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Small-scale rainbow trout farming





Cover photographs:
Images of rainbow trout farms in Central and Eastern Europe. *From top left*: Hungary, Albania, Bosnia and Herzegovina, Albania and Hungary; courtesy of Thomas Moth-Poulsen and András Woynarovich.
All illustrations courtesy of András Woynarovich.

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Preparation of this document

Unemployment-generated poverty in the mountainous regions of the countries of Central and Eastern Europe and of the Caucasus and Central Asia is a considerable problem. The problem exists in spite of the fact that natural resources could provide both income generation and employment in these regions.

Among the available natural resources, water excellent for trout farming is abundant in the mountainous regions. However, instead of being produced locally, the highly valued trout is often imported. Therefore, the utilization of available water resources for trout production is an obvious possibility for both increasing employment opportunities and generating income.

Because of the reasons mentioned above, the present practical reference publication has been designed and elaborated along with three other related trout farming publications. These are the guides to *Small-scale Propagation of Rainbow Trout*, *Small-scale Trout Processing Methods* and *Trout Farming-based Angling Tourism*.

It is hoped that the publications will support initiatives and the creativity of individuals, families and communities in the successful start-up and practice of trout farming and associated activities.

It is envisaged that interested farmers and families will learn the art of trout farming through this general example of rainbow trout farming. It is also hoped that the knowledge gained will help and support the start-up of the production of local trout species that need similar conditions and care.

We thank Jacob Bregnballe, Sales Director of AKVA Group, Denmark, for his valuable comments. We also wish to acknowledge the professional support received from Annamaria Hajduk (FAO Subregional Office for Central and Eastern Europe), Maksim Mikaric, FAO volunteer, Tina Farmer, Marianne Guyonnet and Maria Giannini (FAO Fisheries and Aquaculture Department), and José-Luis Castilla Civit in the finalization of this publication.

Abstract

This technical paper is a basic guide to the starting and successful practice of small-scale trout farming. It summarizes all the technical information that it is important to know for small-scale trout production.

In mountainous regions, where water resources could support profitable trout farming, protection of the environment is also important. Therefore, this technical paper contains sections with information about the basics of efficient treatment of trout farm effluents.

The concept of this technical paper is to guide the reader through the necessary technical information, related practical solutions and the steps of preparation of both investment in and day-to-day operation of a small-scale rainbow trout farm.

In order to satisfy interest for specific details, a glossary has been compiled and tables and annexes attached. Explanations are short but together with their illustrations they should be informative. Hence, it is hoped that this combination will facilitate easy understanding and learning of rainbow trout farming.

Woynarovich, A.; Hoitsy, G.; Moth-Poulsen, T.
Small-scale rainbow trout farming.
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1. Introduction

Trout farming is an ideal option for sustainable use of water resources in mountainous regions because here both surface and underground waters are suitable for this purpose. In regions where income-generating and employment opportunities are scarce, trout farming could help to ensure employment and steady incomes (Figure 1).

In addition to the production, trout farming could also ensure increased income and employment through angling tourism (Figure 2), restaurants (Figure 3) and related services.

The concept of this technical paper is to guide the reader through the necessary basic information of both investment in and day-to-day operation of a small-scale rainbow trout farm.

To satisfy the interest for specific details, a glossary has been compiled and tables and annexes are attached. For the sake of easy identification and finding additional information, a term in italics and followed by an asterisk (*) indicates a term that is explained in the glossary.

The combination of short explanations together with illustrations is aimed for easy understanding. However, it is suggested that users of this publication consult subject specialists, who will help to avoid unnecessary failures and their financial consequences.

