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AMERICAN SHAD

HISTORICAL PERSPECTIVE

Before the colonists came to Virginia, the Indians caught American shad (Alosa sapidissima) in the rivers and streams in large quantities using a seine made of bushes, called a bush net (Walburg and Nichols 1967). Fish were so plentiful that children would spear them with pointed sticks as they swam on the flats (Va. Commission of Fisheries 1875). The early settlers used haul seines, and utilized shad as a major food supply (Walburg and Nichols 1967). By 1740, however, fish were becoming scarce due to dams, seines, traps, and other devices which depleted the stock or prevented the fish from reaching their spawning grounds. The colonists, concerned about the scarcity of fish and obstructions to their passage, passed laws requiring the removal of dams or the building of fish passages, and prohibiting hedges and other obstructions (Va. Commission of Fisheries 1875).

The early fish passages failed to pass fish, and so in 1771, the Virginia assembly passed a law requiring that a gap for fish passage be built in dams adhering to specific dimensions, and that it be kept open from February 10 to the last day of May. Due to the approach of the Revolutionary War, however, this law was never enforced (Va. Commission of Fisheries 1875).

Many of those involved in the early shad fisheries were large plantation owners. Thomas Jefferson brought shad to Monticello.

George Washington ran a shad fishing business, and also leased fishing rights and privilages on his land on the Potomac River (Mansueti and Kolb 1953).

In the early days, haul seines were used almost exclusively, but about 1835 gill nets were introduced, and have since become an important gear for capturing shad in the Chesapeake Bay area (Walburg and Nichols 1967). Pound nets were introduced to the area in 1858, and reached their peak in use in 1930 (Kriete and Merriner).

The shad fishery of Chesapeake Bay became important about 1869, and developed greatly in the ensuing years. Fishing gear used included haul seines, pound nets, and stake gill nets (Walburg and Nichols 1967). The fishery again became depleted and reached a low in 1878. An artificial hatching program was begun in 1875 by the U.S. Fish Commission and Virginia Commission of Fisheries, and in 1879 the fishery began to improve. This increase led biologists to believe that the shad fishery was largely dependent upon artificial propagation, and resulted in an expanded hatchery program. Later studies, however, showed that the upsurge could not be correlated with the output from artificial stocking. In the early 1900's a decline began in the numbers of shad harvested despite improved hatching methods and increased numbers of shad fry released (Mansueti and Kolb 1953).

In 1880 the tributaries of the Chesapeake Bay yielded more than 2,268 metric tons (MT) of shad. In 1896 Virginia ranked second to New Jersey in shad production with 4,990 MT. Usually Virginia ranked

first or second in shad production. In 1908, Virginia's shad catch of 3,311 MT made it the most important fish caught in Virginia and comprised about one fourth of all shad taken in the United States. The main types of fishing gear used in 1908 included drift gill nets, pound nets, stake gill nets, and seines (Walburg and Nichols 1967). Today the primary gear is stake gill nets and drift gill nets, and to a lesser extent, pound nets (Va. Marine Resources Commission 1980). The Virginia shad catch for 1981, based on preliminary data from the Virginia Marine Resources Commission through November, was less than 113 MT.

LIFE HISTORY

Adults

The American shad ranges on the Atlantic coast from the Gulf of St. Lawrence to Florida, but is most abundant from Connecticut to North Carolina (Mansueti and Kolb 1953). It was introduced on the Pacific coast in 1871, where it has spread to southern California and Alaska (Leim and Scott 1966).

Most shad spawn for the first time when they are four or five years old. Males mature and begin spawning at an earlier age than females (Walburg and Nichols 1967). Data reported by Walburg and Nichols (1967) indicated that the age of spawning shad in Virginia rivers ranged from 2 to 8 years, with most of the shad at 4 or 5 years of age. More than 73 percent of the shad were first-time spawners, and less than 9 percent had spawned more than once. Loesch et al.

(1979) reported that the modal age for spawning shad in Virginia was 6 years in 1979 and 1978, and 5 years in 1977. However, the authors noted that these estimates were based on samples from the commercial gillnet fishery, which is selective for larger and older fish.

American shad ascend rivers and streams in the spring to spawn. The time of migration is related to the water temperature, and occurs when the temperature is from 5 to 23°C, but the peak movement occurs at 13 to 16°C (Walburg and Nichols 1967). In Chesapeake Bay, the migration begins in mid-February or March and the shad are gone by early June (Walburg and Nichols 1967; Hildebrand and Schroeder 1928).

Davis et al. (1970) compiled a list of known or probable spawning areas of Alosa species in the river systems of Virginia including the Potomac River. Although it is part of Maryland, many of the fish caught in the Potomac River are landed in Virginia, and therefore, it is included in this discussion. The physical characteristics of the spawning grounds for American shad include waters of less than 1 part per thousand salinity, and usually fresh water (Davis et al. 1970). The shad may spawn anywhere but prefer the shallow sandy flats which border the streams, and the sand bars found up in the tidal freshwater section of the mainstream (Davis et al. 1970; Mansueti and Kolb 1953). Shad also appear to spawn in larger tributary streams to some extent (Davis et al. 1970). Spawning takes place between sundown and midnight (Mansueti and Kolb 1953). The spawning shad swim close to the surface, occasionally breaking the surface and making splashing sounds, referred to as "washing" by some fishermen. In the act of

spawning, the two sexes run along together from the channel toward the shore, ejecting eggs and milt simultaneously. Females have been reported to produce 20,000 to 156,000 eggs, depending on size, but more commonly, the number of eggs produced is 25,000 to 30,000 (Hildebrand and Schroeder 1928; Mansueti and Kolb 1953). Hatching occurs in 6 to 8 days at 17°C, and in 12 to 15 days at 12°C (Liem 1924).

According to Neves and Despres (1979), adult shad, after spawning, return to the sea and migrate to the Gulf of Maine or to an area south of Nantucket shoals, where they remain during the summer and early autumn. Their movements are limited to areas and depths with near-bottom temperatures between 3° and 15°C. They migrate vertically during this time, following the diel movements of zooplankton, on which they feed. During the daylight hours, the shad appear to be closer to the bottom.

In the autumn, with declining water temperature, most shad leave the Gulf of Maine and congregate offshore for the winter, between southern Long Island and Nantucket shoals. In the winter and early spring, the adults move into coastal waters along the Middle Altantic coast and migrate to their spawning rivers (Neves and Despres 1979).

