PRELIMINARY REPORT ON THE SONAR FISH COUNTER AT PINOPOLIS DAM ON COOPER RIVER, SOUTH CAROLINA

TOM A. CURTIS, South Carolina Wildlife and Marine Resources, P. O. Box 170, Bonneau, SC 29431

Abstract: A sonar fish counter installed at the Pinopolis Dam navigation lock near Moncks Corner, South Carolina in 1975 was used during the last 3 springs to enumerate blueback herring (*Alosa aestivalis* Mitchill) passing into the Santee-Cooper Lakes. Construction of the biomass fish counter was based on the design of salmon smolt counters used successfully in Alaska. Characteristics of fish movement and schooling patterns were determined and their relationship to accurate counting of herring was evaluated. Initial tests to prove the accuracy of counts were not successful. However, other population indices indicated that trends were accurately assessed.

Proc. Annual Conf. S.E. Assoc. Fish & Wildlife Agencies 31:387-391

Impoundment of the Santee-Cooper Reservoirs in 1941 impeded access of spawning runs of blueback herring (*Alosa aestivalis* Mitchill) and other anadromous species to the upper Santee River watershed. Although Scruggs and Fuller (1954) found minimal passage of striped bass (*Morone saxatilis* Walbaum) through the navigation lock at Pinopolis Dam on Cooper River, numerous blueback herring were passed into the reservoirs incidental to normal locking operations. These herring spawned in the reservoirs and upper Santee River watershed. Stevens (1957) found herring to be a frequently utilized forage of striped bass in the Santee-Cooper Lakes. Consequently, the lock has been operated 3 to 6 times daily during the spring spawning run for herring passage.

To reduce siltation in Charleston Harbor and the resultant spoil disposal problems, the U.S. Army Corps of Engineers proposes to redivert the major discharge from the Santee-Cooper Reservoirs from Cooper River back to the Santee River. The rediversion will be accomplished by construction of a canal from the west side of Lake Moultrie to the Santee River at a point near the town of Saint Stephen (Fig. 1). A hydroelectric plant on the new canal will replace the Pinopolis power plant. A fish lift will be incorporated into the new dam to allow passage of fishes into the reservoirs. To properly evaluate the new fish lift, the effectiveness of the present lock for fish passage must be determined. The South Carolina Wildlife and Marine Resources Department with the assistance of the U.S. Fish and Wildlife Service and the Corps of Engineers evaluated herring passage into the Santee-Cooper Reservoirs via Pinopolis navigation lock.

A number of physical and biological factors hampered attempts at subsampling within the lock. These factors included size and depth of lock, uneven nature of the lock bottom, large number of fragile herring involved and locking or sampling cycle of 3 times per day.

With unsatisfactory results from conventional sampling methods, the use of modern electronics was then contemplated. Research by the Applied Physics Laboratory of the University of Washington (Acker et al. 1974) indicated that fish passage could be evaluated by use of sonar. The Bendix Corporation of Sylmar, California, then developed a sonar fish counter based on the design of salmon (*Oncorhynchus* sp.) fingerling counters used in Alaska. The counter was installed at the Pinopolis lock in 1975 and has been used during the last 3 spawning seasons.

MATERIALS AND METHODS

Pinopolis Dam is located near Moncks Corner, South Carolina and impounds Lake Moultrie, the smaller of the two Santee-Cooper Reservoirs. A tailrace canal extends 6.4 km downstream to the west branch of Cooper River (Fig. 1). The single-lift lock at Pinopolis Dam provides navigation from Charleston Harbor, located 84 km downstream, to the Santee-Cooper Lakes and the upper Santee River watershed. The lock is 18.3 m wide, 54.9 m long and has a vertical lift of 22.9 m. Minimum water depth is 37 m and varies with tailrace elevations. An ante-lock is formed by 2 concrete wing-walls, one 33.6 m long and the other 111.3 m long, which extend from the upstream lock gate into Lake Moultrie. Water depth in the ante-lock is approximately 9 m and varies with lake elevation. The fish counter was located in the ante-lock just upstream from the upper lock gates (Fig. 2). Placement in this area allows counting only those fish which leave the lock.