FIGURE 1
Direct income generation through trout production

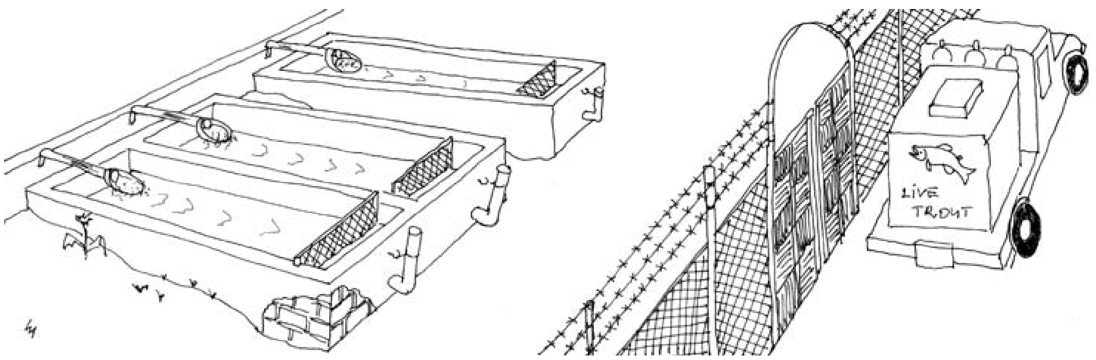
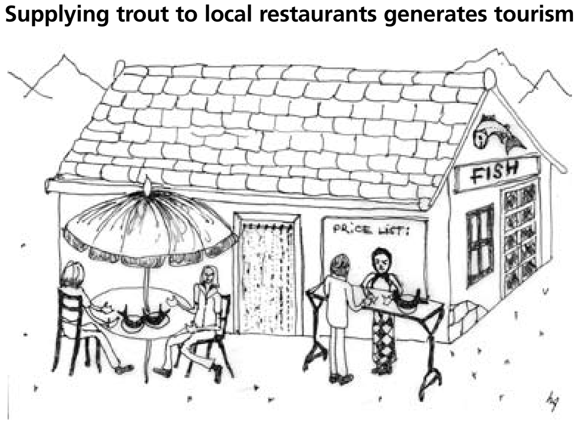


FIGURE 2
Trout farming can support angling tourism

FIGURE 3
Supplying trout to local restaurants generates tourism



2. Important trout species

There are 206 species in the *family** of Salmonidae. Salmonids (*salmon**, *trout**, char and whitefish) are found in practically all continents, partly because they are indigenous there and partly because they have been *introduced**.

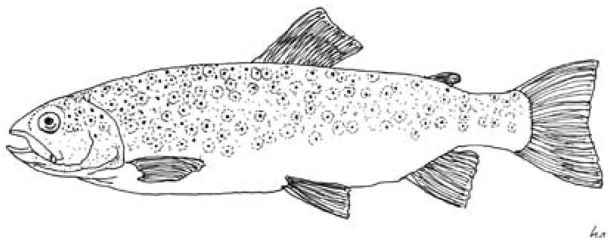
Among trout, brook trout, brown trout, lake trout, sea trout and rainbow trout are the most widely known species.

Brown trout is native to Europe and West Asia (Figure 4). An important market and sport fish, it has been introduced to many different countries all over the world.

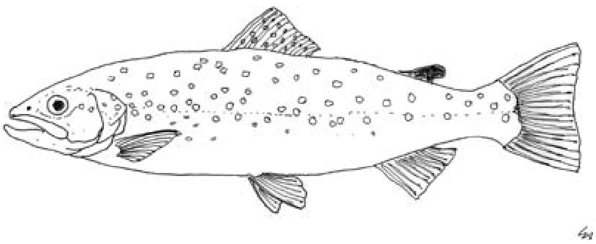
According to their *habitat**, taxonomists distinguish three forms of brown trout. They are the actual brown trout (*Salmo trutta* m. *fario*), lake trout (*Salmo trutta* m. *lacustris*) and sea trout (*Salmo trutta* m. *trutta*) (Figure 4).

FIGURE 4
Brown, lake and sea trout

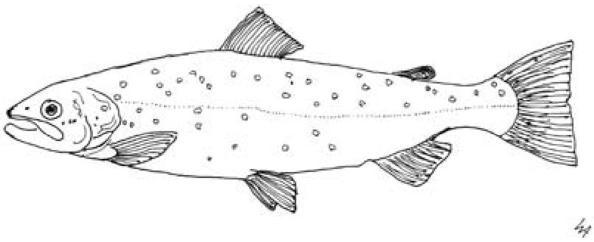
Brown trout (*Salmo trutta* m. *fario*)
Normal adult size in the wild: 1–2 kg
Maximum size and weight: 100 cm *TL**, 20 kg
Maximum age: 8 years
Water temperature of production: 2–16 °C



Lake trout (*Salmo trutta* m. *lacustris*)
Normal adult size: 1–2 kg
Maximum size and weight: 140 cm *SL**, 50 kg
Maximum age: 7 years
Water temperature of production: 2–16 °C



Sea trout (*Salmo trutta* m. *trutta*)
Maximum size and weight: 140 cm TL, 50 kg
Maximum age: 38 years
Water temperature of production: 18–24 °C
Distribution: Europe and Asia, northwest coast of Europe



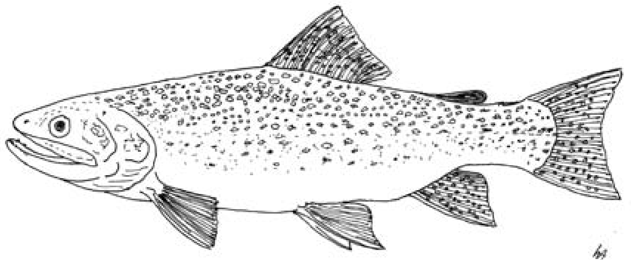
Source: Froese and Pauly (2009).

