ARTIFICIAL SALMON SPAWNING

A Manual

By William W. Smoker
and
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Second Edition

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INTRODUCTION

This manual is designed primarily for the aquaculturist who is just getting started, but it includes tips that should be helpful for veterans as well. The procedures described aren't necessarily the only correct ones. They may be more time-consuming than others. But they are procedures that are least likely to go wrong for the novice egg-taker. With time and experience, changes may be made to suit individual situations.

Even the "Rules of Thumb" presented here are not necessarily hard and fast rules. Not all of this volume's recommended procedures have been scientifically tested; but they have been field-tested, using incubators filled with live eggs. Much of this advice stems from experience gained from egg-takes conducted by the Prince William Sound Aquaculture Corporation, the Southern Southeast Regional Aquaculture Association, the Northern Southeast Regional Aquaculture Association, the Fisheries Rehabilitation, Enhancement and Development Division of the Alaska Department of Fish and Game; Douglas Island Pink and Chum and from other local private nonprofit hatchery personnel.

FISH BEHAVIOR DURING MATURATION

Pink and chum salmon that spawn near tidewater go through three fairly distinct phases as the time of spawning approaches.

FIRST STAGE OF MATURATION

As salmon approach their natal (home) streams they continue physiological changes that started with development of gonads the previous fall. As they move closer to their home streams, feeding activity decreases, and finally stops. Their bright silver color starts to fade. When the fish are still two to three weeks from spawning, they begin the first stage of maturation. Usually their color has changed from bright silver to a spawning color pattern characteristic of their species. Humps are becoming well-developed on male pink salmon, and the female pinks are darkening. Usually, they are still found in saltwater, milling around at or near the stream mouth in schools of 50 or so. At high tide, especially in the evening, they tend to move closer to the stream, often entering the creek mouth, then move back out as the tide recedes.

SECOND STAGE OF MATURATION

After a couple of weeks, fish enter the second (almost mature) stage, staying in water as close to fresh as available, oftentimes in large schools. The fish spend more and more time in the freshwater plume created by the creek discharge. Their color has turned a much darker green or brown. In larger streams the fish will move into fresh water, and remain in stretches of deeper water, headed into the current. In small creeks, the fish continue to move in and out of the plume until spawning time (third stage) arrives. The fish are quite dark, almost black in the case of pink salmon, while chum show bright magenta blotching. In small creeks where straight freshwater holding areas are unavailable, the fish will move into spawning areas at the head of an incoming tide. As the tide recedes, the fish remain and spawn. In larger streams the fish will move from the deeper water into the spawning areas.

THIRD STAGE OF MATURATION

As the spawning time nears, the female will select an area in which to deposit her eggs, guarding the territory against other females. There she will dig shallow depressions in the stream bed, clearing it of silt and sand. To dig, the female turns at an approximate 45 degree angle from the vertical and vigorously moves her body back and forth. While digging her

nest (redd), a fair amount of gravel is moved about. Consequently, the stream bottom often is very irregular. Males also head for the spawning area, but their activity differs. The males are not thought to take part in building the redd, but rather are establishing an order of dominance with other males. Once the redd is complete and the female is ready to spawn, a male will arrive. This is the third phase (mature). Both sexes guard the redd from intruders.

The fish spend about 2.5 weeks in fresh water, with the males entering somewhat earlier than the females.

CAPTURING AND HOLDING ADULTS AT REMOTE SITES

Before gathering brood stock you need to have a clear idea of your objectives. One item that has to be determined is the ratio of males to females.

MALE:FEMALE RATIOS

The purpose of remote eggtakes is to develop a brood stock sufficient to create a run of fish that will sustain itself for many generations. Certain procedures should be followed to minimize potential genetic problems. Salmon hatcheries are difficult enough to operate without basic problems such as inbred stock that can have a reduced ability to survive.

Inbreeding problems are acceptably small if the <u>effective population size</u> is greater than 400. Effective size is calculated by multiplying the number of males by the number of females, dividing the product by the sum of the number of males and the number of females, and then multiplying the resulting number by four:

$$N_e = \frac{4\ N_m\ N_f}{N_m + N_f}$$

where;

N_e = effective population size

N_m = number of males

N_f = number of females

Rule of Thumb No. 1. If taking eggs from fewer than 200 females, take milt from two males for each female if possible. Take milt from one male for each female if spawning between 200 to 300 females. Use one male for every two females if 300 to 500 females are being spawned. For larger eggtakes, use one male for every three females.

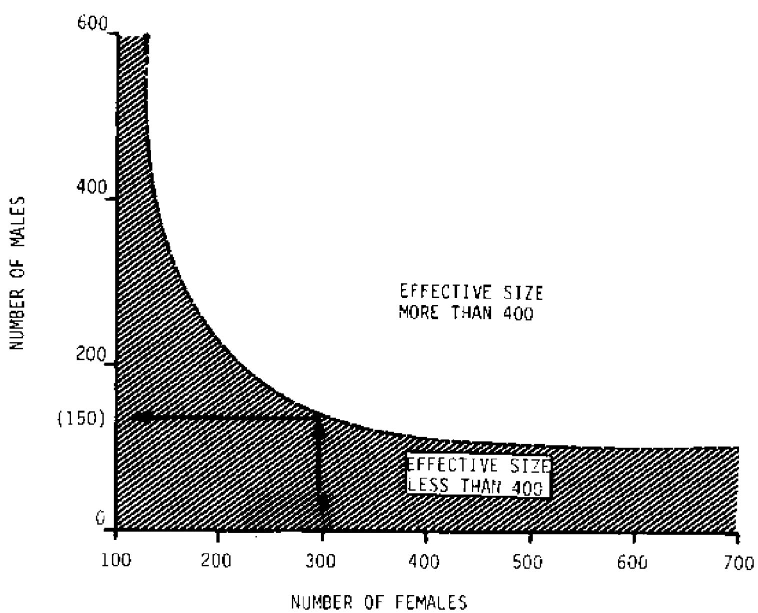


Figure 1. Numbers of spawners required to make the effective population size (N_e) larger than 400 when few spawners are available. The area formed by the dotted lines shows an example: if 300 females are spawned, 150 males must contribute equally in order for N_e to be 400. (Based on a graph prepared by Dr. Robert Davis, principal geneticist, FRED division, Alaska Department of Fish and Game.

Your objective is to start with an effective spawning population of 400 fish, in accordance with Alaska Department of Fish and Game policy. Ideally, you should have at least 125 males. Taking this number of adults will help prevent inbreeding problems that might occur if fewer males are used; and as the size of your eggtake goes up, it's possible to use fewer males than females.

Try to avoid taking all your fish at just one stage of the run. Instead, take fish in a ratio proportional to the natural run: a few during the early stage, most during the height of the run, and a few during the latter part of the run. The idea is to maintain genetic diversity and not alter the run timing. If you can take fish during only one portion of the run, however, the height of the run is probably the best time.

Rule of Thumb No. 2: Take fish randomly.

Resist the temptation to take only the largest, heaviest fish since the smaller ones also may contribute to the health of the population. If the run has more fish than you need for spawning, randomly select the fish used. For example, if there are three times as many males as needed, take every third male you come across in the net, not just the big ones. Do the same for females if there are enough of them. And don't select for any one characteristic. (Animal geneticists commonly use as many as ten characteristics to form the basis of a selection program. Salmonid genetics is not nearly well-enough understood to design a selection program.) Remember, artificially spawned salmon must compete in the wild, unlike domesticated animals.

PERMITS

In Alaska, if you are planning to move fish or eggs to be used in propagation, you will need to secure a fish transport permit. A disease history is generally required. This can take some time, so you should plan accordingly. Contact your local Alaska Department of Fish and Game office for details.

CAPTURING FISH AT REMOTE SITES

During the first years of your hatchery operation, you probably will have to travel to a remote site to take your adult fish for brood stock. There are three main ways to collect brood stock at remote sites, corresponding to the stages of maturation: seine near the stream mouth, catch fish from within the stream in pools or riffles, and collect fish from redds (nests).