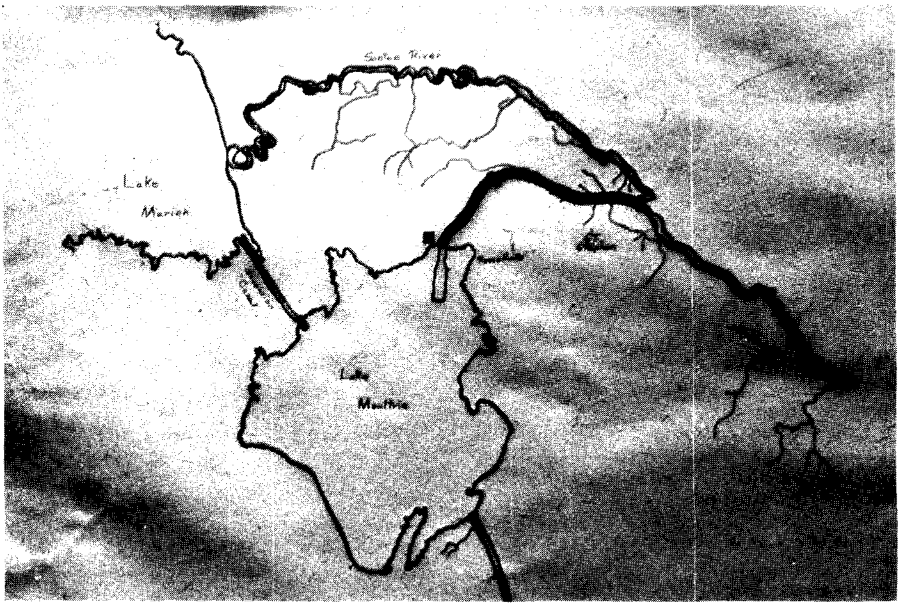

Fig. 1. The study area, Pinopolis Dam navigation lock, near Moncks Corner, South Carolina.

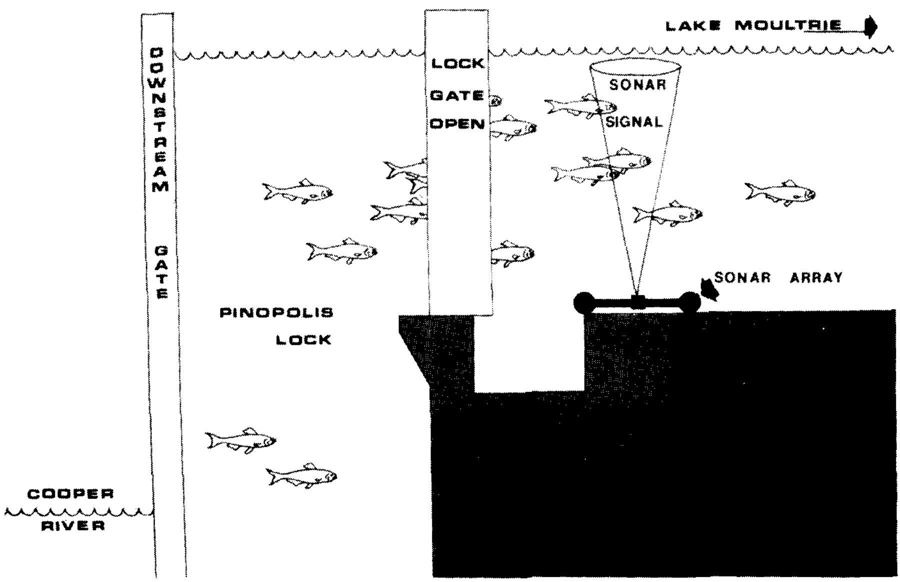

Fig. 2. Schematic side view of sonar fish counting in Pinopolis lock.

Fish locking operations were conducted thrice daily during March and April. Locking was generally initiated when herring were sufficiently concentrated to warrant the expenditure of the necessary time and money. Return of adult herring to the lock from Lake Moultrie signified the termination of the locking season.

The locking cycle started with the opening of the downstream gates for approximately 1 hr to allow fish to enter the lock from the tail-race canal. The lower gates were then closed and the lock filled to the elevation of Lake Moultrie. The upstream gates were then opened for approximately one-half hour to allow fish to exit the lock. The sonar fish counter was activated as the upstream gates were opened and recorded fish passage until the gates were closed.