Juveniles

Young American shad, in the Chesapeake region, spend their first summer in the tidal, freshwater sections of the rivers. Loesch and Kriete (1980) found that, in 1979, juvenile shad in Virginia waters

were most abundant in the York River system. They were found from nautical mile 45 to 70 in the Pamunkey River and from mile 45 to 62 in the Mattaponi River in mid-June. This range was extended down river to mile 35 in both rivers in early July, but by August the range had been moved back to mile 45 in the Pamunkey River and mile 40 in the Mattaponi River. In September and October, the range of juvenile shad extended down to mile 30 in both rivers, and abundance had decreased due to juvenile migration to the sea. Loesch and Kriete (1980) suggested that the juvenile movement upriver in mid-summer was due to the lessening of freshwater runoff and the ensuing encroachment of saline water.

Juvenile shad undergo diel verticial migrations. Loesch et al. (1982) found that catches of shad by bottom trawl were signifigantly greater during the day than at night, and conversely, catches of shad by surface trawl were greater at night than during the day. This day-night vertical migration could result in inaccurate sampling data if the choice of sampling gear is made without regard to the time of sampling.

American shad have a protracted spawning period which builds to a maximum and then decreases extending over about a three-month period. When first hatched the shad fry are less than 10 mm in length, but they grow rapidly. In the Potomac River they reach an average length of 47 mm during the first half of July, 66.5 mm by the last half of August, and 70 mm by the last half of October (Hildebrand and Schroeder 1928). Within the York River system, lengths of shad in the

Pamunkey River have been found to be consistently higher than in the Mattaponi River. Possibly this is due to a lesser food supply in the Mattaponi as indicated by the greater clarity of the water (Loesch and Kriete 1980).

Absolute growth is difficult to measure. Marcy (1976) showed that there was a tendency for the larger juvenile shad to migrate downstream; Loesch (1969) reported the prime downstream drift for large juvenile blueback herring. The measurement of growth is also affected by uneven recruitment. Although anadromous Alosa spawning is protracted, each species has a shorter period in which the bulk of spawning occurs. These juveniles may recruit to the sampling gear in sufficient numbers to cause an apparent negative growth rate; the rate is again positive after the period of peak recruitment. This phenomenon is apparent in the juvenile American shad data reported by Marcy (1976; his Fig. 46); it has also been reported for blueback herring (Loesch 1969), and for juvenile alewife and blueback herring in Virginia waters (Loesch and Kriete 1980). If the larger fish leave the nursery areas, then growth is underestimated.

Instantaneous daily mortality for Amerian shad in the Mattaponi and Pamunkey rivers was estimated at 0.056 and 0.079, respectively, in 1980, and 0.040 and 0.060 in 1979 (Loesch and Kriete 1980). The authors suspected that the 1980 estimates were inflated because of emigration of the larger fish between the first and second sampling periods which occurred later in 1980 than in 1979. The survival of juvenile shad is dependent on many factors including the abundance of

prey organisms, the abundance of predators such as American eels and striped bass, and physical parameters such as turbidity, salinity, and temperature.

The major migration of juvenile shad from the rivers begins in the fall, usually after the water temperature has decreased to less than 15.5° C (Walburg and Nichols 1967), but it is not until near the end of November or the beginning of December that all of the young shad have left the fresh waters in the Chesapeake region (Hildebrand and Schroeder 1928). Most of these young shad probably spend the winter with the adults in the middle Atlantic area (Walburg and Nichols 1967), but a few spend their first winter in the salt water of Chesapeake Bay (Hildebrand and Schroeder 1928).

FISHERIES

Gear Types

The American shad in Virginia are fished commercially with stake gill nets, and to a lesser extent, pound nets and drift gill nets as the primary gear. Other types of gear which have been used include fyke nets and haul seines. The bulk of the fisheries takes place in the rivers between the river mouths and spawning grounds.

Data collected from the James, York, and Rappahannock River systems show that in 1979 stake gill nets accounted for 96 per cent of the catch, 3.8 per cent of the catch was with pound nets, and drift gill nets accounted for the remainder (Loesch et al. 1979). In 1980, 448 stake gill net stands totaling 93,666 meters of net, with 70,437

meters of net fished primarily for American shad, landed an estimated 683,957 kg of shad. Pound nets, which reached a peak of 272 active nets in late May, landed 10,372 kg of shad. In the Potomac River, 6,532 kg of shad were landed by stake, anchor, and drift gill nets combined, and in the James River, 382 kg were landed by fyke nets, which reached a peak of 23 nets in April and May (Loesch and Kriete 1980). Although the Potomac River is part of Maryland, many of the fish are landed in Virginia, and therefore it is included in this discussion. Sport fisherman also fish for shad, casting from shore or boats with artificial lures (Kriete and Merriner).

Status of Stocks

Catch-per-unit-of-effort (CPUE) has been used to monitor the status of the stocks rather than catch alone because changes in total catch may be the result of changes in stock density and/or fishing effort (Loesch and Kriete 1976). However, CPUE must be viewed with caution because of subtle changes that may take place in the fishery. For example, prior to 1977 all stake gill nets were assumed to have been set for American shad. However, in 1977 all of the nets on the Rappahannock River above mile 35 and 40 percent of the nets below mile 35 were found to be large-mesh nets set primarily to capture striped bass which have a higher market value than American shad (Loesch et. al 1979).

The CPUE of American shad caught by stake gill nets increased from 1969 to 1972, then decreased from 1972 to 1975. In 1976 it rose

sharply (Loesch and Kriete 1976). These CPUE's were based on the assumption that all the stake gill nets were set for American shad.

From 1977 to 1979, the CPUE's oscillated in the James and Rappahannock rivers, but increased continually in the York River (Loesch et al. 1979). In 1980, the CPUE increased in the James River and, except for the CPUE of males in the Rappahannock River, declined in the York and Rappahannock rivers (Loesch and Kriete 1980).

No general trend appears from the CPUE data for the American shad stocks in Virginia. Catch data alone show a continuing decline (Fig. 1), but do not reflect changes in effort, as some fishermen have shifted their effort from shad to more valuable species, or have shortened their active fishing periods due to adverse weather conditions or large numbers of blue crabs becoming entangled in the nets. Where CPUE exhibits an increase during years of low yield, this might be indicative not of an improvement in the stock, but rather a removal of marginal or inefficient fishing gear, leaving only the most efficient gear (W. H. Kriete, personal communication).

Possible Reasons for Decline

In previous years concern over heavy fishing of the shad stocks had been an issue in Virginia. Mansuetti and Kolb (1953) quoted Cable and Hollis as suggesting that overfishing has been an important factor in the decimation of the runs and a deterrent to their recuperation. The U.S. Fish Wildlife Service has also in the past contended that Virginia fishermen were depleting the shad supply by

not permitting a sufficient number of fish to escape the nets and continue on to the spawning grounds (Mansueti and Kolb 1953). However, the Virginia Fisheries Commission opposed this view, contending that the available information was not adequate to arrive at such a conclusion (Marshall 1949).