Stream Mouths

In some cases, the easiest way to catch spawners is at a creek mouth at high tide using a small seine. A herring bait seine operated with a couple of skiffs usually is effective. If the topography is suitable and the run large enough, you may be able to use a commercial seine and capture all the adults you need in a few sets. (Figure 2).

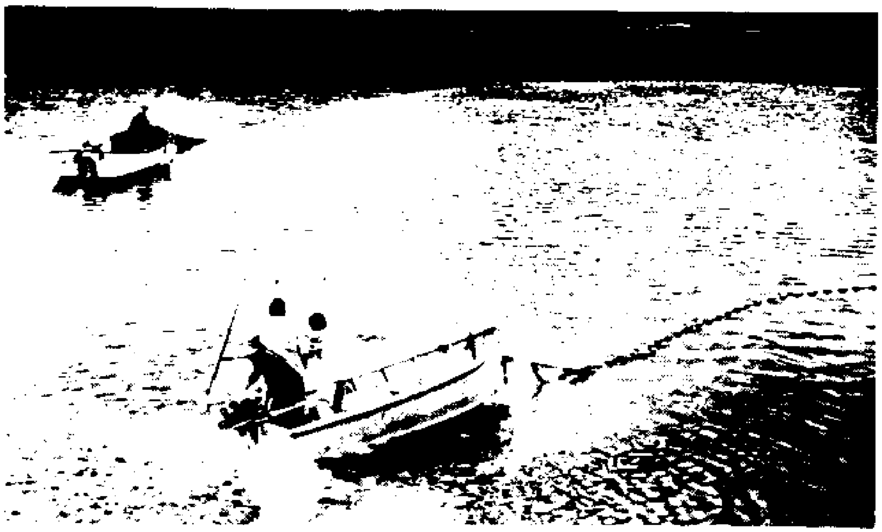


Figure 2. Skiffs seigning.

In Streams

In other situations, particularly involving streams with the large, relatively flat intertidal areas that are typical for chum, fish will have to be caught in fresh water. Long poles tipped with large hooks or wire loops are fairly effective, particularly if a relatively small number of eggs are sought. For large or often-repeated remote eggtakes, electroshockers have proven to be an excellent tool. Fish also can be seined from streams, or the stream can be closed off with a weir.

Seining

Seining is most effective on fish that are holding in pools or riffles. Once the salmon move into the redds, seining becomes rather difficult. Fish, especially females, are missed even if the net is heavily weighted on the lead line (bottom), due to the irregularity of the stream bed. A seine will pass over the fish in the deeper pockets. About the only technique that works on the redds is to station people every two or three feet, each with the toe of one boot wedged in between the lead line and the bottom of the seine. Another disadvantage of using a seine with nearly-ripe and ripe fish is that during the process of maturation, salmon teeth and jaws lengthen to form the characteristic kype, or "hook". Consequently, if you attempt to use a net with fairly open mesh, say 1.5 inches or larger, fish invariably will hang-up in it. And of course they twist and turn until free or dead. If you use a net with mesh fine enough to avoid entanglement, the resistance to current flow makes the net difficult to manipulate. Immature fish must be held until fully ripe.

Despite the disadvantages of nets during normal water conditions, it is still not a bad idea to have one along in case of storms. When the water is deeper and more turbid, it can be almost impossible to spot fish, even when they are spawning.

Weirs

If large numbers of eggs are desired, and the stream you have selected is suitable (relatively stable flows, fairly flat with considerable upstream movement of fish from a prospective weir site), you may be able to use a weir. Weirs can be constructed from a variety of materials such as pipe, wooden slats, or wire fencing, as long as they are sturdy. Moving water carries considerable force. You should construct the weir so that the materials on the upstream side are slanted from the vertical toward downstream. That way the current tends to force debris to the top of the water where it is much easier to spot and remove before blockage occurs.

Weirs block upstream movement of fish. Oftentimes weirs are placed at a 15° to 30° angle to the stream flow. The fish, attempting to move, are led into the point of the weir furthest upstream. A capture box with a "V" inlet retains the fish. From there, they are brailed into holding pens.

On Redds

During the last phase of maturation (once fish move onto redds), poles equipped with a hook or wire loop on one end, or electroshockers work much better than nets.

Poles

Hooks have the disadvantage of killing fish, but are effective. Halibut hooks (size 8/0 to 10/0 for pinks and 10/0 to 12/0 for chum), tightly wired on to the poles and carefully sharpened, work well. If you file off the barb before using the hook, fish that are not kept will sustain less damage, but at the cost of wounding and losing other fish. Keeping the barb probably is best.

The basic technique is to spot a fish on a redd, and slowly guide the hook along the bottom, barb up, toward the fish. Once the hook is a foot or slightly more away, make a rapid plunge toward the fish. Just as the hook reaches the fish, raise both arms and pull the hook upward and backward. Walk quickly toward shore, swinging the fish shoreward as you go. With practice, almost all of the fish can be struck in the head. If you hook fish in the abdomen, you will destroy eggs.

Wire loops require greater skill and stealth but only minimally damage unwanted fish. Loops can be made from plastic-coated, braided stainless steel or other wire that is stiff enough to hold a loop, but sufficiently flexible to be drawn tight. Poles with wire loops also can be purchased in various lengths from sport fishing catalogs. (Anglers land steelhead and Atlantic salmon with them.) They are used by very carefully leading the loop toward the tail of the fish from downstream. Once the loop is over the fish, raise the pole firmly and retreat toward shore holding the tail of the fish above water.

The poles should be light and strong. Dip net handles, 1.5 to 2 inches in diameter work well. Some brands come in 4 to 6 ft lengths that snap together. Usually a 10 to 14 ft pole is sufficient.

Electroshockers

Electroshockers are becoming the chosen instrument of persons who have to take large numbers of fish from streams where seining or weiring is not possible. While electroshockers are fairly expensive, their cost can be spread over several years.

The basic technique is for one person to carry the electroshocker strapped to the back. (WaterPROOF waders are mandatory for all persons in the water near an electroshocking operation, otherwise a dangerous electrical shock can result.) The cathode (negative pole) trails in the water. The anode (positive pole) is held at some distance from the other electrical pole. This sets up an electrical field which stuns or kills fish between the poles. One or two persons work downstream netting fish. (Special fiberglass insulated dip nets must be used to avoid shock while netting.)

Since electroshockers are potentially dangerous, it is best to secure the help of experienced persons for your first use. Follow the manufacturer's instructions closely. Observe all safety precautions. Make sure your equipment is functioning properly, especially the tilt and main switches. If your chest waders become wet inside, STOP electrofishing and let them dry out. Wet boots can conduct electricity. Use electricians' gloves that reach at least to the elbow, with a voltage rating equal to that recommended by the electroshocker manufacturer. If they become wet, STOP electro-fishing and let them dry out. (If you are collecting fish intertidally, electrolysis can to corrode the anode, so have an extra anode on hand.)
Polarized Sunglasses: Sunglasses with polarized lenses are essential equipment for remote eggtakes. The slight advantage they give in spotting fish often means the difference between catch and no catch.

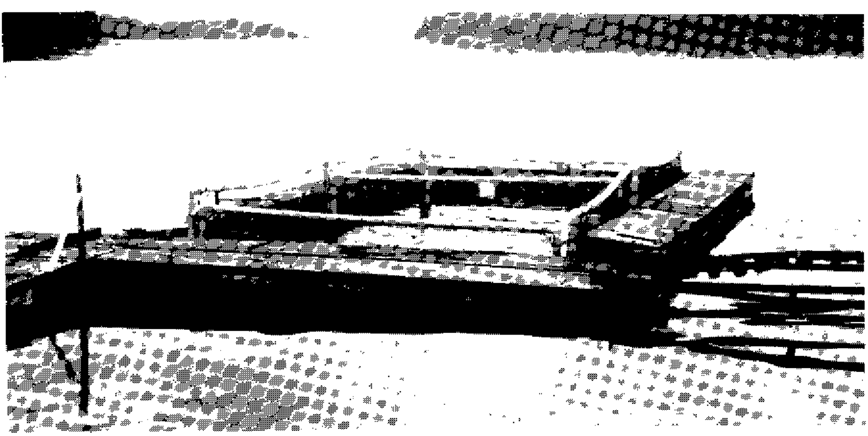


Figure 3. Floating pens.

