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TROUT AND SALMON CULTURE

(Hatchery Methods)

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Recirculation and Aeration

Hatcheries should be operated at maximum capacity for the most economical production of fish. An example is the Fillmore Hatchery in Southern California where there are ten ponds in each of four series (Figure 3). The water is pumped from wells and passes through an aerator to dissipate harmful gases and increase the oxygen before entering the ponds. After the water passes through five ponds in each series, it is pumped through another aerator and then returned to the ponds to pass through five more ponds in each series (Figure 4). This additional aeration midway through the pond series increases the production of fish in the lower ponds. Some of the water from the discharge is then pumped back to the upper end of the pond system and passed through another aerator before being distributed to the pond series to be used a second time. The water temperature is 60° F. The production at this hatchery has been increased considerably by this recirculation and aeration method. The hatchery has produced an average of 15,000 pounds of catchable trout per pond in 1 year.

Reconditioning Hatchery Water

There are built-in dangers in the recirculation system described above. The oxygen can be replenished through aeration and most of the carbon dioxide can be dissipated, but very little of the ammonia can be removed.

Reconditioning the water properly infers that the oxygen will be replenished, carbon dioxide and nitrogen will be dissipated, and ammonia will be removed so the water can be recirculated many times by adding only 2 to 10% new water.

Mad River Hatchery in Humboldt County north of Eureka (Figure 5) operates on reconditioned water that is recirculated. The total water requirement is 30 cfs of which only 3 cfs, or 10%, is supplemental well water which is added to the system. When water is wasted for reasons mentioned below, it is necessary to increase the supplemental water.

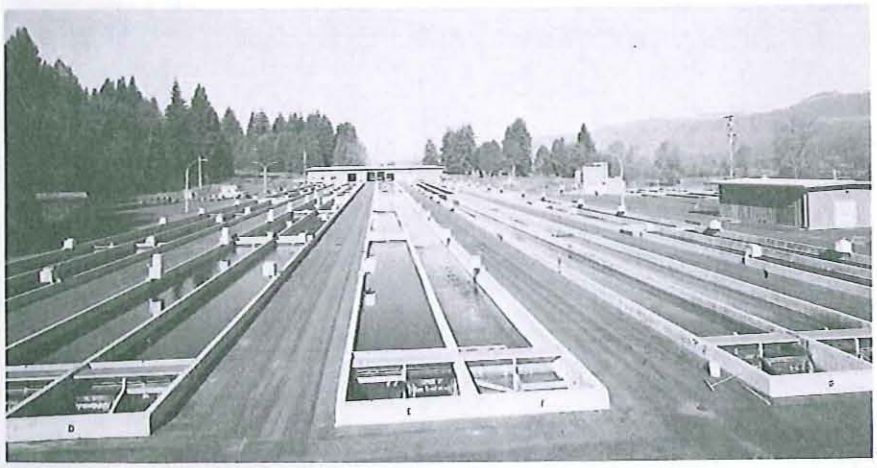


FIGURE 5—Mad River Hatchery, Arcata, Humboldt County, California. Hatchery operates on 30 cfs of water, 90% of which is reconditioned. Only 3 cfs of supplemental water is added to the system. ***Photograph by George Bruley, 1973.***

Ammonia is the principle catabolic product which causes difficulty in water reuse systems. Ammonia can be removed by nitrifying bacteria. In nitrification, ammonia is first converted by *Nitrosococcus* and *Nitrosomonas* to nitrous acid, then by *Nitrobacter* to nitric acid. The acid combines with an available base to form nitrites and nitrates. The ultimate product is nitrate which is harmless in the recirculating water.

Bacterial beds for the culture of nitrifying bacteria are developed in filters for reconditioning of hatchery water by covering a 4 foot deep layer of sharp rock with a 1 foot layer of crushed fresh ocean oyster shells. The oyster shells on top of the rock serve as the filter material to remove solids from the recirculated water and as a source of nutrients for the nitrifying bacteria.