In recent years the fishing effort for American shad has decreased. Because of the paucity of shad, many fishermen early in the shad season will switch to larger mesh to catch the equally scarce, but more valuable striped bass.

In 1972, Tropical Storm Agnes hit Virginia when larvae, post-larvae, and juveniles were present in the tidal freshwater nursery zones. The failure of the 1972 river herring year class to recruit in 1976 was attributed to Tropical Storm Agnes, possibly as a result of eggs and juveniles being physically damaged by the highly turbid conditions, and heavy river flows sweeping them seaward where osmotic imbalance would cause large mortalities (Loesch and Kriete 1976). American shad catch data are biased due to the selective nature of the fishing gear used; however, trends in mean age and distribution in the late 1970's paralleled the finding derived from the unbiased data for alewives and blueback herring. Thus, it is possible that Tropical Storm Agnes also affected the 1972 year class of shad.

Dams built in the 1800's block the upstream passage of anadromous fishes and substantially reduce the amount of available spawning grounds. On the James River, the American shad originally migrated

291 nautical miles upstream. Today, as a result of Boshers Dam, the limit is 91 nautical miles. On the Chickahominy River, a tributary of the James River, a low head dam was built in 1943 at Walker, 19 nautical miles above the mouth of the tributary. In 1896, before the dam had been built, the Chickahominy River contributed 30 per cent of the total shad catch on the James River watershed; in 1960 it contributed only 13 per cent (Walburg and Nichols 1967), and there is no shad fishing on the Chickahominy River today. The area below Walker's Dam had been the lower limit of shad spawning on the Chickahominy River before the dam was built; now it is the major spawning area.

RIVER HERRING

HISTORICAL PERSPECTIVE

River herring is a collective term for two anadromous herring species, the alewife (Alosa pseudoharengus) and blueback herring (Alosa aestivalis). The two species are very similar in appearance, and the commercial landings are simply reported as alewives. However, there are significant behavioral differences (Loesch and Lund 1977; Loesch et al. 1982). These species have long been a important part of Virginia's fisheries. As long ago as 1588, Thomas Hariot wrote that during the months of February through May, herring were "most plentiful, and in best season, which we found to be most delicate and pleasant meat" (de Bry 1590). In the latter half of the 18th century, a decline in abundance of river herring, along with all anadromous fish, prompted the Virginia assembly to pass laws requiring that dams be removed or fish passages built.

River herring, along with shad, were considered the most valuable food fishes in Virginia in 1875. Their ability to keep well when salted added immensely to their value (Va. Fish Commission 1875). However, the fisheries suffered a decline, and by 1879 were no longer profitable (Va. Fish Commission 1879). Artificial propagation was considered to be impractical for river herring due to the glutinous character of the eggs. Instead, measures recommended by the Virginia Fish Commission included a closed season to permit a proportion of the fish to escape upriver and spawn, and a tax on fishing in order to

discourage occasional fishermen and entrepreneurs from entering the fishery and causing fluctuations in production and prices.

In 1920, river herring in Virginia ranked first in quantity and fourth in value, with a catch of 7,258 MT worth 253 thousand dollars. As late as 1969 river herring in Virginia ranked third in quantity and fifth in value, with a catch of 13,608 MT worth 608 thousand dollars (National Marine Fisheries Service 1972). Since the early 1970's, however, the fishery has been declining.

In the early days, haul seines were used to catch the river herring. In 1976, however, more than 99 per cent of the catch was made with pound nets. Other types of gear used include stake gill nets and drift gill nets.

LIFE HISTORY

Alewife

Adults

Alewives are distributed along the Atlantic coast from Newfoundland to North Carolina, and in streams and lakes as far inland as the Great Lakes. In the Great Lakes and many other inland lakes they are landlocked.

Data reported by Loesch et al. (1979) show that from 1977 to 1979 the age of spawning ranged from 3 to 9 years, with the modal age at 4 to 6 years. The higher modal values are few, and associated with years of extremely poor recruitment. The males dominate the younger

age classes, but in the older age classes females, which mature at a later age and have greater longevity, are more abundant (Loesch et al. 1979).

The alewife spawning migration occurs in the spring, and is related to water temperature. It occurs three or four weeks earlier than that of blueback herring, and also precedes the first run of American shad. In the Chesapeake Bay, alewives usually arrive sometime in March (Hildebrand and Schroeder 1928). In the act of spawning, two or more fish swim rapidly with sides touching in tight circles 8 to 12 inches in diameter, spiraling upward from the depths to the surface (Edsall 1964). Kissil (1974) reported that female sea-run alewives produced from about 48,000 to 360,000 eggs, with a mean of 229,000. The eggs are demersal and somewhat adhesive immediately after being laid. Incubation period is dependent upon water temperature. The time to hatching has been reported to range from two to four days at 22.2°C to six days at 15.6°C (Rounsefell and Stringer 1943).

Neves (1981) reported that alewives in the ocean move north to the Nantucket Shoals, Georges Bank, and coastal Gulf of Maine areas during the summer and early fall, and then return south to the mid-Atlantic area in winter and early spring. He found alewives at depths ranging from 20 to 293 meters, but primarily in water depths of less than 100 meters, which corresponds to the occurrence of major zooplankton concentrations, upon which these fish feed. Alewives appear to prefer deeper depths than blueback herring. Neves (1981)

noted that the alewife has a slightly larger eye than the blueback, a feature generally associated with existence at greater depths; also, the dorsum of the alewife is green, a color which generally penetrates deeper into the continental shelf waters than blue, the color of the blueback's dorsum.

Juveniles

Young alewives spend their first summer in freshwater. The major nursery areas for the alewives in Virginia are nautical mile 30 to 70 in the Pamunkey River, mile 30 to 62 in the Mattaponi River, mile 35 to 90 in the Rappahannock River, and mile 60 to 95 in the Potomac River (Loesch and Kriete 1980). Although the Potomac River is part of Maryland, many of the fish are landed in Virginia and therefore, is included in this discussion.

The juvenile alewives begin a seaward migration with the approach of cool weather. This migration is very gradual. In the Potomac River, alewives have been caught as late as December 3 (Hildebrand and Schroeder 1928). From the Chesapeake Bay the majority of the young migrate directly to the ocean, but at least some of them stay in the Chesapeake Bay until they are 1 or 2 years old (Hildebrand and Schroeder 1928).