Darker shades are recommended for bright light conditions, and yellow lenses for overcast days or other low light conditions. It does not hurt to have a pair of each, along with a spare yellow-lensed type. Glass lenses resist scratching but not crushing.

HOLDING ADULTS AT REMOTE SITES

Stream Mouths

Once caught, immature fish must be kept in holding pens until ripe. Pens supported by beach logs or floats that measure anywhere from 10 by 10 ft to 40 by 40 ft and are from 7 ft to 20 ft deep have been used with good results (Figures 3, 4, 5).

The size that is best for you depends upon the number of fish you have to hold, how long they have to be held, and the particular topography of your location. Large pens hold more fish but are more difficult to manage, particularly with small crews. Small pens can cause more damage to fish because they come in contact with more often in small pens than

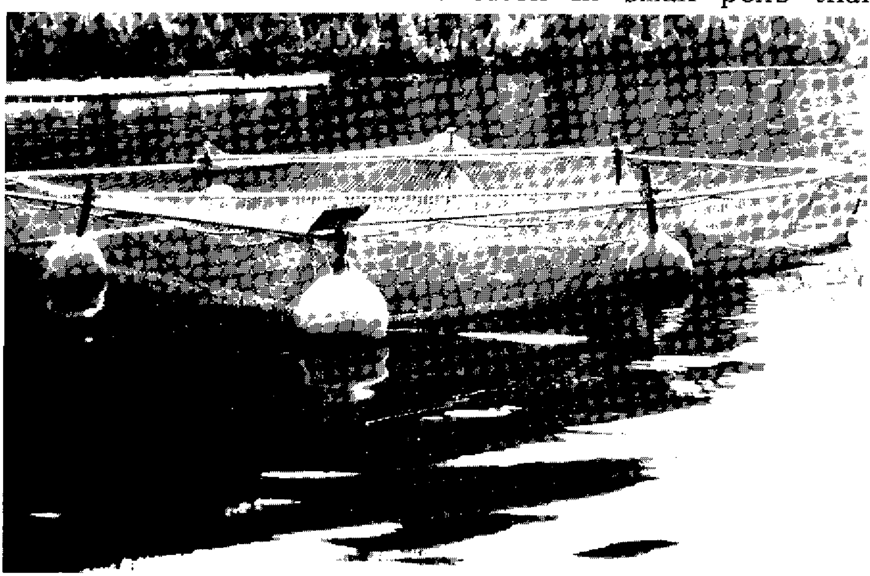


Figure 4. Floating pens.

they do in large ones. If you are planning to hold fish for extended periods, use white mesh for the pens. The fish do not appear to damage themselves as badly on white mesh as they do on dark webbing. Small mesh, ½ to 1 inch, seems to minimize entanglement, but sets up more resistance to current flow.

Floats can be made from beach logs with planks (unplaned or covered with asphalt composition roofing material for sure footing) spiked to the top. The top of the net should extend 2 to 3 ft above the water line to prevent fish from jumping out of the pen. If the remote eggtake is to go on for a number of years, it is safer and more practical to use floats 2 to 4 ft wide that fasten securely together. (The floats can be used later for fry rearing, or for holding cost-recovery adults.)

Pen walls can be held in place against tidal flows by using a rigid frame constructed of material such as 2 in. PVC plastic pipe, or saltwater-corrosion resistant aluminum. PVC is lighter and less expensive but requires more maintenance over the years. Another way to hold the pen walls out is to place weights at the corners. It helps if the weights are attached to bouyant line such as polypropylene. That way the weights can be removed before the net is dried just prior to fish handling.

You will need at least three pens: one for males, one for females, and the third kept empty to receive green females after they have been tested for ripeness. If at all possible, anchor the pens in the freshwater plume created by the stream. Fresh water helps speed the maturing process. Secure the pens well if there is any chance of storm winds or waves.

As salmon approach maturity, they become much more hardy and withstand a surprising amount of handling and crowding. Keep in mind, however, that they can suffocate if too many are jammed in a small space,

Figure 5. Floating pens.

especially at slack tide. For pink salmon, figure one to one-and-a-half fish per cubic foot of pen; for chum salmon stock, three-fourths to one fish per cubic foot. Use the lower densities when holding fish for more than a day or two, or if tidal currents are weak.

If the donor stream is fairly close, you may save time and effort by transporting the fish live to your hatchery site. Salmon will survive towing for fair distances in a pen at speeds of 1 to 2 mph, and for moderate distances at 2 to 4 mph. Try to time the tow so the tides are with you, or wait for the approach of slack water. If towing forces the fish against the rear of the pen for extended periods, losses can be considerable. Water velocity can also be lowered by slowing the boat. Closing some of the openings in the front of the pen by draping weighted plastic sheeting or some other material over it is another solution. You will create the equivalent of a displacement hull, so strong framing will be required. Otherwise, the netting will float upward, decreasing the space for fish. An easier solution is to use a net much larger than is required for holding, secure several weights along the leading edge of the net, and take it easy.

Holding Fish Within a Stream

Cages

Cages can be placed in the creek if you can find relatively quiet water (1 ft per second maximum current velocity) that is deep enough, say, 2 to 4 ft. If high water can be expected, pens should be located where they are protected from high current velocities, such as in a back eddy or side channel. The pens do not have to be large. A 4 ft by 7 ft pen with 3 ft of water flowing through it will hold 40 chum salmon for a week or more, and 60 to 70 for a day or two. This is because water is exchanged far more often and in an estuary with lower current velocities. Leaves or other debris can block off water flows; pens should be checked often, particularly over high water periods. It helps to have three or more pens to sort the fish.

Cages can be constructed from finely meshed, heavy nets lashed onto frames; but rigid, plastic-coated wire is more durable and reduces fish entanglement. If the target species is chum, use heavy-duty, plastic-coated wire. Netting or light wire often will not last the day. The pens should have hinged tops to help prevent fish from jumping out, or--during high water--swimming out of the pen. A way to block off the upstream side should also be provided, to protect pens from water velocity increases or high water.

Bear Hazard

Salmon spawning streams are natural habitat for bears. Give them the right-of-way and let them know you are coming. Seal bombs (small explosives) are a good way to announce your presence. These are available at commercial-fishing tackle shops. If you have a person along who is thoroughly experienced with firearms (guns in the hands of the inexperienced are far more dangerous than the average unprovoked bear), a large caliber rifle or 12 gauge shotgun loaded with 3 inch magnum, 00 buckshot should be carried for protection.

Handling

Fish approaching maturity are hardy and withstand a surprising amount of handling and crowding. But handle the fish as gently as possible, particularly if they are to be held for long periods, because eggs can be easily damaged. Brail the fish one at a time and do not throw them. Do not hold females head down because the pressure of the egg skeins may be too much for their heart. Picking up fish by the tail can also separate the vertebrae and can sever a main artery, thus causing internal hemorrhaging. Use two hands, cradling the fish next to your body.

HOLDING AND MATURING FISH AT A HATCHERY

VOLITIONAL MATURATION

Salmon demonstrate great determination to reproduce. Kypes smashed by boulders, backbones slashed by bears, eyes blinded by gulls, they remain resolute. Hatchery operators can benefit from applying knowledge about salmon behavior.

