty to fifty fathoms of water off North Carolina in March, 1958 by the U. S. Fish and Wildlife Service vessel, *Delaware*. When shad appeared in abundance along the middle and south Atlantic Coast, tagged shad from all areas were with them. For instance, shad tagged in the St. Lawrence River by Vladykov were recovered the following spring as far south as Chesapeake Bay, and those tagged on the spawning grounds of the Hudson River were recovered the following spring as far south as North Carolina. However, 185 Hudson-tagged fish returned to the Hudson, and twenty-three Connecticut-tagged shad returned to the Connecticut, but not

a single tag was found on the spawning grounds of any other stream. This indicates that although shad may migrate many hundreds of miles in the ocean, they return to the same stream to spawn the following year.

Considerable evidence is available to show that shad return to their native stream to spawn. Hollis (1948) and Coker inserted small plastic tags into the belly cavities of juvenile shad. These were released in two areas—one in North Carolina and the other in Maryland. In each case the few returns received three, four, and five years later from mature adult shad came from the area of release or from fish that could have been on their way there. None was returned from an area that would indicate that they might spawn in any place but their "home" stream.

Further, Hammer (1942) made a study of the scales and measurements of shad from tributaries of Chesapeake Bay and found significant differences in shad from various streams, indicating separate populations that return to spawn in the stream of their origin.

As previously noted, shad tagged in rivers south of Chesapeake Bay are never recovered after the spawning period. An examination of the scales from these fish shows that they are spawning for the first time, and hence it can be assumed that they die after spawning. Scales from shad spawning in the more northern streams show that 27 to 50 per cent of the fish are spawning for the second or more times. This is good evidence that few, if any, shad of the northern populations stray into and spawn in the southern streams.

It has also been shown (Fredin 1954; Talbot 1954) for some shad streams that the size of run in each stream is dependent upon the number of shad previously spawning. In other words, each of the runs in a shad stream is self-perpetuating and fluctuates independently of shad runs in other streams. This could only occur if the majority of the shad return to their home stream. The available evidence, therefore, indicates that most shad do return to their native stream to spawn.

From the data presented, we can summarize the migration pattern of Atlantic Coast shad. After spawning, adult shad in streams from Chesapeake Bay and northward migrate to the Gulf of Maine and spend the summer and fall there. Little evidence is available as to where they spend the winter months, but it is presumed that this period is spent in deep water in the middle and south Atlantic area. Beginning in January or February as the spawning season approaches, shad move inshore, and some are taken by the coastal commercial fisheries. They then migrate either north or south to their native streams and spawn, repeating this cycle if they escape natural and fishing mortalities. The young shad leave their native streams in the fall; probably spend the winters in the middle Atlantic area; migrate to the Gulf of Maine each summer along with the adults; and when mature, return to their native streams to spawn. Those that spawn in streams south of Chesapeake Bay, and particularly south of North Carolina, die after spawning.

Knowledge concerning the migration of this fish is not only interesting from a life-history standpoint, but is also useful in the management of the species. In our investigations we have shown that over 80 per cent of the variations in size of populations studied can be accounted for by changes in size of the spawning populations in previous years. The balance of changes can be attributed, partly at least, to variations in the catches outside the rivers. Shad are not fished extensively in the Gulf of Maine because only the female shad bring good prices,

and almost all of the shad in the Gulf of Maine are either immature or spawned out. However, during the last war when fish prices were high, over a million pounds were landed. Again in 1957, fishermen in the Gulf of Maine turned to shad when menhaden failed to appear, and over two million pounds of shad were landed during the summer months. Landing figures of all shad catches outside the usual fishing sites, now that we know the migration pattern, should enable us to better our control of population size and to make even better predictions of abundance than we have previously been able to do.

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