Brook trout, together with *lake trout** (*Salvelinus namaycush*), belongs to the "char" subgroup of salmonids, which distinguishes it from trout and salmon (Froese and Pauly, 2009).

The brook trout is one of the most well-known sport fish (Figure 5) and is native to the northeast of the United States of America and the east region of Canada. It has been introduced to many countries of South America, Oceania and Asia, and to practically all of the countries of Europe and the former Soviet Union.

FIGURE 5
Brook trout (*Salvelinus fontinalis*)

Normal adult size in the wild: 1–2 kg
Maximum size and weight: 86 cm TL, 9.39 kg
Maximum age: 24 years

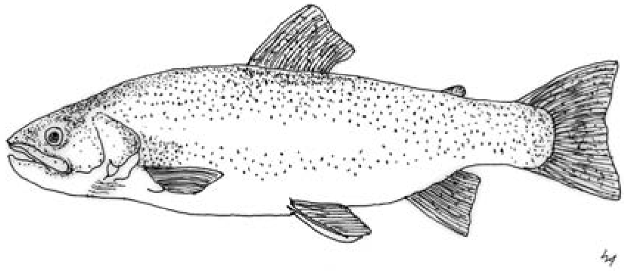


Source: Froese and Pauly (2009).

3. The rainbow trout

Rainbow trout (*Oncorhynchus mykiss*) is a highly commercial sport and market fish (Figure 6).

FIGURE 6
Rainbow trout



A normal adult rainbow trout weighs about 2–3 kg, while its maximum size, weight and age are 120 cm total length (TL), 25.4 kg and 11 years, respectively (Froese and Pauly, 2009). Rainbow trout live in the upper, cold water sections of rivers and seas.

As in the case of other trout, the habitat and food of rainbow trout determine both their actual colour and shape.

The rainbow trout has many local strains, which have developed in the different river systems. Out of these, numerous improved commercial *strains** have been bred. The widely cultured commercial strains have been improved from those original rainbow trout populations that possessed advantageous qualities, such as hardiness, fast growth, resistance to diseases and reliable reproduction under farm conditions.

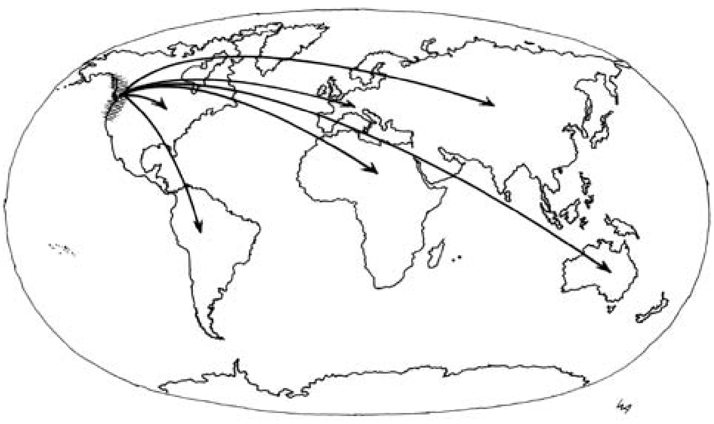
In the wild, there are rainbow trout populations that spawn in autumn and there are other populations that spawn in spring. From these populations, two different commercial strains have been bred. Their qualities are similar, only their spawning seasons differ from each other. This enables the *production capacities** of a rainbow trout farm to be increased.

In many countries, the albino form of rainbow trout is cultured and is often, but mistakenly, called golden trout. This form is a popular ornamental and "put-and-take" fish, even if it is very sensitive to unfavourable environmental and production conditions.

3.1 NATIVE RANGE AND INTERNATIONAL INTRODUCTIONS

Rainbow trout is native to the cold water rivers and lakes of the Pacific coasts of North America and Asia. It has been *introduced** to about 82 countries (Figure 7), practically everywhere the conditions are favourable for its culture, because rainbow trout tolerates a wide range of environmental and production conditions better than other trout species.