While a great deal can be determined about the average life stages in a particular stock of fish, remember that an average is the sum of the behavior of many fish, and does not indicate the state of individual fish. Left to its own choice, an individual fish will select its own best spawning time. Generally, behavior within species and stocks can be predicted, once the stock characteristics are known. If you construct your holding and maturing facilities to accommodate the stock's behavior, a great deal of labor can be saved. Additionally, the quality of the eggs you take should be excellent, with fertilization rates exceeding 95 percent.

Volitional maturation ("volition" means choice) involves providing hatchery habitats for the various stages of salmon maturation, allowing the fish to move freely ("choose") among habitats. The concept involves three basic rules (refer to Figure 6):

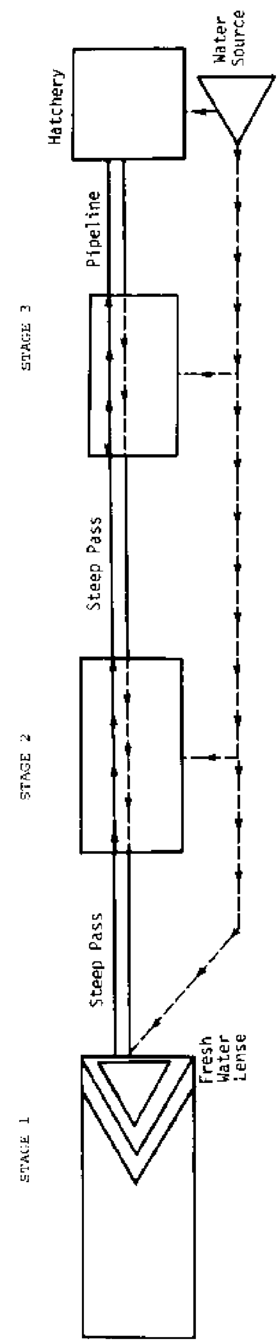
1. Restrain fish only as closely as necessary.

2. Provide for the three basic stages of maturation--green, almost mature, and mature.

3. Allow the fish to move among the three stages by their own choice.

Fish Restraint

Green (immature) fish are relatively susceptible to physical damage. They also frighten easily. A wound that will scarcely slow down a mature fish can kill an immature salmon. Consequently, a great deal more care is required in handling green fish than ripe fish. Ample space is required for green fish. Allow them plenty of room to move in when scared by sea gulls flying low over the water or by human activity. As the fish move into fresh water, holding density may increase. By the time they are ready to spawn, space is no longer a limiting factor. As long as the dissolved oxygen remains high enough (7 to 8 ppm) they can be packed tightly.



Degree of Maturity	Volume	Fish Density (lbs/ft³)	Salinity	Water Requirement (gal/min/ 22 lbs fish)	Water Source	Substraight	Substraight Color	Depth (ft)	Direction of Water Flow	Direction of Fish Movement	Comments
Green	Large	1 (low)	High (with a freshwater lens)	Discharge large quantities for fresh water lens.	Hatchery & stream	Natural	Natural	>6			Steep edge needed
Almost Mature	Medium	2 (medium)	Fresh	1	Hatchery & stream	Smooth	Light	4 to 8			Jump-out protection needed
Mature	Small	3 (large)	Fresh	1	Hatchery	Smooth	Light	3 to 4			Jump-out protection needed

Figure 6. Volitional maturation, conceptual drawing.

Stage 1

Each hatchery site has its own unique physical characteristics, so recommendations on facilities for immature stock cannot be specific. In general, however, you should provide as large an area as is practical for immature fish. This can be as simple as allowing the fish to move freely in salt water. That freedom, however, carries the danger of straying. You've worked too hard to just let your fish spawn elsewhere; if your brood stock was selected from stocks that differ, straying could be harmful to the local stocks.

One example of providing for the first stage is that of the Port San Juan hatchery. They use a 1,000 ft long herring seine to create an enclosure, called a corral, to separate the delta at the head of the bay into which their creek flows from the rest of the bay. At high tide about 8 acres are enclosed, at a minus tide about 3 acres. The fish destined to be used as brood stock are placed into the corral just after they are caught.

Shallow water, especially with any fresh water flowing into salt water, should be avoided. Fish will attempt to remain in or swim up the fresh water. They can become stranded as the tide recedes, or be attacked by gulls.

At locations that have a straight coast line (no bay) a holding area can be constructed by building ponds, adding fencing, or constructing raceways or large floating pens. For large numbers of fish, ponds or fenced areas usually are favored over pens. If you are maturing just a few hundred fish, large pens will suffice.

Whatever method you use, be sure to provide a freshwater lens over the salt water. (Because of its salinity, salt water is heavier than fresh water. Thus, fresh water "floats" over salt water, creating a freshwater "lens.") This can be accomplished by placing pens close to the creek, by piping, or by channeling. In instances where the available quantity of fresh water is small, a skirt can be placed around the pen or fenced area at the waterline; fresh water is piped in to the pen. Oil containment booms are available in custom sizes; however, the booms are expensive. Substitutes can be constructed from heavy gauge, nylon reinforced, plastic sheeting. Weights (old chain or cable works well) should be placed along the bottom. Floats can be made with beach logs, cabled together. Boat fenders also work well. As a rule of thumb, the skirt should be twice as deep as the desired depth of the freshwater lens (a 3 ft skirt will provide about 18 inches of fresh water).

Stage 2

As maturity approaches, the fish spend more and more time in the plume of fresh water created by a creek flowing into salt water. Try to give them access to straight fresh water. If allowed, they will move into the fresh water on their own. Steep passes constructed from aluminum work well. At about every five feet of elevation that the fish have to travel, provide a resting area. Steep passes usually are installed at a 1-in-4 slope. (Refer to Figure 6.)

The second stage requires a good place for fish to ripen, but a poor place to spawn. It should be fairly deep, say 5 to 8 ft, and have a smooth bottom, preferably of a light color, in order to discourage spawning. An ideal setup for the second stage is a pool. Port San Juan uses gabions (heavy wire boxes lashed together and filled with rock) for two sides of their pool; existing rock forms the other two sides. The gabions are grouted with cement to prevent leaks. Nylon-reinforced plastic can be used to seal the walls, but be prepared for problems. Heavy duty hypalon, concrete or aluminum are best. The pool bottom should be as smooth as possible. If gravel or rocks are left, the fish will spawn. Raceways also will work. It is rather expensive to construct raceways that are 8 ft deep, but 4 ft will do. Heavy, plastic-coated wire should be extended about 2 to 3 ft above the waterline to stop fish from jumping out of the enclosure. The mesh should not be much bigger than 1 by 1½ inches to avoid entanglement.

If you decide to use a pool, be sure to plan for high water periods. It is preferable to divert flood water before it reaches the pool. An engineer should be consulted to devise a method for diversion.

Stage 3

The third stage is signaled when fish attempt to get out of the pool. Intertidally-spawning pink salmon require about five to seven days in fresh water before they become fully mature (this can vary from one day to several weeks depending upon a variety of factors). Again, the fish will need a way to move. The ideal attractant is the discharge water from your incubators, flowing through a steep pass as narrow as 10 inches at 150 to 250 gal/min. Because the fish are losing muscle condition, the rise should be lowered to 1 in 5. The attractant water should lead to the maturing pool from one or more raceways. At the upstream end, a collection and sorting area is needed. Build it at a comfortable working height.

Typically, the majority of fish that reach the collection area will be ripe. At certain times, particularly during a heavy rain, 50 percent can be a few days from spawning. Consequently, a chute back to the pool, or even to salt water, is necessary. A large diameter PVC pipe (10 to 12 inches) works well. Avoid square sides in chutes, as the fish tend to pound themselves against them more than against

flow, and tells how much water a given weight of fish require.

Density and volume can be related by the equations:

kg of fish/m^3 = R/.06 (kg of fish/liter/minute)
(density) (loading)

kg of fish/liter/minute = 0.06/r(kg of fish/m^3)
(loading) (density)

where:

R = the exchange rate per hour (volume/hourly flow).

