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HOLDING PONDS FOR ADULT SALMON

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HOLDING PONDS FOR ADULT SALMON

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ABSTRACT

Holding ponds have been developed for the retention of the Pacific salmon (Oncorhynchus) during the interval between the upstream and spawning migrations. This pond type, operated either singly or in series, is a long, narrow channel with a diffused water intake and sloping banks to minimize self-inflicted injuries during the holding period. An average current velocity of 0.2 fps is maintained through the pond when water temperatures exceed 60° F. to reduce the incidence of disease. Both upstream and downstream trapping facilities are installed in the holding ponds to capture the sexually mature adults for artificial propagation. The characteristic reactions of the confined salmon are described. Design drawings of the holding ponds and trapping facilities are included.

HOLDING PONDS FOR ADULT SALMON

INTRODUCTION

Artificial propagation of salmon (Oncorhynchus) can be complicated by the variations encountered in the migration patterns of the several species, races within species, and even individuals within races. The freshwater migration of adult Pacific salmon is divided into two phases, the first is the upstream migration to location, and the second is the spawning migration or search for a spawning site. The interval between these migrations may be but a few hours or as much as three or four months.

The problem is to secure the adults in sufficient numbers to meet the requirements of artificial propagation without incurring prohibitive mortalities. With different migration patterns different solutions are available. When the interval between the upstream and spawning migration is short, the fish may be trapped on the upstream migration and held either in the stream or improvised ponds until sexually mature without prohibitive mortalities. When the fish, at the conclusion of the upstream migration, are concentrated in a holding area, such as a lake, and the spawning migration is out of the lake into tributary streams, trapping at the start of the spawning migration is possible. When the interval between the upstream and spawning migrations is long, in excess of one month; when the fish disperse at the conclusion of the upstream migration; and when the spawning migration consists of a local movement either up or downstream; then, the fish must be diverted while still concentrated on their upstream migration and especially designed holding ponds employed to retain the fish until sexual maturity.

The problems encountered in the retention of adult salmon are not new. Atkins (1884) reports varying degrees of success with different holding pond types used for the retention of Atlantic salmon (Salmo salar). Hume (1893) attempted to hold Pacific salmon in small ponds with some success. The most extensive holding attempt was conducted on the Grand Coulee Project where the entire Upper Columbia River runs of Pacific salmon were transported and held either in streams or holding ponds until sexual maturity. The results of this relocation, together with experiments designed to determine factors influencing successful retention, were reported by Fish (1944).

The holding experiments conducted by Fish indicated that injury and disease, aggravated by unfavorable environmental conditions, were the primary causes of mortality in adult salmon. Subsequent experiments have demonstrated that holding pond design can be a significant factor in the reduction of the holding mortality and that under favorable environmental conditions the effects of injury and disease may be significantly reduced.

Twenty years of experimentation and observation provide background for this report; the men who made active contributions are too numerous to mention. The Branch of Fish Hatcheries of the Bureau of Sport Fisheries and Wildlife and its predecessor organizations financed the building of the experimental holding ponds. Particular gratitude is expressed to Mr. A. V. Tunison and Mr. William Hagen, Jr., of this Bureau and Dr. L. Edward Perry, now with the Bureau of Commercial Fisheries, for their faith and support in the development and testing of the experimental holding pond designs.

Mr. Scott Bair, now of the Chelan County Public Utility District No. 1, prepared the original construction drawings for the Entiat and Winthrop holding ponds and Prof. Harry H. Chenoweth, of the University of Washington Engineering School, the design drawings included in this report.

The holding pond systems described have no single prototype in operation but, rather, are a composite of holding ponds and traps constructed at the Entiat, Winthrop, and Carson, Washington National Fish Hatcheries together with alterations designed to improve operation. The recommended plan for the use of holding ponds in series has not been tested in actual operation. In the presentation, the holding ponds and trapping systems are described separately because of the different problems involved.

RETENTION OF ADULT SALMON

The objectives in holding pond design during the retention period are: first, to prevent the fish from incurring further self-inflicted injuries during the holding period; second, to induce tissue repair in previous injuries; and third, to reduce the incidence of disease.

Holding pond design

The recommended design for holding ponds is shown in figure 1. Ignoring the trapping facilities, it consists of a rectangular pond 150 feet long, 50 feet wide, with a maximum depth of 5 feet, sloping sidewalls, an undershot diffusion for water inflow, and a picket "V" at the outflow. Several of these features are designed to prevent self-inflicted injury.

Prevention of self-inflicted injury:--The undershot diffusion panel introduces the inflowing water at the bottom of the pond 20 feet from any obstruction. Salmon rarely jump at such an inflow and then only if the quantity and velocity of the inflow is such as to produce a marked upwelling at the water surface. Under such circumstances the fish may jump toward the upwelling, but they would have to jump across the 10 feet square diffusion and an additional 20 feet before striking an obstruction. No fish has ever been observed to make such a jump in this type of holding pond. In fact, with 5 feet of water over the diffusion grating and 35 cfs of inflow there is so little surface agitation that the fish do not jump in this area. The tendency is for the fish to sound and nose the diffusion grate but never to the extent that visible injury is incurred. The undershot diffusion, properly placed, eliminates all the dangers of self-inflicted injury normally encountered in vertical picket inflow weirs.