Loesch et al. (1982) reported a vertical segregation of juvenile alewives and bluebacks in tidal freshwater. Both species exhibited a diel vertical migration. In simultaneous samples with bottom and surface trawls, most alewives were caught during daytime in bottom

samples; conversely, most blueback herring were captured at night with the surface trawl. Loesch et al. (1982) suggested that this separation could serve to reduce feeding competition between the two species since their reported diets are identical. Because of the vertical migration and vertical separation of species, care must be used when selecting sampling gear and time. Conflicting measures of relative abundance can result from an inappropriate choice of sampling, and from the effects of varied light intensity when surface waters are sampled (Loesch et al. 1982).

The total length of alewives when hatched ranges from 3.5 to 5 mm (Mansueti and Hardy 1967). They grow rapidly, reaching a size of 55 mm by July, 65 mm by September, and 70 mm by December in the Chesapeake region (Hildebrand and Schroeder 1928). Loesch and Kriete (1980) presented growth curves for juvenile Alosa, and discussed aspects of Alosa behavior that affect such estimates.

Estimates of instantaneous daily mortality rates of alewives in Virginia rivers ranged from 0.033 to 0.040, with a mean of 0.036 in 1980 (Loesch and Kriete 1980).

LIFE HISTORY

Blueback herring

Adults

The blueback herring is found from Nova Scotia to the St. Johns River, Florida (Hildebrand and Schroeder 1928).

The age of blueback herring sampled in Virginia rivers ranged from 3 to 9. Prior to 1976, age 4 blueback herring were the modal age groups for both virgin spawners and all spawners. Because of successive years of poor recruitment, the proportions of age 4 fish in the commercial fisheries have been substantially reduced. Males dominate the younger age classes, while females are more abundant in the older classes. (Loesch et al. 1979).

The blueback herring spawning migration generally begins in the lower Chesapeake region during the first half of April and in the upper reaches of the bay during the last half of April (Hildebrand and Schroeder 1928). By June 1, only stragglers are left. They are reported to use the same spawning grounds as alewives, but are more selective, preferring sites with fast-flowing water and the associated hard substrate (Loesch and Lund 1977). Blueback herring spawn in warmer waters than alewives, 21° to 24°C instead of 13° to 16°C (Bigelow and Schroeder 1953), so their spawning migrations occur about 3 or 4 weeks later than that of the alewives.

The spawning behavior of blueback herring was described by Loesch and Lund (1977) and is similar to that of American shad as reported by Medcof (1957). A spawning group, generally comprised of one female and several males, would swim in a circular pattern. Occasionally a male would nudge the female in the vent region. Swimming speed gradually increased until finally the group descended, releasing eggs and sperm. In relatively shallow streams a female and closely

pressing males faced into the current, swimming only to maintain their position or to advance slowly upstream, and released their sperm and eggs.

Loesch and Lund (1977) reported that variation in ova production for individual fish ranged from 45,800 (238-mm T.L. fish) to 349,700 (310-mm T.L. fish). The range for eggs retained in an ovary pair after spawning was 9,300 (253-mm T.L. fish) to 107,600 (297-mm T.L. fish).

The ocean movements of blueback herring are similar to those for alewives, except that bluebacks do not tend to occur as deep in the water column as alewives (Neves 1981). The mature fish return to the streams to spawn in the spring, and enter the rivers once the water temperature has reached 21°C (Hildebrand 1963).

Juveniles

The juvenile blueback herring in Virginia spend their first summer in the tidal freshwater sections of the rivers. The nursery areas for bluebacks in Virginia extend from nautical mile 40 to 80 on the James River, mile 0 to 20 on the Chickahominy River, mile 30 to 70 on the Pamunkey River, mile 30 to 62 on the Mattaponi River, mile 40 to 90 on the Rappahannock River, and mile 60 to 95 on the Potomac River (Loesch and Kriete 1980). Although they use the same part of the river for a nursery ground as alewives, bluebacks are higher up in the water column than alewives. Possibly this reduces feeding competition between the two species. The river herring migrate

vertically, moving deeper in the water during the day than at night, and changing position in the water column in association with available light, suggesting negative phototropism. The vertical migrations of these fish must be considered when selecting sampling gear and time of sampling or conflicting measures of abundance may result (Loesch et al. 1982).

The young bluebacks are about 3.5 mm long when hatched (Kuntz and Radcliffe 1918). They grow rapidly, reaching an average length of 28 mm by July, 46 mm by September, and 64 mm by December (Hildebrand and Schroeder 1928).

The growth rate of alosids is greater in the Pamunkey River than in the Mattaponi, both of which drain into the York River. This may be due to a lesser food supply in the Mattaponi. Growth rates of blueback herring in the Chickahominy River have also been found to be relatively slow. However, the Chickahominy River has a relatively small nursery zone length, approxmimately 37 km, and the apparent slow growth could be due to emigration of larger juveniles into the James River, which has a relatively high growth rate (Loesch and Kriete 1980).

The estimated daily mortality of juvenile bluebacks in Virginia in 1980, excluding the Chickahominy River, ranged from 0.034 to 0.048 with a mean of 0.040. The estimate for the Chickahominy River was much higher, 0.067, but this statistic could be due to emigration of larger juveniles (Loesch and Kriete 1980).

With the approach of cool water, October and November in the Chesapeake Bay area, the blueback herring leave the freshwater (Hildebrand 1963). Most pass through Chesapeake Bay and migrate out to sea, but some stop in the deeper waters of the bay during their first winter, and a few apparently remain through their second winter (Hildebrand and Schroeder 1928).

FISHERIES

Gear Types

Pound nets are the primary gear used to catch river herring commercially. Other types of gear used include haul seines, stake gill nets, drift gill nets, and fyke nets, but in 1976 these methods accounted for less than one per cent of the total river herring catch in Virginia (National Marine Fisheries Service 1980).

Sport fishermen collect river herring during the spawning run with dip nets. The dip net fishery in Virginia begins in March and continues into May. In 1977 and 1978, the daily catch by dip net fishermen ranged from 30 to 400 fish per fishermen, depending upon time and location of fishing effort (Loesch et al. 1979).

Status of Stocks

Since 1970 there has been a general decline in Virginia landings of river herring (Fig. 2). In 1970, 8,637 MT of river herring were landed in Virginia. By 1975 only 1,839 MT were landed, and in 1976, the landings dropped sharply to 630 MT. In 1980, 537 MT were landed

(Loesch and Kriete 1980) and for 1981 the estimated landings declined to 236 MT (Virginia Marine Resources Commission 1981).

Catch per unit effort has shown an increase since 1977 on the York River, it has oscillated on the Rappahannock River, and has decreased since 1975 on the Potomac River except for 1978, when it showed a large increase (Loesch et al. 1979).

