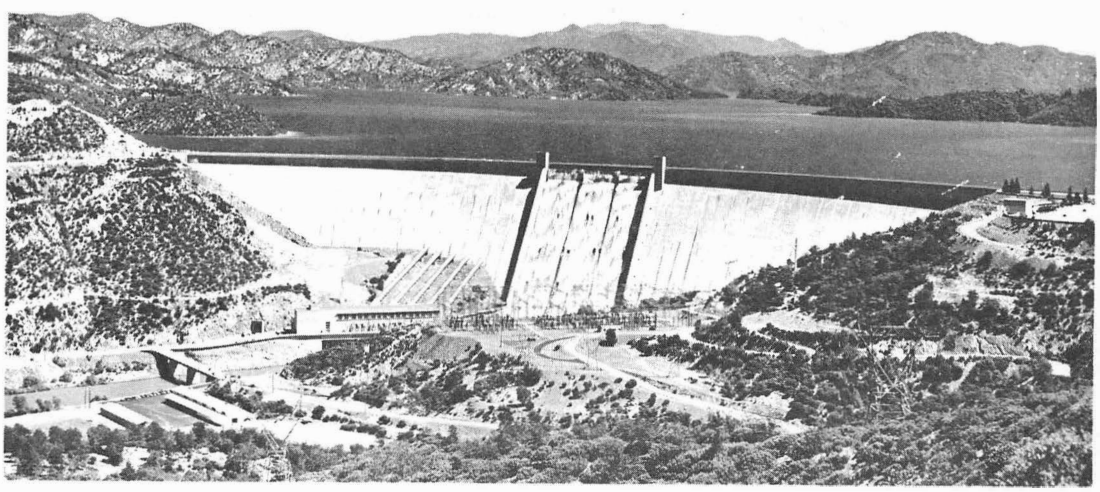
STATE OF CALIFORNIA
THE RESOURCES AGENCY
Department of Fish and Game

OBSERVATIONS ON DOWNSTREAM MIGRANT SALMONIDS SHASTA RESERVOIR CALIFORNIA



OCTOBER 1963

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OBSERVATIONS ON DOWNSTREAM MIGRANT SALMONIDS SHASTA RESERVOIR CALIFORNIA

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WATER PROJECTS BRANCH

OCTOBER 1963

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ABSTRACT

The Shasta Reservoir study was initiated as part of a continuous program, supported by the California Department of Water Resources and conducted by the California Department of Fish and Game to determine effects of water development projects on the anadromous fish resources of California. The U. S. Bureau of Commercial Fisheries signed a cooperative agreement with the Department of Fish and Game whereby it would furnish funds to augment the study in return for information that could be applied to fish passage problems in the Columbia River Basin.

The primary objective of the program was to study the habits of downstream migrating, fall-run, king salmon fingerlings in Shasta Reservoir and to relate these findings to proposed water projects in northern California and the Pacific Northwest.

A total of 1,750,000 king salmon fry from Coleman National Fish Hatchery was released in the upper Sacramento River during 1962 and 1963.

A total of 750,000 swim-up fry was released during February 1962, 25 miles above the reservoir. Fyke net sampling in the river at the head of the impoundment indicated the majority of the migrants entered the reservoir during the first week after release. The 1962 plant produced very poor returns in the reservoir and only two small king salmon, definitely considered to have come from the 1962 plant, were recovered.

One million king salmon fingerlings were released in April 1963, 1 and 1/2 miles above the reservoir. A total of 3,956 of these fingerlings were recovered in Shasta Reservoir with floating lake traps. During the

first 16 days after being planted, fingerlings were observed to have traveled a distance of 23.7 miles down the reservoir. No fingerlings were recovered below the confluence of the Sacramento and Pit River arms of the impoundment. Shasta Dam was spilling during the period of fingerling movement, but there was no indication that any of the young fish left the reservoir via the spill. No formal limnological program was carried on during the study, but preliminary work indicated that surface water temperatures had a direct bearing on the downstream movement of the young salmon. Counter currents observed in the lower end of the Sacramento arm of the reservoir may also have influenced the movement of the migrants.

A complete evaluation of the young king salmon's habits in the reservoir was impossible to obtain because of early termination of the study. However, preliminary data indicate that the young fish planted during the study have taken up at least a temporary residence in the reservoir and have shown no inclination to leave.

INTRODUCTION

This report presents data pertaining to the movement and behavior of planted fingerling king salmon in Shasta Reservoir, a 29,500-acre, fluctuating, multipurpose reservoir on the upper Sacramento River in northern California. The data were obtained during the course of field studies in 1962 and 1963, which were directed towards determination of the ability of young salmon to migrate downstream through reservoirs of the type represented by Shasta Reservoir.

The data presented herein are inconclusive with regard to the primary objective of the study, since study was terminated abruptly about midway through its original schedule. Nevertheless, it is believed that they are worthy of publication as a reference for probable re-initiation of the Shasta Reservoir study at some future date, or for possible application to downstream migrant studies on other streams of the Pacific Coast.

The need for concrete knowledge of the overall effects of impounded waters on the seaward migrations of juvenile salmonids has become pressing in California, as it has in other localities along the west coast of North America. An unprecedented increase in numbers of people in this State in recent years, coupled with both a wide variation in annual natural water supplies and concentration of the major portion of the annual runoff in the least populated region of the State, have lead to a comprehensive plan of development of the State's surface water supplies -- The California Water Plan. This plan proposes the ultimate construction of dams and reservoirs on virtually every major anadromous salmonid stream in California in order to meet increasing requirements for water by a burgeoning human population.

It is the farsighted policy of the State that its public-owned fish and wildlife resources shall be preserved in connection with projects constructed by the State. In addition, fishery enhancement is a purpose of state water development projects. Preservation of anadromous fishes in connection with dams obstructing their spawning grounds can usually be accomplished in a number of ways, depending upon local conditions. Obviously the preservation method that adequately cares for the resource, yet costs the least, usually constitutes the best approach.

In instances where proposed dams and reservoirs would inundate, or otherwise make unavailable, upstream spawning grounds for anadromous salmonids, the problem of preservation becomes relatively simple. Artificial spawning facilities could be constructed and operated below the project or, if downstream spawning areas are sufficiently extensive, an increase in stream flows provided by the project might create the additional habitat required for protection of the existing resource. In some cases where the above measures are not feasible, it might be necessary to increase the productivity of an adjacent stream in the same watershed to accomplish the desired objective. As a rule, these approaches are costly, especially the hatchery approach which might involve sizeable annual operation and maintenance expenditures.

A different and more complex set of conditions confronts the water project planner when an appreciable amount of spawning habitat for anadromous salmonids occurs upstream from a proposed dam and reservoir. Assuming successful passage of adult fish over the dam and through the reservoir and equally safe passage of their progeny downstream through the reservoir into the tailwaters of the dam, provision of passage facilities would almost always be a much less costly means of preservation than artificial spawning facilities or other alternative preservation requirements.

On most conventional impoundment projects, upstream passage facilities can be designed with substantial confidence that they will function adequately. Considerable experience and knowledge of upstream passage facilities has been gained in recent years, and is available to fishery workers and planning engineers.

Successful passage of juvenile salmonids across, around, or through a dam probably could be engineered adequately, providing the young fish are concentrated immediately above the dam. The real problem centers on safe transport of fingerling-sized fish from the spawning grounds to the dam. It is towards this unresolved problem that this study was directed.

Authorization for Study

In 1959, the California Department of Water Resources commenced a comprehensive reconnaissance-level investigation of the water resources of the upper Sacramento River Basin for the purpose of formulating an optimum plan of development of those resources to meet predicted future water requirements. The study area is comprised of a 2,600 square mile drainage area between Shasta Dam and the City of Red Bluff.

At least two alternative plans for development of the basin's water supplies were evident. One plan proposed construction of a 170-foot dam on the main stem of the Sacramento River approximately 4.5 miles northeast of Red Bluff at the Iron Canyon site. A reservoir storing 1,000,000 acre-feet, with 27,400 surface acres at normal pool elevation would be created. The Iron Canyon Reservoir would inundate about 37 miles of the Sacramento River.

The primary alternative to a main stem Iron Canyon Dam and Reservoir is the contemplated construction of smaller dams on the major tributaries to the Sacramento River above the Iron Canyon site. The major tributaries are Cow and Cottonwood Creeks.

The upper Sacramento River possesses the largest, most important king salmon run in North America. Fish produced there constitute the bulk of the California commercial salmon catch, and contribute to catches in Oregon and Washington in addition to supporting a significant sport fishery in the State's coastal waters and in the river itself. Moreover, a sizeable steelhead population depends upon the river for habitat.

Three distinct races of king salmon are identifiable in the upper Sacramento River Basin: fall-run, winter-run, and spring-run. The fall-run is the largest. Estimates of the numbers of adult fall-run fish from 1952 to 1959 range from 83,000 to 451,000 with an average of 252,000 salmon (Fry, 1961). From 1946 to 1956, spring-run salmon estimates have ranged from 9,000 to 33,000 with an average of 19,000. No estimates of the abundance of winter-run fish are available; however, the run has built-up remarkably in recent years and appears to be about the same order of magnitude as the spring-run.

About 80 to 85 percent of the king salmon that migrate into the upper Sacramento River spawn above the proposed Iron Canyon damsite, either in the main stem of the river or in major tributaries. Somewhere between 230,000 and 250,000 king salmon would thus be blocked on an average annual basis by an Iron Canyon Dam.

Hallock, Van Woert, and Shapovalov (1961) estimated that the steelhead run in the upper Sacramento River averaged 20,542 fish during the period 1953 to 1959. Most of these fish spawn above the Iron Canyon damsite.

The California Department of Water Resources is responsible for planning for fish and wildlife preservation and enhancement in connection with water development projects described in The California Water Plan. In meeting this responsibility, that Department contracts with the California Department of Fish and Game for the professional planning services of fish and wildlife biologists.

In 1960, the Department of Water Resources entered into an inter-agency agreement with the Department of Fish and Game for personnel to evaluate the effects of proposed water projects in the upper Sacramento River Basin on fish and wildlife. Preliminary evaluations revealed the vast impact Iron Canyon Dam would have on anadromous fishes.

The Department of Fish and Game retained a fishery consultant to make an independent study of the effects of the Iron Canyon Project on king salmon and to recommend measures required for the preservation of existing salmon populations. A report was submitted by the consultant in 1961 (Eicher, 1961). He recommended several approaches to a solution of the Iron Canyon salmon problem; the most feasible in his eyes being passage of adult fish around the dam to utilize upstream spawning grounds.

This proposed approach immediately raised the question of the ability of fingerling salmon to safely negotiate a 37-mile, warmwater, fluctuating reservoir to the area of the proposed dam where they could be bypassed into the river below. To resolve this question, the two state agencies mutually agreed that an experiment designed to provide conclusive evidence, one way or the other, was necessary immediately. The economic feasibility of Iron Canyon Dam and Reservoir could not be adequately assessed without this vital information since failure of the young fish to pass through the reservoir would necessitate construction of mammoth, costly, artificial spawning facilities below the project.

In 1961-62, Interagency Agreement Numbers 251412 and 451778 between Water Resources and Fish and Game were executed, in the total amount of $28,000, for a study of the movement, behavior, and survival of king salmon fingerlings in Shasta Reservoir. Work began in July 1961.

In 1962-63, Interagency Agreement Number 252087 was entered into by the same agencies for a continuation of the field experiment. The amount was $11,300.

The 1962-63 funding was supplemented by monies from the Bureau of Commercial Fisheries, U. S. Fish and Wildlife Service, in the amount of $13,800, as part of their Accelerated Fish Passage Program. The federal agency believed that the results of the Shasta Reservoir study would be applicable to similar studies being carried on under their auspices in the Columbia River Basin. The federal contribution was authorized under Contract No. 14-17-0007-112.

The 1963 California Legislature did not appropriate funds for a continuation of the State's share of the study in fiscal year 1963-64. It was decided to terminate the field study on June 30, 1963, since federal funding for the study was uncertain. However, the Bureau of Commercial Fisheries entered into Contract Number 14-17-0001-963 with Fish and Game, in an amount of $2,200, for preparation of this report.

Scope and Objectives

The original basic objective of the Shasta Reservoir study was to determine if fingerling king salmon would pass safely through a reservoir similar to the proposed Iron Canyon Reservoir. This was the question to which the Departments of Water Resources and Fish and Game required a valid answer.

The Sacramento River arm of Shasta Reservoir appeared to offer physical characteristics sufficiently similar to the proposed Iron Canyon Reservoir to serve as a study area (Plate 1). The two waters would be roughly the same length and would be generally comparable in quality.

The incorporation of the study into the Accelerated Fish Passage Program of the Bureau of Commercial Fisheries broadened the scope of the study to include acquisition of data that would be usable in the analysis and solution of Columbia River fish passage problems. The specific objectives of the study were as follows:

I. Determine the pattern and rate of movement of fingerling king salmon in Shasta Reservoir.

II. Observe schooling patterns of fingerling king salmon in Shasta Reservoir.

III. Determine the distribution of king salmon in relation to water temperatures and oxygen tensions.

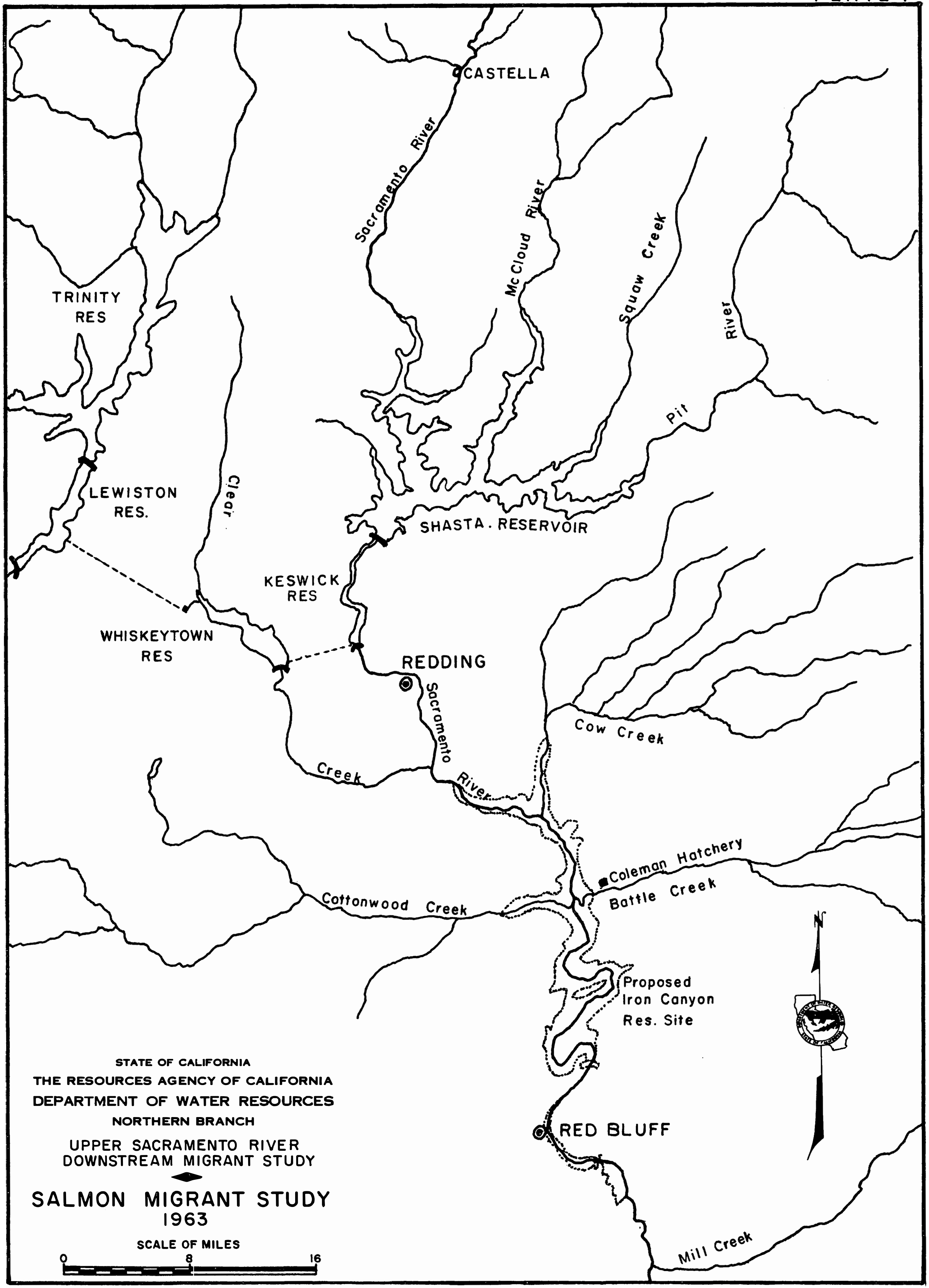
IV. Determine if residualism occurs in Shasta Reservoir and measure the degree of residualism if it occurs.