In addition to fighting the inflow, salmon in confinement will, on occasion, make a series of leaps. If the water at the edges of the pond is deep the fish may jump out on the bank and either injure itself in its struggle to return to the pond or be trapped and die. Sloping the banks so that there is a 1-foot rise in 3 feet appears to provide sufficient warning so that the fish diverts from the shallow water. Salmon also have a tendency to jump at straight side walls; sloping banks avoid this tendency. In this type of holding pond, the diffused water inflow and sloping banks have successfully eliminated the problem of self-inflicted injury.

Factors influencing tissue repair and disease inhibition:--The problems of tissue repair and disease inhibition are related. In fish with open wounds it is a race between healing and the invasion of fungus (Saprolegnia parasitica). Fish and Rucker (1953) demonstrated that the incidence of columnaris disease (Chondrococcus columnaris) was significantly higher in injured fish. Both these diseases become more virulent at water temperatures over 60°F.. Low water temperatures, then, become a significant factor in the successful retention of adult salmon because of the retarding effect on disease development. At high water temperatures, however, some other factor must be employed to reduce the probability of infection.

Salmon seek the deepest water available to them when in confinement. Such water in a holding pond has the slowest current and the lowest rate of interchange. With low water inflows the water tends to stratify and the flow becomes laminar with the deepest areas the most affected. These deep areas, then, without an adequate inflow, become essentially dead and provide excellent locations for the concentration of waterborne disease organisms. The situation is further aggravated by the collection of diseased and injured fish in these areas. At low temperatures when columnaris and fungus are of low virulence the resistance of the fish is usually adequate to combat the infection but at water temperatures of 65°F. or higher the situation can become explosive in nature with the injured fish succumbing first but losses not necessarily confined to this group.

Effect of current velocity on disease inhibition -- A water inflow of 35 cfs is recommended for the holding pond shown in figure 1 if water temperatures above 60°F. are to be expected during the holding period. This pond is 175 square feet in cross section and 35 cfs of inflow provides an average current velocity of 0.2 fps. Actually, of course, such a current does not exist immediately adjacent to the bottom but it has been demonstrated that this average velocity is sufficient to provide the pond with excellent disease inhibition qualities.

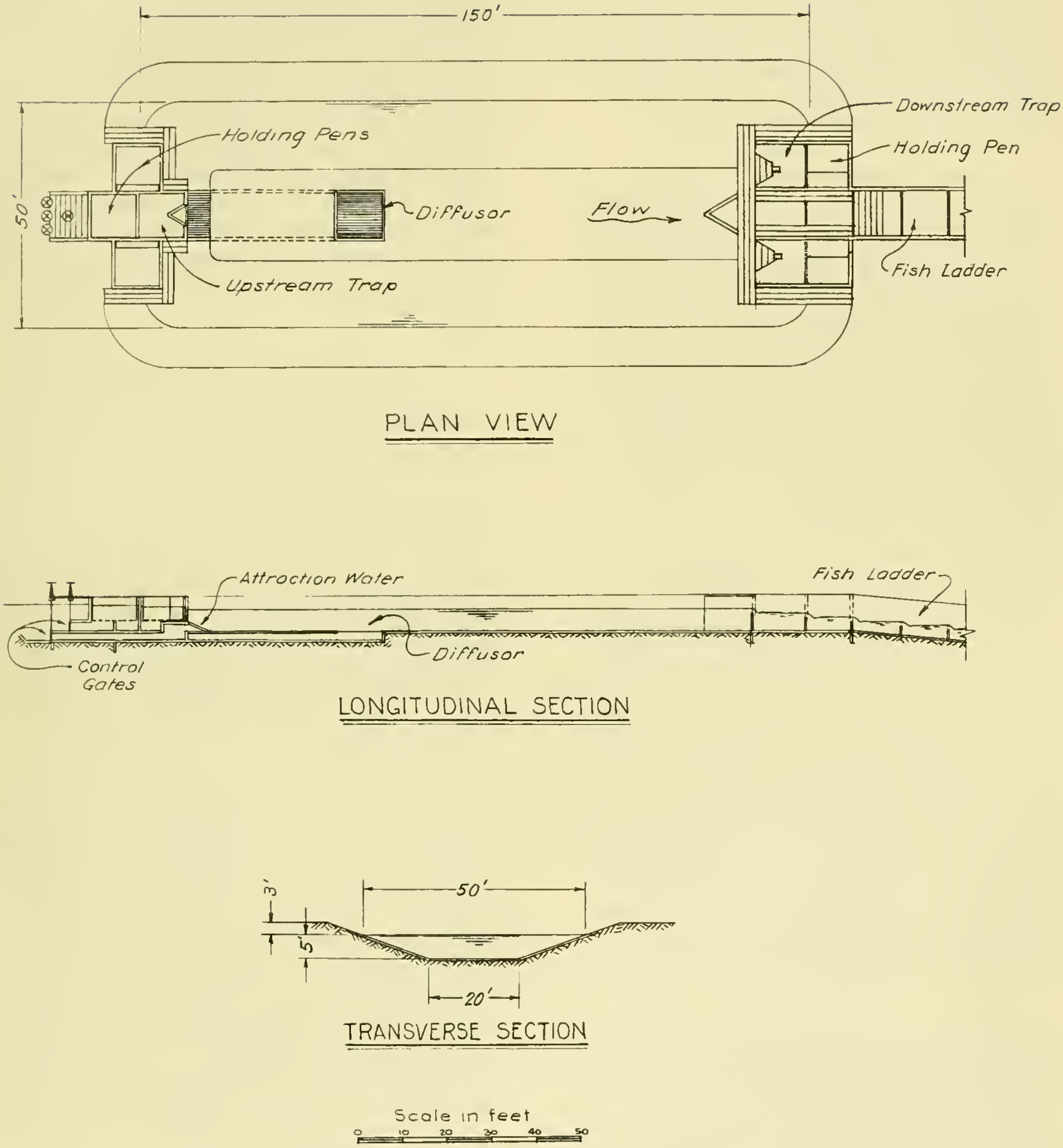

Figure 1:--Design drawings of a single holding pond giving dimensions of the pond, method of water introduction and withdrawal, and location of the trapping facilities.