The nitrifying bacteria are chemosynthetic autotrophs in that they are capable of taking the simple inorganic compounds (ammonia, oxygen, carbon dioxide, carbonate, and bicarbonate) and synthesizing them into carbohydrate, fat, and protein, using the oxidation of ammonia as their energy source. They also require other chemicals including a base for the formation of nitrites and nitrates, and phosphates, magnesium, iron, and other trace minerals. It would appear that nitrifying bacteria are practically self-sufficient in that growth can be either retarded or completely inhibited by the absence of the essential chemicals. The oyster shell supplies principally calcium bicarbonate which provides the base for production of calcium nitrate. Without the base available, nitrous and nitric acids

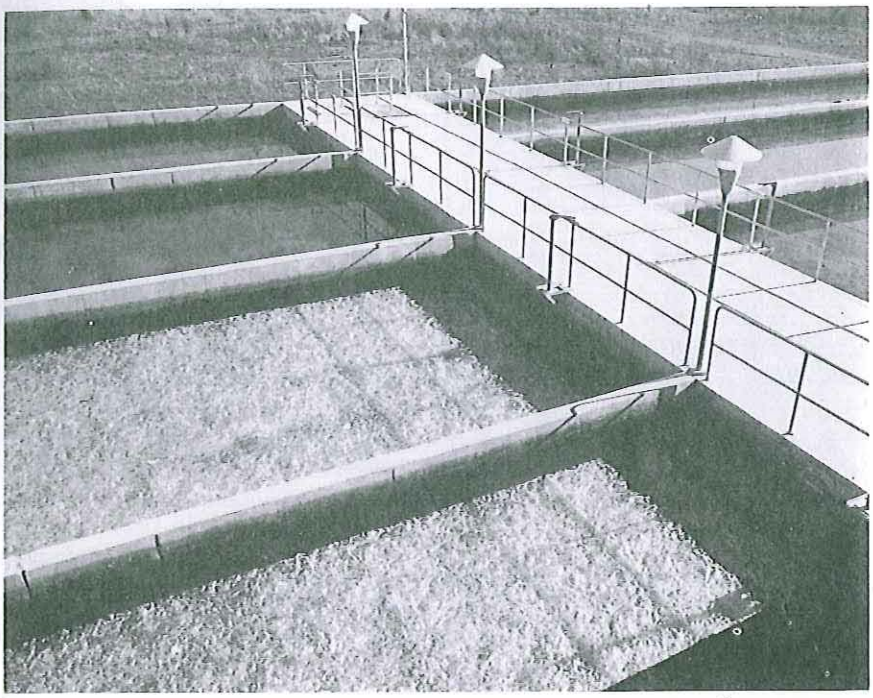


FIGURE 6—There are eight filter beds at Mad River Hatchery. Bubbles can be seen on the surface of the two ponds in the foreground as air surges up through the filter as part of the cleaning process. *Photograph by George Bruley, 1973.*

