with sorghum, oats, smartweed and millet to provide a supply of organic material to enrich the new water and to coagulate and precipitate the suspensoids. Some of the reservoir's water cleared, remained clear and produced good fish crops after refilling. One of the reservoir's remained dry for two years. Then it rained, the reservoir filled, the fish crop grew exceptionally well and it rained and rained some more, exchanging the fertile water with its dissolved organic matter for fresh runoff water with no fertility. We were back where we were before we started.

If there is a next time, I shall insist that we use a watershed program that will at least slow the rate of water exchange.

I have tried to review the problems of fish production in reservoirs in 30 minutes. I have stressed variation in reservoirs and some difficulties one is apt to encounter in attempts to change the characteristics of the impoundment. I have tried to show that productivity can be evaluated through indicies.

I believe we should consider a more complete harvest as a management tool. The crop must be harvested. Why should we improve the impoundment, stock more fish and fertilize the water to raise a greater number of poorer fish to not harvest?

STOCKING AS A MANAGEMENT TOOL IN TENNESSEE RESERVOIRS

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The Tennessee Game and Fish Commission is responsible for the fisheries management of 26 major impoundments (or parts thereof) which total approximately 400,000 acres. The Tennessee Valley Authority has built or acquired, since 1933, nineteen of these impoundments in the Tennessee Valley area. Two dams are owned by private companies and five have been constructed by the U. S. Army Corps of Engineers.

Seven reservoirs on the Tennessee River and two on the Cumberland are main river projects and include navigation locks which permit upstream movements of fish. Dams are not effective obstacles to fish moving downstream. It may be assumed, therefore, that ecological preferences are the major influence on the distribution of fish from the Ohio River at the mouths of the Tennessee and Cumberland rivers to the bases of the storage reservoirs in east and north central Tennessee. All species of game fish and rough fish found in Tennessee storage reservoirs are found in the main stream impoundments. Certain desirable species were occasionally missing from tributary stream projects when their dams were constructed. This paper deals primarily with the known introductions made into these storage reservoirs. Its purpose is simply to summarize available information on the relative success or failure of each introduction and the resulting effect on the sport fishery.

The introduction of a desirable new species which shows up in the creel is a tangible example of reservoir management that the fishing public can appreciate. In a typewritten report dated December 28, 1944, to the Tennessee Conservation Department, Dr. R. W. Eschmeyer of the Tennessee Valley Authority wrote, "In those storage lakes where crappie are not present, they should be (and have been) introduced." However, the records of those introductions and probably those of other species have been lost or forgotten. The oldest introductions recorded in this summary are in 1948.

The author is indebted to the following biologists for supplying much of the information presented below: C. J. Chance (TVA), Glenn Gentry and L. P. Wilkins (Tennessee Game and Fish Commission), and John W. Parsons (U. S. Fish and Wildlife Service).

GIZZARD SHAD AND MISSISSIPPI THREADFIN SHAD

Early in the history of Tennessee reservoir management, gizzard shad, *Dorosoma cepedianum* (Le Sueur), were credited with being the principal inter-

mediate step in the food chain: plankton—shad—game fish. Undoubtedly, some storage reservoirs acquired this species through introduction, but the records show only one stocking, a successful introduction into Great Falls (2,270 acres) in 1948 (Table VI).

An unauthorized introduction of gizzard shad by unknown persons was probably made in 1953 in Watauga Reservoir (6,430 acres). None had been found in rotenone samples in 1950 and 1952. In 1954 and 1955, gizzard shad constituted over 50 per cent by weight of all fish in three rotenone samples.

Since 1948 biological evidence has shown that the gizzard shad has many undesirable characteristics when introduced as a forage fish; *i. e.*, most of the weight of gizzard shad is tied up in large fish that are not available as forage. Mississippi threadfin shad, *Signalosa petenensis atchafaylae* Evermann and Kendall, appear to be more desirable because they are short lived (few reach two years of age) and seldom reach seven inches in length (Parsons and Kimsey, 1954).

Between 200 and 300 threadfin shad were introduced into each of four relatively small impoundments in May, 1953 (Table I). No trace of the fish has been found in McMinnville City Lake and Crossville City Lake which were under 400 acres in area. Great Falls retained its population and threadfins are presently common. In the fall of 1953 fishermen reported finding them regularly in bass stomachs. Threadfins from Great Falls entered Center Hill (18,000 acres) by passing the dam. They were not discovered until the winter of 1954-55 when a few were discharged through the turbines of Center Hill Dam. Large numbers of threadfins came through the dam the following winter. Rainbow trout, *Salmo gairdenerii irideus* Gibbons, (7"-8") stocked in the tailwater utilized these fish heavily, grew rapidly, and experienced greater survival than in previous years.