At water temperatures below 60°F. the virulence of the major disease organisms is reduced and a lower rate of inflow is possible. Under such conditions a single holding pond of this type has been operated successfully on 12 cfs of inflow. Only rarely, however, will such conditions be encountered in salmon holding ponds and, even then, a higher inflow would be more desirable to provide adequate attraction water for the trapping systems.

Results of experimental holding -- This type of holding pond has been under observation at the Entiat Station for ten years. Maximum water temperatures during August varied from 62.5°F. to 72.5°F.. Adult chinook salmon, (O. tshawytscha) have been held from the middle of May until the last of November with an average holding period for individual races of three months. Blueback salmon (O. nerka) have been held in significant numbers only since 1954. This species has a holding period of about two months. During this testing period the condition of the salmon entering the ponds has varied tremendously due to the changing conditions encountered on the upstream migration. The survivals of chinook and blueback salmon, including both the holding and spawning period, are shown in tables 1 and 2. The maximum water temperatures encountered during each holding period are included in the tables. Statistical analyses of these data showed no significant correlation between either the water temperature and survival or the number of fish held and survival. Close surveillance of the fish during the holding period indicated that, in both species, the degree of debilitation at the time the fish entered the holding pond was the principal factor influencing survival. Fish which had deteriorated to the point where a fungus infection was apparent rarely recovered.

The survival records of the Leavenworth holding ponds are in marked contrast to those at Entiat. The same race of summer chinook salmon held in the Leavenworth holding ponds during the years 1940 through 1943, as reported by Fish (1944), showed survivals as follows: 1940-62 percent, 1941-18 percent, 1942-44 percent, and 1943-14 percent. Blueback salmon survivals for the same years were: 59, 5, 37, and 14 percent respectively. Comparing these data with the survivals in the Entiat holding pond, the worst survivals experienced at Entiat were comparable to the best at Leavenworth. With water temperatures similar, the difference in survival may be attributed, at least in part, to the difference in holding pond design. In fact, an experiment conducted at Leavenworth in 1943 was the basis for the present holding pond design. Blueback and chinook salmon held in a narrow, shallow, experimental pond with a perceptible current velocity showed marked recovery from injuries and resistance to disease when compared with similar fish held in the Leavenworth holding ponds. This difference in mortality was the first indication that adequate current velocities could improve the environment sufficiently to compensate for unfavorable water temperatures.

The Leavenworth holding ponds were dammed sections of the Icicle River stream bed. Three stoplog type dams each three feet high created three holding sections each approximately one-quarter mile in length. Although 75 cfs of water was diverted through these sections, there was no perceptible current. Water depths ranged from 2 to 10 feet and the width approximated 150 feet. Fish concentrated in the deep stagnant areas and losses due to disease were high. The Leavenworth type of holding pond is essentially a true pond with slight current velocity and a high degree of stratification while the Entiat type could be better described as a channel with a high current velocity and limited stratification.

Unlike the experience encountered in the Leavenworth ponds, fish which entered the Entiat pond with open wounds usually recovered rapidly. Only those fish which had massive injuries or were seriously debilitated before entering the ponds, as indicated by even a slight fungus condition, failed to recover during the holding period. The numbers of these fish increased during low water years and certain periods of dam construction on the Columbia River. Columnaris disease, while present and a significant factor in the mortality, did not reach truly epidemic proportions.

Carrying capacity

The capacity of the channel-type of holding pond is not known. The Entiat pond has held 1,700 fish, chinook and blueback, of varying sizes and an estimated weight of 17,500 pounds,

Table 1:--Survival of chinook salmon in the Entiat holding pond, 1950-1959

Year	Maximum Water Temperatures	Total Number Fish Held	Percent Survival		
			Males	Females	Total
1950	no data	657	54.6	72.6	63.8
1951	65.0° F.	690	95.2	79.5	90.2
1952	70.5° F.	805	90.3	81.6	86.5
1953	66.0° F.	1151	54.9	61.5	58.0
1954	62.5° F.	1472	82.5	76.3	79.3
1955	68.0° F.	898	73.7	83.3	77.0
1956	66.5° F.	571	95.6	90.0	93.8
1957	68.0° F.	930	88.2	90.4	89.2
1958	72.5° F.	874	86.9	94.5	88.5
1959	63.0° F.	651	85.0	89.1	86.3
		Average Survival	80.7	81.9	81.3