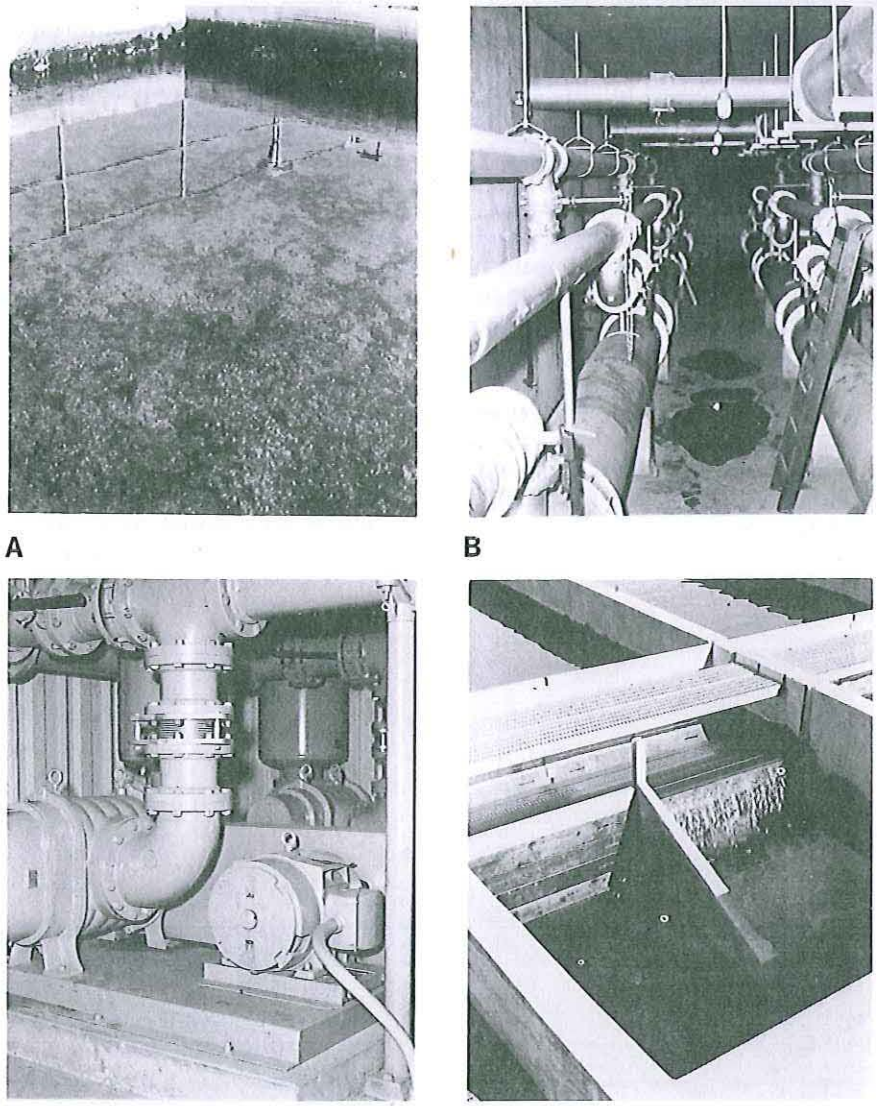


FIGURE 7—Reconditioning water at Mad River Hatchery. A, air surging up through water as filters are cleaned; B, a maze of pipelines in an underground corridor delivering water to and collecting water from eight filter beds and a pipe supplying air to each filter; C, air compressor to provide air to clean filters; D, a double outlet at lower end of pond series so water can be directed to filter beds for reconditioning or be wasted to settling ponds when ponds are being cleaned, or chemicals are used in ponds. *Photographs by George Bruley, 1973.*

are formed which would reduce the pH of the water. The calcium carbonate provided by the oyster shell tends to stabilize the pH at a satisfactory level.

At the Mad River Hatchery there are eight filter beds 20 feet by 75 feet (Figure 6). The size of the filter is calculated on the basis of 1 gallon per minute of recirculating water per square foot of filter surface. The water to be recirculated from the rearing ponds enters the filter ponds and is held at the normal operating level. The water passes through the filter bed, is collected in the filtered water manifold at the bottom of the filter and then pumped under pressure through aspirators into the aeration tower. The reclaimed water is then returned to the rearing ponds by gravity flow.

The filters must be cleaned at least twice each week. This is done by closing off the inflow of water and draining the filter pond down to about 12 inches in depth. The water is drained through the waste pipe. An air blower is activated for 1 to 2 hours. The air surges up through the rock and oyster shell at the rate of 1.33 cfm per square foot of filter area, agitating the oyster shell which cleans it without disturbing the rock layer (Figure 7). During the last 20 minutes of this operation, the raw water from the rearing ponds is turned in to flush the debris into the waste pipe. The filter pond is then filled and ready for operation. If algae becomes a problem, it is sometimes necessary to rake the oyster shell during the cleaning process.

Water should be wasted from the system when rearing ponds or filter beds are being cleaned or when any chemicals are used to treat fish in the ponds (Figure 7D). Chemicals might kill the culture of nitrifying bacteria. Additional water must be added to the system at that time.

Waste Water Discharge Requirements

Water quality standards for waste water discharge from hatcheries have been strengthened by the U. S. Environmental Protection Agency and the State Water Resources Control Board. The Federal authority stems from the 1899 Federal Refuse Act which prohibits discharges into navigable waters of the United States and their tributaries without a permit issued by the Army Corps of Engineers. At this writing it appears that this authority will pass to the state level which was made possible by the Federal Water Pollution Control Act amendments of 1972.

Indications are that dischargers will be required to install at least secondary treatment by 1977 or the best practical control technologies available. Standards will probably be set that no discharge can degrade the quality of the receiving water. In some cases the requirements may be met by passing the discharge water through large settling ponds. By 1983, it is probable that fish hatcheries will have to operate on a closed system of reconditioning the water and reusing it as in the system previously described at Mad River Hatchery. Strict standards would be set for the water that is wasted from such a hatchery before it could pass into a public water.