V. Determine the relationship of predator fish populations to fingerling survival.

VI. Determine if fingerling king salmon would sound to the depth of Shasta Dam turbines and measure survival rates after passage through the turbines.

Valuable data and experience resulted from the study in regard to Objective No. 1; however, in essence, the objectives were not met due to early termination of the field experiment.

A program of endeavor designed to meet the above objectives was formulated. Despite the failure to carry through with the program,


CASTELLA
Sacramento River
McCloud River
Squaw Creek
River
Pit
TRINITY
RES
LEWISTON
RES.
Clear
SHASTA . RESERVOIR
KESWICK
RES
WHISKEYTOWN
RES
REDDING
Sacramento
River
Creek
Cow Creek
Coleman Hatchery
Battle Creek
Cottonwood Creek
Proposed
Iron Canyon
Res. Site
RED BLUFF
Mill Creek
N
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
UPPER SACRAMENTO RIVER
DOWNSTREAM MIGRANT STUDY
SALMON MIGRANT STUDY
1963
SCALE OF MILES
0
8
16

the primary elements are listed below as a reference for future studies of the same type:

A. Acquisition and development of experimental sampling gear.

This was a time-consuming segment of the study, entailing design and construction of a mid-water trawl and floating trap and acquisition of acceptable gill nets.

B. Release of experimental fish.

Fall-run king salmon fingerlings, in sufficient quantity for sampling in a large body of water, released in the Sacramento River far enough upstream so that they could commence their downstream migration in a natural manner.

C. Fish sampling program.

Stream sampling using fyke nets, seines, electrical shocking equipment, and skin diving gear. Lake sampling using trawls, floating traps, and gill nets.

D. Limnological sampling.

Measurement of dissolved oxygen and water temperatures using standard procedures.

E. Measurement of residualism.

Accomplished by marking captured fish and sampling by means of gill nets, hook-and-line fishing, and examining angler catches.

F. Predation studies.

Routine stomach analysis of predator species obtained by angler creel census and population sampling.

G. Turbine studies.

Sampling Shasta Reservoir discharge with fyke nets and floating traps.

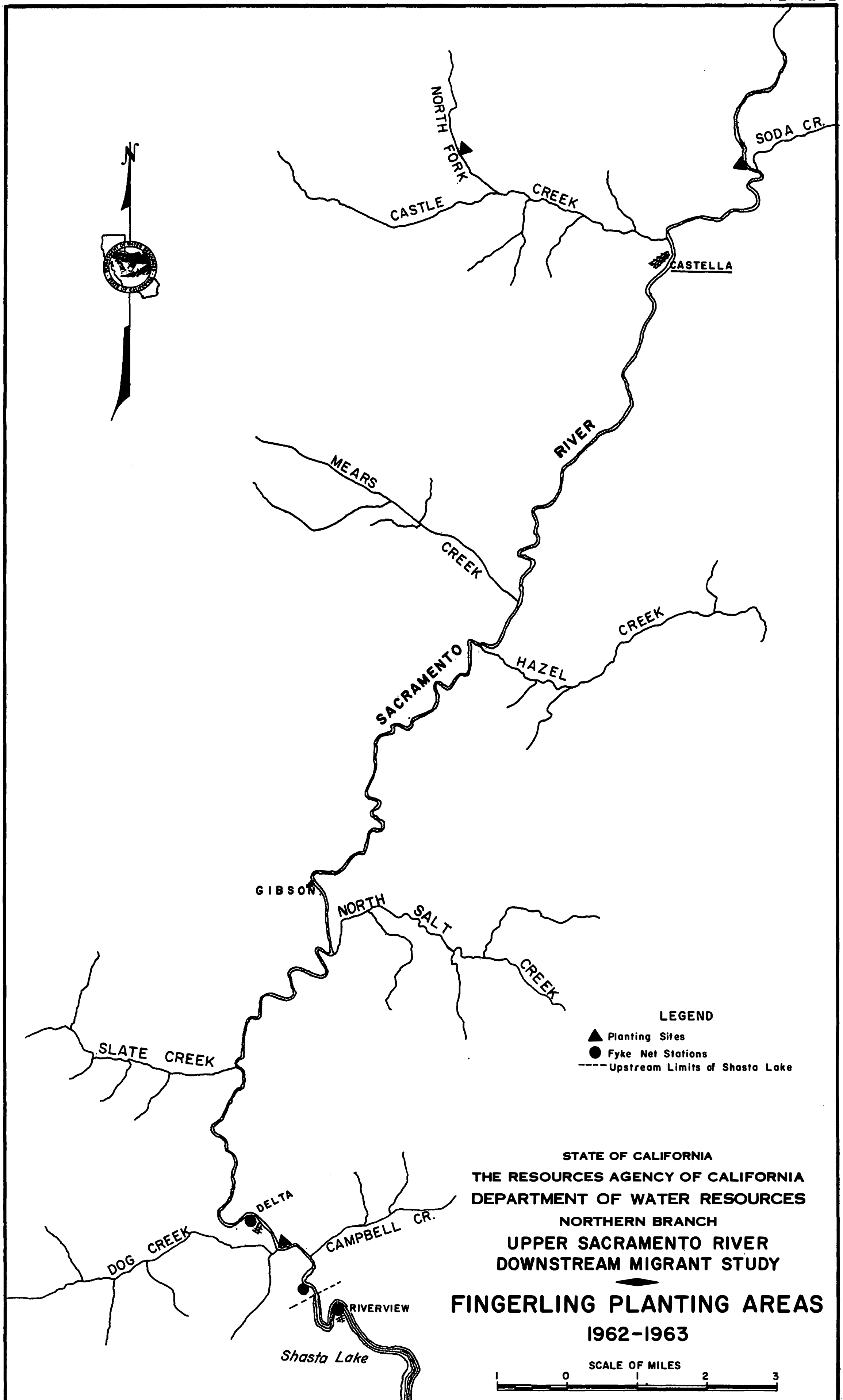
EXPERIMENTAL EQUIPMENT AND PROCEDURES

It was not known if the young salmon, used in the study, would be properly oriented for their downstream migration if planted too close to the reservoir; consequently, they were planted 27 miles upstream to give the young fish an opportunity to become adapted to the river environment before they entered standing water. The downstream movement of the fry was measured by means of riffle fyke nets. The nets were used to obtain an indication of movement and timing of the downstream migration and not to give a total count. Residualism in the area between the planting sites and the reservoir was assessed by means of visual observations, a back pack shocker unit and small seines (Plate 2).

When the fry reached the reservoir, their movements were sampled by means of gill nets, floating traps, and trawls. The gill nets and traps were fished along the shoreline of the lake and the trawls, both mid-water and bottom types, were used in the open water areas.

General Operating Equipment

Equipment used for everyday work on the reservoir consisted of a 21-foot Trojan cruiser, powered by twin 35-hp Johnson outboard motors and a 12-foot glass skiff, powered by a 10-hp Johnson outboard motor. The boats were equipped with trailers to enable them to be transported to different areas of the lake when the need arose, or they could be removed from the lake for repair or storage in bad weather.



STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
UPPER SACRAMENTO RIVER
DOWNSTREAM MIGRANT STUDY

FINGERLING PLANTING AREAS
1962-1963

Fyke Net Sampling

Fyke Net Specifications

The nets used for sampling were modified, riffle fyke nets with a 3 by 4-foot rectangular opening at the large end. The nets tapered down in a distance of 10 feet to a 9-inch opening, that was laced to a square metal frame. The nets were constructed of 1/2-inch stretched-mesh, cotton webbing without the normal fyke constriction and the catch was retained in a perforated, aluminum, live car instead of a cod end. The net and live car were fastened together by slipping the small end of the net into a slot in the end of the live car and closing the lid. By removing the lid and detaching the net, the live car was easily moved to shore and emptied.

The river was carrying large amounts of suspended organic material when fyke net sampling was first started, which made it necessary to clean the net webbing several times a day. When the webbing was dirty or the meshes were plugged with debris, the efficiency of the net was greatly impaired. Not only did the catch drop off, but only very small and weak fish were taken. When the webbing was full of debris a noticeable pressure bulge was built up in front of the net, and it was theorized that young salmon, being pressure sensitive, avoided the net.

In order to overcome the debris problem, the basic net design was modified so that a greater volume of water could be passed through the front section. A straight 6-foot extension was made ahead of the original net, using 1 and 1/4-inch stretched-mesh, cotton webbing instead of the 1/2-inch stretched-mesh material used in the body of the net. The front and middle sections of the net were held open by a 1/2-inch welded pipe frame. The modification acted much the same as wings, but instead of extending outwards at a divergent angle, the extension was closed top and bottom to form a tunnel.

The large mesh webbing ahead of the funnel allowed much of the debris to be swept out through the sides and also allowed the water pressure to diminish before it reached the small end. After the modification, no pressure bulge was detected in front of the net and the net was much easier to keep in place. The catch in the modified net changed noticeably. The catch in the altered net included trout up to 8 inches long, where previously no fish longer than 2 inches were taken.

Many of the fish that were taken in the modified net could have escaped through the sides of the lead section if they had so chosen, but they had a tendency to avoid the webbing. The perforated, aluminum, live car used on the net retained fish in good condition and the force of the water entering the car kept the catch from escaping.

Fyke Net Sampling Procedures

The fyke nets were always fished in a strong current with the sides of the lead section parallel to the flow. Fyke net sites were located on the lower end of riffles where the current was heaviest and where there was sufficient depth to float the live car (Figure 1).

Unstable river conditions in the study area, during the spring of the year, caused considerable damage to the nets and on one occasion the loss of an entire net. Thereafter, to guard against excessive damage or loss of gear, a steel cable was used to moor the inside edge of the fyke net to the shore while the outboard edge was moored to a 35-pound kedge anchor with a light break-away line. When a sudden freshet would raise the level of the river and cause undue strain on the net, the light line would carry away and let the fyke net swing in against the shore.

Gill Net Sampling

Gill nets were used for sampling areas of the reservoir that could not be sampled efficiently by other means. These areas included shorelines, narrow inlets, and shallow water with a rough bottom.

Gill Net Specifications

The gill nets used in the study were 100 feet long and 8 feet deep. Each net consisted of two panels of different mesh size, each of which were 50 feet long. Mesh sizes used were 3/8", 1/2", 5/8", 3/4", 1", and 1-1/4" stretched measure. The webbing was multifilament nylon of two and three-filament construction. The nets were hung without floats or weights to facilitate handling and storage. Floats and weights were attached, as needed, with shower curtain rings which not only added to the versatility of the nets, but also reduced the cost of construction (Figure 2).

The gill net floats were painted with a fluorescent red-orange paint, which made them readily visible even in rough water. Galvanized iron rings two inches in diameter were used for net weights to reduce tangling. Cast iron window sash weights were used for gill net anchors and empty 1/2-gallon plastic bleach bottles were used for anchor buoys. The anchor buoys were also painted with fluorescent paint to keep boaters away from the sets.

Figure 1.
Fyke net station at Delta, February 1962.

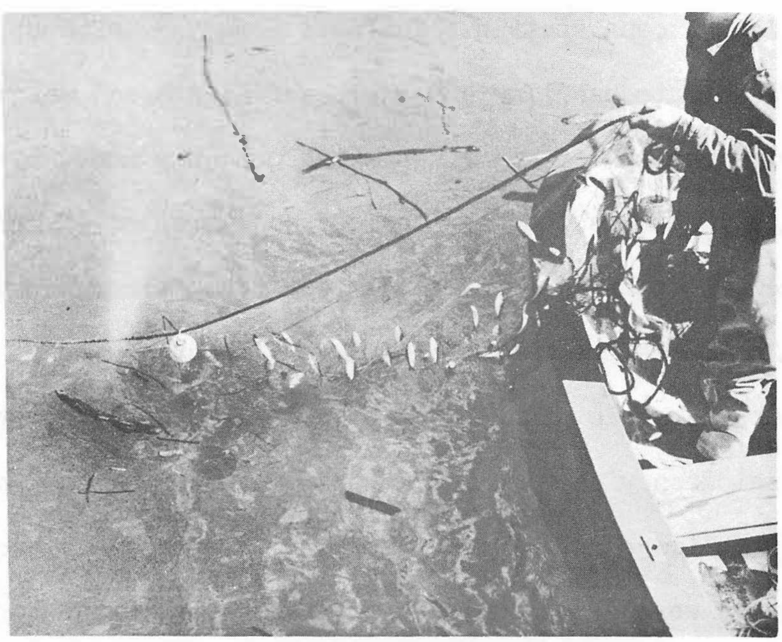


Figure 2.
Small mesh gill net showing method of attaching floats.

Gill Net Sampling Procedures

Gill nets were set and fished out of the project's small skiff. In the upper end of the reservoir, where the reservoir was narrow, only shore sets were made. In the lower end of the lake in open, deep water areas both onshore and offshore sets were made. Offshore sets were made in the manner described by Korn and Gunsolus (1962) so that sets could be made between the surface and bottom.

Trap Net Sampling

Floating fish traps were chosen to be used at Shasta Reservoir, because of their excellent fish catching ability and the small amount of up-keep normally required to maintain them.

Trap Net Specifications

The traps used during the investigation were of the floating type similar to those designed for use in Lake Merwin, Washington. The original trap design was modified somewhat, but the modifications consisted primarily of the materials used in construction. The major difference in materials was the smaller mesh webbing used in the Shasta Lake traps and in the greater depth of the lead and wings. The Lake Merwin traps were constructed of 7/8-inch stretched-mesh material because of the large size of the fish that were sampled.

The small size of the fish released for the Shasta Lake study necessitated the use of a much smaller mesh size than was used in the original traps. The webbing used in the project's traps was 1/2-inch stretched-mesh Saran netting, a Japanese synthetic material. A smaller mesh size would have retained the smallest fingerlings better but would have added to the trap cleaning problems. When the surface water of the lake began to warm in the spring it became necessary to clean the trap webbing at least once a week to remove the algal growth. The efficiency of the traps was greatly reduced when the flow of water through the webbing was restricted. Hand-cleaning of the trap webbing was ineffectual and inefficient because of the time required to clean the trap thoroughly. A portable 3-inch fire pump was found to be the most effective means of keeping the trap webbing clean. The high pressure stream of water delivered by the pump not only removed the algae quickly, but thoroughly, which allowed for a longer period between cleanings.

The frame of the first trap was constructed of 4 x 4 timbers with a deck of 2 x 12 planks. Flotation was furnished by sixteen 50-gallon drums (Figure 3). The trap fished well, but because of the heavy construction of the frame it was cumbersome and awkward to handle while being assembled or moved.

The trap, consisting of two enclosures of netting connected by a tunnel, was suspended from the inside of the trap frame. Fish were guided into the trap by means of a lead and wings. The lead was moored to the shoreline and guided fish out to the trap which was anchored in deep water. The fish entered the front chamber of the trap, swam through the connecting tunnel and into the back chamber where they were retained.

The trap was composed of four main sections; the lead, the heart, the pot, and the spiller. The lead was 100 feet long and 35 feet deep. The heart section, which consisted of the wings and the end of the lead, was 30 feet wide and 35 feet deep at the outer end and tapered down to a

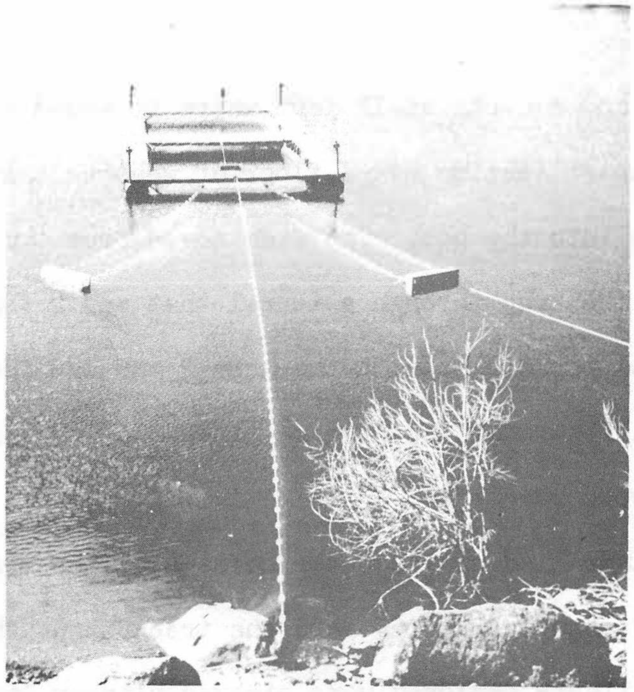


Figure 3.
The floating trap built in 1962, using steel drums for flotation.