0.06 = the volume in cubic meters of a flow of 1 liter per minute for 1 hour.

Small fish require more space than do an equal weight of larger fish. They also require more oxygen. As a result, the formula for density is given in terms of fish per unit of volume per unit of length. By experience, fish culturists have found that 8 kg of coho, pink, and chum can be held in a cubic meter of water per centimeter of length. That is to say, 8 kg of fish can be held in 1 cubic meter of water if they are 1 cm long.

It follows that 16 kg of fish can be held in the same cubic meter of water if they are 2 cm long. To calculate in pounds of fish per cubic foot, multiply the fish length in inches by 0.4. For example, you can hold 4 lbs of 10 inch fish in a cubic foot of water.

Piper _et al_. gave the formula:

$$W = D \times V \times L$$

where:

W = permissible weight of fish

curved sides. A garden hose-sized flow of water speeds the fish along.

Sizing the maturing system

Usually, the fish will not all mature at the same time. Consequently, you do not have to provide a volume of fresh water sufficient for all the fish at one time. With an eggtake that lasts about three weeks, a maximum of 40 percent of your brood stock will need straight fresh water at any one time. The percentage might be higher if your fish mature over a shorter period. Each stock of fish can have slightly different characteristics, so it pays to build temporary structures and modify them as you learn more about your stock. It is quite helpful to tag fish, noting the time it takes them to move between the various stages. Tag fish (say 50 from each batch, or two to three times per week), as they are placed within the first stage of confinement. A record of the tag numbers, along with the date the individual fish moves through the various stages, will suffice to measure the time between stages. This time probably will vary over the season. Early fish generally take longer; the last of the run will mature much faster. After the information is gathered, the holding areas can be designed with greater precision.

Holding densities

Density and loading rate are two concepts that must be understood before you can accurately estimate how much volume and how much water you will need for a given quantity of fish:

> Density is expressed in kilograms (or pounds) of fish per cubic meter (or foot), and tells how many fish you can put in a given volume of water.
>
> Loading rate is expressed in kilograms (or pounds) of fish per liter (or gallon) of water

> D = density index (0.4 for pink and chum)
>
> V = volume of raceway in cubic feet
>
> L = length of fish in inches

Fish held in non-moving water at a high density will quickly use all the available oxygen, so additional water has to be introduced. The rate of water exchange would be from one to four times per hour. In other words, if a raceway holds 1,000 gal of water, and 50 gal of water are added every minute, you will exchange the water three times per hour (50 gal per minute x 60 min per hr = 3,000 gal per hour; 3,000 gal/1,000 gal per hour = three exchanges per hour).

> Rule of Thumb No. 3: For pools and raceways, hold no more than 3 lbs of fish per cubic foot of volume. Introduce at least 1 gal per minute of water per 22 lbs of fish.

You should check the dissolved oxygen levels of the outflow. Values should remain above 7 mg/liter and never fall below 5 mg/liter. The closer to atmospheric saturation the better.

Flexibility

A cardinal rule of fish hatchery design is to build as much flexibility into the water routing system as is feasible. Digging up a water line to add a valve with a "T" fitting is far more costly than using a "T" in the first place. More importantly, an emergency can arise when least expected. If you can change water flows it may save fish that would otherwise be lost. As our knowledge increases, techniques change; consequently, so do procedures.

SORTING AND TESTING FOR RIPENESS

SORTING

When holding fish over a smooth substrate, sorting is not necessary. At a remote site, males should be separated from females because it makes handling and processing the eggs and milt easier and more efficient. Male-female separation also lessens the chance that fish will spawn prematurely in the holding pens (a hazard if the fish are held in pens with gravel bottoms). Males are readily identified by the pronounced hook at the end of the upper jaw. Females are not so readily identified. When viewed from underneath, their abdominal region appears much rounder than the males' due to the presence of eggs. If the fish are bright and silvery, they are probably better off if released. If you are using relatively small saltwater pens, 1 percent per day (of the total number) mortality can result. If 30 or 40 days are required before the fish are ripe, dead fish can amount to 30 or 40 percent of the total number held.

Testing Females for Ripeness

After the female is dipped out of the pen, grab her by the thin part of the tail, the caudal peduncle. A sure grip is needed, for which cotton gloves are a must. With one hand under her belly, cradle the fish against your chest or stomach. Then, with your other hand, cock her tail up; and with the cradling hand apply a gentle stroking pressure from throat to vent along her belly.

If the eggs fall readily, quickly cradle the fish belly up so as not to lose any more eggs than necessary. If 50 to 100 eggs are lost from each female, 20 to 40 extra females will be required per million eggs taken.

> Rule of Thumb No. 4: The fish is ready to spawn if the belly muscles are soft and a few eggs are expelled from the vent. If you have to use more than a gentle pressure, the fish is not ripe and should be placed in the holding pen for immature females.

After you have collected a fairly large number of immature females, keep a close watch on them--but don't overdo it. Check them every few days to observe their ripening process, but no more than 25 fish on any given day. In this way you will avoid unnecessary handling of fish and save time and effort.

When many of the females are ripe, check them all and take eggs from the ripe ones. It does not hurt to wait a day before spawning them. Once they are ripe they do not last long, however. Informal tests by Sheldon Jackson College aquaculture training program personnel have shown that ripe pink salmon can be held over a concrete bottom for up to 11 days. In most instances, however, particularly on remote egg-takes, you shouldn't figure on more than three or four days, especially if the water is above 10°C (50°F). The quality of the eggs soon deteriorates.

For this situation it will help if you have several holding pens so that you can sort the "nearly ripe" from the "very green" females. The fish judged to be ripe should be placed in a pen by themselves if they are not to be spawned immediately, so they will not have to be sorted again.

Testing Males for Ripeness

The male is held in the same manner as the female. Strip the male by squeezing from throat to vent along the belly with the thumb and forefinger of the hand not cradling the fish. If milt is readily produced, the fish is ripe.

Anesthetizing Fish

Workers from the Southern Southeast Regional Aquaculture Association have reported excellent results using carbon dioxide to anesthetize chum salmon prior to checking for ripeness and spawning. Their procedure was to place an aluminum box measuring 3 by 8 by 2 ft deep into the pen containing fish, and then bubble carbon dioxide from a bottle of compressed CO_2 through micropore tubing secured to the bottom of the box. About ten fish can be held safely at any one time. It takes only a couple of seconds to slow the fish enough, so it is not a bad idea to leave the fish in a dip net while they are in the carbon dioxide. The water should be changed two or three times a day, or whenever it becomes murky or frothy.

This technique can be used in salt water without adding a buffer, but carbon dioxide dramatically reduces the pH of fresh water. Fish are highly sensitive to pH changes, so if you use carbon dioxide in fresh water you will need someone along who understands water chemistry. The carbon dioxide content does not have to be rigorously monitored, but you should attempt to maintain a concentration that slows the fishes' swimming movements in 3 to 4 seconds.

SPAWNING

TAKING EGGS

You will need:

- a club,
- a knife, (a roe knife or skinning knife with a hooked blade, such as that manufactured by Zak Tackle Company),
- a smooth bucket or basin, plastic or enameled, to catch the eggs, and
- shelter, if only a plastic rain fly.

Killing Fish

A ripe female is killed with a club, striking sharply between and behind the eyes. The blow should hit the skull, forward of the muscle. It should be only hard enough to kill the fish. Striking the fish too far back or too hard can result in internal bleeding and rupture eggs. Striking too lightly can result in the fish thrashing while eggs are being removed. Fish also can be killed with a heavy knife or cleaver. The fish's head is placed on a solid support and struck just behind the eye. The cut should be deep enough to sever the dorsal aorta. Fish killed with a cleaver need to be placed on a rack and left to bleed for a few minutes; otherwise, blood can run into the eggs being spawned.