STRUCTURE OF THE TROUT EGG

Which came first, the egg or the fish? Rather than debate this subject here, we will turn to the hatchery which does not produce its own eggs. Here the egg comes first.

While much has been learned and written regarding the taking and care of fish eggs, a great deal remains to be learned. In comparing the work at many hatcher-

TROUT AND SALMON NUTRITION

Almost no phase of fish culture is more important than nutrition and feedin For many years, it was quite generally assumed that beef liver was a complet diet for trout, and beef liver was fed in trout hatcheries in greater amounts tha any other food. Fortunately, rather large amounts of condemned livers (liver condemned because of fluke infestation), which kept the price within a reasonabl range, were available to hatcheries situated west of the Rocky Mountains.

As larger trout were produced, it became evident that beef liver, while it wa one of the best trout feeds available, was not a complete trout food and it becam common practice to supplement a liver diet with other packing-house products such as lungs, hearts, and spleens. Early fish culturists in this country suspende freshly killed beef heads over their ponds. After a few days maggots would fal from the heads into the ponds. This is probably one of the earliest attempts t provide a natural food for hatchery fish. Such products as ground whole fish, botl ocean and freshwater varieties, fish cannery by-products, and numerous cereal were also used to supplement hatchery diets of packinghouse products. A balanced ration of dried meals, vitamins, and supplements in pelletized form o various sizes is now the conventional diet in hatcheries throughout the nation

The nutritional requirements of trout and salmon are not yet fully determined. Fish nutrition, when compared to that of other domestic animals, is still in its infancy. Obvious reasons for this are the lack of work in this field and the difficulty of working with fish. The amount of research in trout nutrition is constantly increasing. In future years the trout production industry may be abreast of other fields in nutritional knowledge. In the meantime, many of the requirements of trout are based on the dietary needs of other animals. In general, this is a safe assumption. However, fish are cold-blooded animals, their body being of the same temperature as the water surrounding them, and their ability to assimilate food under varying conditions must be taken into account.

The intestinal tract of a trout is that of a typical carnivore. Both small and large intestines are very short, and the total length of the digestive system is not great enough to allow any important synthesis of vitamins by bacteria in the intestines. Most of these requirements must be supplied in a digestible form in the food.

Realization of these shortcomings in a trout's digestive system is a long stride forward in understanding its food requirements.

Present nutritional knowledge has been built around five principal groups of nutrients. They are fats, carbohydrates, proteins, minerals, and vitamins.

Fats

The three sources of fat used to meet bodily requirements are fat of the diet, fat produced by excess dietary protein, and fat produced by excess carbohydrates.

Most dietary fat is changed to fatty acids and glycerol in the small intestine before absorption. The ease of this process is primarily dependent on the melting point of the fat. Soft fats are easier to digest than very hard fats. Digestibility varies from 70 to 90%, depending on the melting point and body temperature.

Hard fats may retard or prevent the digestion of protein and carbohydrates by coating their molecules. This insulates them from the action of the protein- and carbohydrate-digesting enzymes and acids. Small trout have special difficulty in digesting hard fat. It is believed that hard fats also lessen a trout's ability to adjust to water temperature changes.

The body uses fats for energy, insulation, and cushioning of vital organs, and as an internal lubricant. They are also stored for future use.

Fats aid in the absorption of the fat soluble vitamins, which are necessary for normal health and growth. Phospholipides are kinds of fat which contain phosphorus, fatty acids, and choline, or other important bases.

There are two types of fat deposits in the body: one is the natural fat of the animal manufactured from the protein and carbohydrate of the diet; the other is deposited from fat in the diet. Fat deposited from dietary fat is similar to that of the original food. Excessive fat deposits may be caused either by overfeeding or by high fat content of the food.

Excessive dietary fat can cause body damage resulting in death. Important food conversions take place in the liver; fatty infiltration of the liver may cause anemia resulting in the death of the fish. Kidneys damaged by excessive fat deposits may result in edema, i.e., an accumulation of water in the body.

The principal sources of fats are fish meal and oil, cottonseed meal, rice bran, fresh fish and meat, and meat and bone scrap.