FIGURE 7
Native range and international introductions of rainbow trout

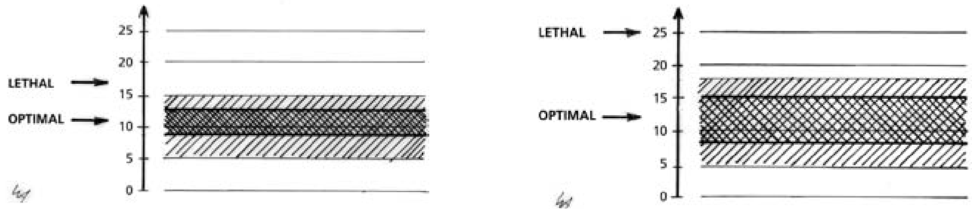


3.2 HABITAT FACTORS

There are four vital habitat factors that basically influence the growth of rainbow trout. These include basic water qualities and the abundance of *natural food**.

Cold water: Rainbow trout is a typical *cold water fish** (Figure 8).

FIGURE 8
Temperature ranges for rainbow trout at various development stages

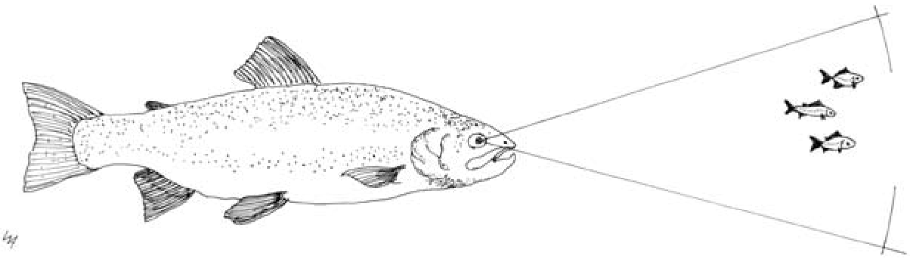


Optimal and lethal range of water temperature during incubation of eggs and sac fry.

Optimal and lethal range of water temperature during the growth of fish.

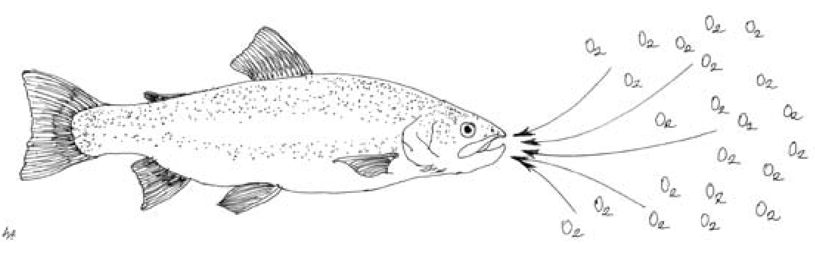
Clear water: Keen eyesight is crucial for the efficient feeding of trout (Figure 9).

FIGURE 9
Clear water enables efficient feeding



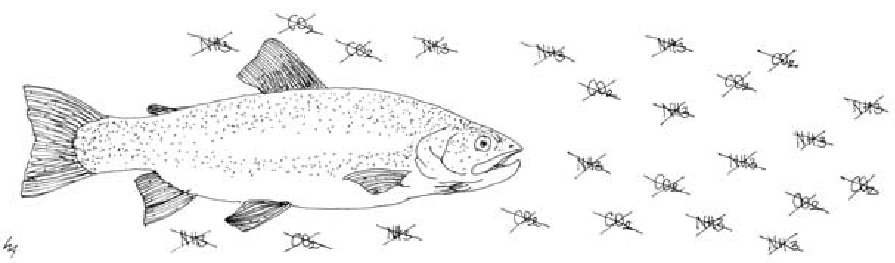
Dissolved oxygen: Water should sustain *DO** in high concentrations, in order to ensure smooth respiration (Figure 10).

FIGURE 10
High concentrations of dissolved oxygen enable smooth respiration



Clean water: Water should be free of *harmful solid** and *harmful gaseous** waste materials produced during metabolism and respiration (Figure 11).

FIGURE 11
Trout need water that is free of harmful solid or gaseous waste materials

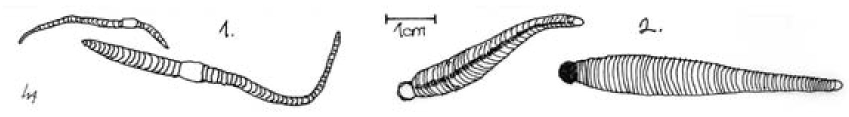


Natural food: The actual natural food of rainbow trout depends on the age and size of fish, on the size of food item and on the habitat occupied. Rainbow trout are aggressive and greedy in feeding (Hoitsy, 2002). They are opportunistic feeders that grab and eat almost anything. Figure 12 summarizes the most frequent natural food items of rainbow trout.

Terrestrial insects are also consumed when they fall into the water. These insects are adult beetles (Coleoptera), flies (Diptera), ants (Formicidae) and larvae of Lepidoptera (moths and butterflies) (Montgomery and Bernstein, 2008).