Table 2:--Survival of blueback salmon in the Entiat holding pond, 1954-1959

Year	Maximum Water Temperatures	Total Number Fish Held	Percent Survival		
			Males	Females	Total
1954	62.5° F.	250	73.6	89.6	80.4
1955	68.0° F.	200	91.3	97.2	94.5
1956	66.5° F.	195	100.0	94.2	96.9
1957	68.0° F.	220	89.9	91.6	90.9
1958	72.5° F.	382	91.3	92.5	91.9
1959	63.0° F.	438	85.3	94.7	89.7
		Average Survival	90.2	93.3	90.7

with no evidence of overcrowding. On this basis, 25,000 pounds would be a fair estimate of the density at which the pond could be stocked. The volume of water introduced is more than adequate to meet the oxygen requirements of the fish. Fingerling chinook salmon require 0.5 ppm of oxygen per pound of fish per gallon of water inflow at a water temperature of 57°F. to maintain a normal activity level. There is no reason to assume that large adult salmon in practically a dormant condition will exceed the oxygen demand of fast growing, normally active fingerling even at water temperatures of 70°F.. Fry (1957) demonstrates that while the oxygen consumption in trout increases with temperature it also decreases much more rapidly, per unit of weight, with an increase in fish size. In chinook salmon fingerling the oxygen requirement increases .025 ppm per pound of fish per gpm per degree F. from 47° F. to 57°F. To provide an adequate margin of safety the oxygen requirement of the chinook fingerling at 57°F. was used to calculate the carrying capacity of the inflowing water for the adult fish. On this basis it is estimated that 35 cfs of oxygen-saturated water at 70°F. will maintain 126,000 pounds of salmon, i.e., 5,000, 25-pound chinook or 21,000, 6-pound blueback salmon, without additional aeration and still leave 5 ppm of oxygen at the outflow. Such an inflow would be more than adequate to prevent the accumulation of deleterious concentrations of excretory products as the fish are not feeding and practically quiescent.

A single pond of the dimensions shown in fig. 1 could not handle the carrying capacity of the water supply without exceeding the estimated capacity of the pond. There is no reason, however, why such ponds cannot be run in series and, with adequate aeration between ponds, the actual carrying capacity of the inflow increased.

Ponds in series:--Figure 2 shows the layout for a series of holding ponds of the channel type. In this plan the fish are directed into the individual ponds but move of their own volition. Once the fish are diverted into the fish ladder they are offered but a single upstream course to pursue. The earliest appearing fish are diverted into the upper pond by proceeding up the right fish ladder. When the capcity of this pond is reached the course of the water is changed by activating the second pond and the fish proceed up the left fish ladder. In figure 2, the next to last pond is fishing and the last pond is still inactive.

The number of ponds that would constitute a series would be dependent not only on the carrying capacity of the water supply but on the concentration and virulence of the disease organisms in the last ponds of a series. High water temperatures could be expected to increase the virulence of diseases. An infected water source would increase the incidence of disease. The condition of the fish as they entered the ponds and the length of the holding period would have a significant effect on the survival rate and the number of ponds used in series. With water temperatures in the low seventies and a preinfected stock, I would estimate that at least four ponds could be operated in series. Under more favorable conditions, such as water temperatures in the low sixties, I believe that six and possibly eight ponds could be operated in a single series with a 35 cfs inflow.

Adaptations:--With a smaller inflow available the holding pond may be reduced in cross-sectional area to maintain the desired .2 fps of average velocity. The maximum practical reduction would be a pond 25 feet wide by 3 feet deep, increasing the length to 200 feet, but retaining the 3 on 1 slope of the banks. Such a pond would have a cross-sectional area of 48 square feet and require approximately 10 cfs of inflow. The holding capacity of this pond, based on the area of water 3 feet in depth as compared to the area 3 feet or more in depth in the large pond, would be 30 percent of the larger pond. Area rather than volume was used as the criterion because the fish tend to stratify in a single layer rather than utilize the entire pond volume. On this basis, the small pond should hold approximately 7,500 pounds of fish. The carrying capacity of the 10 cfs water supply, however, is 36,000 pounds. Smaller ponds in series, then, could be employed to use the total capacity of the water supply. It will be noted that the length of the smaller pond has been increased to 200 feet. The increase in pond length is desirable in order to more efficiently utilize the trapping facilities.

If large numbers of fish, different species, or races within a species are to be held , the use

