FISHERY MANAGEMENT OF YELLOWSTONE LAKE, WYOMING

AS RELATED TO WATER SUPPLY FORECASTS

By

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INTRODUCTION

Water supply forecasts, based on snow surveys, are essential for maximum utilization of water resources in Western United States. Prediction of seasonal runoff several months in advance of its occurrence enables the farmer to select his crops according to the amount of irrigation water he expects to receive. Organizations engaged in flood control can regulate reservoir drawdown to eliminate or reduce flood damage. Irrigation companies can plan reservoir regulation well in advance of spring runoff.

A further use of water supply forecasts is in the field of fisheries management. The relation of water levels to fish reproduction has been well documented in literature (e. g., McKernan, et al.[1/]; Brett,[2/]; Johnson,[3/]; Vernon,[4/]; Wickett,[5/]; and Gangmark and Bakkala,[6/]). Excessive runoff may limit access to the better spawning areas, reduce efficiency of egg deposition because of spawner fatigue, or actually wash away and destroy eggs and young. Deficient flow may cause excessive density of spawners with resulting superimposition of redds, failure of adults to reach suitable spawning areas, and death of spawners, eggs and young from predation, stranding or unsuitable water temperatures and oxygen content. Thus, if water conditions are unsuitable, fish production in a given year may be completely lost even though spawner numbers are adequate. If the acquatic environment is optimum for spawning and survival of young, a strong year-class may be produced by a minimum number of spawners.

To efficiently manage a fishery where water conditions have been isolated as a major factor limiting production, accurate forecasts of water levels and streamflow are of substantial value. Foreknowledge of the success of natural reproduction several months before it occurs gives the fishery manager time to program additional hatching to strengthen weak year-classes with supplemental stocking of young after the critical water period. Stocking is impractical with many species, but knowledge obtained from water level and streamflow data indicating strength of a year-class several years before recruitment into the fishery allows commercial fishermen to efficiently exploit abundant year-classes and turn their efforts toward other species in years when weak year-classes are anticipated. In a sport fishery where stocking is impractical, creel limits can be adjusted in accordance with the anticipated size of year-classes entering the fishery.

In this paper the use of water supply forecast data in managing the cutthroat trout fishery in Yellowstone Lake, Wyoming is discussed.

YELLOWSTONE LAKE AND FISHERY

Yellowstone Lake is located within the boundary of Yellowstone National Park on the east slope of the continental divide at an elevation of 7,730 feet. Surface area is approximately 137 square miles. The lake is fed by 14 major and 26 minor tributary streams that drain 1,006 square miles (fig. 1).

Annual changes in the lake water level vary from 3.0 to 5.5 feet. The lake water level is lowest from January to April, rises to a peak generally in late June or early July, as the snow melts, then recedes to complete the yearly cycle. Daily stage hydrographs, May through August, for the extreme years of 1941 and 1956 as well as the 1937-60 mean are shown in Figure 2.

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Records of water levels in Yellowstone Lake at Lake Hotel are published by the Geological Survey. Since 1936 the National Park Service, in cooperation with the Soil Conservation Service, has conducted snow surveys at several locations in the Yellowstone Lake drainage (fig. 1).

Yellowstone cutthroat trout, Salmo clarki lewisi, is the only species of sport fish inhabiting Yellowstone Lake. Cutthroat in this lake are a composite group representing fish which hatch out in a number of different tributaries. Adults move from the lake into these tributaries to spawn during May, June and July, and most of them return to the lake within a few weeks after spawning. Eggs are deposited from a few days to several weeks after spawners enter the streams and fry emerge from the gravel on an average of 30 days after egg deposition. The young migrate downstream to the lake usually during the first two years of life. Mortality from the time the immatures leave the parent stream until they return as spawners is relatively low.[7] The population supports an important sport fishery which maintained a mean actual catch of approximately 275,000 fish from 1950 to 1960.[7]

Pelican Creek, one of the major spawning streams which supports the northern area fishery of Yellowstone Lake, enters the lake less than one mile from Fishing Bridge Campground near the lake outlet. Like other snow-fed streams, discharges are large during spring runoff and the spawning period, and decrease to much smaller flows (about 40 cubic feet per second) in August and September.