Take eggs out of the weather. Erect a shelter such as a plastic tent for protection from both the sun and the rain. Once killed, neither male nor female fish should be left in the sun for more than a few minutes. Keep eggs and milt away from any contact with water; otherwise fertility can be seriously reduced or even lost.

Temperature

Avoid extreme temperatures, especially when taking fish from water warmer than 10°C (50°F). During mid-summer, water temperatures can rise to a point that is lethal for even adult fish (23°C or 74°F). Southern Southeast Regional Aquaculture Association eggtakes of summer chum have been most successful when unfertilized eggs are chilled to near 0°C (32°F) soon after removal from the female.

> Rule of Thumb No. 5: Keep the unspawned fish, the spawned eggs, and the milt cool. Where possible, put eggs and milt on ice.

Removing Eggs

One or two spawn-takers can be employed for the egg-taking.

When two are involved, they stand facing each other on either side of a table or bench that holds the spawning basins. The first spawn-taker, who should wear cotton gloves, grasps the female's head with one hand, hooking the forefinger and middle finger under the fish's gill covers. The other hand grasps the tail. The fish is then lifted and held head up with the belly toward the basin and the anal fin (the one behind the vent opening on the belly side) draped over the rim of the basin. Using a splitting knife, the second spawn-taker slits the belly from vent opening to throat, cutting around, not between, the pelvic fins (the pair of fins just in front of the vent).

If the fish is fully ripe, her eggs will spill quickly into the basin (Figure 7). If she is just barely ripe,

Figure 7. Ripe eggs will spill quickly into basin.

Figure 8.

Figure 9.

not all eggs will readily fall. The second spawn-taker holds the body cavity open with the one hand and runs the forefinger and thumb of the other hand along the body wall on each side, tearing away the membranes but being careful not to squeeze any eggs (Figure 8). This action opens up any pockets that might trap eggs. The fore-ends of the large skeins or sacs of eggs on either side are then grasped and gently shaken to loosen the eggs.

When one egg-taker is used, the procedure is similar. A glove should be worn on the hand used to hold the fish. After the fish is properly positioned over the spawning basin, the egg-taker holds the fish under the gill covers with one hand, using the other hand to slit the fish, again from the vent, cutting around the pelvic fins to the throat (Figure 9). A knife with finger holes in the handle, such as the Zak knife, works well as it leaves two fingers free to gently shake the skein (egg mass membrane), freeing any loose eggs (Figure 10).

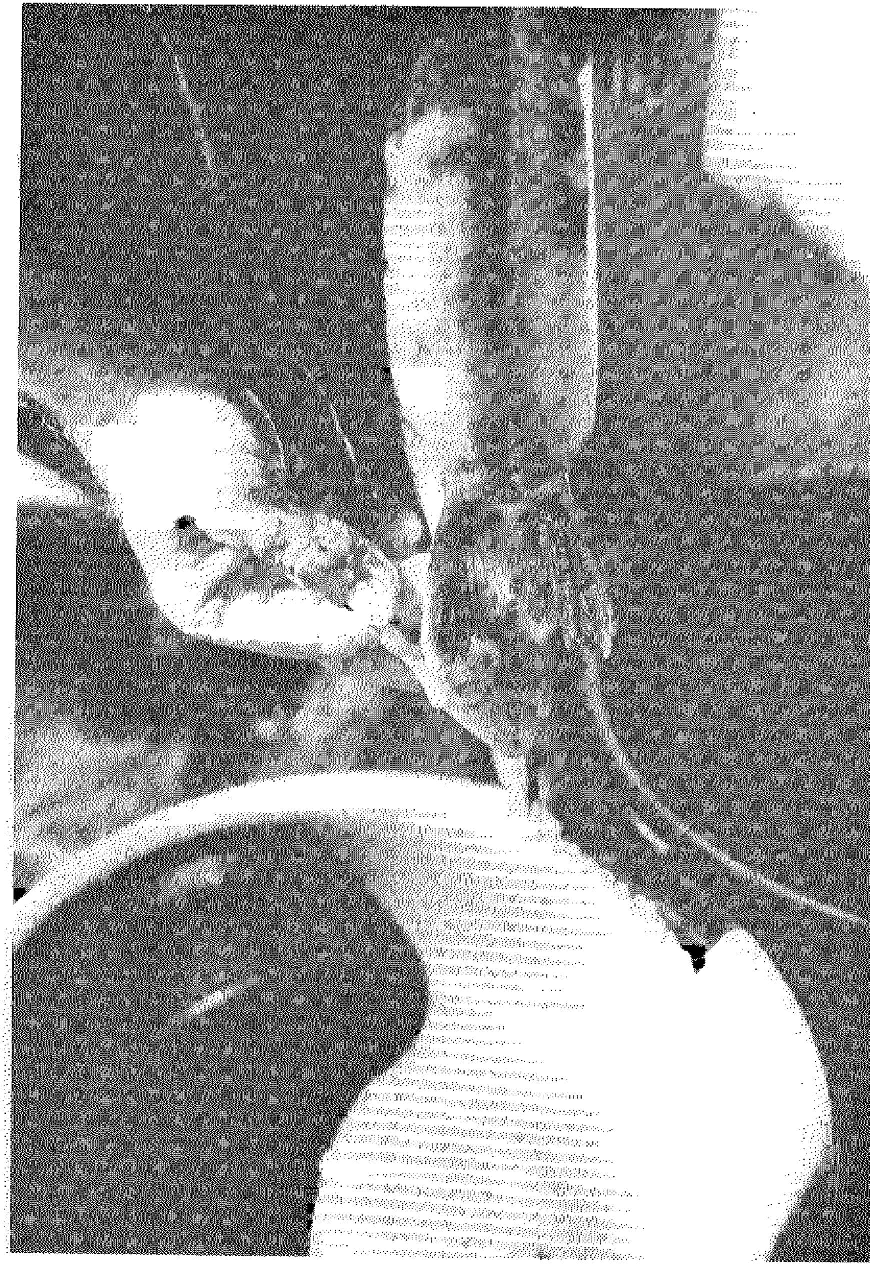


Figure 10. Inserting the Zak knife.

If just a few eggs readily spill, and the rest are still firmly attached, the fish is not fully ripe and should be discarded. It helps the persons who are killing the fish if they are told every time an unripe fish is found. Another condition found is water-hardened eggs, or "bullets". These eggs will have already absorbed water and cannot be fertilized. Bullets are caused by holding a fish too long after it has become ripe. Such eggs should be discarded.

Eggs from just one female at a time should be spawned into the dishpan. Otherwise, green or water-hardened eggs might inadvertently be mixed with good eggs. Occasionally you will find clotted blood. Small clots shouldn't matter; however, if you notice a blood clot that surrounds several eggs, remove and discard it. Chances are the eggs will not develop properly.

> Rule of Thumb No. 6: Any ripe eggs will fall into the basin. Eggs that do not readily fall away from the sac are green and will not fertilize.

> Rule of Thumb No. 7: Blood, slime, and especially broken eggs and water interfere with good fertilization and should be kept out of the basin. Broken eggs are a sign of excessively rough handling.

TAKING MILT

You will need:

- Some small (pint-sized) self-closing polyethylene bags.

Take milt from males by the same method used to test them for ripeness, but use more pressure and stroke the area several times until no more milt is released. Males need not be killed, but usually it is convenient to do so. If you have a shortage of males, they may be anesthetized, kept alive, and stripped several times. Allow enough time between spawnings to permit the milt to build up again--usually 4 to 6 hours. If you have a temporary shortage of males, they can be milked again, even after death, by waiting 20 to 30 minutes and repeating the original procedures.

The ducts which carry the milt from the testes to the vent often contain urine. Flush the ducts with milt by wasting the first jet of milt that you strip from a male. Then strip the remaining milt into a polyethylene bag. Be careful not to get any water in the bag, and enclose plenty of air. Milt is sensitive to water, living only a few seconds after contact.