Loesch et al. (1979) reported that the annual percentage of blueback herring relative to alewife was significantly greater in the Virginia commercial catches from 1974 to 1979. In addition, the authors noted that the data indicated a six year trend of increasing dominance of blueback herring over alewife. Thus, as the Virginia river herring stock declined since the early 1970's, the rate of decline for alewife appears to have been greater than the rate for blueback herring.

Possible reasons for decline of stocks

In 1969 the reported landings of river herring by foreign fishing fleets, primarily the USSR, East Germany, Bulgaria, and Poland, increased relative to previous years (Hoagman and Kriete 1975). These fleets operated east of the Virginia Capes and the Delmarva Peninsula from January to May, and harvested river herring that would have otherwise spawned in rivers of the mid-Atlantic states. The 1969 river herring landings for Virginia were about 24,300 MT, but in 1970 the landings decreased to 8,637 MT, and from 1971 to 1975 averaged about 5,000 MT (Loesch et al. 1979).

Since 1973 the catch by offshore foreign fishing fleets has been relatively low as a result of agreements between the USA and foreign countries, and enactment of the 200 mile limit (PL 94-265). However, the continued lack of strong recruitment has resulted in a continued decline of the stocks (Loesch et al. 1979).

In 1976 there was a further decline in catch resulting from the absence of the 1972 year class of river herring, which is believed to have been decimated by the occurrence of Tropical Storm Agnes that year. Eggs and young-of-the-year may have been physically damaged by the highly turbid conditions. Also, heavy river flows may have swept them seaward where large mortalities would have occurred because of osmotic imbalance (Loesch and Kriete 1976).

Over the longer period of time, the creation of impoundments on Virginia rivers has resulted in a loss of spawning grounds for river herring. Loesch and Kriete (1980) theorized that impoundments could have a greater impact on alewives than on blueback herring. Alewives prefer spawning grounds in slow moving water or lentic environments, while bluebacks prefer fast-flowing water, and could spawn in the rapid flow below the impoundments. Except for Walker's Dam on the Chickahominy River, which was built in 1943 (Walburg and Nichols 1967), there has been no dam construction since 1897 on large waterways in Virginia. However, impoundments have been constructed on small streams which exclude river herring from former spawning grounds. The contribution of these exclusions to the present decline in river herring stocks is not known.

Contamination from agrichemicals, pesticides used in the 1960's and 1970's, and herbicides used in conjunction with no-till farming may also have contributed to the decline of the river herring stock. The agrichemical contamination may have had a greater effect on alewives spawning in minor tributaries, where the contamination would be more concentrated, than on blueback herring spawning in the larger main streams, where the contamination would be more diluted. This could result in the differing rates of decline for alewives and blueback herring (Loesch and Kriete 1980).

Cohort Contributions to the River Herring Fishery

Loesch and Kriete (1980) estimated the annual and total cohort (year-class) contributions in metric tons to the Potomac and Rappahannock river herring fisheries (Tables 1-4). Cohort biomass in the Potomac fishery was determined from monthly estimates of sex ratios, age structure, and mean weight-at-age, and the reported monthly landings. The monthly cohort contributions were summed over the fishing season to obtain the annual biomass harvested. Annual cohort biomass values for the Rappahannock fishery, at this time, have not been weighted by landings in the sampling periods, i.e., the values are derived from seasonal estimates of sex ratio, age structure, and mean weight-at-age, and the report total harvest.

The strongest contributor of record to the Potomac River alewife fishery (Table 1) was the 1966 cohort (635 MT). Other relatively strong contributors were the 1970 and 1971 cohorts (398 and 373 MT).

Although more effort (net days) was associated with the catch of the 1966 cohort, CPUE data (mean catch in numbers/net/day) indicated it was a stronger year class than were the 1970 and 1971 cohorts. During the 5 years (1969-1973) the 1966 cohort persisted in the fishery, CPUE was 132 for 21,557 net days. In contrast, the CPUE for the 1970 cohort was 118 for 20,268 net days during the 5 year period 1973-1977; CPUE was 119 for 16,685 net days for the 1971 cohort which persisted for 4 years, 1975-1978.

Prior to the 1972 cohort, which first recruited to the fishery in 1976, total year-class contributions to the alewife fishery in the Potomac River ranged from 251 to 635 MT (Table 1). Age 4 fish were a substantial proportion of these landings, particularly in the years 1973 through 1975. Total landings of the 1972, 1973 and 1974 cohorts dramatically decreased. The decline is attributed to low reproductive success, as indicated by the extremely low proportion of age 4 fish in the 1976, 1977 and 1978 landings. There was a modest increase in the proportion of age 4 biomass in the 1979 and 1980 landings. The precipitous drop in landings in 1976 was attributed to the decimation of the 1972 year class by Tropical Storm Agnes (Loesch and Kriete 1976). Reasons for continued poor year-class strength are unknown, but may include such factors as discussed in species composition.

The same general patterns discussed above are reflected in the findings for the blueback herring fishery in the Potomac River (Table 2), and for both river herring species in the Rappahannock River fishery (Tables 3 and 4).

HICKORY SHAD

HISTORICAL PERSPECTIVE

One of the first fish to be caught in the spring, hickory shad (Alosa mediocris) in the late 19th and 20th centuries were caught in pound nets and often sold in the cities as American shad to people who were not well-informed. The market for them would soon cease, after which they would be sold as fertilizer with river herring, at twice the value of river herring (McDonald 1884, Jordan and Evermann 1937). The market for hickory shad today continues to exist primarily in the spring before the American shad arrive.

Hickory shad is of minor importance as a foodfish, mainly because the meat is bony and considered inferior in flavor to the American shad (Hildebrand 1963). However, hickory shad roe is often considered superior to that of American shad.

LIFE HISTORY

Adults

Hickory shad, are found on the Atlantic coast from Maine to Florida. They are rare north of Cape Cod, are apparently more numerous in southern New England than in the Middle Atlantic States, and are most abundant in Virginia and North Carolina (Hildebrand 1963).

Hickory shad generally mature at three to five years (Mansueti 1958), but a few of both sexes mature at 2 years (Pate 1972). They

spend most of their lives in the sea, returning to streams and tributaries to spawn. Hildebrand and Schroeder (1928) reported that there was a definite spring run and a somewhat less definite fall run of hickory shad in the Chesapeake Bay. They have been reported in Virginia rivers as early as February and have been found on the spawning grounds until late May (Davis et al. 1970). The fall run occurs from November until at least December (Hildebrand and Schroeder 1928).

Hickory shad swim as far upstream as possible and spawn below the first insurmountable barrier encountered (Davis et al. 1970). They found shad in running-ripe and spent condition in both tributary streams and mainstreams in Virginia. Pate (1972), however, working on the Neuse River, North Carolina, was only able to collect hickory shad eggs and larvae from tributary creeks and not from the mainstream.

