Farming Trout.

Habitat and biology

The rainbow trout is a hardy fish that is easy to spawn, fast growing, tolerant of a wide range of environments and handling, and the large fry can be easily weaned on to an artificial diet (usually feeding on zooplankton). Capable of occupying many different habitats, ranging from an anadromous life history (strain known as steelhead, living in the ocean but spawning in gravel-bottomed, fast-flowing, well-oxygenated rivers and streams) to permanently inhabiting lakes. The anadromous strain is known for its rapid growth, achieving 7-10 kg within 3 years, whereas the freshwater strain can only attain 4.5 kg in the same time span. The species can withstand vast ranges of temperature variation (0-27 °C), but spawning and growth occurs in a narrower range (9-14 °C). The optimum water temperature for rainbow trout culture is below 21 °C. As a result, temperature and food availability influence growth and maturation, causing age at maturity to vary; though it is usually 3-4 years.

Females are able to produce up to 2,000 eggs/kg of body weight. Eggs are relatively large in diameter (3-7 mm). Most fish only spawn once, in spring (January-May), although selective breeding and photoperiod adjustment has developed hatchery strains that can mature earlier and spawn all year round. Superior characteristic selection is also achieved by cross breeding, increasing growth rates, resistance to disease, and profligacy, and improving meat quality and taste. Genetic manipulation of the embryo sex chromosomes producing sterile, triploid females, hence avoiding the "hook-like" jaw that does not appeal to the customer, and ensuring that introduced/escaped individuals cannot breed. Trout will not spawn naturally in culture systems; thus, juveniles must be obtained either by artificial spawning in a hatchery or by collecting eggs from wild stocks. Larvae are well developed at hatching.

In the wild, adult trout feed on aquatic and terrestrial insects, molluscs, crustaceans, fish eggs, minnows and other small fishes, but the most important food is freshwater shrimp, containing the carotenoid pigments responsible for the orange-pink colour in the flesh. In aquaculture, the inclusion of the synthetic pigments astaxanthin and canthaxanthin in aquafeeds causes this pink colouration to be produced (where desired).

Production

Production systems

Monoculture is the most common practice in rainbow trout culture, and intensive systems are considered necessary in most situations to make the operation economically attractive. Ground water can be used where pumping is not required but aeration may be necessary in some cases. Supersaturated well water with dissolved nitrogen can cause gas bubbles to form in the blood of fish, preventing circulation, a condition known as gas-bubble disease. Alternatively, river water can be used but temperature and flow fluctuations alter production capacity. Where these criteria are met, trout are generally on-grown in raceways or ponds supplied with flowing water, but some are produced in cages and recirculating systems.

Seed supply

Development of broodstock

Trout will not spawn naturally in aquaculture systems; hence eggs are artificially spawned from high quality brood fish when fully mature (ripe); although two-year-old trout start spawning, females are seldom used for propagation before they are three or four years old.

The number of broodstock required is dependent on the number of fry or fingerlings required to meet the production schedule of the farm. The number can be back-calculated based on survival rates at the different life stages and the fecundity of the broodstock females. Generally, one male to three females is deemed a satisfactory sex ratio for broodstock. Males and females are generally kept separate. Broodstock maintenance can be costly and labour intensive, causing some farms to purchase eyed eggs from other sources; these should be "certified disease free", although they should be treated with iodine (100 mg/litre for 10 min) upon arrival and gradually raised to the hatchery temperature.

Broodstock are selected for fast growth and early maturation (usually after 2 years). One frequently used management tool is the use of sex-reversed, all-female broodstock to produce all-female progeny that grow faster. Functional males are produced by oral administration of the male hormone 17-methyl testosterone through starter feeds at the fry stage.

Stripping and fertilisation

The reproduction of rainbow trout is well understood and the techniques are well-developed. The dry method of fertilisation without admixture of water is the most common approach. Eggs are removed manually from females (under anaesthetics) by applying pressure from the pelvic fins to the vent area or by air spawning, causing the fish less stress and producing cleaner, healthier eggs. Insertion of a hypodermic needle about 10 mm into the body cavity near the pelvic fins and air pressure (2 psi) expels the eggs. The air is removed from the body cavity by massaging the sides of the fish. Up to 2 000 eggs/kg body weight are collected in a dry pan and kept dry, improving fertilisation. Males are stripped in the same way as females, collecting milt in a bowl, avoiding water and urine contamination. Milt from more than one male (ensures good fertilisation) is mixed with the eggs. It is recommended that milt from three or four males is mixed prior to fertilisation to reduce inbreeding.

Water is added to activate the sperm and cause the eggs to increase in size by about 20 percent by filling the perivitelline space between the shell and yoke; a process known as "water-hardening". Fertilised eggs can be transported after 20 minutes, and up to 48 hours after fertilisation, but then not until the eyed stage (eyes are visible through the shell). Direct exposure to light should be avoided during all development stages, as it will kill embryos. A technique that has been developed to improve production output is the use of monosex culture of females, or triploids. Triploidy is induced by exposing the eggs to pressure or heat whilst monosex are produced by fertilising normal female eggs (XX chromosomes) with milt from sex-reversed, masculinised females (XXX chromosomes).