Watauga (6,430 acres) was stocked with threadfins in May, 1953. Excellent reproduction occurred and thousands were drawn through the turbines that winter. Again the tailwater trout profited by this extra food supply. A cold snap in the winter of 1953 and again in 1954 apparently eliminated the threadfin population, for none have been reported or found to date despite two additional stockings in May of 1955 and 1956.

Similar introductions in 1955 and 1956 in South Holston Reservoir (7,580 acres) fifteen miles north of Watauga also failed as far as is known. However, threadfins introduced in May, 1956, in Douglas (30,500 acres) and Norris (34,200 acres) Reservoirs, situated 75 and 100 miles east, respectively, reproduced and the young fish were common in population samples taken in coves by emulsified rotenone in August.

Cherokee Reservoir (30,200 acres), downstream from Watauga and South Holston, was not stocked directly, but supports an abundant threadfin population. The fish probably entered by passing Watauga, Wilbur, Boone, and Fort Patrick Henry Dams.*

Threadfins stocked in the spring of 1954 in Dale Hollow Reservoir (27,700 acres) have reproduced each year up to the present. They have remained relatively rare but congregate in small schools in scattered locations. Gizzard shad reproduction was rare in 1955 and 1956. Threadfins have supplied the only jump fishing for bass in the last two years.

Woods Reservoir (4,000 acres) has supported a good threadfin population since introduction in May, 1955, despite a heavy mortality in the winter of 1955-56.

A further example of downstream movement, probably in winter, 1954-55, occurred in the Cumberland Basin. Threadfins from either Dale Hollow or Center Hill passed these dams and appeared in large numbers in two partially impounded main stream reservoirs where they were previously unrecorded, Old Hickory (22,500 acres) and Cheatham (7,450 acres).

* The latter three reservoirs and Ocoee Reservoirs Nos. 1, 2, and 3 have not been included in any stocking data as they are not representative of typical large impoundment environment due either to temperature, capacity, or pollution.

WHITE CRAPPIE

In a poll of fisheries biologists working in Tennessee in 1956, crappie were selected as being the top fish, numerically, in the annual sport fishing harvest. White crappie, *Pomoxis annularis* Rafinesque, probably outnumber black crappie, *Pomoxis nigro-maculatus* (Le Sueur), in the catch by ten to one. Dock operators consider white crappie their bread and butter fish with regard to boat rentals. Confronted with these opinions, it is logical to introduce white crappie into any large impoundment where they are absent in Tennessee, provided that biological examinations show desirable ecological conditions.

TVA biologists found no trace of white crappie in Norris Reservoir from 1936 to 1954, despite the introduction of 200 adults in 1948 (Table II). Black crappie supplied very good fishing in 1944-45, but crappie fishing has been mediocre since then. In early 1953 and 1954, a total of 2,202 adult white crappie were introduced. Young-of-the-year first showed in two rotenone samples in October, 1954, and white crappie predominated over black crappie in a similar sample in 1955. In the spring of 1955, a few small white crappie entered the catch. During 1956, white crappie have become important in the creel.

White crappie were introduced in Woods Reservoir in October, 1954. Threadfin shad were stocked the following spring in the hope that their fry would be a source of food for the young crappie and other game fish. Both introductions were successful. Young-of-the-year crappie made up 16 per cent by number and 12 per cent by weight in a rotenone sample taken in August, 1955. As yet the yearling crappie have not entered the sport fishery.

Watauga Dam was closed in December, 1948. Two reports are available concerning the introduction of white crappie: (1) they were introduced by sportsmen in 1949; (2) they were introduced by the State Conservation Department in Wilbur Reservoir below Watauga before Watauga Dam was closed. Notwithstanding the method of introduction, white crappie are abundant and since 1953 the crappie fishery has been important.

YELLOW WALLEYE

Tennessee can only claim one reservoir, Norris, where yellow walleye, *Stizostedion vitreum vitreum* (Mitchill), ever made up more than one per cent, numerically, of the annual catch. However, the importance of walleye as a glamorous trophy fish and its psychological impact on the angler cannot be overestimated in this state. Growth of the walleye is rapid in certain storage reservoirs and females attain great size. Two walleye over 19 pounds have been caught this year and 10 pound fish are relatively common.

Our fry stocking program, started in 1954, has been successful to a minor degree in four of seven major reservoirs (Table III). Introductions in two reservoirs have resulted in small walleye beginning to enter the catch. Three successive years of fry stocking in Center Hill, where the indigenous population verges on extinction, has resulted in scattered reports of small walleye entering the catch in 1955 and 1956.