> Rule of Thumb No. 8: Always waste the first shot of milt from the male. Fish matured in fresh water are particularly susceptible to having watery milt.

Put the milt from only one male in each bag. Some males produce watery milt that could contaminate other milt. The milt samples should not be mixed together until just before fertilizing the eggs. Tie the bag shut so that some air is trapped inside to provide the milt cells with oxygen. Place the collected sample on ice immediately. It will live longest at temperatures just above freezing.

> Rule of Thumb No. 9: Keep your gloves clean.

Cotton or polypropylene gloves of the type worn by cannery workers are an essential piece of equipment. Some egg-takers prefer to use fingerless gloves. Whatever the type, the gloves should be cleaned several times a day. A good cleaning procedure is to keep a bucket of a bleach solution handy. It should be changed at least every day and whenever the strong odor of chlorine is lost. At every break and at lunch, rinse and wring out the gloves two or three times, then hang them to dry. Alternatively, the

gloves can be left in the solution after rinsing. Use a 50 ppm solution of bleach (two "glugs" in a five-gal bucket). Wash gloves thoroughly and dry every night if possible. If gloves are not disinfected, workers can contact "fisherman's poisoning," caused by the staph bacteria that lives on fish skin. It is not harmful unless the bacteria enter a break in the skin. If they do invade tissue, swelling results. If gloves contaminated with blood and slime are used for several days, it is relatively common for hands to become swollen to the point of uselessness. In extreme cases, there is generalized infection accompanied by fever.

TRANSPORTATION

You will need:

- insulated shipping boxes (or picnic coolers),
- crushed ice,
- some large (gallon size) polyethylene self-closing plastic bags, and
- cloth, such as burlap.

> Rule of Thumb No. 10: Keep eggs and milt ice cold, exposed to plenty of air (pure oxygen helps), away from water (but don't allow them to dry out), and separated from direct contact with ice by cloth.

Eggs and milt can be safely transported in insulated shipping boxes packed with crushed ice. Gently pour the eggs from the spawning basin into polyethylene bags. Use one bag for each female's eggs. In order to insure that eggs have adequate oxygen, they should be no more than four eggs deep in the bag; there should be an approximate 30:1 air volume to egg volume ratio in the bag. Chill the eggs on ice, always separating the ice from eggs and milt with a couple of layers of cloth to avoid freezing, as soon as possible. Solid containers, such as gallon-sized mustard or mayonnaise jars, may be used also. Be careful not to introduce water into the containers. Tie the bags or close the containers tightly, enclosing plenty of air, and pack them in the transportation box.

Transport milt in the individual polyethylene bags in which it was collected. To insure that the sperm cells have adequate oxygen, don't let the milt be any deeper than 5 mm (1/4 in.). Pack the bags containing milt on their sides. Survival of the sperm for long periods can be helped by filling the bags with oxygen before closing. Allow as much gas volume in the bag as is practical. Chill the milt over ice that is separated from the bags of milt by several layers of cloth. Packed in this way, the eggs and milt will last a fairly long time--even until the next day. If your transportation breaks down or the weather blows up, you will have some time to spare.

FERTILIZATION

On remote egg-takes there are two basic ways to fertilize eggs: delayed (at the hatchery) and immediate. Water is always used in the delayed fertilization process, but is optional in the immediate fertilization process.

DELAYED FERTILIZATION

After transporting eggs and milt to the hatchery, take them off the ice and allow them to come to within 2°C (4°F) of hatchery water temperature. A water bath speeds temperature changes. Be sure that the gametes do not contact water. You may be required to incubate eggs from each female separately from all others to satisfy fish health regulations (Figure 11). If so, fertilize each bag of eggs by putting the eggs in a dry bucket or pan, spilling some milt onto the eggs (very little is required), and flooding the container with water. You may put some milt from more

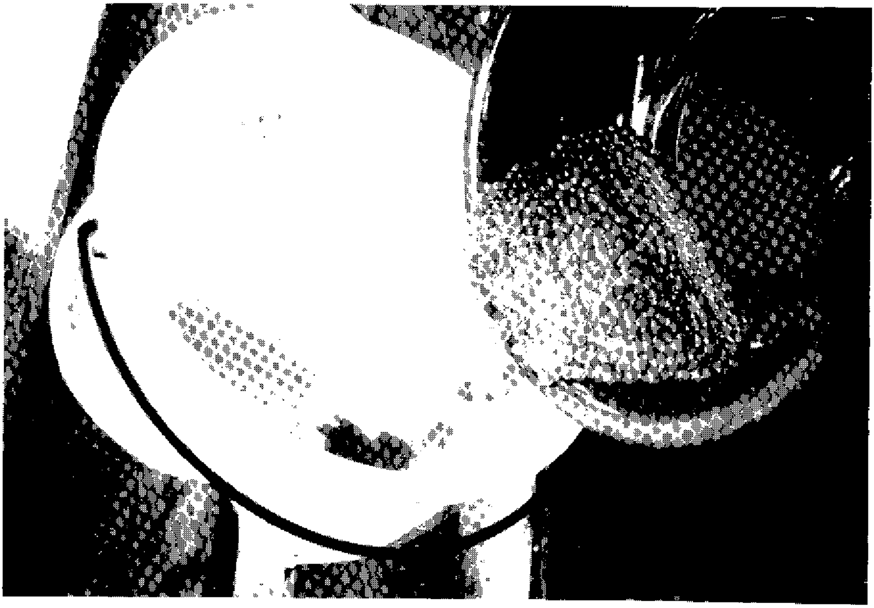


Figure 11. Adding eggs from one female to bucket.

than one male in the container, but unless the milt samples are introduced simultaneously, the first male is likely to fertilize all the eggs, especially in the presence of water.

If you aren't required to keep eggs from each female isolated, you may pool them in a bucket or pan before fertilizing. In this case, mix some milt from at least two males in a dry container (such as a measuring cup) and add it to the eggs. (Some experienced egg-takers always add milt to the bucket before any eggs are added.) You may rinse the cup into the egg container but remember that once water is introduced, the sperm cells have only about 15 seconds to fertilize the eggs. They also are activated by the ovarian fluid that covers the eggs and will fertilize eggs without water being added. Sperm cell life span in ovarian fluid is longer than in water. If any milt sample is suspect (watery), be careful not to mix it with other milt before adding it to the eggs because it will activate other milt. Add it simultaneously.

Use milt from different males in each bucket of eggs. This will help prevent inbreeding (Rule No. 1).

Gently flood the fertilization container with water. Let it stand for a minute, then pour off the milty water, flood the bucket, and drain twice more in order to rinse (Figure 12).

If you are going to disinfect the eggs (a highly recommended procedure), allow rinsed eggs to stand quietly for one hour in the bucket of clean water. This allows them to water-harden before they are washed in the disinfectant.

If you do not need to disinfect the eggs, they can be water-hardened in the incubator. Pour them into the incubators right away, however. While water-hardening they are very sensitive to shock and should not be disturbed.

Figure 12. Rinsing eggs before placing in incubator.

Rule of Thumb No. 11: When using delayed fertilization, always add water. After adding milt to the container of eggs, quickly and gently mix the gametes by swirling the container; then flood with water to complete fertilization.

Dry fertilization, when using eggs and milt from fish killed earlier, can result in a lower fertilization rate.

IMMEDIATE FERTILIZATION

Eggs and milt can be united just after removal from the fish. This technique, when used at a remote eggtake, requires especially delicate handling. The basic technique is to fertilize the eggs, then rinse them three times. After rinsing, the eggs are placed in a perforated aluminum or wire frame that is lined with heavy burlap or other porous cloth. The aluminum or wire insert is sized to fit snugly into your coolers, and to hold the eggs of 8 to 10 females. The eggs are water-hardened either in the stream or in a cooler. After two hours, the eggs are gently drained and stored in coolers. The cloth and insert hold the eggs in place so that they can be moved with minimum disturbance. Ideally, the eggs should be taken to your hatchery within five hours. If weather prevents it, however, the eggs can be placed back into the creek. When the eggs arrive at the hatchery, they are disinfected then gently weighed; cloth, inserts and all. After weighing, the eggs are lowered beneath the water line of the incubator and poured in slowly. The cloth and insert are weighed again, so that a net weight of eggs can be determined.