Bulkley and Benson[8] examined factors suspected of causing wide variations in year-class strength of cutthroat trout produced in Pelican Creek and found that 94.3 per cent ($R = 0.978$) of the variation from 1948 to 1956 was associated with mean Yellowstone Lake water levels during the spring spawning period (fig. 3). The stream level in Pelican Creek was found to fluctuate similarily to the level of Yellowstone Lake except that the lake lagged approximately a week behind the stream. Records for Pelican Creek would have been better had they been available. Whenever mean June-July stage of the lake approached or exceeded 4.75 feet, trout production in Pelican Creek dropped regardless of the number of spawners available. Production increased when the lake level was low during June and July.

Knowledge of the cause of these fluctuations is important because year-class strength of spawners in this stream is similar to year-class strength in the northern area fishery which contributed over 60 percent of the entire lake catch. If year-class strength could be maintained somewhere near the high levels produced in 1953 and 1955 (fig. 3), the fishery could be expanded without depleting the population. From available information, one way to accomplish this would be to strengthen weak year-classes by stocking of fry or small fingerlings after the critical spring water period. The policy of the National Park Service to maintain fauna in the natural state as much as possible precludes the planting of larger fish. There is some evidence that fry planting in streams may serve to stabilize year-class strength.[7] Planting in years of high natural reproduction, such as in 1953 and 1955, could actually decrease the size of the year-class through factors such as disease, increased predation and competition. The population would derive the most benefit if fry plantings were made only in years when natural reproduction was inadequate.

If a management program is to be based on water conditions where fish planting is desirable in some years and not in others, reliable forecasts of lake levels, several months in advance, are essential. Advance preparation must be made for the taking of spawn and for hatchery operations. Funds must be allotted, personnel organized and equipment checked and placed in working order.

FORECASTING LAKE LEVEL FROM SNOW SURVEY DATA

Since Yellowstone Lake has a natural, uncontrolled outlet, water levels are a function of volume and can be related directly to snow water equivalent measured at established snow courses. The first attempt to predict Yellowstone Lake water levels utilizing snow survey data was made early in 1961. Snow survey data from 1937 through 1960 were plotted graphically against peak stage and the number of days the lake level exceeded the 3.00 feet stage. Other plots were made to estimate the stage on June 1 and the number of days to peak from the 3.00 feet stage. Utilizing these data, a hydrograph could be drawn. On March 1, 1961 the first forecast was made. The peak stage was forecast to be 4.50

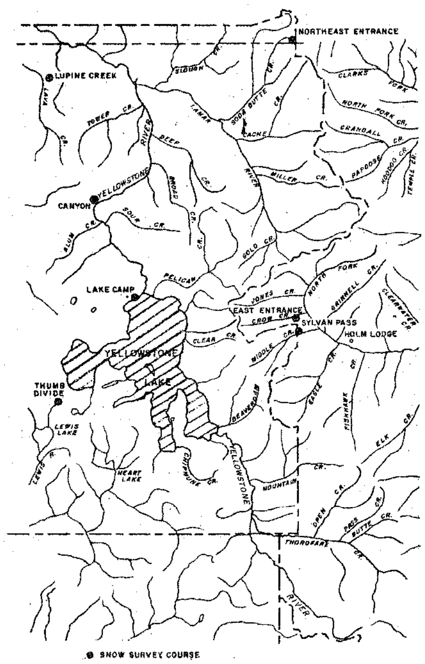

Figure 1. Yellowstone Lake Drainage and Snow Course Location.