Pate (1972) found hickory shad eggs and larvae in flooded swamps and sloughs located off the main channels of the creeks. The eggs are apparently broadcast at random. They tend to be bouyant and are slightly adhesive (Mansueti and Hardy 1967). The number of eggs per female has been found to range from 43,556 eggs in a 325 mm, 3 year old female to 347,610 eggs in a 434 mm, 6 year old female (Pate 1972). The eggs hatch in two or three days at 18.3 to 21.1°C (Mansueti 1962).

The adult hickory shad, after spawning, returns to an area near the sea, and in the fall moves back into the lower estuaries before moving out to sea (Mansueti 1958). A small number of hickory shad are

found almost every month of the year, under a wide variety of estuarine conditions (Mansueti 1962). No information is available concerning the movements of hickory shad in the ocean.

Juveniles

The nurseries of the hickory shad in Virginia are in the fresh tidal sections of the James River, Pamunkey River, Mattaponi River, Rappahannock River, and Potomac River (Davis et al. 1970). Massman (1953) reported that hickory shad migrate into salt water much earlier than American shad, alewives, or blueback herring. Mansueti (1958) stated that the shad spends about 6 to 10 months in brackish water after hatching before going to sea. However, Pate (1972), working on the Neuse River, North Carolina, suggested that the young hickory shad may migrate to a more saline environment without utilizing the oligohaline portion of the estuary as a nursery area. He noted that the freshwater zone which forms on the scales of anadromous clupeids was far less evident on scales of adult hickory shad.

Bottom trawls conducted by the Virginia Institute of Marine Science (VIMS) in the Rappahannock River during 1968 and 1969 captured juvenile hickory shad at river mile 35 in September, 1968, mile 20 in October, 1968, and mile 35 to 40 in July and August, 1969.

Hickory shad larvae average 6.1 mm in length when hatched (Mansueti 1962). The growth rate of young hickory shad is much greater than that of other alosa species. Juveniles collected during VIMS surveys in the Rappahannock River during 1968 and 1969 ranged in

length from 66 to 78 mm with a mean of 73 mm in July and August, 1969. On September 18, 1968 they averaged 118 mm, and one hickory shad caught on October 20, 1968 measured 138 mm. By contrast, alewives reach an average length of 65 mm by September, blueback herring reach an average length of 46 mm by September, and American shad reach an average length of 70 mm by the last half of October (Hildebrand and Schroeder 1928).

No information is available concerning the mortality rates of juvenile hickory shad in Virginia.

FISHERIES

Gear Types

The principal gear for catching hickory shad is stake gill nets, accounting for 71 percent of the hickory shad landed in 1976. Pound nets were second, with 26 percent, and drift gill nets caught 3 percent. Other types of gear which have been used include haul seines, fyke nets, and slat traps (National Marine Fisheries Service 1980, Power 1960). In 1981, most of the hickory shad caught commercially on the Rappahannock River were taken by stake and anchor gill net fishermen using 100 mm and 112 mm mesh net. Other gill net fishermen using 125 mm mesh net caught no hickory shad, and pound net fishermen took them only in small numbers (J. Owens, personal communication).

A sport fishery exists for hickory shad near the spawning grounds beyond the influence of the tide. Sport fishermen take hickory shad

by casting for them with shad darts, spoons, and spinners (Kriete and Merriner 1978).

Status of Stocks

The peak recorded catch of hickory shad in Virginia since 1920 occurred in 1925 when 107 MT tons were landed (Fig. 3). In 1970 the catch was 11 MT, and from 1970 to 1975 it ranged from 5 to 25 MT. In 1976 there was a sharp decrease to 1.6 MT, and a further decrease to 629 kg in 1977. Since 1977, the catch has remained fairly steady at that level.

Possible Reasons for Decline

The hickory shad is not an abundant commercial fish in Virginia. It is one of the first fish caught in the spring and one of the last to be caught in the fall in considerable quantities, but relatively few are caught during the summer (Hildebrand and Schroeder 1928). The fishery is not intense enough to greatly affect their abundance (Hildebrand 1963).

The occurrance of Tropical Storm Agnes in 1972 resulted in high mortalities of the 1972 year class. Juvenile fish were destroyed through physical damage from highly turbid water conditions, or by osmotic imbalances created when the fish were swept seaward by the heavy river flows (Loesch and Kriete 1976).

It is difficult to assess the impact of impoundments on spawning hickory shad. Prior to 1962, a dispute existed between scientists as to whether hickory shad even spawned in freshwater or whether they

returned to sea to spawn. Mansueti (1962) determined that hickory shad do spawn in freshwater in Maryland. In Virginia, anadromous fish studies conducted at the VIMS show that juvenile hickory shad have been caught in the tidal, freshwater sections of the Virginia rivers. Davis et al. (1970) reported that spawning hickory shad swim upstream until they encounter an insummountable barrier. They have been found below the dam on the Rappahannock river at Fredericksburg, at Walker's Dam on the Chickahominy River, and below the first dam at Richmond on the James River. They have also been found in several tributary streams in these rivers. Pate (1972) found that a low-head dam in the Neuse River, North Carolina hampered the progress of the hickory shad, although some were able to negotiate a fishway at the dam. It is likely, therefore, that the construction of impoundments in Virginia Rivers has resulted in a loss of spawning grounds.

Contamination of rivers with agrichemicals, pesticide, and herbicides used in conjunction with no-till farming may also have contributed to the decline of hickory shad, as with the other Alosa species.

MANAGEMENT - ALOSA FISHERIES

Virginia has traditionally been very conservative in applying new regulations to its fisheries. Former director of the Virginia Fisheries Laboratory, Nelson Marshall, wrote in 1949, "Extreme caution should be exercised in the adoption of measures restricting, in the name of conservation, the methods of fishing and the size and quantity of fish taken."

Management of Virginia's fisheries in tidal waters is charged to the Virginia Marine Resources Commission (VMRC) except in the Potomac River, where the Potomac River Fisheries Commission (PRFC) has jurisdiction. The VMRC is authorized to adopt such regulations as it deems necessary to protect and promote the industry (Va. Marine Resources Commission 1980). The PRFC may, by regulation, prescribe the type, size, and description of all species of finfish and shellfish which may be taken or caught within its jurisdiction, the places where they may be caught or taken, and the manner of catching or taking (Va. law sec. 28.1-203).