The fish counter is comprised of 2 major units and can be installed in about 4 hrs by 2 divers and 2 assistants. The underwater unit or array is constructed of 2 side members (15 cm PVC) and 11 cross members located at 0.6 m intervals in a ladder-like fashion. At the center of each cross member an upward facing sonar transducer is attached. Two brackets approximately 6 m apart are bolted to the lock bottom and the array is held flat in these brackets by screen door springs on each end of the 2 side members. The side members are capped and fitted with valves to allow filling with water for sinking and filling with compressed air when the array is to be retrieved. A 61 m electronic cable connects each transducer to the on-shore receiver housed in a waterproof metal box approximately 6 cm square.

Features of the counter include an on-off switch and a 7 digit numerical display that provides a cumulative count of fish from a given starting time determined by the operator. A data storage printer automatically records the cumulative count on paper at operator selected intervals. A water depth control allows counting at different lake elevations and elimination of false signals from the surface. A fish velocity control permits synchronization of counts with the average swimming speed of herring passing over the array.

On signal from the counter unit, each of the 11 transducers transmits a burst of high frequency sound in a conical pattern and then automatically reverts to a listening mode. The transducers at this phase of operation receive echoes relative in strength to the biomass of fish swimming through the beam. These echoes are then routed to receivers which amplify, square and further process them (Menin 1974). The known shape and average size of blueback herring in Cooper River allows echoes to be electronically converted to numbers of fish and displayed as a digital cumulative count. This transmit-listening sequence automatically repeats at a repetition rate determined by the swimming velocity setting on the counter.

Before actual counts could be conducted, fish movement and schooling patterns had to be determined. The use of these data allowed the counter to be adjusted electronically or operationally to provide the most accurate count under the specialized conditions. To insure that each herring is counted only once as it traversees the sonic beam, average speed of fish passing the array was set on the counter. An error in this fish velocity setting would result in a directly proportional fish count error. Fish velocity over the array was established in 1975 prior to actual counts and reconfirmed at the beginning of the 1976 season. Simultaneous oscilloscope observations were made by 2 investigators as herring traversed a distance of 9.2 m. Findings from 5 experiments yielded a mean swimming speed of 1.1 m/sec after the 2 highest and lowest of the combined observations were omitted. Attempts at reconfirming the fish velocity at the beginning of the 1977 season were inconclusive. An increase in fish activity confused oscilloscope observations and prevented timing of the herring passage. The fish velocity established in 1975 was used throughout the study. If future experiments prove this figure incorrect, count data from previous years can be adjusted.

The spatial distribution of fish passing over the array was determined in 1975. A horizontally facing transducer placed at a depth of 4.6 m monitored fish movement throughout the locking operation. The transducer signals were projected on the oscilloscope and photographed. The first test was conducted with the lock gates fully open to their 18.3 m width. As the leading edge of the school passed the array, the vast majority of herring were in the count area. However, as time elapsed a more even and scattered horizontal distribution was observed. By the time approximately two-thirds of the school had passed, the majority of fish were moving along the wall in an uncounted area. Manipulation of sonar signals to compensate for such a variable distribution was unacceptable. Therefore, a method to concentrate the fish over the transducers had to be devised.

The second test was conducted with the gates open approximately 6 m. The gates in this position acted as a funnel and directed fish over the array before they moved to the walls. Horizontal distribution varied only slightly with the abundance of fish present or with the lapse of time from the opening of the gates. Throughout the passage, between 75 and 95 percent of the fish migrated within the sonified area. Compensation for this variable was accomplished within the logic portion of the counter and a gate opening of 6 m utilized throughout the project.

Vertical distribution was evaluated by oscilloscope readings of the signals from an upward facing transducer on the bottom. Photographs of fish signals over the array revealed that virtually no fish migrated within 1 to 1.5 m of the surface or bottom. Not having to count to the surface allows for the elimination or "gating" of signals well below floating debris or intrained air while allowing maximum fish counts. Similar tests of vertical and horizontal distribution in 1976 and 1977 confirmed these findings.

Based on laboratory tests using fish as sonar targets the logic portion of the counter was designed to enumerate sonar signals in "herring units". Fish of greatly different size, body proportions or swimming speed would produce faulty counts. Therefore, species composition and relative abundance of fish utilizing the lock required investigation. A trammel net evaluation from April 1954 to April 1955 collected 14 species utilizing the lock (Scruggs 1955, Job Completion Report, Project F-1-R-3, South Carolina Wildlife Department). Blueback herring numerically dominated the samples and represented 67 percent of the catch. Atlantic needlefish (*Strongylura marina* Walbaum) was the second most abundant species collected.