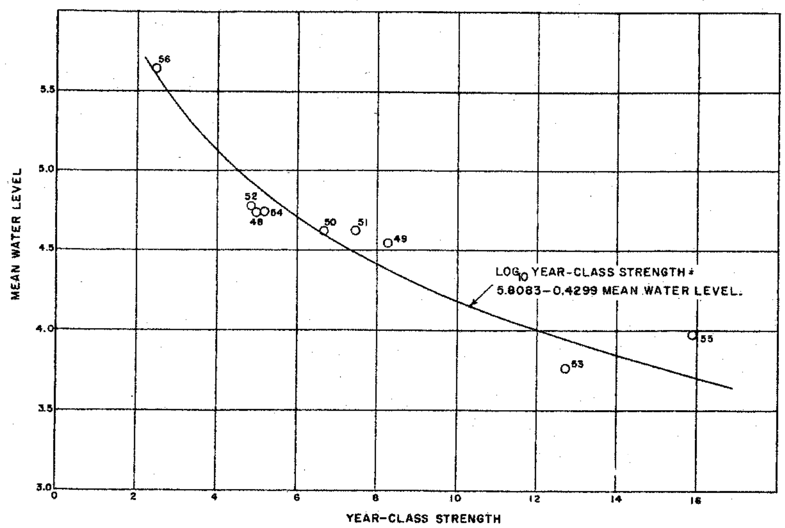

Figure 3. Mean June-July water stage (feet) of Yellowstone Lake in relation to recruitment to the Pelican Creek spawning runs from each year-class expressed in thousands of fish.

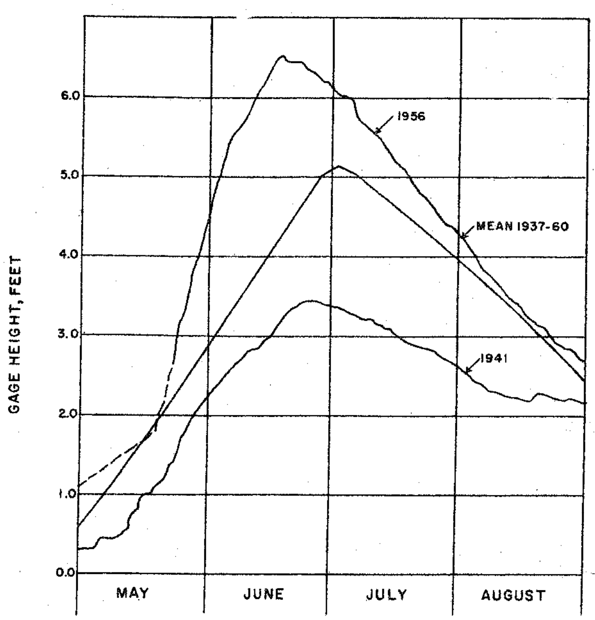

Figure 2. Daily Stage Hydrographs of Yellowstone Lake at Lake Hotel

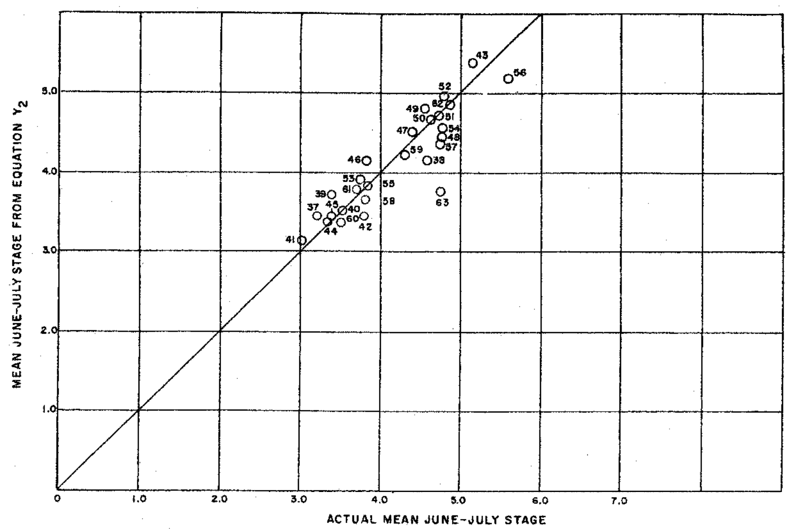

Figure 4. Comparison of actual mean June-July stage with those obtained from equation Y_2.