The mature testes of sex-reversed fish are large and rounded but have no vent. The testes are removed from the abdomen and lacerated to drain the milt into containers. An equal volume of extension fluid is added to make the sperm motile, and ready for fertilising normal ova. One advantage of this technique is that only the broodstock is sex-reversed, and they can be grown separately, while the marketed fish are not exposed to hormonal treatment.

Hatchery production

Eggs are incubated undisturbed until the eyed stage is reached, in hatching troughs, vertical flow incubators or hatching jars. Hatching and rearing troughs are 40-50 cm wide, 20 cm deep, and up to about 4 m in length. They usually have 2 layers of eggs placed in wire baskets or screened trays supported 5 cm above the bottom, and water passes through the tray (3-4 L/min). As the eggs hatch (4-14 weeks) the fry drop through the mesh to a bottom

trough. The alternative is vertical flow incubators (Heath incubators) that stack up to 16 trays on top of each other. A single water source flows (3-4 L/min) up through the eggs, spills over into the tray below, thus becoming aerated, allowing large numbers of eggs to hatch in a minimal amount of space and water. Sac fry can remain in trays until swim-up at about 10 to 14 days after hatching. Time taken for hatching varies depending on water temperature, taking 100 days at 3.9 °C and 21 days at 14.4 °C (about 370 degree days).

Hatching jars, available commercially or constructed from a 40 L drum and PVC pipe, introduce water from the bottom and flow from the top. 50,000 eggs can be incubated inexpensively suspended in a water flow that rolls the eggs, provided that the incubator contains two-thirds of the incubator volume in eggs, and the flow rate lifts the eggs 50 percent of their static depth. In all the above methods dead eggs are removed regularly to limit fungal infection. Fungal infections can be controlled using formalin (37 percent solution of formaldehyde) in the inflow water at 1:600 dilution for 15 minutes daily, but not within 24 hours of hatching. Upon reaching the eyed stage addling (dropping eggs 40 cm) removes weak and undeveloped eggs.

Trout hatch (typically 95 percent) with a reserve of food in a yolk sac (which lasts for 2-4 weeks), hence are referred to as yolk-sac fry, or alevins.

Hatching of the batch of eggs usually takes 2-3 days, during which time all eggshells are regularly removed, as well as dead and deformed fry. Eggs incubated separately from rearing troughs are transferred to rearing troughs after hatching. After hatching, the trays are removed and trough water depth is kept shallow (8-10 cm) with a reduced flow until fry reach "swim-up" stage, the yolk sac is absorbed, and active food searching begins.

Rearing fry

Fry are traditionally reared in fibreglass or concrete tanks, preferably circular in shape, to maintain a regular current and uniform distribution of the fry, but square tanks are also found. Tanks are usually 2 m in diameter or 2 x 2 m square, with depths of 50-60 cm.

Water is delivered to the side of the tank using an elbow pipe or a spray bar to create a circulation of water. The drain is in the centre of the tank and is protected by a mesh screen. This position ensures that the water forms a vortex towards the centre that accumulates

wastes for easy removal. The sump or drain pipe is connected to an elbow pipe on the side of the tank that can be used to regulate water level. Fry are fed specially prepared starter feeds using automatic feeders, starting from when approximately 50 percent have reached the swim-up stage. When most fish are actively feeding, 10 percent of the fish weight should be introduced daily for 2-3 weeks, preferably on a continuous basis using clockwork belt feeders. The feed pellets, made of fish meal (80 percent), fish oils and grains, provide nutritional balance, encouraging growth and product quality, and are formulated to contain approximately 50 percent protein, 12-15 percent fat, vitamins (A, D and E), minerals (calcium, phosphorus and sodium) and a pigment to achieve pink flesh (where desirable).

High-energy commercial feeds and good feeding practices yield FCRs as low as 0.8:1. When the fry are 15-25 mm long feeding is based on published charts, related to temperature and fish size. Automatic feeders are useful but hand feeding is recommended in the early stages to ensure overfeeding does not occur, although demand feeders are more efficient for larger fish. As growth continues, dissolved oxygen is monitored and fish moved to larger tanks to reduce density.

Water Temperature and Oxygen Content for Trout Farming

Rainbow trout (which are usually preferred for intensive growing over the other varieties) are an amazingly hardy breed, but if you're to have the most *productive* ponds possible, you'll need to provide your fish with the right environment. Temperature also influences the amount of oxygen that water can hold, so an overly warm pond imposes a double threat.

Keep Trout Aquaculture Water Contaminant-Free

Of course, the ponds used for trout aquaculture must also be kept very clean. Only plastic or aluminium conduits are used in trout farming. The fish can also be adversely affected by the runoff from any fertilizers or pesticides that might be used by farmers on sites above pond location(s). In general, spring or well water is considered best—simply because it's much less susceptible to contamination than is a major surface watercourse—but there *are* cautions to be observed when using liquid from even those relatively pristine sources. Iron bacteria found in the groundwater, for example, can accumulate on the gills of the fish, reducing their ability to breathe.