Cod liver oil has been found to increase growth under certain conditions, but it is not clear whether this effect is caused by the lipides themselves or the vitamin A and D present in the oil. Due to possible kidney and liver damage, caution should be used in feeding cod liver oil in cold water. Oxidation of fish oils such as cod liver oil, when mixed into the diet, will cause destruction of vitamin E.

Insofar as is now known, the trout diet should contain not less than 5% and not more than 8% fat.

Minerals

Minerals are generally considered important in building strong bones. The important part they play in the functional activities of the body is not widely appreciated. Blood circulation, respiration, digestion, and food assimilation, as well as excretion, are dependent on the presence of minerals in suitable compounds. The major minerals important in trout and salmon nutrition are calcium and phosphorus (Table 8).

TABLE 8

Important Nutritional Minerals

Major	Use	Trace	Use
Calcium	Bones, teeth, blood coagulant	Cobalt	Red blood cells
Phosphorus	Bones, teeth	Iron	Red blood cells
		Copper	Red blood cells; enhances enzyme action
		Magnesium	Bones, teeth
		Sodium	Osmotic cell pressure
		Chlorine	Osmotic cell pressure, digestion
		Potassium	Osmotic cell pressure
		Manganese	Growth
		Fluorine	Teeth, bones
		Iodine	Regulates metabolism

Usually minerals are needed in only small amounts. While calcium, phosphorus, and iron are used in building the body and blood, most of the minerals function as catalysts.

Trout have the ability to absorb calcium, cobalt, and phosphorus from the water. Enough for bodily needs may be absorbed if there is enough present in the

APPENDIX A. CONVERSION TABLES

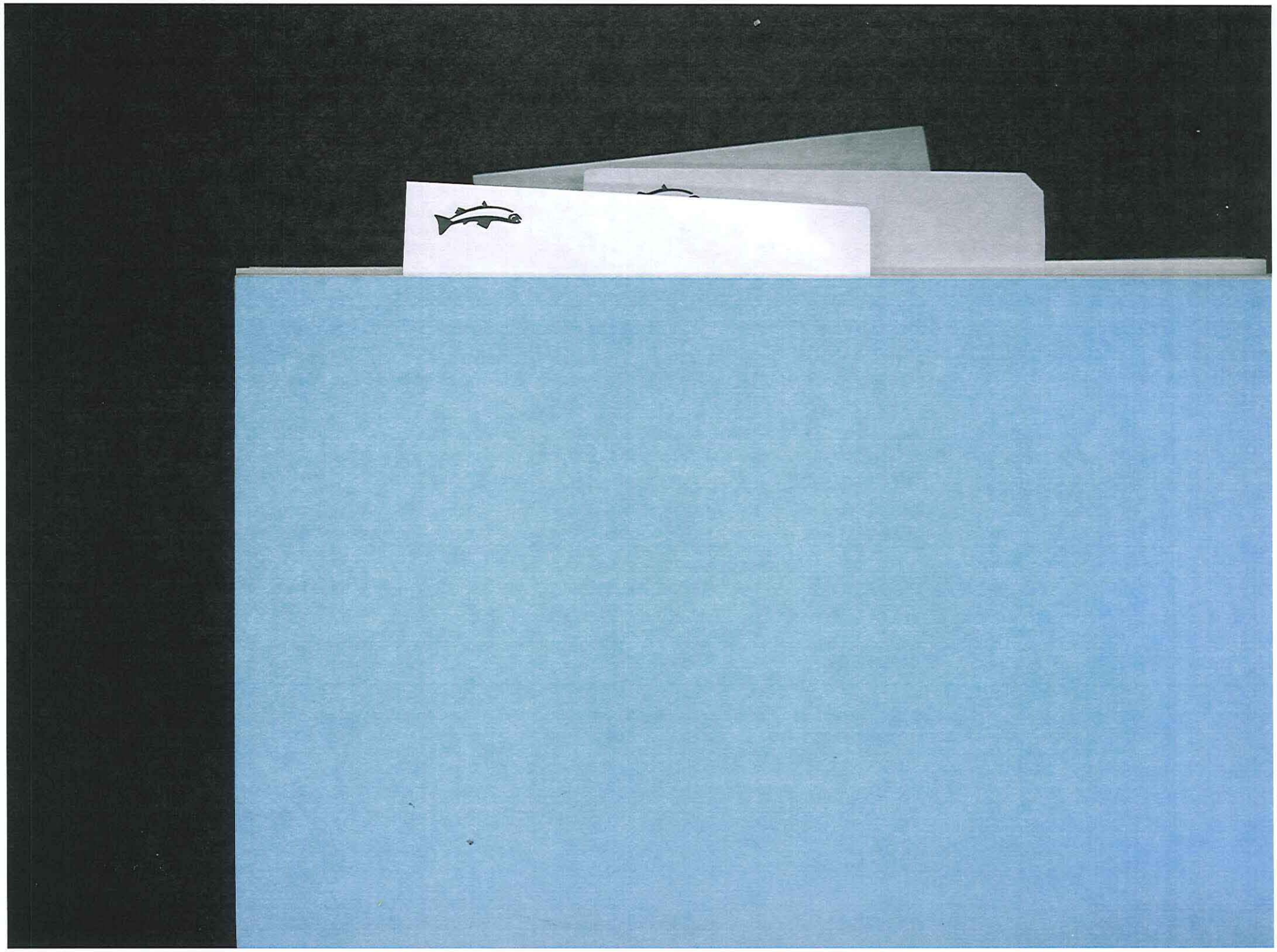
Common Water Measurements Useful to Fisheries Workers