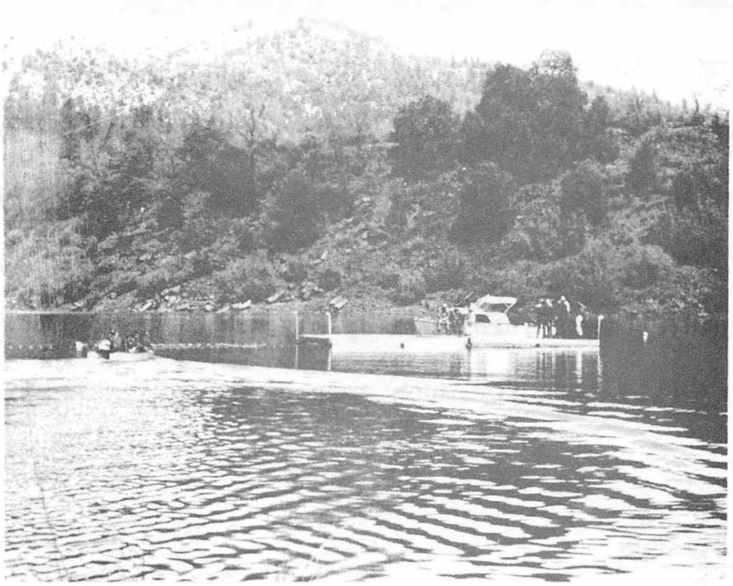


Figure 4.
The floating trap built in 1963, using styrofoam logs for flotation.

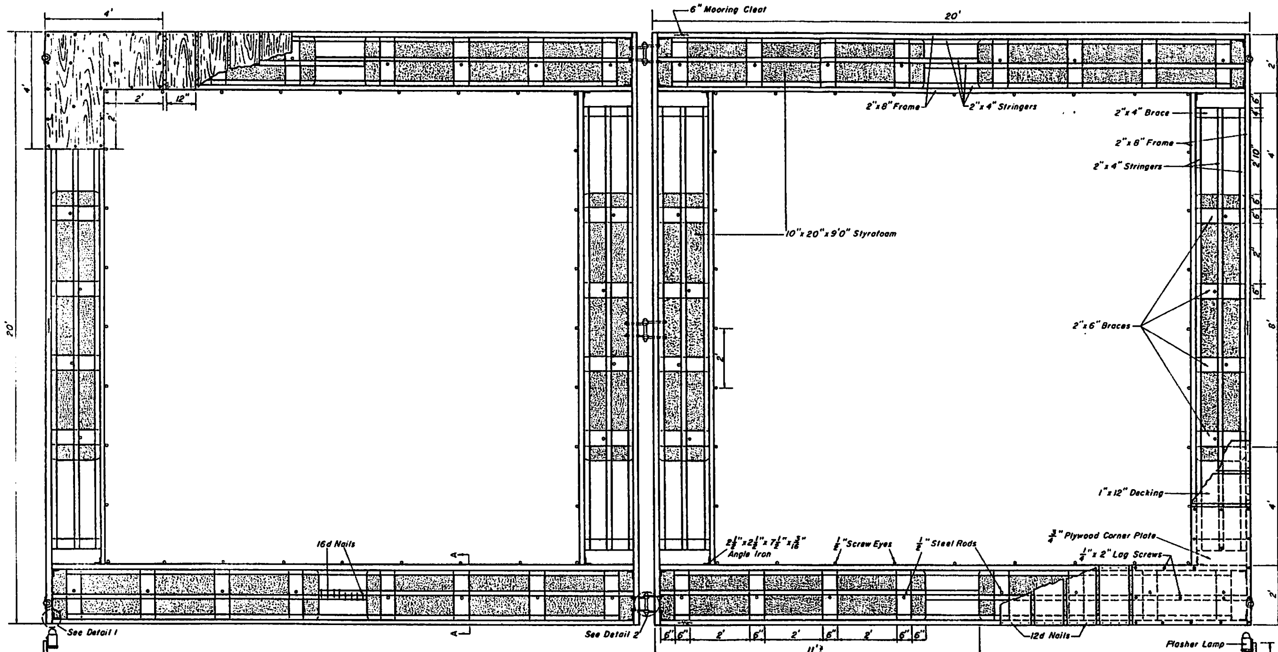
width of twelve inches and a depth of 12 feet where it ended 6 feet inside the pot section. The heart section had a floor of webbing that guided the fish from the depths up into the pot. The fish moved from the pot into the spiller section of the trap through a tunnel that was 4 feet square and 7 feet long. The tunnel tapered down in the last 2 and 1/2 feet to an opening 4 by 12 inches. The small opening retained the fish in the spiller very well, until they were removed.

Lights were installed on the outer corners of the trap frame to keep boaters from inadvertantly running into the trap during the hours of darkness. The type of lights employed were highway blinker lights, used to mark construction zones. The lights were equipped with 360° radius red lenses instead of the usual two-way type. The lights were battery-powered and could be operated for two months continually without the batteries being replaced. The lights were mounted approximately 5 feet above the water and could be seen for about 3 miles on a clear night.

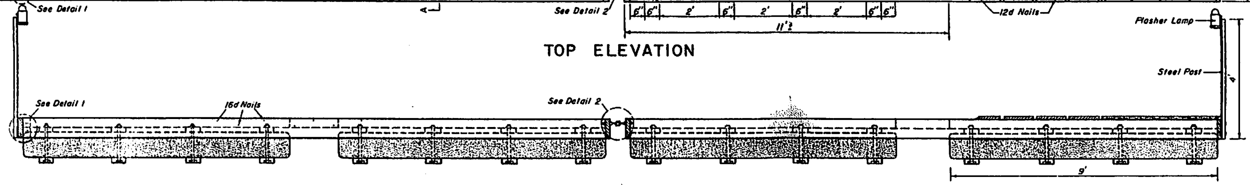
Two floating traps were used during the second year of the study. The second trap built for the project was designed for greater ease in handling and transporting (Figure 4). The trap frames were prefabricated in sections so they could be dismantled with a minimum of effort and stored when not in use. Flotation was furnished by styrofoam logs which not only allowed for a lower profile, but for much greater stability while fishing (Plate 3 and 3A).

Trap Net Sampling Procedure

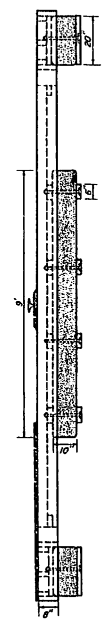
The floating traps were positioned off points in the reservoir that had deep water on all sides. In this manner any fish migrating along



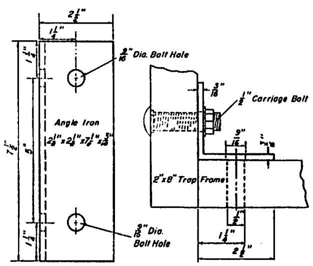
TOP ELEVATION



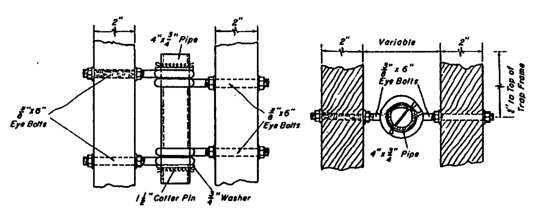
SIDE ELEVATION



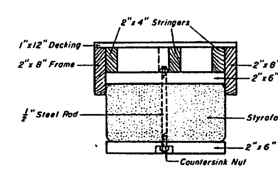
END ELEVATION



DETAIL I. CORNER BRACKET AND MOUNTING
NO SCALE



DETAIL 2. TRAP HINGE
NO SCALE



SECTION A-A
NO SCALE

MATERIAL LIST AND SPECIFICATIONS

LUMBER
- 12 Pc. 2 x 8 x 20'-0" No. 2 & Better Douglas Fir S4S (Trap Frame)
- 4 Pc. 2 x 8 x 16'-0" No. 2 & Better Douglas Fir S4S (Trap Frame)
- 8 Pc. 2 x 4 x 12'-0" No. 2 & Better Douglas Fir S4S (Deck Stringers)
- 16 Pc. 2 x 4 x 10'-0" No. 2 & Better Douglas Fir S4S (Deck Stringers)
- 24 Pc. 2 x 4 x 8'-0" No. 2 & Better Douglas Fir S4S (Deck Stringers)
- 30 Pc. 1 x 12 x 10'-0" Unfinished No. 2 & Better Douglas Fir (Deck)
- 24 Pc. 2 x 6 x 8'-0" Unfinished Foundation Grade Redwood (For Securing Styrofoam)
- 4 Sheets 3/4" Douglas Fir Marine Plywood (Deck Corners)

BOLTS
- 200 - 1/2" Galvanized Nuts
- 80 - 1/2" x 4" Galvanized Carriage Bolts & Nuts
- 75 - 1/2" x 2-1/2" Galvanized Carriage Bolts & Nuts
- 12 - 3/8" x 6" Galvanized Eye Bolts &
- 24 - 3/8" Galvanized Nuts (Trap Hinges)

WASHERS
- 6 Pc. 1-1/2" Cotter Pins
- 8 lbs. 1/2" Galvanized Cut Washers
- 170 - 1/4" Galvanized Cut Washers
- 24 - 3/8" Galvanized Cut Washers
- 6 - 3/4" Galvanized Cut Washers

SCREWS
- 8 - 5/16" x 6" Lag Screws (For Mounting Mooring Cleats)
- 170 - 1/4" x 2" Galvanized Lag Screws (For Securing Plywood Deck Sections)
- 64 - 1/2" Galvanized Screw Eyes (For Attaching Trap Webbing)

NAILS
- 25 lbs. 12d Galvanized Common (Deck)
- 25 lbs. 16d Galvanized Common (Blocking & Cross Pieces)

HARDWARE
- 24 Pc. 2-1/2" x 2-1/2" x 7-1/2" x 3/16" Angle Iron (Corner Brackets)
  Drill or punch two 9/16" holes each way.
- 96 Pc. 1/2" Dia. x 15" M. Stl. Rod - Thread 2 ends of Ea., 1" Long
- 4 Pc. 6" Galvanized Deck Cleats (For Mooring)
- 4 Pc. 4' Galvanized Steel Fence Posts (Highway Guide Posts OK) (Light Brackets)
- 3 Pc. 3/4" x 4" Galvanized Pipe (Trap Hinge Pins)
- 4 - ST Flasher Lamps with Mount Bolts

BUOYANCY
- 12 Styrofoam Planks 10" x 20" x 9'-0"

MISCELLANEOUS
Wood Preservative: 3 Gallons Copper Napthanate
3 Gallons Boiled Linseed Oil
3 Gallons Grey Deck Paint

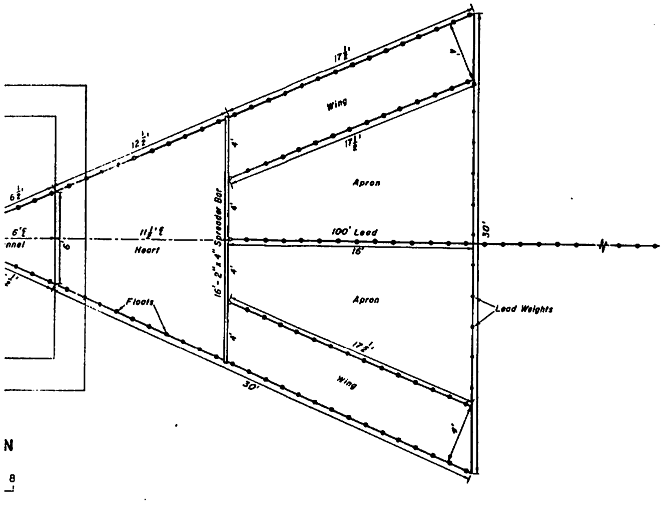
GENERAL

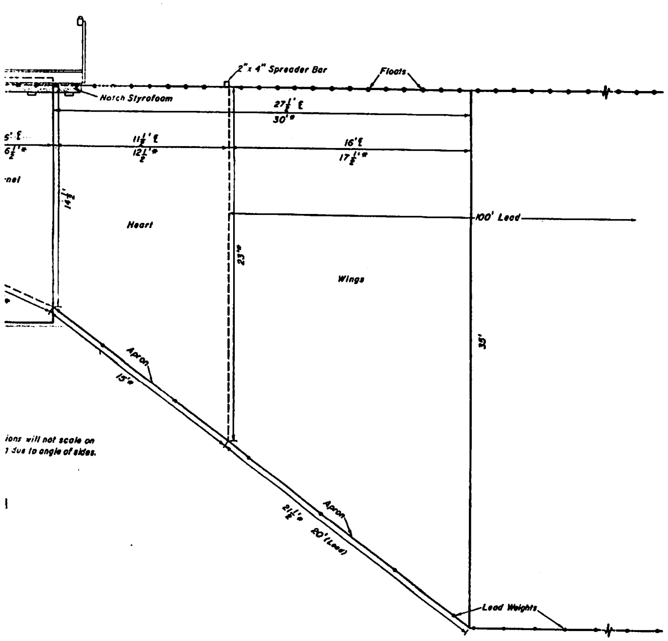
Each of the two 20 x 20 foot sections comes apart in four pieces for portability, and the corners are numbered for easy assembly in the water. The corners of each trap section are covered by an "L" shaped plywood plate held down by lag screws. The plates are numbered to correspond with the corners. When disassembling the trap, the plates are removed to reach the bolts securing the corners. Only two of the bolts in each angle iron bracket need be removed for disassembly. The styrofoam is permanently secured to the 2 x 6 redwood frames with 1/2 inch diameter thru rods. Drill the 2 x 6 and drive the rod through the styrofoam. Countersink the lower end of the rod for ease in stacking the trap sections out of the water. The 2 x 6 upper redwood cross members and deck stringers are nailed with 16d nails. The 1 x 12 deck is secured with 12d nails. The underside of the trap frame and deck is treated with copper napthanate. The outside of the trap frame and deck is treated with boiled linseed oil and painted with a good quality deck paint to reduce weathering. The plywood corner plates are sprinkled with sand while the paint is still wet, for secure footing. The blinker lights are attached to metal posts, highway guide posts are excellent for this purpose, and bolted to the outer corners of the trap frames before the plywood plates are in place. The two trap sections are held together by three hinges consisting of four matching 3/8 inch eye bolts held together by a section of 3/4 inch pipe secured at the ends with large washers and cotter pins. The pipe sections run through the eye bolts allow the trap to hinge in the middle so that the trap can stabilize itself in rough water.

FLOATING FISH TRAP FRAME

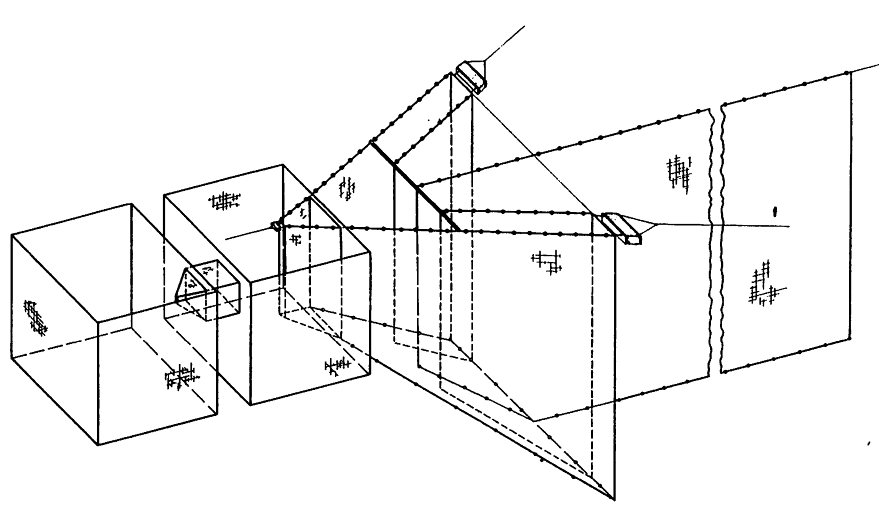
Designed by:
Emil J. Smith, Jr.
Fishery Biologist III
California Department of Fish and Game

SCALE IN FEET
2 0 2 4





ions will not scale on
) due to angle of sides.