feet and date of peak estimated to be June 27. On April 1 the peak forecast was lowered to 4.46 feet and peak date estimated at June 29. Both forecasts indicated excellent natural spawning conditions as the mean June-July level estimated from the hydrographs at about 3.90 feet would be well below the 3.75 feet stage. In 1961 the peak occurred on June 21 and was 4.43 feet. Mean June-July stage was 3.69 feet. In 1962, similar forecasts were made estimating the peak to be 5.40 feet on March 1 and 5.39 feet on April 1. Mean June-July level would then be around 4.70 feet. Date of peak was forecast to be June 27 on March 1 and July 3 on April 1. The peak occurred on July 1 at 5.73 feet, with a mean June-July stage of 4.86 feet.

Early in 1963 it was decided to forecast the mean June-July level in addition to the peak and number of days the level would exceed 3.00 feet. Forecasting equations were then developed using multiple regression analyses. In addition to snow survey data, fall precipitation was included.

Accuracy of these forecasts is influenced somewhat by the amount of precipitation during spring and early summer and by air temperatures during the melt season, but since these variables are not known on March 1 or April 1, they have not been included in the equations. These advance forecasts are sufficiently accurate to determine whether water conditions will be suitable for natural cutthroat reproduction.

Following are the equations developed in 1963:

March 1 Forecast Equation

$$Y_1 = 0.104X_1 + 0.039X_2 + 0.014X_3 + 0.014X_4 + 2.10 \qquad (R^2 = .809)$$

April 1 Forecast Equation

$$Y_2 = 0.044X_1 + 0.089X_2 + 0.024X_3 + 0.017X_4 + 1.89 \qquad (R^2 = .887)$$

Where: Y = mean June-July lake level at Lake Hotel staff gage, in feet.

X_1 = Canyon, March 1 snow water equivalent in Y_1
April 1 snow water equivalent in Y_2

X_2 = Northeast Entrance, March 1 snow water equivalent in Y_1
April 1 snow water equivalent in Y_2

X_3 = Thumb Divide, March 1 snow water equivalent in Y_1
April 1 snow water equivalent in Y_2

X_4 = Sum, Yellowstone Park, Tower Falls, Northeast Entrance, Lammar and Lake Yellowstone, Sept. + Oct. + Nov. precipitation.

Note: Snow water equivalent and precipitation shown in inches.

Data from 1937 through 1962 were used to derive these equations. Average forecast error of the April 1 equation, substituting the original data in the derived equation, is 0.16 foot with a maximum error of 0.44 foot. Figure 4 shows the relationship between the mean June-July lake level and original data substituted in the derived equation, including 1963.

In 1963 the mean June-July stage was forecast to be 3.99 feet on March 1 and 3.75 feet on April 1. The decrease reflects deficient March precipitation. Above average precipitation in April, May and June, together with above average temperatures in May, resulted in an observed mean June-July level of 4.74 feet. It is believed that this large deviation between the forecast and actual stage is near the maximum that can be anticipated, and that the average error will probably be near 0.20 foot. Forecast equations have also been prepared for peak water level and number of days the level will exceed 3.00 feet. However, only the mean June-July lake level forecast is presented since operations of the fishery are based on this factor.

Table I lists the mean June-July stage, peak stage, date of peak and number of days the level exceeds the 3.00 feet stage for Yellowstone Lake at Lake Hotel.

SUMMARY

Snow survey data used in early season forecasts for Yellowstone Lake levels may aid in managing this sport fishery for optimum production. Foreknowledge of spawning conditions through these early season forecasts allows sufficient time to prepare artificial spawning facilities, if desired, should conditions for natural production be unsuitable.

Since the Soil Conservation Service makes water supply forecasts based on snow survey data for most gaged streams and rivers in the Western United States, procedures and methods discussed in this paper may be adapted for better management of many other fisheries.

With expanding population subjecting our sport fisheries to ever-increasing pressures, practical and economical fisheries management becomes increasingly vital.

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