Attempts at determining species composition during the 1975 season were limited. However, electrofishing and seine hauls revealed Atlantic needlefish and blueback herring numerically dominate. Use of any kill-type capture method, rotenone or netting, was avoided because of large numbers of herring visible in the lock. Collections in 1975 compared favorably with 1954-55 samples in species composition and relative abundance with the exception of an increase in Atlantic needlefish. Visual observations in 1975 and in previous seasons indicated that needlefish generally stay close to the surface as they leave the lock. Elimination or "gating" of needlefish signals was accomplished by varying the water depth control on the counter so that counts would not be made within 0.3 m of the surface. Since tests had shown that herring do not migrate within 1 to 1.5 m of the surface, elimination of needlefish signals at the surface would not alter the counting of herring.

Evaluation of the species composition and relative abundance data collected during the spring of 1975-77 indicated that 21 species utilized the lock at some time during the blueback herring run. However, if all the fish collected in the lock other than herring were converted to "herring units" and counted as herring, these false counts would be only 2.8 percent of the count during the average 1977 locking operations. Therefore, counts produced by fish other than herring do not constitute an unacceptable error. However, efforts to further evaluate and reduce this error will continue.

RESULTS AND DISCUSSION

In 1975, counts were made on 28 days during the months of March and April. A total of 2,166,921 fish were counted in that period. The locks were operated 71 times and the average count per locking period was 30,520 fish.

In 1976, a total of 2,464,752 fish were counted in 39 locking operations. The average count per locking period was 63,199 and showed a marked increase over the 1975 season. Census of commercial harvests in Cooper River and visual observations of herring in Lake Moultrie and Pinopolis Sanctuary verified the increased abundance. The sonar fish counter was installed, calibrated and functional by March 19. Counts were made until March 29 when a malfunction in the printer occurred. Although counts could have continued using only the digital readout, with no paper printout, counting was discontinued for 7 days while the counter was completely tested in California. Only the printer proved faulty and the counter was reactivated. The printer is a modular unit and easily plugged into the counter.

Locking operations for the 1977 season began on March 9 and were terminated on April 15. A total of 6,328,572 herring were counted in 45 lockings. An average of 140,635 fish were counted per locking period. The increased abundance of herring was again verified by visual observations and census of commercial fisheries.

In the last 3 seasons several attempts were made to evaluate the accuracy of the fish counter. None of these attempts was successfully completed. On 19 April 1977, the lock was purged and a known quantity of fish were released into the lock. The following day fish were to be counted as they were released from the lock. However, death of many fish and poor condition of remaining fish invalidated the test. Inability to recover tagged fish from over 1,000 marked herring prevented evaluation by a mark-recapture estimate on 27 March 1976. An attempt to count fish entering the lock and later validate the number by rotenone failed when 2 transducers were accidentally damaged. With modification in procedures this method appears the most feasible and attempts will be made during the 1978 season to evaluate the counter by this procedure.

The fish counter has proven to be easily installed and readily adjusted to the requirements of the particular location. It is easily operated by 1 man and does not interfere with normal navigation or operation of the lock. It has accurately assessed trends in herring passage and provided an index to herring abundance. If in addition its accuracy is proven, the sonar fish counter should become an indispensable fisheries tool. Applications for sonar fish counting are not restricted to artificial situations like the Pinopolis lock. Free flowing streams where large numbers of a single species migrate could easily be evaluated by this technique.

LITERATURE CITED

Acker, W. C., J. E. Ehrenberg and R. E. Thorne. 1974. Results of feasibility study to assess blueback herring at Pinopolis Lock, South Carolina. Applied Physics Laboratory, University of Washington, Seattle. 11 pp. (unpublished).

Menin, A. 1974. Fish counting by acoustic means. IEEE International Conference on Engineering in the Ocean Environment. 1:166-168.

Scruggs, G. D., Jr., and J. C. Fuller, Jr. 1954. Indications of a freshwater population of striped bass (*Roccus saxatilis* Walbaum) in Santee-Cooper reservoirs. Proc. Annual Conf. Southeastern Assoc. Game. Fish. Comm. 8:64-69.

Stevens, R. E. 1957. The striped bass of the Santee-Cooper reservoir. Proc. Annual Conf. Southeastern Assoc. Game. Fish. Comm. 11:253-264.