NET LAYOUT
NO SCALE

CONSTRUCTION MATERIAL LIST AND SPECIFICATIONS

NETTING
140 pounds M2, 1/2" Stretched-Mesh Saran Netting

HANGING TWINE
6 pounds 12 Thread Nylon Seine Twine(For hanging lead and wings)
4 pounds 6 Thread Nylon Seine Twine(For lacing together Trap Sections)

ROPE
500 feet 5/16-inch Polypropaline Rope(Cork and lead lines)
650 feet 3/16-inch Nylon Rope(Rib and brailer lines)

MISCELLANEOUS CONSTRUCTION MATERIALS
160 each Plastic Net Floats, 3/8-inch diameter hole, 3-3/4"x2-5/8"OM

200 each 2 ounce Clamp On Leads(Wings and lead)

MISCELLANEOUS TRAP EQUIPMENT
600 feet 5/16-inch polypropaline rope(anchor lines)
450 feet 3/16-inch polypropaline rope(anchor buoy lines)
400 feet 3/16-inch polypropaline rope(wing lines)

3 each 25-30 pound kedge anchors(for anchoring trap)

3 each anchor buoys

2 each wing buoys(styrofoam is excellent for this purpose)

Shasta Lake Migrant Trap

The trap consists of three basic components, the spiller, pot and heart. The trap will be constructed as per the instructions below and the attached drawing. The lead for the trap is constructed separately and is discussed below.

Trap Construction

Spiller: 16 feet square and 16 feet deep

Pot : 16 feet square and 16 feet deep

Rope loops are to be attached to the upper and lower corners of both the pot and spiller. The lower loops to be on the outside corners.

Spiller Tunnel: Total length of 7 feet: The entrance is 4 feet square with the last 2-1/2 feet tapering down to an opening 4 inches wide and 12 inches long at the exit. The tunnel is positioned in the rear wall 2 feet in from the right corner and 18 inches down from the top edge of the pot. The tunnel pierces the forward wall of the spiller section two feet in from the right side and 18 inches down from the top. The tunnel is sewn into the wall of the spiller so that it extends 2-1/2 feet into the spiller with the exit of the tunnel 3 feet below the surface.

Pot Tunnel: 6 feet wide and 14-1/2 feet deep at the entrance and 12 inches wide and 12 feet deep at the exit. The tunnel will extend 6 feet into the pot and will include a floor.

Heart: The outer wings are to be connected to the pot tunnel wings and are 30 feet in length and 30 feet apart at the outermost point. The wings are 35 feet deep at the outermost point and slope up to a depth of 14-1/2 feet at the entrance to the pot tunnel. The inner wing is to be placed 4 feet away and parallel to the outer wing and extends back 17-1/2 feet towards the pot tunnel. This wall is to be sewn to the floor of the heart. The entire heart is to be floored (Apron) and this floor is to be secured to the pot tunnel floor.

The heart lead is to be centered with the outermost point of the heart wings, extends to within 11-1/2 feet of the tunnel entrance and is even with the ends of the inner wings. The heart lead is also sewn to the heart floor (Apron).

Trap Lead: The trap lead is 35 feet deep where it joins the heart lead and is 100 feet long (composed of two 50 foot sections).

Material Specifications

Spiller:

Netting: 1/2-inch stretched mesh, SN-6 Saran, Knotted Seine webbing, Hirata Net Co.(Japanese) or equal.

Cork Rib and Brailer lines: 3/16-inch nylon rope(soak and stretch before hanging net).

Floats: None

Lead: None(except sash weights may be hung on corners when heavy currents are running).

Spiller tunnel:

Netting: Same as spiller.

Pot:

Netting: 1/2-inch stretched mesh, SN-6 Saran, Knotted seine webbing, Hirata Net Co. (Japanese)or equal.

Cork Rib and Brailer lines: 3/16-inch nylon rope(soak and stretch before hanging net).

Floats: None

Lead: None(except sash weights may be hung on corners when heavy currents are running).

Pot tunnel:

Netting: Same as pot.

Cork and rib lines: 5/16-inch polypropaline rope.

Corks: 3-3/4"x2-5/8" plastic floats on 18" centers

Lead: None.

Heart:

Netting: Same as pot.

Cork, corner and lead lines: 5/16-inch polypropaline rope.

Corks: Inner and outer wings 3-3/4"x2-5/8" plastic floats on 18" centers.

Leads: (1) Outer wings-2 ounce clamp on leads, on 18" centers.

(2) Inner wings-none.

Heart lead:

Netting: Same as heart.

Cork, rib and lead lines: 5/16-inch polypropaline rope.

Corks: 3-3/4"x2-5/8" plastic floats on 18" centers.

Leads: 2 ounce clamp on leads, on 18" centers.

Trap leads:

Netting: Same as heart.

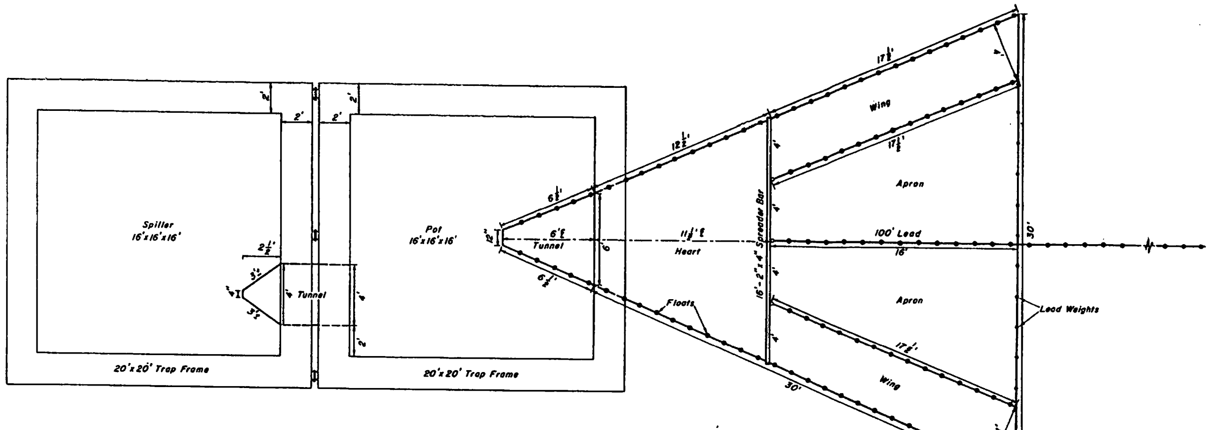
Cork lead and rib lines: 5/16-inch polypropaline rope.

Corks: 3-3/4"x2-5/8" plastic floats on 18" centers.

Leads: 2 ounce clamp on leads on 18" centers.

FLOATING FISH TRAP WEBBING PLANS

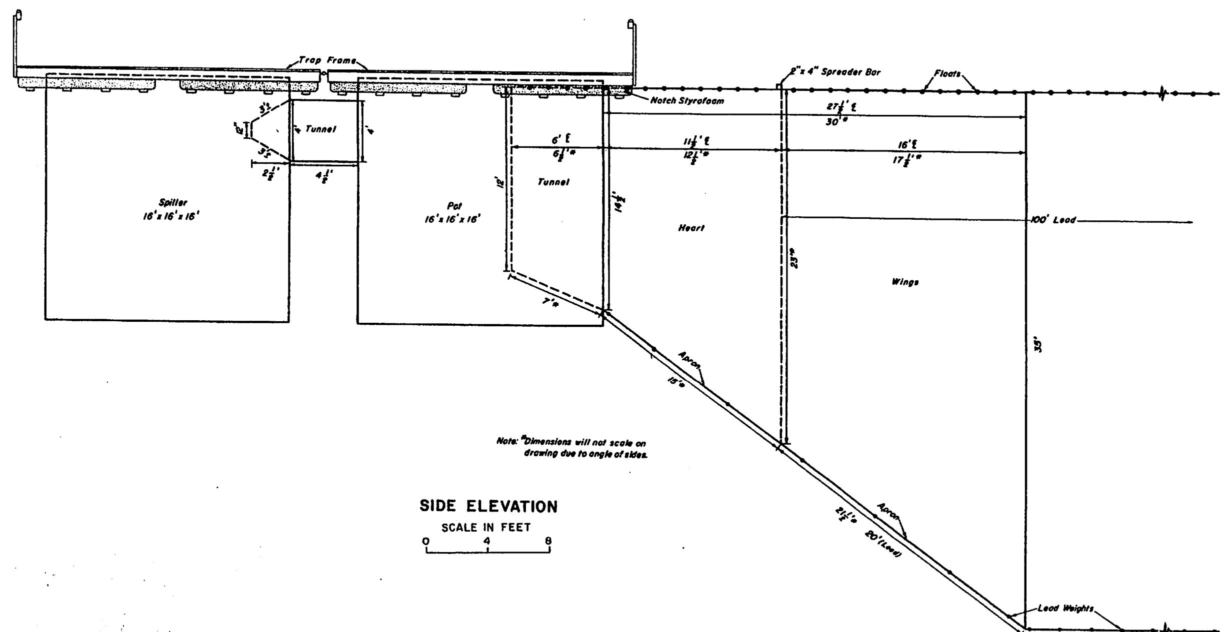
PLATE 3a



TOP ELEVATION

SCALE IN FEET

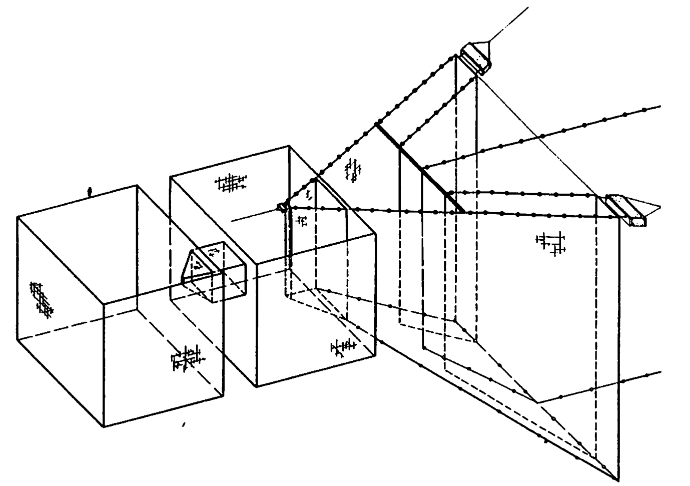
0 4 8



SIDE ELEVATION

SCALE IN FEET

0 4 8



NET LAYOUT

NO SCALE

CONSTRUCTION MATERIAL LIST AND SPECIFICATIONS

NETTING

140 pounds M2, 1/2" Stretched-Mesh Saran Netting

HANGING TWINE

6 pounds 12 Thread Nylon Seine Twine(For hanging lead and wings)

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650 feet 3/16-inch Nylon Rope(Rib and brailer lines)

MISCELLANEOUS CONSTRUCTION MATERIALS

160 each Plastic Net Floats, 3/8-inch diameter hole, 3-3/4"x2-5/8"OM

200 each 2 ounce Clamp On Leads(Wings and lead)

MISCELLANEOUS TRAP EQUIPMENT

600 feet 5/16-inch polypropaline rope(anchor lines)
450 feet 3/16-inch polypropaline rope(anchor buoy lines)
400 feet 3/16-inch polypropaline rope(wing lines)

3 each 25-30 pound kedge anchors(for anchoring trap)

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Trap Construction

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Pot : 16 feet square and 16 feet deep

Rope loops are to be attached to the upper and lower corners of both the pot and spiller. The lower loops to be on the outside corners.

Spiller Tunnel: Total length of 7 feet: The e[illegible] with the last 2-1/2 feet tape[illegible] inches wide and 12 inches lo[illegible] is positioned in the rear wal[illegible] corner and 18 inches down t[illegible] pot. The tunnel pierces the spiller section two feet in fr[illegible] 18 inches down from the top. into the wall of the spiller se[illegible] feet into the spiller with the below the surface.

Pot Tunnel: 6 feet wide and 14-1/2 feet d[illegible] 12 inches wide and 12 feet de[illegible] tunnel will extend 6 feet into a floor.

Heart: The outer wings are to be co[illegible] wings and are 30 feet in leng[illegible] the outermost point. The wi[illegible] the outermost point and slop[illegible] feet at the entrance to the po[illegible] wing is to be placed 4 feet a[illegible] outer wing and extends back pot tunnel. This wall is to b[illegible] the heart. The entire heart and this floor is to be secure[illegible] floor.

The heart lead is to be cente[illegible] point of the heart wings, exte[illegible] feet of the tunnel entrance an[illegible] of the inner wings. The hear[illegible] the heart floor (Apron).

Trap Lead: The trap lead is 35 feet deep lead and is 100 feet long (co[illegible] sections).

Material Specifications

Spiller:

Netting: 1/2-inch stretched me[illegible] Seine webbing, Hirata equal.

the shoreline would be guided naturally to the lead and into the trap. The traps were moored in position by three 35-pound kedge anchors on the offshore side and by the lead and lines attached to the wings on the onshore side. The traps were moved from site to site by the skiff on short moves or by the large boat when towing across open water areas. When a trap was moved, the webbing was pulled up on the trap frame, the anchors lifted and piled on the trap frame ready for resetting, the tow boat was hooked on, and the trap was moved to the next site for resetting.

The trap catch was normally removed each day because the fish could usually find their way out if left for more than 24 hours. The catch was removed by first lifting the pot webbing and thereby forcing the fish from that section through the tunnel and into the spiller. This first operation kept predators from taking up residence in the pot. The webbing in the spiller was raised to force the catch into one corner for removal.

Trawl Net Sampling

To properly cover a body of water as large as Shasta Lake, with many arms and open areas several miles wide, something other than stationary gear had to be employed that would assess the open water areas more efficiently. The best equipment with which to sample the open water areas of the lake was considered to be trawls, both bottom and mid-water types.

Many areas of Shasta Lake were not suitable for sampling with a mid-water type trawl because of shallow water. Korn and Gunsolus (1961) found as a result of their SCUBA work that small salmonids were to be found in close proximity to the bottom, during the hours of darkness, where mid-water type trawls cannot be used efficiently. After much consideration, 16 and 24-foot semi-balloon trawls were purchased for use in the shallow water areas.

Mid-water Trawl

In recent years, the California Department of Fish and Game has obtained excellent results in capturing small salmon in the Sacramento River Delta with a single boat mid-water trawl (Commercial Fisheries Review). The trawls used by the Department were towed from two cables and were held open by four plywood quarter doors. The nets used were approximately 15 and 25 feet square at the mouth when fishing. The trawls were not only efficient in catching fish, but could be handled by two men. After observing the operation of the Department's mid-water trawl, one net was constructed for testing at Shasta Lake.

In view of the power restrictions of the project's outboard-powered boats, a mid-water trawl, approximately one-third the size of the Department's large trawl, was designed and built for use on the lake. The experimental trawl was 8 feet square at the mouth and was approximately 25 feet long. The trawl was constructed of 12-thread nylon in mesh sizes of 1 and 1/4, 1, and 1/2-inch stretched-mesh. The quarter doors were made of 1/2-inch marine plywood with the outer dimensions of 12 x 15 inches. The trawl was originally rigged to be towed with a single warp but it would not handle properly, so the project's boat was re-rigged with trawl davits at the corners of the stern so double warps could be used. The small mid-water trawl handled well with the double warps and was easy to set.

Mid-water Trawl Sampling Procedures

With the trawl davits mounted in the stern of the project's boat, the procedure for handling the mid-water trawl was relatively simple. Even so, the net sometimes became fouled in the outboard motors. The way the net was normally carried between stations was to have the quarter doors pulled up tight against the towing davits while the body of the net was carried in the cockpit of the boat. When a set was made, the cod end was thrown over the side clear of the motors and the net was then let out to hang from the davits. The brake on the trawl winch was then released and the towing warp was let out till the quarter doors were submerged. When the quarter doors were submerged the winch brake was applied until the doors set properly, then the brake was once again released till the desired length of cable was let out and the brake was re-set.

When the net was retrieved, the winch was started up and the quarter doors were brought up tight against the davits. The boat was then turned around sharp to the left, bringing the net alongside, and the net was pulled into the cockpit.

Semi-balloon Trawl Net Specifications

The semi-balloon trawls purchased for the study were constructed of 1-1/2-inch stretched-mesh nylon with a 1/2-inch stretched-mesh, knotless, nylon liner in the cod end. The 24-foot trawl had iron bound hardwood doors that measured 15 by 30 inches. The doors for the 16-foot trawl measured 12 by 24 inches. The trawls were designed to be towed by a single warp but because of the outboard motors they were towed by the double warp arrangement like the mid-water trawl.

Semi-balloon Trawl Net Sampling Procedures

The semi-balloon trawls were set and retrieved in the same manner as the mid-water trawl. The semi-balloon trawls, however, were set with the aid of a fathometer. The extremely rough bottom of Shasta Reservoir made it necessary to scan the bottom for obstacles before making a tow. Not only was a fathometer used before making a tow, but it was also used during the tows to enable the net to be retrieved if an obstruction was detected.