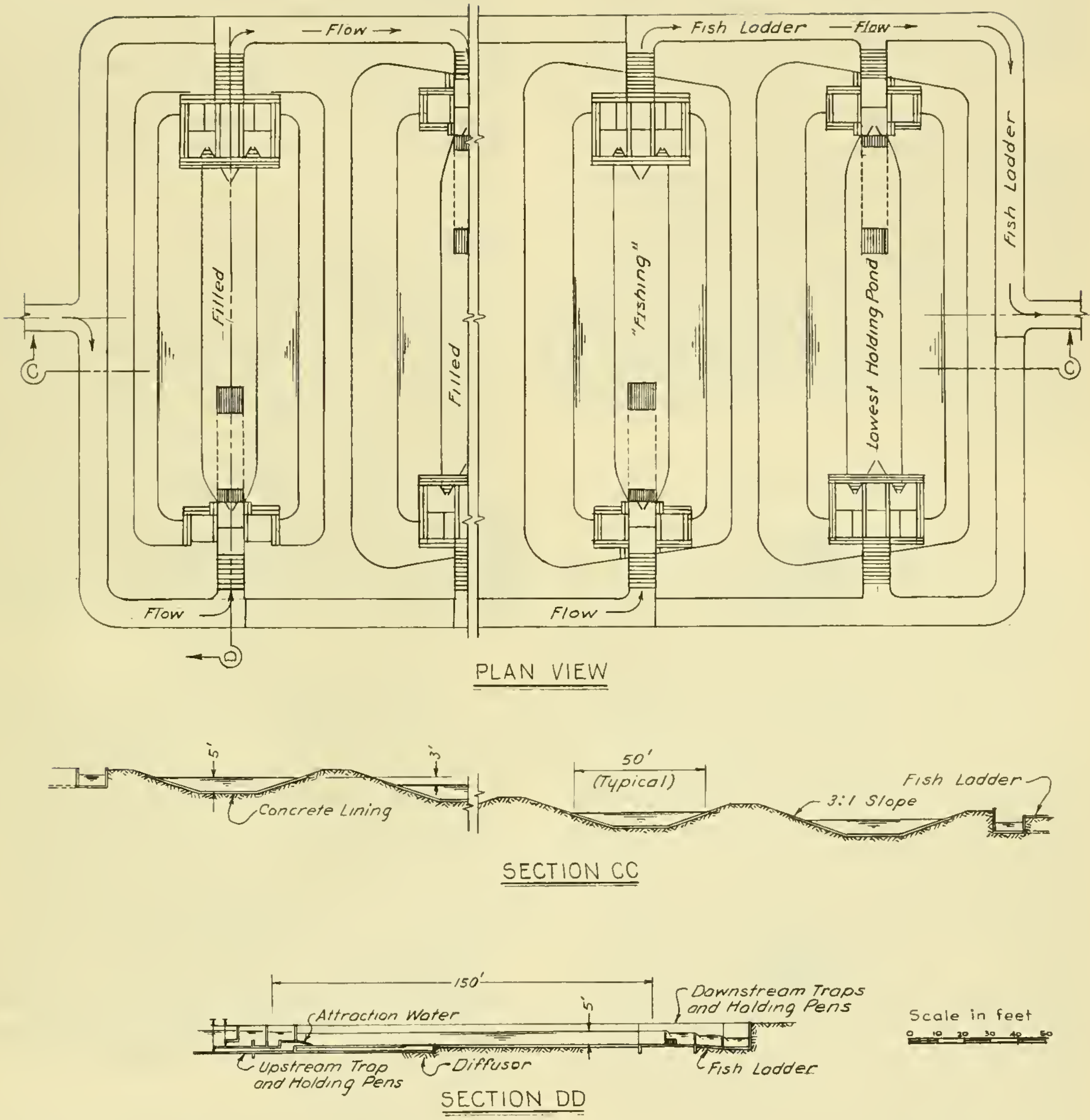

Figure 2:--Plan for operation of holding ponds in series showing double fishway system.

of a series of ponds of the dimensions shown in figure 2 in preference to a single long pond is recommended. One advantage is that the fish are segregated according to time of appearance which rather grossly separates races and species and tends to shorten the spawntaking period within an individual pond. A second advantage is that the capacity of the trapping facilities within a pond is not exceeded with the smaller concentrations of fish.

The retention of the adult fish until sexual maturity is one problem for which the channel type of holding pond offers an effective solution. The design prevents self-inflicted injury, and rapid passage aids in disease inhibition. A second problem, that of the capture of the sexually mature fish for spawntaking, is of equal importance to the holding problem. If proper methods of capture are not employed, the effectiveness of successful retention can be nullified by the mortality incurred during the spawntaking period.

HOLDING POND TRAPS

Capture of the sexually-mature salmon for egg-taking operations is complicated by several characteristic environmental and physiological reactions of the maturing fish. The spawning migration of salmon may be either upstream or downstream and consists of a movement of but a few feet or several miles. A species or a race within a species may move predominately upstream or downstream in its migration but this does not preclude the possibility of individuals within a group differing from the majority. Sexual maturation is influenced by both light and temperature. Combs et al.(1959) have demonstrated that light is the dominant factor but temperature has a definite effect. Unseasonably warm or cold temperatures may delay the spawning migration but not necessarily sexual maturity. Sexual maturity does not occur simultaneously in all fish within a race or species of salmon. Usually within a race the spawning period is confined to a single month but where several races and species are involved it is possible to have sexually-mature fish occurring over a six-month period. These factors affect the capture of mature fish for egg-taking operations.

During the spawning period, salmon are still susceptible to injury and disease. At this time mortalities as high or higher than those during the holding period can be induced by improper handling. Regardless of the race involved, if the temperatures are high and the fish are repeatedly handled to check for ripeness, few of the late-spawning females will survive to maturity. At water temperatures in the sixties the losses can be disastrous. At low water temperatures, in the forties, losses may be light enough to be tolerated. Any method of capture which will reduce handling to a minimum is to be preferred.

Holding pond trap design

Trapping has proved to be a most effective method of capture of sexually mature salmon in holding ponds. Certain characteristic reactions of the confined fish make trapping particularly feasible. For the first week or ten days of confinement in holding ponds the salmon are extremely restless, cruising the pond, seeking an avenue of escape. After this initial period the fish settle down in the deeper areas. As sexual maturity approaches, the female followed by one or several males begins the spawning migration. It is on this migration that the fish may be successfully trapped.

The extent and persistance of the desire of certain individuals to move downstream on the spawning migration was not realized when the Entiat holding pond was designed and constructed. Only a single upstream trap was included in the original installation. As a result, some fish refused to enter the upstream trap and natural spawning in the pond occurred. The pond has since been altered to include two downstream traps in the positions shown in figure 1. After their installation approximately 60 percent of the summer chinook and 35 percent of the blueback salmon have been taken in the downstream traps and natural spawning within the pond has been virtually eliminated.