There are few laws regulating the Alosa fishery in Virginia. Those laws which affect the fishery are primarily directed toward regulating the fishing gear, as follows:

Pound nets must have a minimum stretched mesh size of 51 mm. The maximum length of haul seines is 914 meters long, and when more than 183 meters long, they must have at least a 76 mm stretched mesh (Va. law, sec. 28.1-5.1).

The maximum length of any fishing structure in Chespeake Bay is 366 meters. There must be at least 61 meters between successive fishing structures and 274 meters between adjoining rows of structures (Va. law sec. 28.1-52).

No net may be set across any river, bay, estuary, creek, or inlet which is longer than one fourth the width of the body of water, and the net shall not be set or fished more than one half the distance across the channel of the water (Va. law sec. 28.1-53).

Except in the James River, there are no regulations concerning the size, number, or season for catching Alosa fishes in Virginia waters. In the James River, a regulation by the Virginia State Water Control Board prohibits fishing when they determine that the Kepone contamination levels are greater than .3 ppm.

Management of the offshore foreign fishing fleet operating within the 200 mile Fishery Conservation Zone is provided for by the Magnusen Fishery Conservation and Management Act (PL 94-265).

The Virginia Institute of Marine Science (VIMS) has been actively engaged in research of the anadromous Alosa since 1965. Based on recent data, VIMS management recommendations included a reduction in the river herring by-catch of foreign fishing vessels to 100 MT or less, and the development of a contingency management plan by the VMRC that would provide for increased escapement of river herring from the fishery until the advent of stronger recruitment (Loesch et al. 1979).

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Table 1. Annual and total year-class contributions (MT) to the Potomac River alewife fishery, 1968-1980.

Year	Year Class 1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1968	10.93												
1969	97.51	124.05											
1970	38.69	136.99	16.01										
1971	37.55	190.93	115.21	7.89									
1972	61.26	169.34	180.59	210.70	81.24								
1973	5.44	13.84	21.22	58.88	144.51	6.10							
1974			5.29	8.04	26.51	254.45							
1975				13.44	6.81	62.34	298.17	1.86					
1976				1.47	15.26	72.96	49.97	1.98					
1977					0.04	2.16	16.66	12.56	3.04				
1978							8.41	17.31	20.51	2.16			
1979									1.26	1.39	7.11	1.73	
1980										0.56	14.86	18.15	
Year Class Total	251.38	635.15	338.32	300.42	274.37	398.01	373.21	33.71	24.81	4.11	21.97	19.88	

Table 2. Annual and total year-class contributions (MT) to the Potomac River blueback fishery, 1968-1980.

	Year Class												
Year	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	977
1968	20.03												
1969	646.78	99.65											
1970	492.09	1671.00	23.95										
1971	203.66	1053.98	1000.96	16.24									
1972	74.38	294.52	439.86	576.54	2.56								
1973	2.11	20.61	67.21	151.59	135.26	1.95							
1974		7.06	18.85	51.80	157.71	1068.90							
1975			0.81	37.13	116.23	335.23	1560.10	0.83					
1976			3.54	4.70	98.72	233.70	87.33	4.20					
1977					1.02	31.79	108.67	36.25	1.43				
1978						26.27	157.82	318.41	106.39	1.54			
1979									37.10	79.67	285.31	34.16	
1980									4.22	28.79	213.49	23.72	1.67
Year Class Total	1439.05	3146.82	1555.18	838.00	511.50	1697.84	1913.92	359.69	149.14	110.00	498.80	57.88	1.67

Table 3. Annual and total year-class contributions (MT) to the Rappahannock River alewife fishery, 1968-1980.

Year	Year Class 1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1968	49.79												
1969	44.49	13.21											
1970	47.31	73.36	7.75										
1971	30.62	94.20	57.73	4.48									
1972	18.04	51.10	60.52	54.51	8.82								
1973	1.96	8.00	18.87	39.84	81.20	0.90							
1974		5.40	1.08	18.78	55.90	134.04	0.65						
1975			0.07	0.43	1.16	9.68	59.66	1.23					
1976				0.13	1.71	14.43	25.39	2.15					
1977				0.34	0.17	4.32	41.24	36.16	2.46				
1978						1.83	11.38	54.67	57.03	5.89			
1979								0.28	2.41	14.84	19.89	18.60	
1980										2.49	7.03	12.87	0.88
Year Class Total	192.21	245.27	146.02	118.51	148.96	165.20	138.32	94.49	61.90	23.22	26.92	31.47	0.88

Table 4. Annual and total year-class contributions (MT) to the Rappahannock River blueback fishery, 1968-1980.

Year	Year Class 1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
1968	10.68												
1969	90.10	11.39											
1970	14.76	25.48	0.97										
1971	18.19	107.12	72.15	1.01									
1972	8.56	33.17	52.83	37.58									
1973	1.69	8.94	37.34	74.14	118.34	0.97							
1974		1.56	6.00	20.48	46.19	55.97	0.26						
1975				0.52	3.44	19.94	146.82	1.03					
1976				0.07	2.44	26.88	36.05	2.38	0.07				
1977						8.58	107.09	88.06	5.23				
1978					0.38	1.91	78.25	211.10	84.74	4.96			
1979								7.62	42.36	127.51	229.18	16.94	
1980								1.17	6.25	20.32	140.46	26.57	0.59
Year Class Total	143.98	187.66	169.29	133.80	170.79	114.25	368.47	311.36	138.65	152.79	369.64	43.51	0.59

Figure 1. Virginia American Shad Landings, 1880-1981.