Trawl Winch

After the decision was made to use trawl nets to sample the open water areas of Shasta Reservoir, the problem of obtaining a suitable winch for retrieving the gear arose. The project's boat, being outboard-powered, had neither sufficient electrical power nor power take-off to run an ordinary trawl winch. The only alternative was to secure a self-powered winch driven by a gasoline engine. The winch had to be small because of the cramped space available on the boat. It had to have a retrieve ratio fast enough and a torque sufficiently high enough to bring in the trawl while the boat was underway in order to keep the catch from escaping. The only commercial winch available that would meet the size requirement had a gear ratio so low that it would have been impractical to use for trawling in deep water. When no suitable winch could be found, project personnel were forced to construct a winch to project specifications.

The winch designed and built by project personnel (Figures 5 and 6) was powered by a three-horsepower, air-cooled Briggs and Stratton engine with 6:1 gear reduction. The drive speed was further reduced and the torque increased by a Harley-Davidson three-speed motorcycle transmission. The

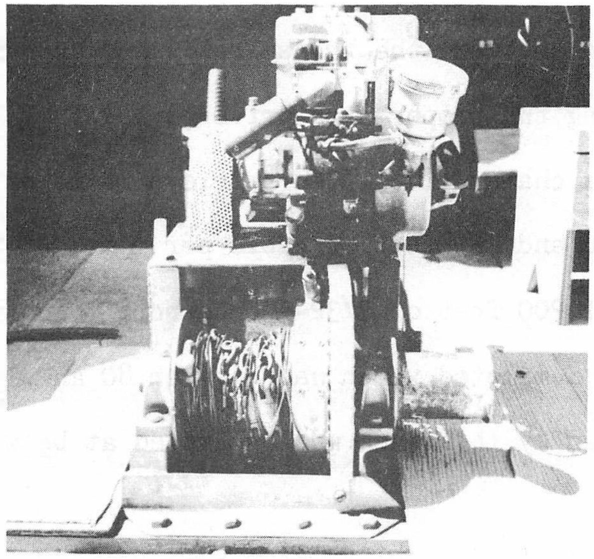


Figure 5.
Trawl winch designed for outboard trawling in Shasta Reservoir. Front view.

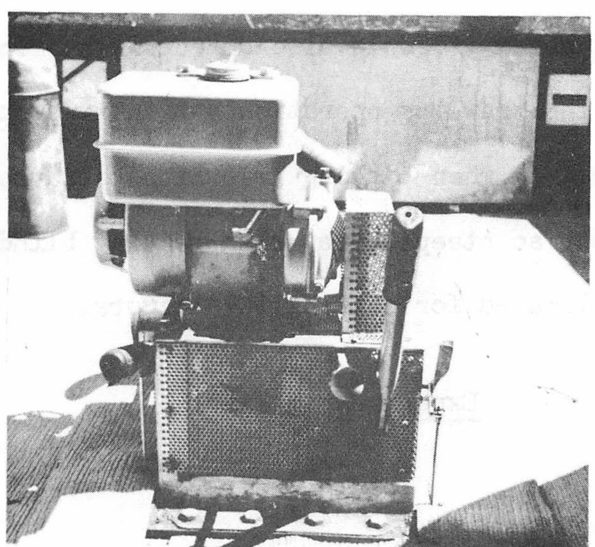


Figure 6.
Trawl winch designed for outboard trawling in Shasta Reservoir. Rear view.

final speed reduction between the transmission and the winch drum was achieved by selecting the proper size drive sprockets. Power was transmitted by means of a chain drive. The retrieve ratio of the winch could be varied between 50 and 100 feet of cable per minute. The capacity of the winch drum was 1,200 feet of 3/32-inch aircraft control cable. The total weight of the completed winch was between 80 and 100 pounds. Maximum torque developed by the winch was estimated at between 900 and 1,000 pounds.

Recording Fathometer

There are many dangers inherent in trawling blindly with either mid-water or bottom trawls. To help overcome some of the problems, a Bendix recording fathometer, Model DR-19, was installed in the project's large boat. The fathometer not only picked up obstructions on the bottom, but when properly adjusted it could also detect fish. The fathometer was not only helpful in the trawling operation but in trap operations as well. The fathometer was useful when picking trap sites because in some areas the bottom dropped off so steeply that when setting blindly, suitable bottom could not be located for setting the anchors.

Experimental Fish

Source

The king salmon fingerlings released during the study were the progeny of fall-run fish trapped at Keswick Dam. A total of 1,750,000 of these fingerlings were hatched and reared at Coleman National Fish

Hatchery on Battle Creek. The fingerlings were transported to the planting sites in 500-gallon tankers supplied by the Department of Fish and Game's Darrah Springs Hatchery.

The trucks used to transport the small fish had special screening installed to keep the fingerlings out of the circulating system. In addition, the circulating pumps on the trucks were kept at a constant 7 to 7 and 1/2 pounds pressure to avoid undue agitation of the tanks.

Characteristics of 1962 Plant

The consignment of 750,000 fish allotment for the 1962 plant was received from Coleman National Fish Hatchery on February 20 and 21. The small salmon averaged 34.6-mm FL and varied from fry barely buttoned up to fingerlings with their yolk sacs completely absorbed, that had started to feed. The small fish appeared vigorous and averaged 1,200 to the pound.

On February 20, an estimated 250,000 fry were hauled in one truck and 200,000 in the other. The distance from the hatchery to the planting site, 3 miles above the town of Castella, was 70 miles. The fingerlings appeared to withstand the 3 and 1/2-hour haul with no ill effects. Less than 100 dead fish were observed and these appeared to have been killed during loading.

The Sacramento River flow was high and the temperature cold when the plant was made, but the water level was receding from the high flows brought about by a storm that hit the area the preceding week. The water temperature was 42°F when the fish were planted and had a slight greenish cast from snow melt. The strong flow of the river scattered fingerlings downstream quite rapidly but fair numbers, judged to be the stronger fish, were observed in the pool at the planting site and in small groups along the shore line for some distance downstream.

On February 21, the second half of the allotment was planted. The two planting trucks hauled approximately 150,000 fingerlings apiece to avoid crowding in one truck. There were still small fish in the area of the first day's plant in the main river, so in order to spread them out better, the second half of the plant was made in the North Fork of Castle Creek, a tributary that joins the Sacramento River at the town of Castella (Plate 2).

There was no apparent mortality, due to transport, in the second plant and the fingerlings appeared vigorous and healthy. The water temperature in Castle Creek was also 42°F at the time of planting.

Characteristics of 1963 Plant

The 1963 planting allotment from Coleman Hatchery totaled 1,000,000 fingerlings, averaging 60 fish to the ounce. The fish were transported by two of the Department's 500-gallon tankers in six loads of approximately 200 pounds of fish per load. Two loads of fingerlings per day were planted in the Sacramento River, opposite the mouth of Dog Creek, on April 9-10 and 11 (Plate 4). The fingerlings in the 1963 allotment were vigorous and healthy and no dead fish were observed at the time of planting.

During the second season of study, information gained the first year was put to good use. The poor results obtained from the first plants were considered to have been brought about by a combination of heavy mortality from predation and residualism in the river between the planting sites and the lake. In order to offset the problems encountered the first year, a different planting procedure was initiated for the second season.

The fingerlings planted during the 1963 season were fed 30 days before their release. Rutter (1902) found, upon examination of stomach contents of fish taken during his Sacramento River studies, that when king salmon fingerlings were planted at swim-up, they were preyed upon by most of the fish in the river. When the fingerlings were fed for at least 30 days before release, however, they were able to escape predation quite well. The 1963 plants were made as close to the lake as was possible in order to reduce residualism and what predation would occur between the upstream planting sites and the head of the lake. It was anticipated that the fingerlings would not only enter the reservoir quicker and in larger numbers, when released farther downstream, but the necessity of fyke netting would be eliminated.

Field Headquarters and Personnel

Field headquarters for the study was established at Lakeshore Resort at the upper end of the Sacramento arm of Shasta Reservoir. The location was approximately 25 miles north of Redding, the closest point of supply. The headquarters was located at Lakeshore because it was approximately half way between the upstream planting sites and Shasta Dam. In addition to the good location, the resort offered a sturdy dock for mooring the project's boats and had gasoline available during the entire year in an area that was normally run on a seasonal basis. An excellent, paved, boat launching ramp was available at the U. S. Forest Service campground, only a short distance from headquarters. The boat launching ramp was found to be indispensable in keeping the project's boats in repair.

The project was manned by a staff of two biologists and between two and three seasonal employees. During the first season, only one permanent biologist was assigned to the study, with temporary help being supplied from other projects when available. Two permanent biologists were assigned to the project during the second season when a regular sampling program was initiated.

RESULTS

1962 Study

The 1962 field program began on February 15, when the Shasta Lake Field Station was activated. Seasonal employees were hired and instructed in the use of sampling equipment. The project's fyke nets were prepared for fishing and final arrangements were made for receiving the first planting allotment.

Observations in the Upper Sacramento River

The 1962 fingerling plants were made on February 20 and 21. Immediatly after the first plant was made fyke net monitoring began.

The first fyke net station was established at the town of Delta, 27 miles below the planting site. The net was checked at 1400 on February 21, for the first time after the initial plant. A total catch of 204 live and 159 dead fingerling kings were removed from the net. All of the dead fish were barely buttoned up and could not hold their own against the currents in the live car. An evening check on the same day revealed no further fish.

The fyke net was checked the following morning at 1100 and a catch of 85 live and 5 dead fingerlings were removed. From the first observations and the ones made during the balance of the season, it was obvious that downstream migration of salmon fingerlings in the upper Sacramento River occurs at night or they were able to avoid the fyke net during daylight hours.

One fyke net at a time was fished from February 20 till July 9, when it appeared that the downstream migration was over (Table 1). Nets were fished at three different locations (Plate 2). A fyke net was fished at the town of Delta from February 20 to February 26, when a reduction in the river flow made it necessary to move to a better fishing site at Riverview. The fyke net station at Riverview was fished until March 16, when the net was washed away by a freshet. By the time the freshet had subsided, the lake had risen to cover the Riverview station; consequently, the fyke net station was moved back upstream to a point 200 yards below the mouth of Campbell Creek. For the balance of the season, fyke netting was carried on at the Campbell Creek station.

A total of 493 king salmon fingerlings were taken in the fyke nets during the study. The majority of the fingerlings (99.8 percent) were taken in the first nine days after planting. The last noticeable movement of small salmon took place between May 23 and June 4, when five fingerlings were captured. A total of 253 other fish were also taken in the fyke nets, the most numerous of which were squawfish, suckers, and cottids in that order (Tables 1 and 2).

Reconnaissance trips for studying fingerling residualism, were made periodically along the Sacramento River from the planting sites to the reservoir from the time of planting until July 17. King salmon fingerlings were observed swimming about in the area of the plant in the main river for several days after planting, but fingerlings planted in North Fork Castle Creek disappeared from sight immediately. Subsequent investigations showed fingerlings to be hiding under rubble below both planting sites and for some distance downstream.

When the fry were first observed under the rubble, as many as ten per rock could be found, but as the season progressed they had a tendency to disperse and only a few rocks in an area would be found to be harboring small salmon. On March 9, sixteen days after the first release, no fingerlings were found in the area of the main river plant,

TABLE 1

UPPER SACRAMENTO RIVER

FYKE NET CATCH BY DAYS

Month	Days	Location	Hours fished	No. of Salmon	No. of Trout	Other Species
February	20-21	Delta	18	363	-	23
"	21-22	"	21	90	-	-
"	22-23	"	20	10	-	-
"	23-24	"	24	12	-	-
"	24-25	"	24	6	-	-
"	25-26	"	24	1	-	-
"	26-27 (1)	Riverview	24	0	-	-
"	27 - March 1	"	24	3	1	2
March	1-2	"	24	-	-	-
"	2-3	"	24	-	-	-
"	3-4	"	24	-	-	-
"	4-5	"	24	-	-	-
"	5-6	"	24	-	-	-
"	6-7	"	24	-	-	-
"	7-8	"	24	-	-	-
"	8-9	"	24	-	-	-
"	9-10	"	24	-	-	-
"	10-16 (2)	Net not fishing				
"	16-17	Campbell Creek	24	-	-	1
"	17-18	"	24	-	-	-
"	18-19	"	24	-	-	-
"	19-20	"	24	-	-	-
"	20-21	"	24	-	-	1
"	21-22	"	24	-	-	-
"	22-23	"	24	-	-	-
"	23-24	"	24	-	1	-
"	24-25	"	24	-	-	-
"	25-26	"	24	-	-	-
"	26-27	"	24	-	-	1
"	27-28	"	24	2	-	1
"	28 - April 2	Net not fishing (3)				
April	2-3	Campbell Creek	24	-	-	-
"	3-4	"	24	-	1	2
"	4-5	"	24	-	-	1
"	5-6	"	24	-	-	5
"	6-7	"	24	-	-	2
"	7-8	"	24	1	-	3
"	8-9	"	24	-	-	4
"	9-10	"	24	-	-	3
"	10-11	"	24	-	-	3
"	11-12	"	24	-	-	1
"	12-13	"	24	-	-	-
"	13-16	Net not fishing (4)				
"	16-17	Campbell Creek	24	-	-	-
"	17-18	"	24	-	-	-
"	18-19	"	24	-	-	1
"	19-20	"	24	-	-	-
"	20-23	Net not fishing (5)				
"	23-24	Campbell Creek	24	-	-	3
"	24-25	"	24	-	-	2
"	25-26	"	24	-	-	-
"	26-27	"	24	-	-	-
"	27 - May 3	Net not fishing (6)				
May	3-4	Campbell Creek	24	-	-	1
"	4-5	"	24	-	-	5
"	5-6	"	24	-	-	2
"	6-7	"	24	-	-	3
"	7-8	"	24	-	-	-
"	8-9	Net not fishing (4)				

TABLE 1
(Continued)

Month	Days	Location	Hours fished	No. of Salmon	No. of Trout	Other Species
May	9-10	Campbell Creek	24	-	-	-
"	10-11	"	24	-	-	-
"	11-12	"	24	-	-	1
"	12-13	"	24	-	-	1
"	13-14	"	24	-	-	2
"	14-15	"	24	-	-	1
"	15-16	"	24	-	-	2
"	16-17	"	24	-	-	3
"	17-18	"	24	-	-	5
"	18-19	"	24	-	-	10
"	19-20	"	24	-	-	3
"	20-21	"	24	-	-	5
"	21-22	"	24	-	-	4
"	22-23	"	24	-	-	5
"	23-24	"	24	1	-	2
"	24-25	"	24	-	-	2
"	25-26	"	24	-	3	4
"	26-27	"	24	1	-	1
"	27-28	"	24	-	-	-
"	28-29	"	24	1	1	3
"	29-30	"	24	-	-	2
"	30-31	"	24	-	-	9
"	31 - June 1	"	24	-	-	-
June	1-2	"	24	-	1	3
"	2-3	"	24	-	-	5
"	3-4	"	24	2	-	1
"	4-5	"	24	-	-	4
"	5-6	"	24	-	-	4
"	6-7	"	24	-	-	8
"	7-8	"	24	-	1	1
"	8-11	"	72	-	-	14
"	11-12	"	24	-	-	2
"	12-13	"	24	-	-	1
"	13-14	"	24	-	-	-
"	14-15	"	24	-	-	-
"	15-18	"	72	-	1	-
"	18-19	"	24	-	-	1
"	19-20	"	24	-	-	1
"	20-21	"	24	-	-	-
"	21-26	Net not fishing (4)				
"	26-27	Campbell Creek	24	-	-	1
"	27-29	"	48	-	1	1
"	29 - July 2	"	72	-	-	2
July	2-3	"	24	-	-	3
"	3-4	"	24	-	-	5
"	4-5	"	24	-	-	17
"	5-6	"	24	-	-	24
"	6-9	"	72	-	-	17
"	9	Discontinued fyke netting for the season				

TOTAL of fish taken in fyke net operations:

Salmon	-	493
Trout	-	22
Squawfish	-	126
Suckers	-	65
Cottids	-	33
Dace	-	26
Chub	-	1
Roach	-	1

(1) Moved fyke net downstream to new location at Riverview.
(2) Fyke net washed away by freshet.
(3) Net pulled out of water because no crew on duty.
(4) Removed net from water -- no crew on duty.
(5) Removed net from river for repair.
(6) Removed net from river for repair.

TABLE 2

SPECIES OF FISH CAPTURED BY
FYKE NET DURING 1962 SEASON

SALMONIDAE - Salmon and Trout Family

Oncorhynchus tshawytscha (Walbaum). King salmon.

Salmo gairdnerii Richardson. Rainbow trout.

CATOSTOMIDAE - Sucker Family

Catostomus occidentalis Ayers. Western sucker.

CYPRINIDAE - Minnow Family

Ptychocheilus grandis (Ayers). Sacramento squawfish.

Hesperoleucus symmetricus (Baird & Girard). Western roach.

Siphateles bicolor (Girard). Tui chub.

Rhinichthys osculus (Girard). Speckled dace.