Both upstream and downstream traps are considered advisable in any holding pond installation. Figure 3 shows the recommended design for the upstream trap and figure 4 the design for the downstream traps. In both designs holding

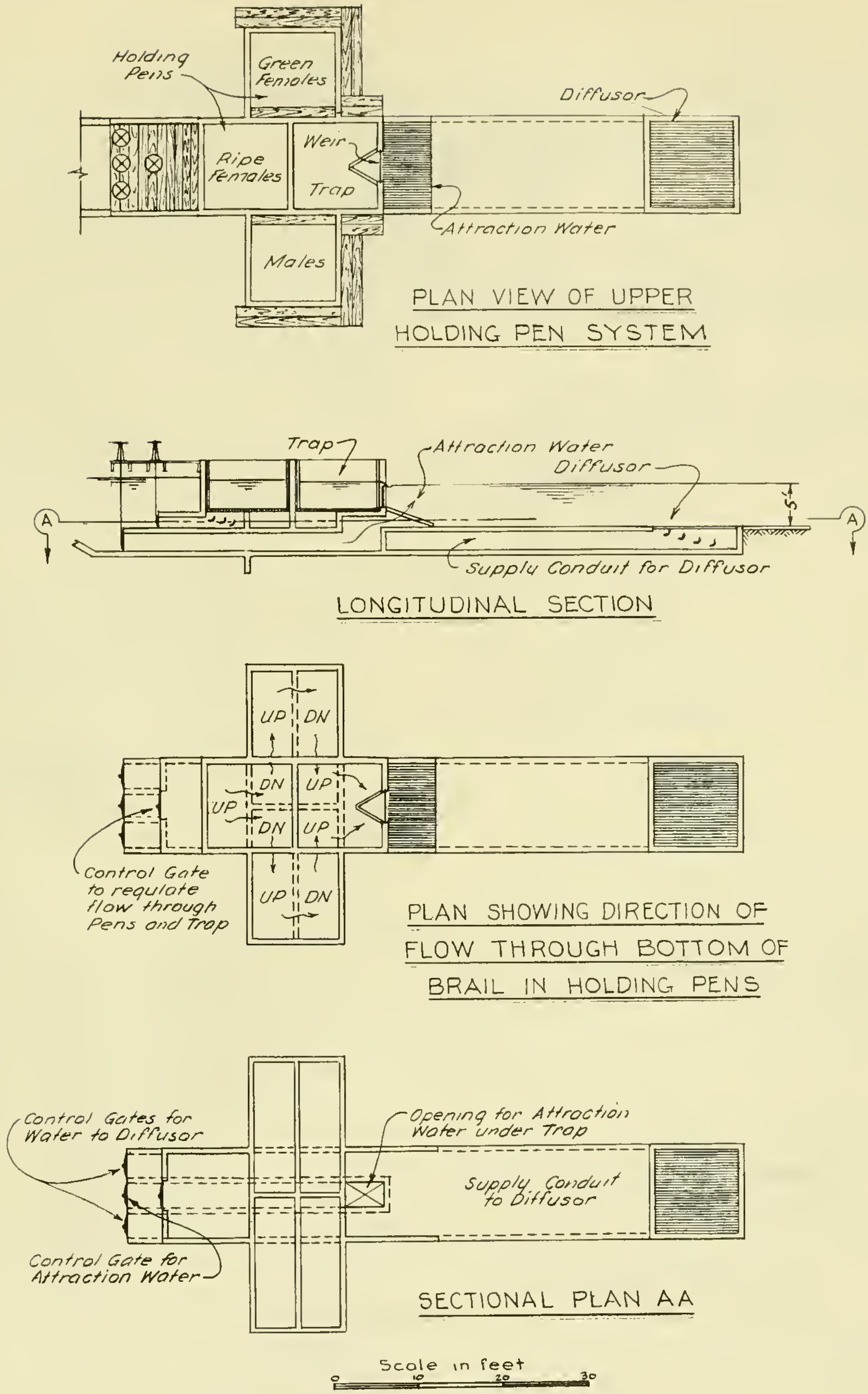

Figure 3:--Design drawings of upstream trapping system including trap and holding pens. The water path through the holding pens and trap is indicated.