1 acre-foot	43,560 cubic feet
1 acre-foot	325,850 gallons
1 cubic foot of water	7.48 gallons
1 cubic foot of water	62.4 pounds
1,000,000 cubic feet	22.95 acre-feet
1 gallon	231 cubic inches
1 gallon	0.1337 cubic feet
1 gallon of water	8.34 pounds
100 gallons per minute	0.223 second-feet
100 gallons per minute	0.442 acre-feet per day
1,000,000 gallons per day	1.55 second-feet
1,000,000 gallons per day	3.07 acre-feet
1,000,000 gallons per day	694 gallons per minute
1 horsepower	1 second-foot of water falling 8.8 feet
1 inch deep on 1 square mile	2,323,000 cubic feet
1 inch deep on 1 square mile	0.0735 second-feet annually
100 miner's inches *	4.96 acre-feet per day
100 miner's inches *	18.7 gallons per second
1 second-foot	1 acre-inch per hour
1 second-foot	86,400 cubic feet per day
1 second-foot	approximately 2 acre-feet per day
1 second-foot	7.48 gallons per second or 448.8 gallons per minute
1 second-foot	646,317 gallons per day
1 second-foot	40 miner's inches *

$$\frac{\text{Second-feet} \times \text{fall in feet}}{11} = \text{horsepower on waterwheel operating at 80 percent efficiency.}$$

$$\frac{\text{Acre-feet} \times 43{,}560}{86{,}400 \times X} = \text{second-feet discharge over a period X days.}$$

Discharge in second-feet

1 second-foot for 1 day = 1.983 acre-feet; for 30 days— 59.5 acre-feet
2 second-feet for 1 day = 3.967 acre-feet; for 30 days—119.0 acre-feet
3 second-feet for 1 day = 5.950 acre-feet; for 30 days—178.5 acre-feet
4 second-feet for 1 day = 7.934 acre-feet; for 30 days—238.0 acre-feet
5 second-feet for 1 day = 9.917 acre-feet; for 30 days—297.5 acre-feet
6 second-feet for 1 day = 11.90 acre-feet; for 30 days—357.0 acre-feet
7 second-feet for 1 day = 13.88 acre-feet; for 30 days—416.0 acre-feet
8 second-feet for 1 day = 15.87 acre-feet; for 30 days—476.0 acre-feet
9 second-feet for 1 day = 17.85 acre-feet; for 30 days—535.5 acre-feet

* The second-foot (cubic foot per second = c.f.s.) is the universal unit for determining water measurements. The miner's inch is used in sections where mining activities are common. It is not standard and in California two standards are in common use. In the northern parts of the State 1 second-foot is considered to equal 40 miner's inches, while in the southern part the second-foot is considered to equal 50 miner's inches. In other western states, other values are placed on the miner's inch, so that when miner's inches are used in water measurements it is necessary to apply the standard in use in that particular area. In the above, the miner's inch (40 to 1 second-foot) is used. See California law 1901.