COTTIDAE - Sculpin Family

Cottus gulosus (Girard). Riffle sculpin.

but two fish were observed at Gibson, several miles downstream. On this date, small king salmon were still to be found a short distance below the Castle Creek planting site, although much more wary and harder to catch.

On May 11, no fingerlings could be found in the area of the plants. On May 16, however, 18 fingerlings were seined from a side channel of Castle Creek one mile above the confluence with the Sacramento River. The last fingerlings to be recovered above the fyke net stations were taken with a seine in Castle Creek on May 13, when four fingerlings were caught.

During the period immediately following the first plant and during the ensuing summer months, the area from the planting site to the head of the lake was periodically sampled by direct observations, both above and below the water surface, by seines, and a back-pack shocker (Plate 2). The use of the small shocker unit, however, was restricted to the upper reaches of Castle Creek because of the limited range of the unit. Underwater observations were made with snorkle gear in the Sacramento River from the area of Gibson to the lake.

Sections of the main Sacramento River were sampled with snorkle equipment on July 5 and July 17. On the first trip three miles of the upper area, below the planting site, were surveyed. Nine small salmon were observed in a pool area near Gibson. On the second trip, in the area from Delta to Riverview, no salmon were observed but many trout, suckers, and squawfish were seen.

Many reports were received from trout fishermen, during the summer and early fall months, that they took small kings on bait and flies in the area between Castella and Delta. None of these fish were identified by project personnel, but several catches were verified by other Department employees.

Observations made by Cloudsley Rutter (1902), in the area of the Sacramento River in which our study took place, tend to substantiate our findings:

> "After planting, the fry begin to drift downstream from one resting place to another. If many are planted in one place, the movement downstream is quite rapid, and within 24 hours will be scattered evenly along the stream below the place of planting. Most of them seek the bottom and crowd into crevices between the pebbles or behind large boulders. Others find their way into quiet water along the edge of the stream, where they remain exposed to view. After a few hours of moving about they become quiet, retaining their places for several days. The fry begin feeding and start their downstream migration as soon as the yolk is absorbed and they are able to swim. The fry drift downstream tail first, traveling mostly at night and averaging about 10 miles a day."

Mr. Rutter further stated that fall-run downstream migrants passed the Balls Ferry area, between Redding and the mouth of Battle Creek, between January 6 and April 25.

The fish used in our first plant were from a late egg take at Keswick Dam. Cold weather throughout the winter slowed the development of the eggs and larvae in the hatchery and when they were planted, the river was very cold from snow melt. Considering all the factors, it is no wonder that there appeared to be a larger population of residual fish in the river than was anticipated. Mr. Rutter's work also showed that there was little downstream migration between May and December. Our studies showed that as the river water temperatures rose, the young kings that had not migrated left their hiding places in the rubble on the stream bottom and also sought out the pool areas where they were to be found throughout the summer and fall.

Observations in Shasta Reservoir

The program was delayed at the beginning of the first season because the sampling equipment was not ready for use by the time the salmon fingerlings were planted. The gill nets were not received from the supplier until ten days after the plant was made and the trap was not complete for an additional three months.

Gill Netting. Gill nets produced generally poor catches throughout the study and, although seven different species of fish were taken the first season, only one king salmon fingerling was caught (Table 3). Bluegill were taken most frequently, with squawfish, dace, and green sunfish following in that order. The gill nets were always set with their smallest mesh size close to shore, which may account for the largest catches being made in the 3/8- and 5/8-inch sections.

The 3/8-inch stretched-mesh nets were tested to determine their ability for catching small salmon, after no fish of any kind were caught during the first week of fishing. King salmon fingerlings, for the study, were collected in the planting area of North Fork Castle Creek and placed in a test tank at project headquarters. The fingerlings were slender and averaged 35-mm FL. These small fish, typical of small salmonids that have not fed for any length of time, had bodies the same diameter or slightly smaller than their heads. A section of one of the 3/8-inch gill nets was hung across the middle of the test tank and the fingerlings were forced to swim through it. Subsequent observations revealed that the fingerlings could swim through the net with relative ease.

No further tests were conducted to determine the fish catching ability of the gill nets as this was determined by other species of fish that were periodically caught. However, the size of the fingerlings that were collected at the planting sites and in the fyke nets was carefully noted so that gill nets of the proper mesh size, as determined by Rees (1957) were being fished.

The only king salmon fingerling taken in a gill net during the study was captured on June 8, 1962, almost 3 and 1/2 months after being planted. The fingerling was 84-mm FL and was taken in a 5/8-inch stretched-mesh net set approximately 1/2 mile below Trap Site No. 1, on the north shore of the reservoir (Plate 4). The fingerling was taken 10 feet from shore, at a depth of 5 feet in a surface net, and was traveling in a downstream direction.

Debris and large fish caused considerable damage to the small mesh nets, because of their light-weight construction, and much fishing time was lost while they were being repaired. Many of the holes in the

TABLE 3

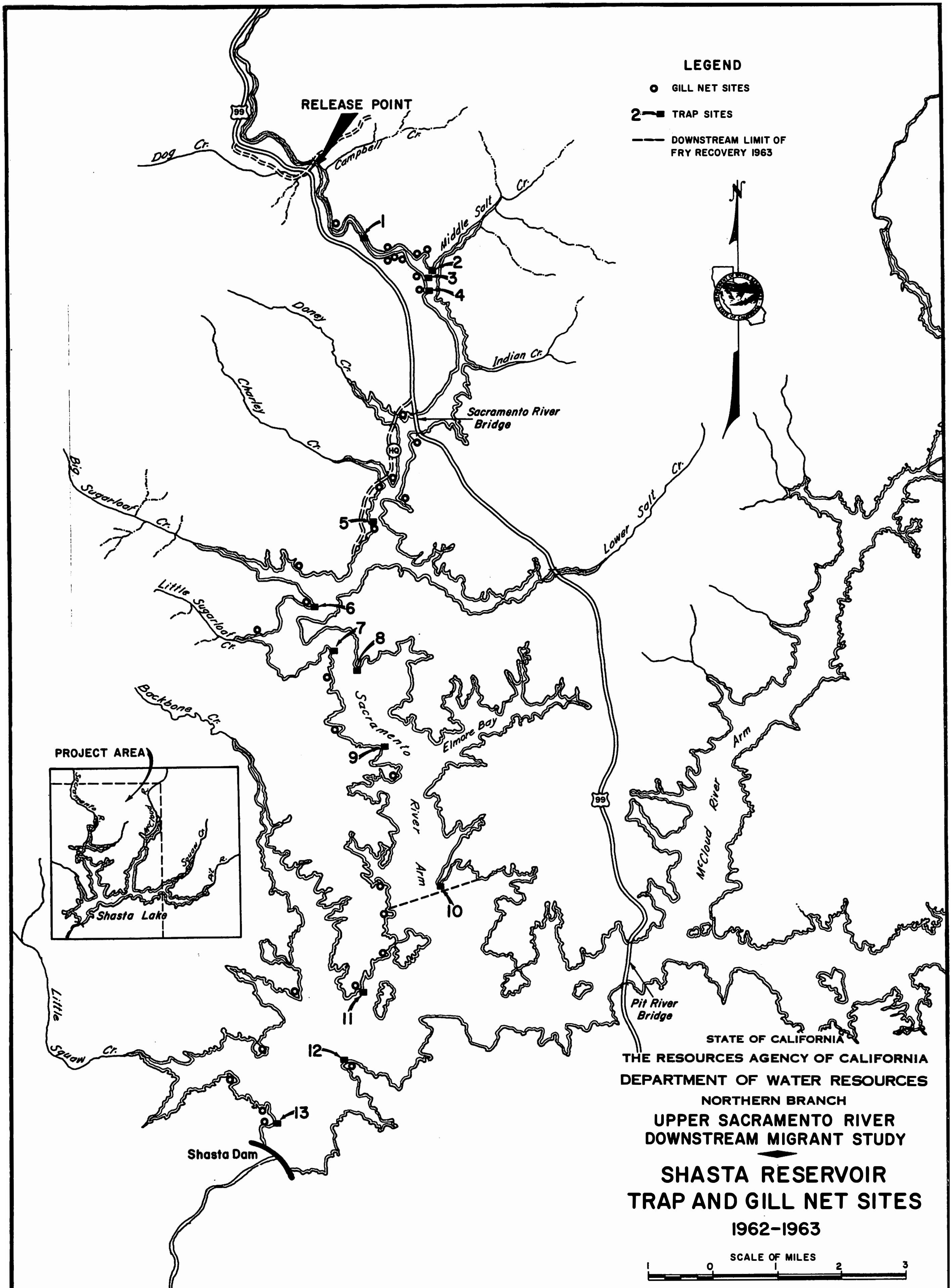
NUMBERS OF FISH CAUGHT WITH GILL NETS IN SHASTA RESERVOIR, BY SPECIES AND MESH SIZE 1962-63

Species	Mesh size						
	3/8	1/2	5/8	3/4	1	1-1/4	Total
King salmon (fingerlings)	0	0	1	0	0	0	1
Rainbow trout	0	0	0	0	0	3	3
Kokanee	0	0	0	0	2	0	2
Squawfish	9	0	25	3	4	0	41
Bluegill	5	0	59	4	1	0	69
Dave	10	0	0	0	0	0	10
Threadfin shad	0	0	0	0	731	630	1,361
Suckers	1	0	0	0	0	0	1
Largemouth bass	0	0	1	1	0	0	2
Green sunfish	0	0	7	0	0	0	7
Golden shiner	0	0	1	0	0	0	1
Carp	0	0	0	3	0	0	3

NOTE: 3/8 and 1/2, 5/8 and 3/4-inch nets used during 1962 season; 5/8 and 3/4, 1 and 1-1/4-inch nets used during 1963 season.

nets could have been caused by large predators preying on the catch of small fish. The remains of small dace and squawfish were removed from badly torn sections of the nets on many occasions and this could possibly account for the absence of small salmon in the catch.

The waters of the Sacramento arm of Shasta Reservoir are normally clear, except during periods of heavy runoff. The project's gill nets were dyed various colors in an attempt to increase their fish-catching ability.



STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
UPPER SACRAMENTO RIVER
DOWNSTREAM MIGRANT STUDY

SHASTA RESERVOIR TRAP AND GILL NET SITES 1962-1963

A light green color was determined to be the best net camouflage, but even after being dyed the catch of the 3/8- and 1/2-inch nets did not increase significantly.

Trapping. The first lake trap was not completed before the surface waters of Shasta Reservoir began to warm; consequently, the primary objectives of the trapping operation were changed. The warm upper layers of the reservoir precluded the possibility of the trap taking many salmonids, therefore, the first season was dedicated to perfecting trapping techniques.

Lake trapping began in May and continued until August 1962. Two trap locations were fished the first season. Trap Site No. 2 was fished from May 24 until July 12, and Trap Site No. 7 was fished from July 13 until August 24 (see Plate 4).

The prediction that few salmonids would be caught the first season was borne out when only two rainbow trout and no salmon were taken (Table 4). A total of 12 different species of fish were captured, however, which allowed project personnel to develop good trap fishing techniques (Tables 4 and 5).

Trawling. Trawling with the experimental mid-water trawl produced unsatisfactory results. The small mesh size of the net, coupled with the heavy materials used in construction, offered too great a resistance to the water. Maximum speed attained, with the trawl fishing properly, was three-fourths mile per hour. When the trawl was towed in excess of three-fourths mile per hour, a noticeable pressure wave built up in front of it and the net became unsteady.

Mid-water trawling was never conducted on a regular schedule, but only on an experimental basis. The catches were composed, primarily, of larvel and juvenile centrarchids and threadfin shad. When mid-water tows were made through areas known to contain large concentrations of fish,

TABLE 4

NUMBERS OF FISH TAKEN IN SHASTA RESERVOIR FLOATING TRAPS, BY SPECIES AND FREQUENCY OF OCCURRENCE DURING THE 1962-63 FIELD SEASONS BY MONTH OF CATCH

Species	1962					1963				
	May	June	July	August	Total	Mar.	April	May	June	Total
Threadfin shad	1	31	348	1,181	1,561	107	14,861	479,098	6,830	500,896
King salmon	-	-	-	-	-	1	3,942[1/]	13	-	3,956
Kokanee	-	-	-	-	-	-	177	553	-	730
Brown trout	-	-	-	-	-	-	2	3	-	5
Rainbow trout	1	1	1	-	3	15	74	29	-	118
Dolly Varden	-	-	-	-	-	-	-	1	-	1
Sucker	9	25	-	-	34	3	36	69	6	114
Carp	1	58	32	6	97	1	44	131	4	180
Golden shiner	1	1	4	-	6	-	8	15	-	23
Sacramento blackfish	-	-	-	-	-	-	-	210[2/]	1	250[2/]
Hardhead	28	41	-	-	69	1	38		-	
Sacramento squawfish	39	48	56	5	148	12	56	32	4	104
White catfish	-	-	-	-	-	-	-	6	-	6
Brown bullhead	-	3	1	-	4	-	3	19	1	23
Black bullhead	-	-	-	-	-	-	-	1	-	1
Smallmouth bass	-	-	-	-	-	2	-	2	-	4
Largemouth bass	-	6	18	9	33	15	3	12	8	38
Green sunfish	-	4	31	12	47	1	9	24	1	35
Bluegill	1,005	978	2,405	1,094	5,482	101	1,062	1,317	78	2,558
Sunfish hybrids	-	-	3	-	3	-	1	-	-	1

1/ The estimated 1,200 fry that escaped through the trap webbing are not included.

2/ Some mixing of hardheads and blackfish.

TABLE 5

SPECIES OF FISH TAKEN BY
FLOATING TRAPS IN SHASTA RESERVOIR
1962-63

CLUPEIDAE - Herring Family

Dorosoma petenese (Gunther). Threadfin shad.

SALMONIDAE - Salmon and Trout Family

Oncorhynchus tshawytscha (Walbaum). King salmon.

Oncorhynchus nerka kennerlyi (Suckley). Kokanee.

Salmo trutta Linne. Brown trout.

Salmo gairdnerii Richardson. Rainbow trout.

Salvelinus malma (Walbaum). Dolly Varden.

CATOSTOMIDAE - Sucker Family

Catostomus occidentalis Ayres. Western sucker.

CYPRINIDAE - Minnow Family

Cyprinus carpio Linne. Carp.

Notemigonus crysoleucas (Mitchill). Golden shiner.

Orthodon microlepidotus (Ayres). Sacramento blackfish.

Mylopharodon conocephalus (Baird and Girard). Hardhead.

Ptychocheilus grandis (Ayres). Sacramento squawfish.

ICTALURIDAE - Catfish Family

Ictalurus catus (Linne). White catfish.

Ictalurus nebulosus (Le Sueur). Brown bullhead.

Ictalurus melas (Rafinesque). Black bullhead.

CENTRARCHIDAE - Sunfish Family

Micropterus dolomieu Lacepede. Smallmouth bass.

Micropterus salmoides (Lacepede). Largemouth bass.

Lepomis cyanellus Rafinesque. Green sunfish.

Lepomis macrochirus Rafinesque. Bluegill.

Also bluegill-green sunfish hybrids.

normally few were taken. The general consensus drawn from the mid-water trawl experiments was that most fish could avoid the trawl with ease.

Semi-balloon trawls used in the study captured no salmonids. However, they produced better catches than the mid-water trawl. The 16-foot trawls took more fish than the 24-foot model because the large trawls repeatedly hung up on the rough bottom. Trawl tows were made with the aid of a recording fathometer. The bottom trawls normally made catches when fish were evident on the fathometer chart and when no fish were detected by the fathometer, rarely were any taken. The semi-balloon trawls were towed both on the bottom and at mid-water depths, with the best catches being made on the bottom.

A ten minute tow, made in 40 feet of water, on July 25, 1962, produced a catch of 36 fish which consisted of: five bluegill fry 1/2-inch long, one green sunfish 1/2-inch long, three bluegill 3 - 4 inches long, ten suckers 3 - 4 inches long, two squawfish 6 - 7 inches long, one largemouth bass 11 inches long, and fourteen carp 12 - 24 inches long.