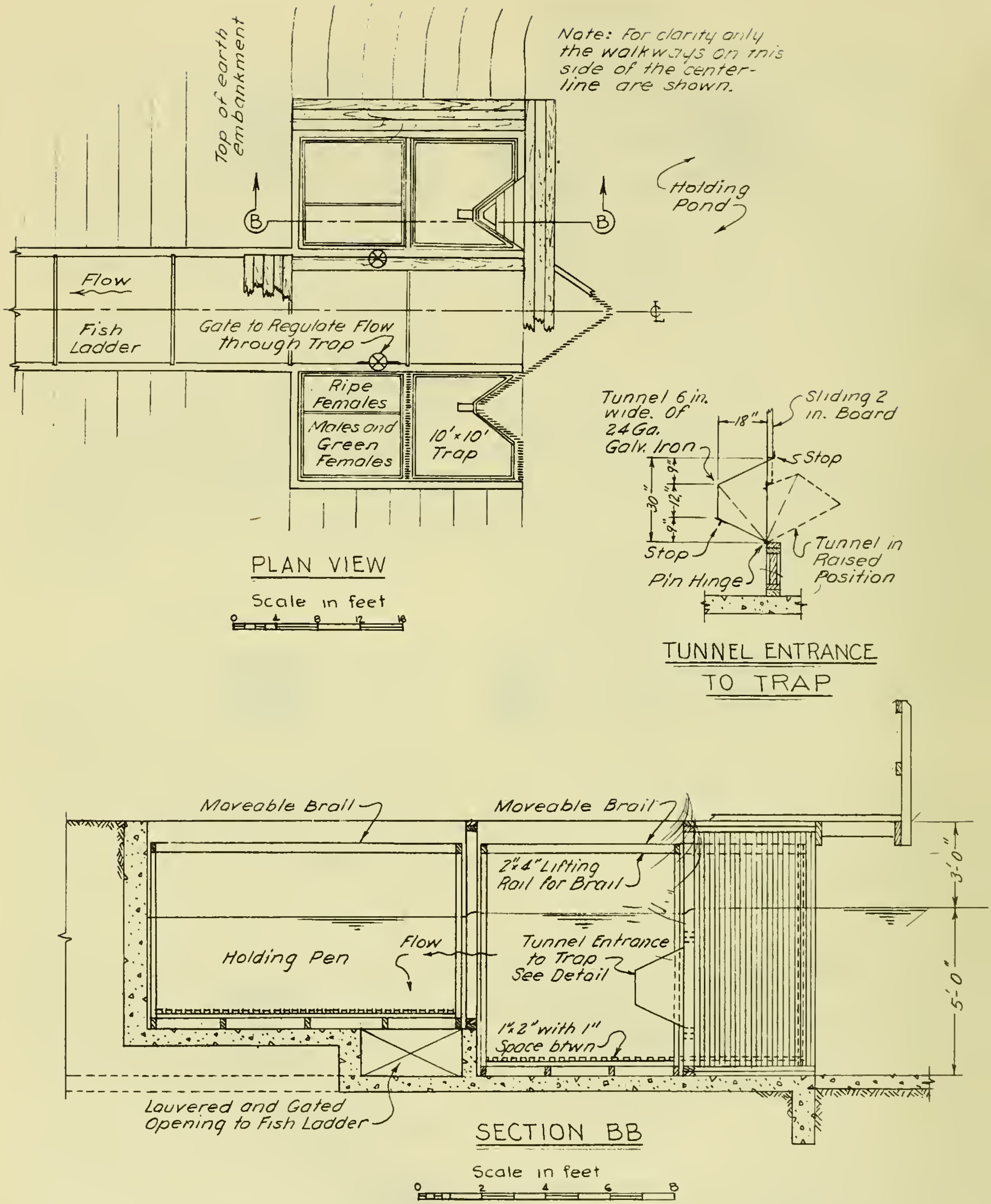

Figure 4:--Design drawings of downstream trapping system including trap and holding pen. Details of the tunnel entrance and flow pattern are shown.

pens are included. Females entering the traps will not be more than 3 or 4 days from ripeness unless the pond is still receiving fish while trapping is in progress. Under the latter conditions immature fish may enter the traps. Females more than 3 or 4 days from maturity should be returned to the pond, those approaching ripeness are held separately from those fully mature. The holding pens are used to segregate the green and ripe females and retain the males. The ripe pens are essential in order that the fully mature females may be held an additional day before taking the eggs. All pens and traps are equipped with brails or false bottoms to facilitate the manual sorting of the fish.

The upstream trapping system: -- The introduction of water into the upstream holding pens and trap, as shown in figure 3, employs the diffusion principal. The sidewalls with the exception of the picketed entrance "V" are solid and the water directed by means of conduits and baffles. The water upwells through the brail in the upstream half of the ripe pen, is withdrawn through the brail in the downstream half of the pen, divided and diverted into the two side pens in the same manner, upwells through the upstream half of the trap and flows through the picketed "V" into the pond. The upstream trapping system is designed to operate on approximately 15 cfs of water with the remaining 20 cfs diverted by conduit to the sloping diffusion panel at the trap entrance to provide attraction water when the trap is in operation.

The downstream trapping system: -- The water pattern in the downstream traps, as shown in figure 4, is practically the reverse of that employed in the upstream trapping system. In the trap itself only the sidewalls and bottom are solid with the water entering through the vertical picket sections of the trap face and "V" and passing through a second vertical picket section at the downstream end of the trap into the holding pens. In the holding pens the water is withdrawn through a bottom conduit discharging into the fish ladder. The depth of water in the pond and the flow through the downstream traps is controlled by the height of the upper set of stoplogs in the ladder and the conduit gates which discharge below these logs. Flow through the traps is regulated to approximately 10 cfs each, during trapping operations.

The angle to the current of the main "V" is continued in those of the two downstream traps. The trap entrances must be restricted by means of the swinging tunnel, shown in figure 4, otherwise large numbers of trapped fish will find the entrance and escape. The use of the tunnel-type entrance, however, has proved very effective in the retention of the trapped fish. When built to the specifications shown, the tunnel will retain fish from 2 pounds to 60 pounds in weight without impeding the ingress of the larger fish.

All traps and pens are equipped with removable, framed, folding, canvas covers. The darkness and protection provided by the covers cause the fish to rest more quietly in both the traps and pens. While the diffusion method of water introduction is designed to reduce jumping at the inflow, some fish may jump at the straight sidewalls of the traps and pens. Should jumping occur it may be necessary to float wide, canvas strips on the water surface. Salmon recognize an obstruction located at the water surface. The fish will attempt to jump through a similar barrier located even two or three inches above the water surface.

Operation of the trapping facilities

Approaching ripeness in the female is indicated by a constriction of the generally distended abdomen in the area directly anterior to the vent, a general restlessness as indicated by cruising in the shallow areas of the pond, and interest by the males. When these symptoms are first shown by a few fish it is time to activate the traps by opening the "V"s and rerouting the water through the trapping system.