Dry Fertilization

For eggs taken where transportation is unnecessary, "dry" fertilization can be used. The milt from one male is stripped into the bottom of a clean, dry, two gallon plastic bucket. Eggs are added from the number of females representing the correct ratio of your total eggtake (Rule of Thumb No. 1). For example, if you are spawning fewer than 200 females, add the milt from two males (Figure 13) to the eggs from one female; if the ratio is 1:3 add the milt from one male to the eggs from three females. Add the milt and eggs in alternating layers. Repeat until the bucket is almost full. Layering eggs and milt in this way will help insure a high degree of fertilization. The milt added later may, however, fertilize fewer eggs than does the milt added earlier. Avoid this if you are dealing with small numbers of spawners (fewer than 300 females). In that case, pool milt from several males before adding it to the eggs.

If the buckets are placed on a rack that is tilted at an approximate 40° angle, and eggs are added until they reach the lower lip of the bucket, then a somewhat crude but useful estimation of the number of eggs taken can be made by figuring the number of eggs in one bucket and counting the number of buckets filled. Once filled, gently swirl the bucket to mix

Figure 13. Spawning males.

the eggs and milt (Figure 14). Rinse the eggs by gently submerging the lip of the bucket under water and fill. Discard the milty water. Repeat twice more. The eggs should be emptied into the incubators as quickly as possible, as the rinse water is starting the process of water-hardening.

LOADING INCUBATORS

Hold the lip of the bucket under the water surface and pour the eggs in a layer onto the incubator screen. Avoid pouring eggs from above the water line. This can kill eggs.

During their first hour in the incubator, the fertilized eggs are water-hardening--taking up water and swelling into a rigid shape. They are especially tender at this time. After the water-hardening process is completed, the eggs are fairly resistant to physical shock for 8 to 12 hours, and will tolerate some gentle

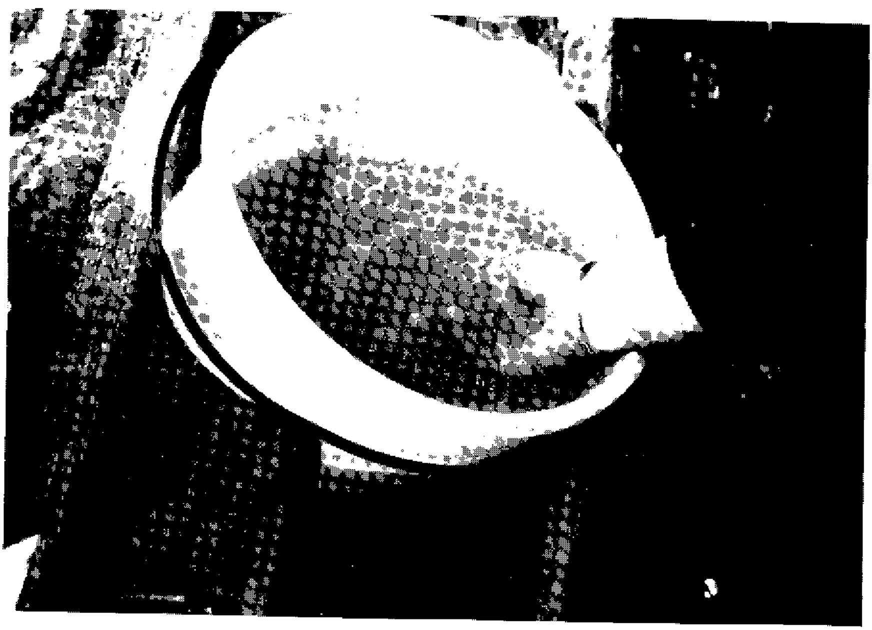


Figure 14. Stirring eggs to fertilize, showing the 30-degree tilt.

handling. You can check for dead eggs (they are white) and remove them. After that time, they must be left in absolute quiet for several weeks until the pigment of the eyes is visible. Even strong vibrations through the hatchery floor can be harmful. Keep the eggs out of the light as much as possible. Provide a cover for the incubators. (See Table 1.)

FERTILIZATION TEST

You can test your eggs for fertilization by looking at them under magnification (10 power) after the first day or so. Unfertilized eggs will have an irregular white mass (the blastodisc) 1 or 2 mm across on the top of the egg; in fertilized eggs, that mass will be cleaved (divided into two, four, eight or more distinct cells). After ten days or so the blastodisc will have disappeared from unfertilized eggs, while in fertilized eggs the embryo will be visible. All of these structures are underneath the egg's shell; it will be easier to see them if the eggs are soaked in 10 percent acetic acid for several minutes. White vinegar will work, though it's only 1 percent.

A mortality rate of 2 or 3 percent is not unusual, but 20 to 30 percent indicates trouble somewhere along the line. If there is no obvious reason for poor fertilization, you may need to use antibiotics to help preserve the gametes during transport, or use special procedures to chill gametes soon after they are taken. It may be that holding fish while they are ripening has interfered with their fertility. Review your procedures to ensure that all possible care is being taken to keep the eggs and milt clean, dry, and cool.

DISINFECTION

Whenever eggs are delivered to a hatchery from a different stream or river, they should be disinfected before being taken into the hatchery facility. This precaution helps prevent the spread of diseases. The

Table 1. Results of Smirnov (1955) shock study[1]

Time after fertilization	Stage of development	Sensitivity and range in percentage mortality in two sets
0 to 15 min	Before water hardening	Highly resistant to shock (0.5 to 0.9)
15 min to 2 hr	Water hardening	Highly sensitive to shock (8.6 to 89.0)
2 to 8 hr	Completion of water hardening to cell division	Resistant to shock (1.0 to 18.2)
8 hr to 5 days	Beginning of cell division to formation of caudal knob	Moderate sensitivity to shock (3.5 to 17.4)
6 days	Early embryo formation (caudal knob visible)	Marked increase in sensitivity to shock (18.5 to 32.5)
8 to 12 days	Embryonic streak visible	Resistant to shock (1.6 to 17.8)
15 days	Closure of blastopore[1]	Sensitive to shock (20.5 to 24.7)
18 days to hatching	Closure of blastopore to hatching	Resistant to shock (0.0 to 1.2)

[1] Eggs were subjected to mechanical agitation at various stages of development. Eggs developed in water temperatures from 8° to 9.6°C.

[2] Smirnov noted that eggs were highly resistant to shock after the blastopore closed (18 days and 174°C degree-days). This stage was reached before eye pigmentation (22 days and 211.5°C degree-days), when fish culturists normally consider eggs resistant to handling. He did not find any increased mortality from shock just before hatching.

shipping containers, plastic bags and other transport equipment should not be allowed to contaminate the hatchery facility.

Water-hardened eggs are rinsed in an iodophor (tamed iodine--for example, Wescodyne, Betadine, Argentyne). Follow the manufacturer's instructions to make a "100 parts per million active ingredient" solution. Most of these products come in a 1 percent solution which means they should be diluted 100 times before use (6 to 7 oz in a 5 gal bucket of water). Be sure that the solution is buffered; you can kill eggs at low pH, and without a buffer the disinfectant has an acid (low) pH. It will say on the label if the disinfectant is buffered. If it is not, add some sodium bicarbonate (baking soda) to the solution (1/4 cup in 5 gals). If a precipitate forms, it will not be harmful.

Dip the eggs in the solution for ten minutes. Rinse them well. The solution can be re-used. It is dark brown when fresh. When it turns pale, make some new disinfectant.

Test your disinfectant procedures on a few eggs first to be sure you are safe. Dead eggs will turn white.

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