Limnological Observations. A limnological program was planned to run concurrently with the biological studies but it never materialized, due to a lack of funds and personnel. Instantaneous temperatures were taken in the reservoir intermittently throughout the summer, but no formal program was followed. A thermograph was installed on March 28, in the Sacramento River above the reservoir and was operated until October 3, (Table 6). It was located above the mouth of Dog Creek, a short distance upstream from the Campbell Creek Fyke Net Station. The unit's thermocouple was secured between boulders in fast water 3 feet from shore and at a depth of 3 feet. Temperatures were taken concurrently with the operation of the fyke nets, so that the temperature preferences of the downstream migrants could be

TABLE 6

SACRAMENTO RIVER WATER TEMPERATURES, 1962.
THERMOGRAPH LOCATED 100 FEET ABOVE MOUTH OF DOG CREEK

Day	March			April			May			June		
	Temperature in degrees F			Temperature in degrees F			Temperature in degrees F			Temperature in degrees F		
	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.
1				49.0	46.5	44.0	53.0	51.0	49.0	59.0	56.0	53.0
2				---	---	---	55.0	52.5	50.0	57.5	56.0	54.0
3				---	---	---	55.0	52.5	49.5	55.5	53.5	51.5
4				---	---	---	53.5	51.0	48.0	54.0	52.5	49.5*
5				---	---	---	54.5	51.0	48.0	57.0	53.5	50.5
6				---	---	---	53.0	51.0	49.0	59.0	56.0	53.0
7				51.0	---	---	53.0	51.0	49.0	60.0	57.5	54.5
8				50.0	47.5	45.0*	52.5	50.5	48.5	61.0	58.5	56.0*
9				49.0	46.0	43.0	49.0	47.5	46.5	63.5	60.5	57.5
10				49.0	46.0	43.0	49.5	48.0	47.0	63.5	61.0	59.0
11				50.5	47.0	44.0	52.0	49.5	47.0	63.0	60.5	58.0
12				51.5	48.5	45.5	50.5	49.0	47.0	63.5	61.0	58.5
13				50.5	48.0	45.5	50.0	49.0	48.0	62.0	60.0	58.0
14				52.0	49.0	46.0	50.5	48.0	46.0	61.0	59.5	57.5
15				50.5	48.0	45.0	51.0	49.5	47.5	63.0	60.5	57.5
16				50.0	47.5	44.5	53.0	49.5	46.5	65.0	62.5	59.5
17				51.0	47.5	44.5	55.0	52.5	50.0	66.0	63.5	61.0
18				50.0	47.5	45.5	55.5	53.0	51.0	67.0	64.5	62.0
19				49.0	46.5	44.0	54.0	51.5	49.0	68.5	66.0	64.0
20				48.5	45.5	42.5	50.0	47.5	45.5	69.0	66.5	64.0
21				51.0	47.5	44.5	54.0	50.5	47.0	70.0	67.5	65.0
22				53.0	50.0	47.0	52.5	51.0	49.5	70.5	67.0	66.0
23				52.0	50.0	47.5	52.5	51.0	49.5	70.0	67.5	65.5
24				50.5	49.0	46.5	52.0	50.5	49.0	70.0	67.0	65.0
25				50.5	48.0	45.0	51.0	50.0	49.0	70.5	68.0	65.5
26				51.0	48.5	45.5	54.5	52.0	49.5	70.0	67.0	64.5
27				50.0	47.5	45.0	57.5	54.0	50.0*	70.0	67.0	64.0
28	47.5	---	---	46.0	44.5	42.5	54.0	53.5	53.0	70.5	68.0	64.5
29	48.0	45.5	43.0	48.5	45.0	42.0	58.5	55.0	52.0*	70.0	67.0	64.0
30	48.0	45.5	43.0	50.0	47.0	44.0	58.0	55.5	53.0	69.5	67.0	64.0
31	49.0	46.0	43.0				58.0	55.0	52.0			

* Indicates days in which KS were taken in fyke net or gill net.

TABLE 6
(Continued)

Day	July Temperature in degrees F			August Temperature in degrees F			September Temperature in degrees F			October Temperature in degrees F		
	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.
1	70.5	67.0	64.0	77.0	73.5	70.0	71.0	67.0	63.0	63.0	60.0	57.0
2	70.0	67.0	64.0	76.0	73.0	70.0	72.0	67.5	64.5	63.0	60.5	58.0
3	71.0	67.5	64.0	70.0	69.0	68.0	72.5	69.0	65.5	61.0	58.5	56.5
4	71.5	68.0	64.0	71.0	68.5	65.5	72.0	68.5	65.0			
5	73.0	69.5	66.0	72.5	69.0	66.0	72.0	68.5	65.0			
6	73.5	70.0	66.0	71.0	68.5	66.5	72.5	69.5	66.0			
7	73.0	69.5	66.0	68.0	65.5	62.5	72.0	69.0	66.0			
8	74.0	70.5	67.0	62.0	61.0	60.0	Inopera-	68.5	65.0			
9	74.0	70.5	67.0	64.5	62.5	60.0	tive	---	---			
10	74.0	70.5	67.0	69.0	65.5	62.0	67.5	65	62.0			
11	74.0	71.5	67.0	72.0	68.0	64.0	68.5	65.0	62.0			
12	74.0	71.5	67.0	73.5	70.0	66.5	69.0	66.0	62.5			
13	74.5	70.25	66.0	74.0	70.0	66.5	68.0	65.0	62.0			
14	72.0	69.0	66.0	74.0	70.5	67.0	68.0	64.5	61.0			
15	72.5	69.0	65.5	74.5	70.5	67.0	68.5	65.0	61.5			
16	73.5	69.5	66.0	74.0	70.5	67.0	69.5	66.0	62.5			
17	74.5	71.0	67.5	74.5	71.0	67.5	69.5	66.0	62.0			
18	74.0	70.5	67.0	74.5	71.0	67.5	67.5	64.5	61.5			
19	75.0	72.0	68.0	74.5	71.0	67.5	65.0	62.0	59.0			
20	75.0	71.25	68.5	75.0	70.5	66.0	64.5	61.0	57.5			
21	74.5	71.0	67.5	75.0	71.5	68.0	65.5	62.0	58.0			
22	75.0	71.25	67.5	74.0	71.0	68.0	66.0	62.5	59.0			
23	75.0	72.0	68.0	73.5	70.0	66.5	66.0	63.0	59.5			
24	76.5	72.5	68.5	73.0	69.5	65.5	66.0	62.5	59.0			
25	77.0	73.0	69.0	73.5	69.5	66.0	65.0	62.0	59.0			
26	78.0	74.0	70.0	73.5	69.5	66.0	64.5	61.5	58.0			
27	78.5	74.5	70.5	71.5	68.0	65.0	60.5	59.5	58.0			
28	78.0	74.5	71.0	70.5	67.0	64.0	58.0	56.5	55.0			
29	76.5	73.5	70.5	70.5	67.0	63.5	60.0	57.0	54.0			
30	77.0	73.0	69.0	70.5	66.5	63.0	62.0	59.0	56.0			
31	77.0	73.5	69.5	71.0	67.0	63.0						

measured. The last two king salmon fingerlings were taken in the fyke net on June 4, when the minimum river temperature was 49.5°F and the maximum was 54°F. The last fingerling to be taken during the season, however, was taken in a gill net in the upper end of the reservoir when the river temperature ranged between 56-61°F. Unfortunately, the lake surface temperature was not recorded when the fingerling was taken and there was no way of knowing how long the fish had been in the reservoir before being captured.

General Observations. Visual observations were made throughout the reservoir during the 1962 season. Small salmon were observed on only two occasions, May 30, and June 4. On these two dates, small schools of fingerlings were observed feeding on a hatch of tiny may flies in the reservoir above Riverview. The schools were very wild and could be approached only with difficulty. The clarity of the water, however, enabled a positive identification of the young salmon to be made.

Predator stomachs were examined during the first year of the study, but no king salmon remains were ever identified. Many of the stomachs examined were empty, but the ones that held fish remains most often contained small squawfish, dace, and bluegill.

During the month of November 1962, the U. S. Army Corps of Engineers conducted fish passage experiments at the Shasta Dam powerhouse. Marked king salmon and rainbow trout fingerlings were introduced into the penstocks above the powerhouse and recovered in fyke nets in the turbine tailraces. At the time of the experiments, the water was approximately 200 feet deep over the penstock intakes. Many different species of fish, present in the reservoir, were recovered in the fyke nets, but no unmarked king salmon fingerlings were taken.

All field work was suspended at the end of August 1962, for lack of funds. The equipment was stored and the seasonal help was discharged.

1963 Study

When the contractual agreement for the Shasta Lake study was received from the Bureau of Commercial Fisheries on January 22, 1963, work was resumed immediately on the field program, idle since the preceding August.

The Shasta Lake Field Station was reactivated on February 20, and the original lease was expanded to include a warehouse to be used as a shop and for the storage of equipment. The project was staffed by the end of February and the project was in full operation on March 1.

Equipment used during the first year was surveyed for damage, and repairs were made where necessary. The floating trap required considerable work to make it fishable again after being stored in the open during the winter.

A second floating trap was constructed, incorporating design changes developed during the first season of trapping (Plate 3). The new trap was finished and launched in the lake by the middle of March. The new trap and the one built during the first season were outfitted and were both fishing by March 27. Every effort was made to have all equipment ready by the time the first planting allotment was received.

Trapping

The project's floating traps were fishing for two weeks prior to the 1963 fingerling plants. A yearling king salmon, 5-1/4 inches fork length, was taken at Trap Site No. 2 on March 31, five days after the traps were set (Table 4). The yearling, presumably one of the 1962 plant, was healthy and robust. It was impossible to determine if the yearling, if it was one of the previous plant, was a late migrant out of the upper river, or had been a lake resident. The traps were fished for 3 months after the yearling was taken and, although many salmonids were caught, no more fish from the original plants were observed.

The project's traps were set at Site No. 2 and No. 4 during the first week of the 1963 season. The lake level was rising quite rapidly during this period because of heavy and prolonged rainfall in the area, and after 1 week the trap fishing at Site No. 4 was moved upstream to Site No. 3 (Plate 4). The 1963 planting site was located approximately 1 and 1/2 miles above the head of the reservoir, which allowed the fingerlings to orient themselves to the river current before encountering the slower velocities within the impoundment. An appreciable current was still evident at Trap Sites 2 and 3, located approximately 4 miles below the planting site (Table 7). On April 10, 24 hours after the initial release, 1,136 king salmon fingerlings were removed from the trap set at Site 2. An additional number,perhaps half again as many as were recovered, escaped through the sides of the trap when the webbing was lifted to remove the catch (Table 4). King salmon fingerlings were observed in the trap fishing at Site 3 on the same day, but they all escaped through the webbing before they could be recovered. The main current coming down the reservoir at this point followed the old river channel and crossed from the west to the east bank 100 yards above Trap Site 3. The majority of the fingerlings, at this point, were evidently still following the river current.

On April 11, the morning following the second plant, a total of 1,517 king salmon fingerlings were removed from the traps with all but

TABLE 7

THE DISTANCE IN MILES BETWEEN PLANTING AND TRAP SITES, SHASTA LAKE 1963

Trap site number	Miles
1	2.5
2	3.7
3	3.7
4	3.7
5	8.4
6	10.8
7	13.6
8	14.6
9	16.8
10	23.7
11	22.1
12	29.8
13	29.8

NOTE: Distances measured on Kennet Reservoir Site Survey sheets scaled at 5-5/16 inches per mile. Theoretical migration routes were followed down both sides of the reservoir, parallel to the high water line, with a map measure.

130 fish again being removed from the trap on the east side of the reservoir. On April 11, as on the previous day, large numbers of fingerlings were observed escaping through the trap webbing. On the day following the last plant only 641 fingerlings were removed from the traps. On April 12,

however, the majority of the fingerlings were taken in the trap at Site 3, for no apparent reason. On April 12, as on the 2 previous days, the trap catches consisted of only the larger fingerlings.

A severe storm, that lasted from April 12 to 14, caused extensive damage when wind-driven debris tore large holes in the trap webbing. During this period the catch began to decline until a low catch of 32 fingerlings was reached on April 16, indicating that the majority of the migrants had passed the trap sites.

On April 16, the trap fishing at Site 3 was moved down the reservoir approximately 5 miles to Site No. 5. The first fingerling was observed entering the trap as the final adjustments were being made, at 5 o'clock the same afternoon. The fingerling was swimming at a depth of 8 to 10 inches, 1 foot out from the inside of the right wing, when first noticed, and was moving at a slow, steady pace. The fingerling followed along the wing of the trap and entered the pot section without hesitation.

The catch at Site 5 on April 17, was 37 fingerlings while the catch at Site 2 was 44 fingerlings. The trap at Site 2 was moved down the lake to Site 8 on April 17, a distance of approximately 10 miles. On April 18, four fingerlings were removed from the trap at Site 5, but no king salmon were caught at Site 8. On April 19, however, the trap at Site 8 produced two fingerlings and one fingerling was removed from the stomach of an 8-inch rainbow trout taken in a gill net set on the west side of the lake opposite the trap.

The traps were fished at Sites 5 and 8 for approximately 1 week, and during this period the trap on the east side of the reservoir caught an average of 15 fingerlings per day, while the trap on the west side of the lake averaged just under 50 fingerlings. At Trap Site 8 the water was very clear and the fingerlings taken there were wary. The fingerlings taken at the upper sites, where the water was murky from spring runoff, were very quiet and easy to remove from the traps, but within a period of 1 month in the clearer water of the lower lake they had become very nervous and would sound to the bottom of the trap when the slightest shadow passed over them.

The trap fishing at Site 5 was moved down the reservoir to Site No. 9 on April 22, approximately 17 miles below the planting site. On April 23, the trap fishing at Site 8 was moved down the lake 9 miles to Trap Site No. 10, a distance of almost 24 miles below the planting site. The project, with only two traps available, could not attempt to determine at what time the majority of the fingerlings passed a given point, except at the first stations. The main objective of the study was to keep the traps ahead of the main body of migrants, to assess their migration speed, and to determine on which side of the reservoir the majority of the migrants were traveling. The catches from the two sides of the reservoir, although they varied from day to day, indicated that the largest number of fingerlings moved down the west shore.

The initial movement of king salmon fingerlings stopped on April 25. The weather between April 25 and 30 was warm and clear, which caused the surface temperature of the reservoir to rise appreciably. However, a storm blew into the area on April 30, and for the next week the sky was heavily overcast with occasional rain and strong wind. The cool weather lowered the surface water temperature of the lake, and on May 2, one fingerling was captured in the trap fishing at Site No. 10. On May 3, the trap at Site No. 10 was moved back up the reservoir to Site No. 6, where it took fingerlings on May 6, 7, 8, and 10, at which time they again disappeared from the catch.

The trap fishing at Site No. 9 was moved down the lake to Site No. 11 on April 26, and when no fingerlings were taken the trap was moved to Site No. 13 near the west abutment of the dam. When no fingerlings were taken at Site 13, the trap was moved back up the lake to Site No. 12, where it fished until it was taken out of the lake for the season. The dam was spilling from May 7 to June 7, while the trap was fishing in the area, but there was no indication that the young king salmon attempted to leave the reservoir.

During the month of May, reports were received that anglers were taking yearling king salmon with hook and line in the upper end of the Sacramento arm. On May 23, in an attempt to take some of these fish, the trap fishing at Site No. 6 was moved up the lake to Site No. 1. This last move, like later sets in the lower end of the reservoir, produced no additional king salmon fingerlings.

The last king salmon of the season was taken on May 10, but kokanee continued to be taken in good numbers up until May 20, when they too dropped from the catch. The last salmonid to be taken in the study was a rainbow trout, captured at Trap No. 1 on May 24. In all, 20 different species of fish were taken during the second season of trapping on Shasta Lake (Table 4).

Threadfin shad replaced the bluegill as the dominant species in the catch during the second season. During the period from May 20 to 24, catches of shad were extremely heavy, and on May 22, the catch in the trap at Site No. 12 was estimated to have exceeded 2,000 pounds. It became exceedingly difficult, with catches of this magnitude, to separate different species in the catch unless they were large specimens. On May 28, the temperature range through the fishing depth of the trap at Site No. 12 was 64° to 72°F; well past the range favored by salmonids. Therefore, on May 29, the trap was towed back to headquarters for dismantling and storage.

Gill Netting

During the second gill netting season, the 3/8 and 1/2-inch stretched-mesh nets were not used. It was felt that more information could be gained by fishing nets large enough to capture the predator species than by trying to catch the small fingerlings of the 1963 plant, a large precentage of which could slip through 1/2-inch mesh webbing. Threadfin shad dominated the gill net catch during the second season (Table 3), and were found in all areas of the reservoir and at all depths fished. The project gill nets were fished from the surface to 40 feet during the second season and again the clarity of Shasta Reservoir water was considered to have been the cause of the limited catch. The few rainbow trout and kokanee in the catch were taken when the water was murky from spring storms.

Trawling

Little trawling was done during the 1963 season, due to mechanical failure of the engines on the large boat and the long distances between headquarters and the trapping sites, which required much traveling time. After the lower trap was removed from the lake, however, some time was spent on designing a suitable mid-water trawl for the study. It was determined, from our work that a 15-foot square trawl could be handled by the project boat, but before a new trawl could be constructed and tested the project was discontinued.