Routine procedures: --Once spawning operations are underway the daily routine in the upstream trapping system is as follows:

1. The brail in the ripe pen is raised and the males and females spawned. This procedure empties the ripe pen.

2. The brail in the green pen is raised, a movable separator introduced, the fish sorted, and the ripe females transferred to the ripe pen.

3. The brail of the trap is raised and the fish sorted, ripe females into the ripe pen, green

females into the green pen, and males into either the male pen or the ripe pen to conform with the number of ripe females available.

4. If necessary the brail of the male pen is raised and the required number of males transferred to the ripe pen.

A similar routine is followed in the downstream trapping systems with the exception that males surplus to the daily requirement are either held in the green pen or transferred to the male pen in the adjacent upstream trapping system. By raising the brails until the water is only a foot in depth the sorters can get in with the fish, catch, check, and place them in any desired pen.

We have found the practice of retaining the mature females an additional day before spawning to be a practical, efficient procedure. All eggs are not freed from the follicles simultaneously but ripeness progresses from the posterior portion of the ovary forward to the anterior end. In large, heavy-walled fish in particular, all external symptoms, even the free flow of eggs from the genital pore, may indicate ripeness, but when the fish are killed, a portion of the eggs in the anterior end of the ovary may not be free from the follicles. Under normal conditions retention of the fish for an additional 24 hours insures complete maturity. With complete maturity the percentage survival of the eggs is also increased. The time required for spawntaking is reduced because the eggs fall freely from the follicles. Ripe pens in the trapping system are considered essential if unwarranted losses in both fish and eggs are to be avoided.

Abnormal situations:--Normally the combination of upstream and downstream traps will remove all the fish from the holding pond and seining of the stragglers is not required. When exotic races are held in an abnormal environment, however, the spawning desire may be submerged and seining required. This type of situation occurs in the Entiat holding pond where an exotic run of late-spawning summer chinook salmon has been developed. These fish normally spawn in the main Columbia River and the lower reaches of large tributary streams from the first of October to the last of November while water temperatures are still above 40° F.. The Entiat River which supplies the water to the holding pond usually drops abruptly to below 40° F. the forepart of November. When this temperature drop occurs the female chinook apparently lose the spawning urge. Although the process of maturation continues, the fish are lethargic and if left undisturbed will become overripe and eventually die without making any attempt to enter the traps or construct spawning redds in the pond. Under such conditions repeated seining is necessary in order to procure the ripe females. Fortunately the cold water temperatures impede disease development and if the fish are handled carefully no mortality results.

A similar effect has been noted when unseasonably warm water temperatures occur during the spawning period. Trapping activity practically ceases. However, a drop in water temperature reactivates the migration tendency and an abnormal influx of ripe and overripe fish is the result. Seining should not be considered under these conditions as catastrophic mortalities could be the result.

Installation of trapping facilities increases the initial cost of the holding pond but also reduces operating costs. A two-man spawning crew can operate two or three holding ponds. By no other known method can the fish be removed from holding ponds as efficiently.

The trapping systems described above offer the best method developed to date for the procurement of the sexually mature salmon from holding ponds. The method takes advantage of the instinct of the fish to search for a spawning site and thereby segregates the immature and mature fish without excessive handling. Because handling is avoided mortalities are reduced. The trapping systems are a necessary and indispensable adjunct of the channel-type holding pond because of their contribution to the reduction in mortality of both fish and eggs.

CONSTRUCTION

The design drawings, figures 1-4, indicate concrete construction of all permanent facilities including the holding pond itself.

Concrete is desirable but not necessary, particularly in temporary or experimental installations. The holding ponds themselves can be roughed out of the material available. Preferably they should be brought to grade and lined with clay. Gravel bottoms and sides are to be avoided if possible. The conduits and walls of the trapping systems and fishways may be made of heavy planking. The Entiat traps and ladders are of wooden construction and, surprisingly enough, are still in fair condition after 10 years of use. While substitutions may be made in the materials of construction, alterations should not be made in the design without previous experimentation to determine the reaction of the fish.

SUMMARY

Holding ponds of the channel-type offer a most efficient method for the retention of adult salmon if the interval between the upstream and spawning migration is longer than three or four weeks. The channel-type pond is designed to minimize self-inflicted injuries by means of a submerged, diffused water intake and sloping pond banks. Disease inhibition and recuperation are enhanced by means of a favorable environment in which an average current velocity of 0.2 fps is maintained at least during periods of high water temperature. Rapid water passage is demonstrated to be as effective as cold water temperatures in disease inhibition. In the Entiat holding pond no correlation exists between holding survivals and the maximum water temperatures encountered over a 10-year period. The average survival for chinook salmon of 81 percent is much superior to that encountered in other types of holding ponds. In order to fully exploit the carrying capacity of the water supply, it is suggested that the holding ponds be operated in series.

Upstream and downstream trapping systems are an essential and integral part of this holding pond. Salmon on the spawning migration move either upstream or downstream. If both types of traps are available the mature fish may be captured with a minimum of handling. Because injury to the fish is avoided, losses during the spawning period are reduced. The trapping systems employ holding pens for the retention of the segregated ripe and green females. Ripe females are held for an additional day after all symptoms of sexual maturity are present to insure fully mature ovaries. More eggs per female and increased egg survival are the result of this procedure.

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