Virginia American Shad Landings
1880–1981

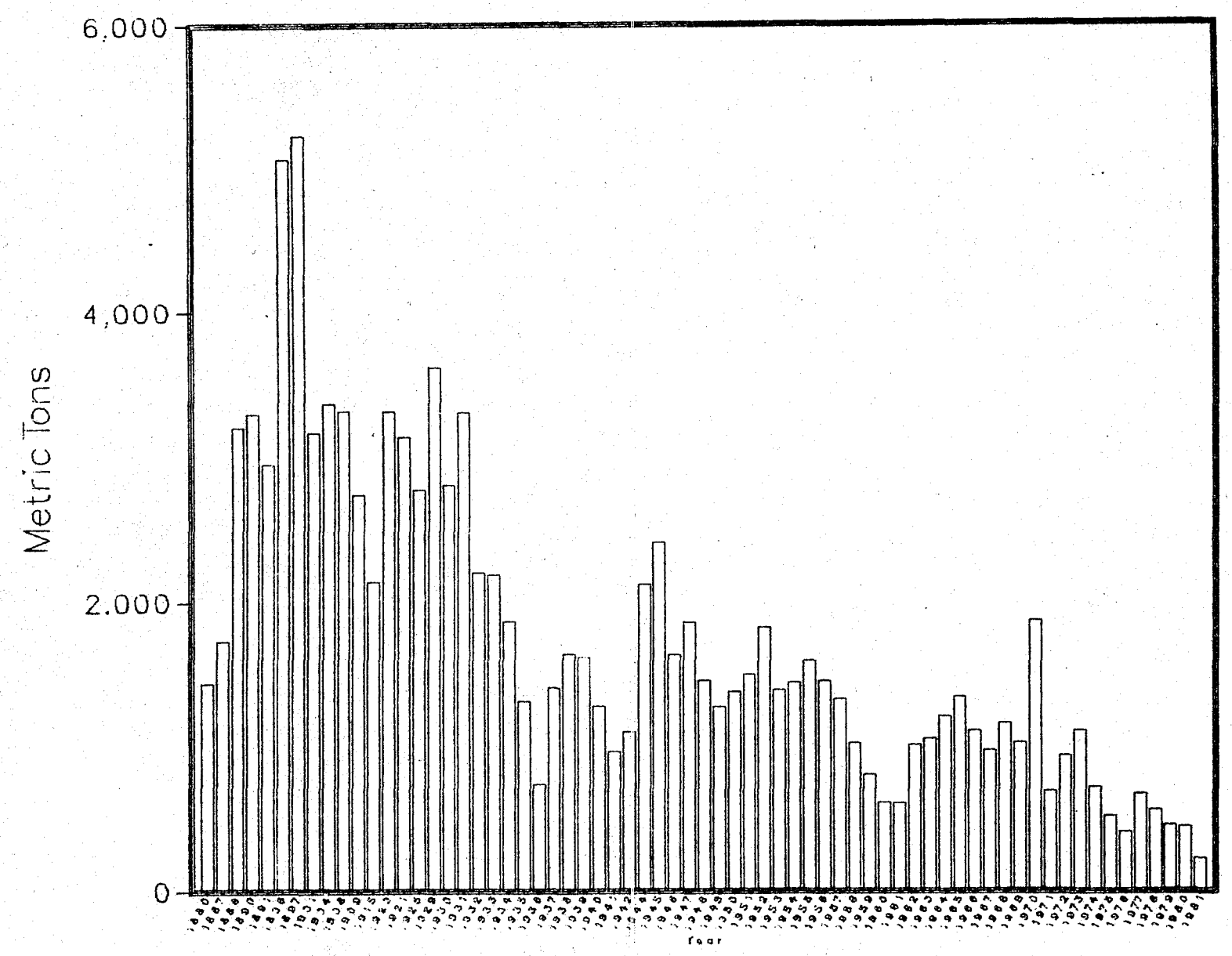

Figure 2. Virginia River Herring Landings, 1880-1981.

Virginia River Herring Landings
1880–1981

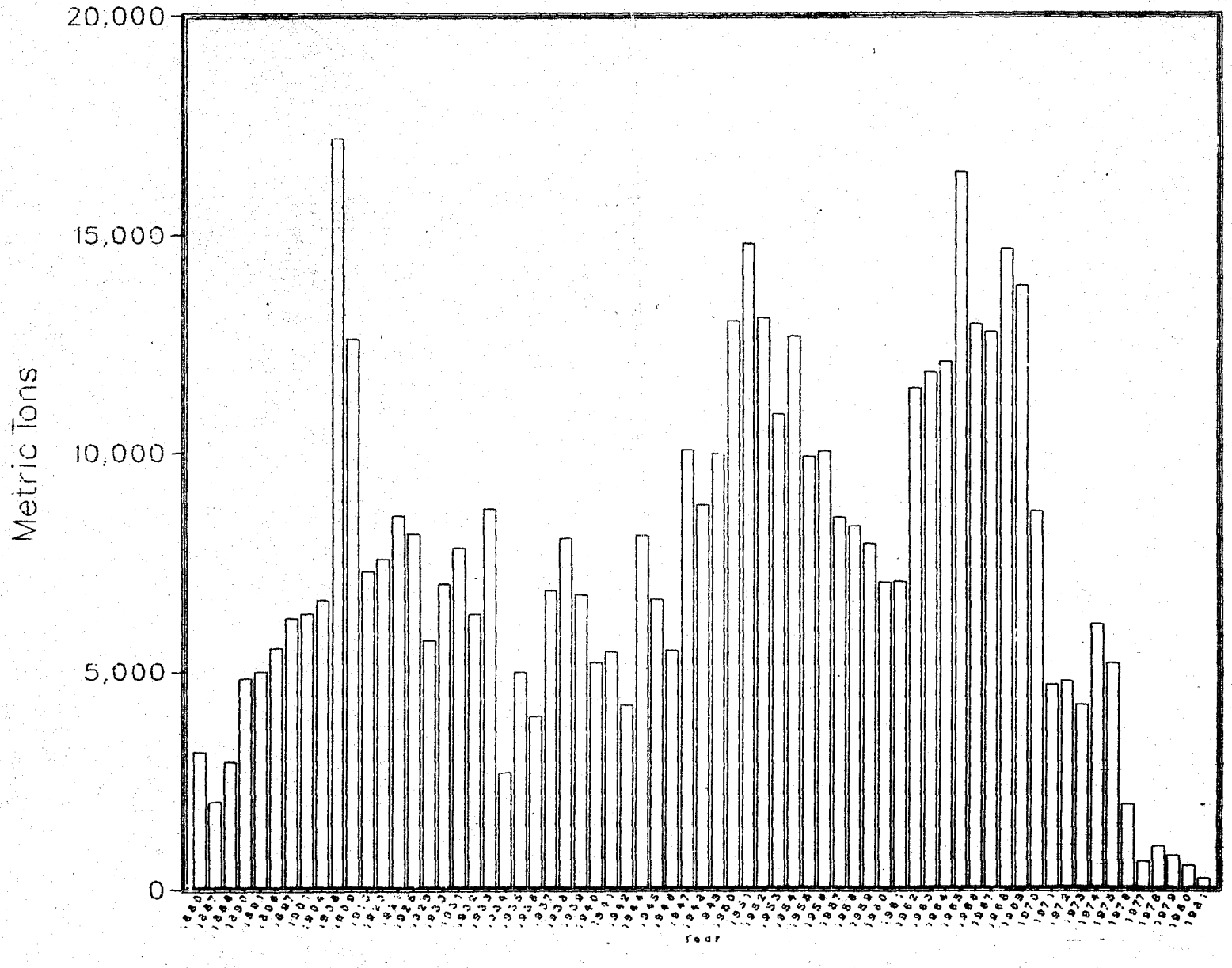

Figure 3. Virginia Hickory Shad Landings, 1920-1981.

Virginia Hickory Shad Landings
1920–1981