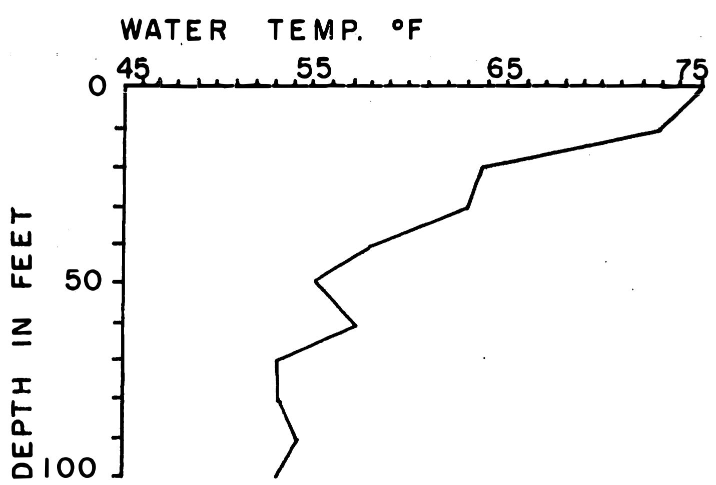
Limnological Observations

No regular limnological program was started in 1963 because of insufficient funds and personnel. Temperatures, however, were taken at both floating traps with maximum-minimum thermometers during May and June. The surface temperatures of Shasta Reservoir rose steadily during the month of May, and by May 23, the daily temperatures at the traps, at a depth of 16 feet, ranged from 62° to 70°F.

With a rise in surface temperatures, the catch of salmonids began to decline with a subsequent rise in the catch of warmwater species. Water temperature measurements taken from headquarters dock on May 28, showed stratification had taken place (Figure 7). The maximum and minimum temperatures at the traps from the surface to a depth of 16 feet on May 28, ranged from 72° to 64°F at Trap Site 1, and from 74° to 66°F at Trap Site 12.

FIGURE 7

Temperature profile at headquarters dock May 28, 1963, surface to 100 ft.



On June 10, temperature profiles were run at seven different points on the Sacramento River arm of the lake (Plate 4 and Figure 8). The plotted temperatures taken on that day show that a deep thermocline was established. The depth of the thermocline was further established by sport fishermen, during this period, when they found it necessary to troll at a depth of from 50 to 75 feet to take rainbow trout, brown trout, and king salmon they had previously been taking at shallow depths. During the period that the project's traps had been taking salmonids, anglers had also been taking them at shallow depths.

King salmon taken by anglers were determined to be 1 and 1/2 years old. It is not known definitely at this time whether these fish came from our artificial plants or from natural reproduction by king salmon planted in the reservoir in 1958, as there was a great disparity in size between these fish and the yearling taken in the trap on March 31.

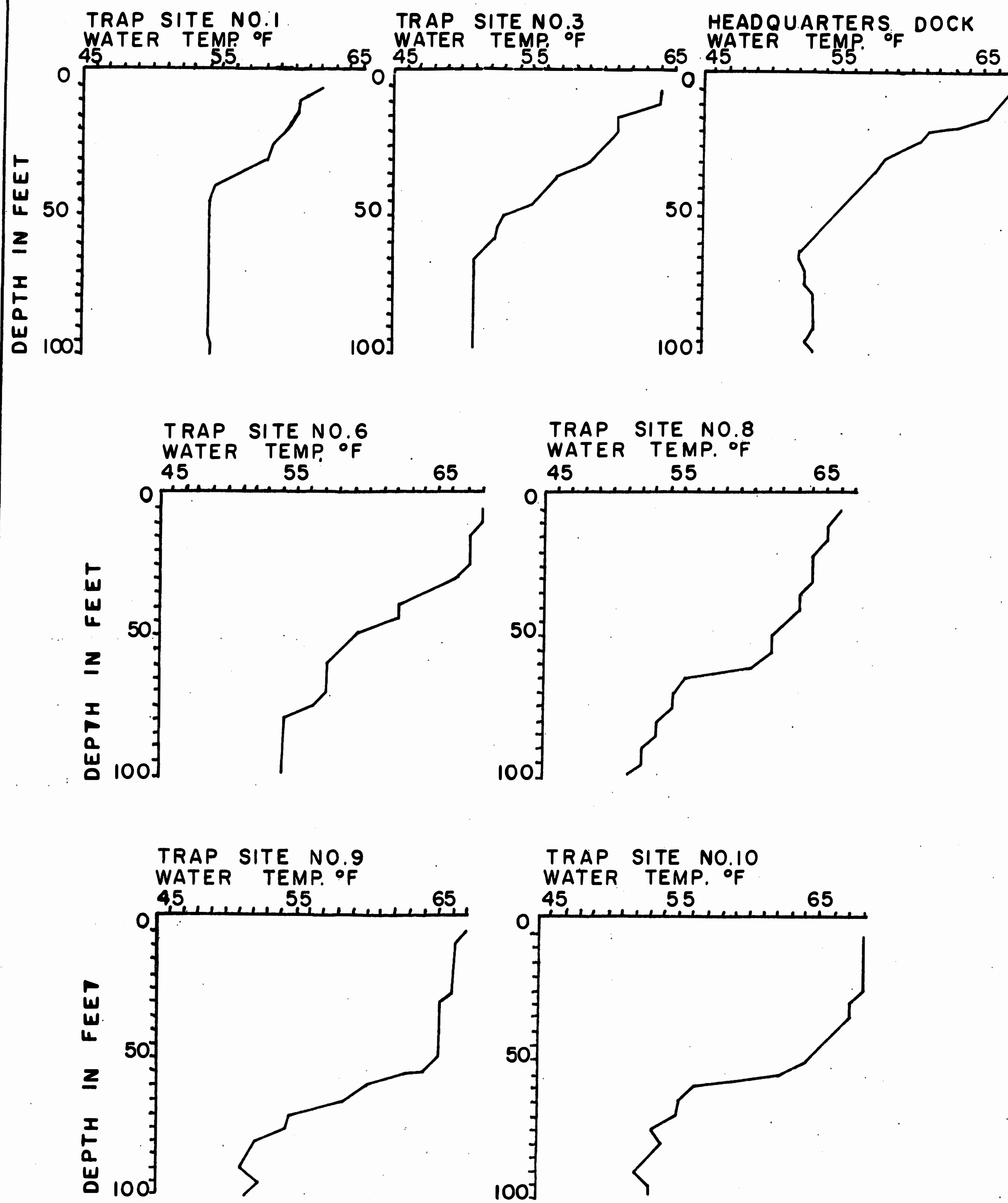
In the lower end of the reservoir strong currents were often noted early in the year. These currents, though not as strong as those caused by spring freshets in the upper end of the reservoir, are at times quite strong and were found to run counter to the main current on the Sacramento River. The exact cause of these currents was not determined, but it could have been a combination of wind and the density currents of the other arms mingling with those of the Sacramento in the area where they join. It was in the lower end of the Sacramento arm of the reservoir where contact was lost with the fingerlings. It would be interesting to know what part these currents played in the downstream movement of the fingerlings.

Predation

A study was made of predator stomachs to determine the food habits of the fish in Shasta Reservoir. Most of the stomachs examined

FIGURE 8

Temperature profiles from Shasta Reservoir June 10, 1963. Surface to 100 feet.



came from fish taken in the floating traps. The stomachs of most of the fish taken in the gill nets were empty with few exceptions. The only king salmon fingerling removed from a gill-net-caught fish was taken from the stomach of an 8-inch rainbow trout caught on April 19, just below Trap Site 7. The one small salmon fingerling was the only item in the trout's stomach.

King salmon fingerlings were removed from the stomachs of both rainbow and brown trout and bluegill taken in the traps, but rainbow trout appeared to be the main predator. Many bass and squawfish stomachs were examined during the 2-year study, but no salmonid remains were ever detected. During the first year of the study small bluegill were the food item most often seen in the stomachs of the larger predators. During the second year the most plentiful item in the diet was threadfin shad. Threadfin shad were removed from the stomachs of trout, bass, bluegill, catfish, squawfish, and green sunfish.

Marking Experiment

An attempt was made, during the second year of the study, to develop a suitable method for marking the young fish other than by the excision of fins. A branding technique that had been used by Elwell (1961) for marking salmon and steelhead yearlings was tried on the small project fingerlings. The yearling fish branded by Elwell had well-defined marks that were still clearly legible after 9 months at Nimbus Hatchery, when they were released.

A sample of 50 fingerlings was taken from the trap catch on April 11, 1963, to be used in the experiment. The fingerlings were anesthetized in a solution of Tricaine Methanesulfonate (MS-222) and then marked on the dorsal surface and the opercle with various patterns made with an electric marking pencil. The marking pencil was powered by a 12-volt lantern battery. The marking tip was a small loop of nichrome wire that was heated to a white heat when the current was applied. The 1 and 1/2-inch fish that were used in the experiment were very delicate. A 100 percent mortality was sustained within 4 days after they were marked. The mortality was evidently due to shock, since many of the fingerlings suffered deep burns during the marking process. It was extremely difficult to judge the depth of the mark.

The marking technique was not developed to a point where it could be applied to large numbers of small fingerlings. Following the initial large catches, insufficient fingerlings were available for continued, large-scale, marking studies. It was evident that a satisfactory branding technique for very small fish would have to include a jig to enable the operator to control the depth of the mark.

Termination of Study

On June 30, 1963, field activities were officially terminated, when no funds were allocated by the California State Legislature for the 1964 fiscal year. Equipment used during the study was dismantled and stored against the time the program might be re-activated. The field station lease was terminated and all vehicles were returned to Sacramento for re-assignment. The seasonal employees working on the project were discharged and permanent employees were transferred to other duty stations.

DISCUSSION

The Shasta Lake Migrant Study was planned as a long-range program to solve problems that will be imposed on downstream migrating salmon fingerlings by large impoundments, such as Shasta Reservoir. The badly needed information that should have been forthcoming from the study, was not obtained due to the untimely termination of the investigation.

The major problems posed by the study still exist and have not been resolved. These problems are:

I. Determine the pattern and rate of movement of fingerling king salmon in Shasta Reservoir.

II. Observe schooling patterns of fingerling king salmon in Shasta Reservoir.

III. Determine the distribution of king salmon in relation to water temperatures and oxygen tensions.

IV. Determine if residualism occurs in Shasta Reservoir and measure the degree of residualism if it occurs.

V. Determine the relationship of predator fish populations to fingerling survival.

VI. Determine if fingerling king salmon would sound to the depth of Shasta Dam turbines and measure survival rates after passage through the turbines.

The results that were obtained during the study were primarily qualitative in nature. It is extremely valuable to know how fast and how far the fingerlings will travel in a reservoir, during a given period, but it is even more valuable to know how many of them will do this.

In order to have obtained quantitative data from the Shasta Lake study a greal deal more equipment would have been necessary. A minimum of four traps would have been needed in order to mark and recover fingerlings from one area to another. In addition, as originally planned, scoop traps or floating migrant traps should have been fished in Keswick Reservoir to ascertain whether or not migrants were actually leaving the reservoir through the turbines.

A program large enough to collect good quantitative data in Shasta Reservoir would not only require additional equipment above that provided for the initial study, but it would also require a much larger staff.

The exploratory study carried on during 1962 provided valuable information for setting up the 1963 program. The information gained from the initial trapping studies in 1962 enabled project personnel to design and construct a much more efficient trap during the second year of operation. Fyke netting and trawling techniques that were developed showed great promise, and a portable trawl winch that was developed proved very satisfactory.

Many problems were solved during the 2 years of the study, but one major problem persisted to the end. The projects large outboard-powered boat proved to be entirely inadequate to do the job that it was required to do. The major problem was in the outboard motors. One or both of the engines was broken down most of the time during the two years and much valuable time was wasted while they were being repaired. To operate on a lake the size of Shasta Reservoir, where much long distance traveling is required, and to engage in trawl operations, an inboard-powered boat is essential. Large outboard-powered boats are not only uneconomical for studies like those conducted on Shasta Lake, but they do not develop sufficient horsepower or have enough stamina for the heavy hauling jobs.

The 1962 and 1963 programs could have been greatly improved by the addition of a limnological program. To fully understand the behavior of salmonids in reservoirs, we must have a greater knowledge of the environment produced in these impoundments. The counter currents observed briefly in the lower Sacramento River arm of the reservoir during the spring of 1963 are only one of the many phenomona present that are not understood. These and many other things must be known before we can fully understand the reasons why salmonids will either pass through or become residual in a reservoir.

SUMMARY AND CONCLUSIONS

A study to determine if fall-run king salmon fingerlings could pass successfully downstream through a large, warmwater, fluctuating reservoir, was conducted by the California Department of Fish and Game during 1962 and 1963. Funds were provided for the study by the California Department of Water Resources and the Bureau of Commercial Fisheries of the U. S. Fish and Wildlife Service.

Field studies were conducted on Shasta Reservoir in the Sacramento River. The objectives of the investigation included: determination of the pattern and rate of movement; observation of schooling patterns; determination of distribution of fingerling king salmon in relation to water temperature and dissolved oxygen; determination of the extent of residualism of young fish; relationship of predator populations to fingerling survival; and determination of fingerling survival through powerhouse turbines.

A total of 1,750,000 fall-run king salmon fingerlings were released in the river above Shasta Reservoir. The fingerlings were progeny of fish trapped at Keswick Dam, and were hatched and reared at Coleman National Fish Hatchery.

The 1962 plant, consisting of 750,000 swim-up fry, produced very poor returns. Fyke net catches indicated that the majority of the fry migrated the 27 miles from the planting site to the reservoir within the first week after being planted. Reconnaissance work in the area between the planting sites and the reservoir revealed that a small percentage of fry remained in the river during the first summer.

Only two small king salmon from the 1962 plant were recovered in the upper end of the reservoir; one in a gill net on June 8, 3-1/2 months after the plant, and the other in a lake trap set at the mouth of Middle Salt Creek in the spring of 1963. King salmon, weighing from 3 to 5 pounds, were caught in the lower reservoir during the early summer of 1963 and from scale analysis were determined to have but one annulus. Scales from only two fish were examined for the age determination. Although they appeared to be the same age it would be pure conjecture on our part to state positively that these fish were from the 1962 plant. However, the size of these young king salmon compared favorably with the size of fish in the same age group taken in the ocean.

King salmon planted in Shasta Reservoir in 1958 reached a size of 8 pounds before disappearing from the catch. The forage present in the lake during that period was poor and consisted primarily of native minnows, centrarchids, and kokanee. The primary difference between fresh and salt water growth in salmon is usually determined by the amount and type of food available. In 1961 the Department of Fish and Game introduced threadfin shad into Shasta Reservoir and by 1963 a tremendous population of these fish had built up, as evidenced by the project's trap catches (Table 4). It is possible that fry from the 1962 plant were carried down into the reservoir and grew at an accelerated rate, due to the excellent forage conditions provided by the shad. No salmon in this size group were taken in the project's traps during 1963, although the numbers and distribution of the fish taken by sportsmen would indicate the presence of a sizeable population.

The 1963 plant was composed of 1,000,000 fingerlings that were fed for 30 days prior to their release. This plant was made approximately 2 and

1/2 miles above the reservoir. A total of 3,956 fingerlings were recovered in the reservoir with traps before thermal strafication occurred. The fingerlings were followed a distance of 23.7 miles during the first 16 days after being planted, but no fingerlings were taken past that point.

Shasta Reservoir spilled for 1 month while the fingerlings were moving down the lake, but none of them were taken in the area near the dam, although trap and gill nets were being fished in the area during the entire period. Currents observed in the lower end of the Sacramento River arm of the impoundment may have caused the migrants to discontinue their downstream movement.

It is believed that surface water temperatures of Shasta Reservoir had a direct bearing on the downstream movement of the young salmon, although no formal limnological program was followed. King salmon fingerlings vanished from the trap catch after the first warm weather of the 1963 season. A week of cold, windy weather followed the early warm weather and the fingerlings again made their appearance. However, with a resumption of warm weather, the fingerlings again disappeared from the catch, and none were taken during the balance of the study.

The examination of stomach contents of predator fishes, taken primarily in lake traps, disclosed that rainbow trout were the main predator. The remains of king salmon fingerlings, however, were removed from rainbow trout, brown trout, and bluegill. Many bass and squawfish stomachs were examined, but no salmonid remains were detected.

The U. S. Army Corps of Engineers conducted fish passage experiments at the Shasta Dam powerhouse in November 1962. Marked king salmon and rainbow trout fingerlings were introduced into the penstocks above the powerhouse and were recovered in fyke nets moored in the turbine tailraces. No unmarked king salmon fingerlings were recovered, but many other species of fish, present in the reservoir, were taken. The Corps study took place, however, long after the normal fall migration would have started.

The investigation was terminated before a full evaluation could be made of the fingerling's habits. However, this incomplete study indicates that a grave problem of residualism may exist when fall-run king salmon fingerlings are forced to negotiate a large, warmwater, fluctuating reservoir on their way to sea.

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