On Dale Hollow, where the natural spawning grounds are affected by mine pollution, the majority of dock operators report improved walleye fishing since the fry stocking program commenced.

To achieve better survival, plans have been made to increase the number of advanced fry available for stocking. There is no evidence of survival from any of 140 adult walleye introduced in two impoundments.

The possible danger of creating competition with other carnivorous species is minimal when shad, either gizzard or threadfin, are present to serve as a buffer.

WHITE BASS

Four known introductions of white bass, *Lepibema chrysops* (Rafinesque), have been made (Table IV). Two of these introductions have provided specialized fisheries that would have not otherwise been available to fishermen.

The species first appeared in Norris Reservoir creels in 1950 following its introduction in the winter of 1948-49. By 1952, an important spring headwaters fishery had developed. Since that time night fishing for white bass has become popular in the lower end of the lake.

In Dale Hollow this species has followed the above pattern since its introduction in January, 1951. Dock operators who were against introducing this fish because of alleged competition with other bass have become more tolerant after savoring the business generated by the night fishermen.

White bass stocked in Great Falls in November, 1954, have never been reported from this reservoir. However, the white bass passed Great Falls Dam and are now present in Center Hill Reservoir. First reports were noted in early spring, 1955. Approximately 100 yearlings have been caught during 1956.

South Holston Dam and the greater part of the reservoir is in Tennessee, but the headwater is in Virginia. It is believed that Virginia fishermen introduced white bass in 1955 in the hopes of creating a spring run in Virginia waters. None were taken in one rotenone sample in Tennessee in 1956, but the report of the introduction will probably be valid.

RAINBOW TROUT

In the past three years, fingerling stockings of rainbow trout in two impoundments have proven successful (Table V). Watauga Reservoir produces occasional catches of 16"-22" fish for deep trolling fishermen. In February, 1955, observers noted a run of rainbow trout in the lower section of a tributary trout stream, Doe Creek. In 1956, the same run developed with fish in greater numbers and larger sizes, but the trout season did not open until most of the fish had returned to the reservoir. Restrictions will be lifted in 1957 to make these fish available to anglers.

Calderwood Reservoir (536 acres) is influenced by the cold tailwater of Fontana Dam in North Carolina. Before the original stocking of 60,000 two-inch fish in 1955, a few trout were present. Since the introduction, a spring run developed in Cheoah River in North Carolina and some limit catches of 12"-14" trout have been made in the reservoir proper. Fingerling stockings on a put-and-take basis can be justified, if these fisheries develop as expected.

MISCELLANEOUS

Calderwood has low bottom organism production and maintains high oxygen content at all depths. To provide a forage fish for trout, 200,000 American smelt, *Osmerus mordax* (Mitchill), were introduced in 1956 (Table VI). In two rotenone samples taken in October, 1956, no smelt were recovered.

Crappie were unknown from Dale Hollow for the first five years of impoundment. In 1948, five thousand black crappie were successfully introduced, but the resulting fishery was mediocre. White crappie, possibly present since impoundment, were first noted in 1952 and since that time have become dominant in the sport fishery, gradually replacing the established black crappie. White crappie have provided a more dependable fishery and the overall harvest of crappie has increased.

About ten sub-adult Ohio muskellunge, *Esox masquinongy ohioensis* Kirtland, were introduced in Dale Hollow in 1953 and 1954. There are three reports of these fish being caught. Two fish were captured shortly after introduction. One fish, captured after 11 months of reservoir life, and grown from 2½ pounds to 7¼ pounds.

Tennessee has attempted a musky propagation program for two years. This fall the first fish will be released in selected impoundments. If a musky fishery can be established, its public relations value would be unparalleled.

DISCUSSION

There is no evidence that any introduction made in Tennessee reservoirs has been detrimental to populations already present. Care should be exercised, however, before introducing a new species. Idealogically, detailed population studies by rotenone, growth studies, creel census, and possibly food studies should be made before and after introductions to determine any changes effected. Most game and fish commissions are forced to undertake these studies on a small scale sampling basis. The encouraging part is that these studies usually suffice for general evaluation.

Rough fish production in reservoirs is much greater than that of game fish. Funneling a larger segment of the production into game fish for the sport fisherman is one aim of fisheries biologists. The introduction of additional game fish species probably has little effect on rough fish populations unless their feeding habits are different from those carnivores already present. If the introduced species can be caught by angling, such a stocking makes more of the total fish production available to harvest by sport fishing methods.

If biologists want credit for introducing new species, they should act before the sportsman does. It is difficult to stop unauthorized introductions by any interested persons once the idea becomes established.