Water Hardness and pH

Hardness and pH are two additional factors that, while both important, can be somewhat at odds with each other. Trout absorb very few minerals through their gills, so the nutritional advantages of hard water are of little benefit to them. Furthermore, water with only a small mineral content has more ability to hold oxygen, so the dissolved oxygen content in soft water is typically greater. Actually, were it not for the lack of pH-buffering capability of mineral-poor water, the low-hardness liquid would *always* be preferred. However, should a low-pH rain squall (perhaps one that's been acidified by airborne pollution) drain into the stream supplying a pond with soft water, the liquid could become so acidic that the fish would be injured (or killed). Several major kills have, in fact, occurred in the southern Appalachians, and only prompt and thorough liming of the water (to raise the pH level) can ward off the disastrous results of the soft water/low-pH rain combination.

How Much Water to Use in Trout Farming

The final environmental prerequisite for successful trout farming is an ample *amount* of water. As we've already suggested, though, the carrying capacity of a gallon of water depends on temperature, hardness, dissolved oxygen content, and other factors like the flow of water. If there's *enough* flow, however, the total production can still be quite high, even if the water itself has a low carrying capacity.

Care and Feeding of Trout

The fish in the pond are fed a 38% protein commercial feed twice a day, if the environmental conditions are right. Should the water become too warm (or the oxygen content drop too low), the person responsible for taking care of the fish may feed them only once a day, or even hold off for a couple of days. Feeding has been one of the trickiest aspects of the business to get the hang of, since the correct amount and frequency can be learned only by experience.

Trout Health

As is the case with any intensively grown livestock, rainbow trout *are* susceptible to diseases. One of those diseases is called "red mouth" because of its major symptom, can bring about losses of more than 30% if unchecked. The illness is usually picked up at the hatchery, so it

pays to keep different batches of fingerlings separated in order to prevent healthy fish from contracting the disease. Fortunately, red mouth can be treated by mixing a small dose of Tetramycin in with the feed.

The other common ailment in our area is bacteria gill, which, again, is often introduced to farming operations by hatchery stock (it's particularly prevalent in those hatcheries using hard well water). Amazingly enough, the general cure for bacteria gill is to give the fish a salt bath! If the trout are left in a 30% salt solution for about 30 minutes, they'll come out with clean gills. (This may sound like a strange treatment for freshwater fish, but bear in mind that trout are Salmonids, and many of them are anadromous, that is, they migrate between fresh and salt water.)

Each day, you should check for dead fish and for any that are discoloured or have bulging red eyes. With each mortality (they average about one per week, usually from a condition called egg lock), try to determine what killed the fish. Should three or more trout die in one week, you need to become concerned and probably take a sample to a biologist to determine the cause.

Other daily chores include testing the water for temperature, pH, oxygen content, hardness, and occasionally for dissolved carbon dioxide. Observation is also an important part of tending the "flock." Contented fish generally swim in a circle that faces them directly into the flow of water during a portion of their orbit, and if the trout are swimming about *erratically*, it's a sure sign that they're agitated. Furthermore, about once a month the algae have to be cleaned from the concrete pond walls and bottoms and from the spillways. (So far, at least, the spillways have shown the most accumulation.) If all these observations above are met, one should, on a miniature fish farm for example, be expected to produce a tidy supplementary income, not to mention a mighty tasty meal from time to time!

Feed supply

Feeds for rainbow trout have been modified over the years and cooking-extrusion processing of foods now provide compact nutritious pelleted diets for all life stages. Pellets made in this way absorb high amounts of added fish oil and permit the production of high-energy feeds, with over 16 percent fat. Dietary protein levels in feeds have increased from 35-45 percent and dietary fat levels now exceed 22 percent in high energy feeds.

Harvesting techniques

Methods of harvesting vary but water levels in the holding facilities are generally lowered and the fish netted out. In pens and cages, the fish are crowded using sweep nets and are either pumped from the holding pen alive and transported to the slaughter plant, generally by well boat, or slaughtered on the side of the pens. The whole process is carried out with the aim of keeping stress to a minimum, thus maximising flesh quality.

Handling and processing

Fish intended for restocking for angling purposes are handled carefully and checked for fin quality, size and any external signs of disease before being put into a special pond to await transport. Fish destined for the table are killed humanely after similar, but less stringent, checks. Before slaughter, all fish should be starved for 3 days and, once killed humanely, the head should be left on; beheaded fish spoil more quickly. Rainbow trout are supplied to markets either fresh or frozen, and their shelf life is 10-14 days if kept on ice. Trout are marketed as gutted whole fish, fillets (often boneless), or as value-added products, such as smoked trout.

Diseases and control measures

There are a variety of diseases and parasites that can affect rainbow trout in aquaculture. Prevention is the most important measure; good hatchery sanitation by restricting access, installing disinfectant footbaths and disinfecting equipment reduces the exposure of vulnerable fish to disease-causing agents.

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