At this writing, the North Alabama Conservation Club is urging their state fisheries biologists to introduce striped bass, *Roccus saxatilis* (Walbaum) in Wheeler and Wilson Reservoirs. Passage through navigation locks will open the entire chain of TVA main stream impoundments to the striped bass. Dr. A. H. Wiebe, Chief, Fish and Game Branch, TVA, urges careful determinations regarding the adaptation of this species to the Tennessee River environment, its acceptability to rank and file anglers, and the effect upon native species. Dr. Wiebe has asked for a consultation between Game and Fish Divisions of Kentucky, Mississippi, Alabama, and Tennessee, as well as the Atlanta Office of the U. S. Fish and Wildlife Service.

Carefully planned introductions as a tool of reservoir management should not be overlooked as a means of putting more fish in the anglers creel.

LITERATURE CITED

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Presented to the Southern Division of the American Fisheries Society at the meeting of the Southeastern Association of Game and Fish Commissioners in Little Rock, Arkansas, October 8, 9, 10, 1956.

TABLE I

INTRODUCTIONS OF MISSISSIPPI THREADFIN SHAD IN TENNESSEE RESERVOIRS

Reservoir and Date of Closure	*Stocking Dates*	*Number*	*Reproduction*	*Population Status*	*Comments*
Watauga 1948	5/53	200	Yes	Common	None taken in one rotenone sample, but thousands came through turbines that winter. Heavy winter kill in '54-'55.
	5/4/55	1,000	No	—	None taken in two rotenone samples, '55.
	5/18/56	900	No	—	None taken in two rotenone samples, '56.
South Holston 1950	5/4/55	1,000	No	—	None taken in one rotenone sample, '55.
	4/26/56	1,200	No	—	None taken in one rotenone sample, '56.
Cherokee 1941	Winter '53-'54	migration from upstream impoundment	Yes	Abundant	Species made up 73.2% by number, 26.5% by weight in one rotenone sample, '55.
Norris 1936	5/17 & 21/56	1,290	Yes	Common	Common in rotenone sample, '56.
Douglas 1943	5/2, 9, 18/56	1,400	Yes	Common	Common in rotenone sample, '56.
Woods 1952	Spring '55	400	Yes	Common	Heavy winter kill, '55-'56, but sufficient nos. survived to supply moderate population in '56.
McMinnville City 1906	Spring '53	200	No	—	None have been reported or found.
Great Falls 1916	Spring '53	200 and migration from upstream impoundment	Yes	Common	Species common in rotenone sample, '56.
Center Hill 1949	Probably Spring '53	migration from upstream impoundments	Yes	Abundant	Species common in rotenone sample, '56.
Dale Hollow 1943	Spring '54	400	Yes	Rare	Species rare in rotenone samples, '55 and '56.
Old Hickory 1956	Probably in Winter '54-'55	migration from upstream impoundments	Yes	Abundant	Species abundant in rotenone samples, '55.
Cheatham 1956	Probably in Winter '54-'55	migration from upstream impoundments	Yes	Common	Species common in rotenone samples, '55.
Crossville City 1938	Spring '53	300	No	—	None have been reported or found.

TABLE II

INTRODUCTIONS OF WHITE CRAPPIE IN TENNESSEE RESERVOIRS

Reservoir and Date of Closure	*Stocking Dates*	*Number*	*Size*	*Population Status*	*Resulting Fishery*
Woods 1952	10/54	950	Adult	Young-of-year (4") made up 16% by number and 12% by weight in one rotenone sample, 8/55.	— — — — — —
				Yearlings (7") common in rotenone sample, young-of-year rare, 9/56.	Adult stocking provided some harvest of one-pound fish, but their offspring have not entered harvest, '56.
Norris 1936	Spring '48	200	Adult	No trace found.	— — — — — —
	Winter '52-'53	516	8"-15"	None found in one rotenone sample, 9/53.	In spring of '55 a few small white crappie entered the catch. During spring '56, white crappie became very important in the fisherman's catch.
	Winter '53-'54	1,686	Adult	12 young-of-year taken in two rotenone samples, 10/54.	— — — — — —
				Two rotenone samples yielded 845 young-of-year 2"-5" and 74 yearlings 6"-9", 9/55.	— — — — — —
				Common in rotenone sample, '56.	— — — — — —
Watauga 1948	Probably '49	Unknown, introduced by sportsmen.		None found in one rotenone sample, 8/51.	An important fishery resulted from this introduction.
				Four rotenone samples from coves during '52-'56 have always yielded young-of-year and adult fish.	— — — — — —

TABLE III

INTRODUCTIONS AND OTHER STOCKINGS OF YELLOW WALLEYE IN TENNESSEE RESERVOIRS

Reservoir and Date of Closure	*Stocking Dates*	*Number*	*Size*	*Indigenous Population*	*Population Status of Introduced Fish*	*Resulting Fishery*
Woods 1952	5/14/55	500,000	Fry	No	Eight 6″-7″ fish taken in one rotenone sample, 8/55. None taken in same area by similar methods, 9/56.	A few 15″-17″ fish taken at head of lake and in river below dam in spring '56. Occasional fish caught in main lake during summer.
Center Hill 1949	5/ 2/54 5/14/55 5/16/56	1,500,000 1,500,000 650,000	Fry Fry Fry	Yes	One 7″ fish taken in rotenone sample, 8/56. No young walleyes found in seven samples during '52 and '53.	Fishery dependent on successful spawning in '49 and '50. Those year classes becoming extinct. Few small fish caught in '55-'56.
Dale Hollow 1943	5/ 2/54 5/14/55 5/16/56	1,500,000 1,000,000 750,000	Fry Fry Fry	Yes	Unknown, because limited natural reproduction occurs.	Majority of dock operators report improved walleye fishing since fry stocking program commenced.
Great Falls 1916	3/53 3/54 4/54 5/ 2/54 5/ 3/54 5/15/56	40 Males 15 Females 5 Females 10 Males 1,000,000 750,000 100,000	Adult Adult Adult Adult Fry Fry Fry	No	Live walleye have never been reported from this reservoir.	— — — — — —
Old Hickory 1956	5/15/56	250,000	Fry	Yes	Unknown.	No increase reported.
Cherokee 1941	5/21/55	556,200	Fry	Yes	Placed in isolated pothole of reservoir. Salvaged in fall '55. 1,500 10″-12″ fish placed in reservoir proper.	No increase noted.
Watauga 1948	Winter '52 through Spring '54	70	Adults	No	None taken in three rotenone samples, '54-'55.	Small walleye are beginning to enter the catch, '56. No large fish have been caught.
	Spring '54	1,000,000	Fry			

Table IV

Introductions of White Bass in Tennessee Reservoirs

Reservoir and Date of Closure	*Stocking Dates*	*Number*	*Size*	*Population Status*	*Resulting Fishery*
Dale Hollow 1943	1/51	296	Adults	Spawning occurred in '51 and from that year-class the population expanded tremendously.	Fall and spring fisheries first developed in October '52 and have continued to the present. Summer '55 started an important night fishery that is still expanding.
Great Falls 1916	11/8/54	200	12″	No white bass have been reported from this reservoir.	— — — — — — —
Center Hill 1949	Winter '54-'55	Migration from upstream imp'dment		Three young-of-year (7″) taken in one rotenone sample, 8/56.	Approximately 100 yearlings have been caught in '56.
Norris 1936	Winter '48-'49	250	Adults	By '52 young-of-year were abundant in rotenone samples.	A very important spring fishery in upper lake as well as good, steady, summertime night fishing in main lake.

Table V

Introductions of Rainbow Trout in Tennessee Reservoirs

Reservoir and Date of Closure	*Stocking Dates*	*Number*	*Size*	*Population Status*	*Resulting Fishery*
Calderwood 1930	7/13/55	60,000	2″	Relatively poor survival. Excellent growth.	A spring run developed in Cheoah River in North Carolina.
	2/21/56	5,000	4″		A few limit catches have been made in reservoir proper.
Watauga 1948	11/16/54	11,733	3″-4″	Excellent growth and fair survival.	Occasional catches of 16″-22″ fish made by deep trollers.
	2/55	12,000	3″-4″	— — — — — —	In February '55, a run of trout was noted in Doe Creek.
	2/56	15,000	3″-4″	— — — — — —	In February '56, a heavy run of large trout occurred in Doe Creek.

TABLE VI

MISCELLANEOUS INTRODUCTIONS IN TENNESSEE RESERVOIRS

Species	*Reservoir and Date of Closure*	*Stocking Dates*	*Number*	*Size*	*Population Status*	*Resulting Fishery*
Black Crappie	*Dale Hollow* 1943	1948	5,000	3"-4"	Common	Species has seldom been caught in large numbers and has gradually been replaced by white crappie, which now make up an estimated 90% of the crappie harvest.
Gizzard Shad	*Great Falls* 1916	1948	Unknown	Unknown	Common	— — — — — —
Smelt	*Calderwood* 1930	5/8/56	200,000	Fry	Unknown	None found in two rotenone samples, '56.