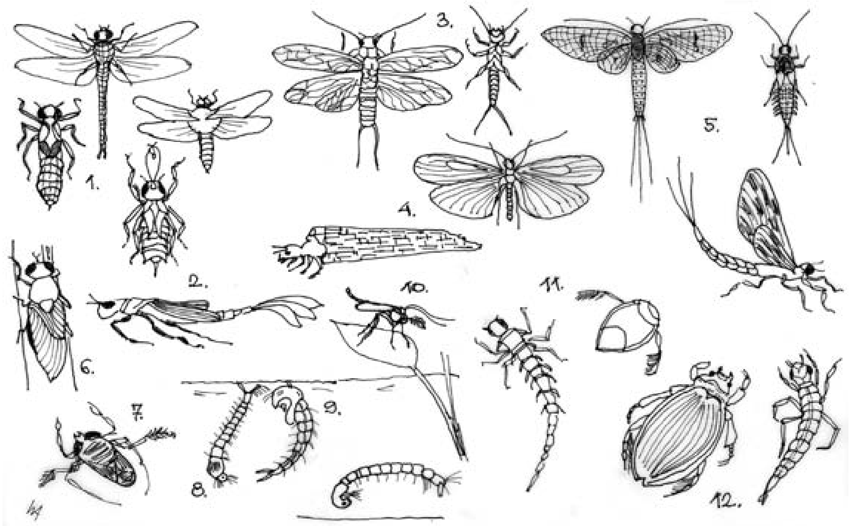
FIGURE 12
Most frequent natural food items of rainbow trout

Annelids*
1. Worms
2. Leeches

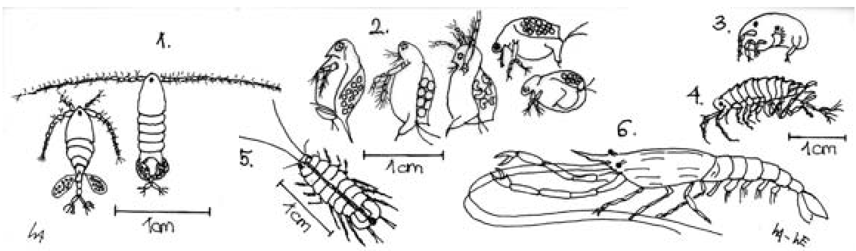


Different development forms of aquatic insects
1. Dragonflies
2. Damselflies
3. Stoneflies
4. Caddis flies
5. Mayflies
6. Soldier flies
7. Water boatman
8. Mosquito larvae
9. Mosquito pupae
10. Chironomus
11. Haliplid beetles
12. Dytiscid beetles

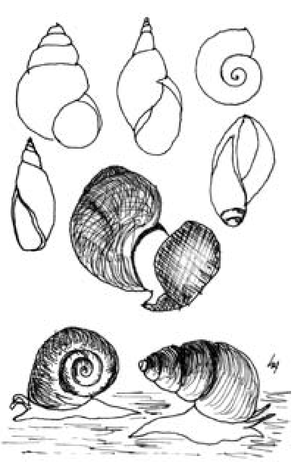
Others: Midges, black flies, crane flies, etc.



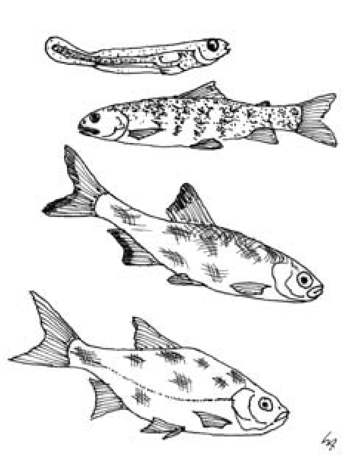
Small and large aquatic crustaceans
1. Copepods
2. Cladocerans
3. Ostracods
4. Amphipods
5. Water louse
6. Crayfish



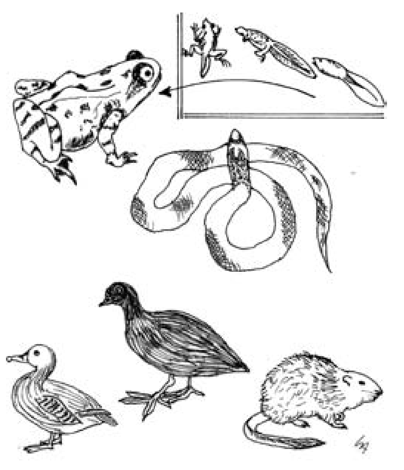
Water snails and molluscs



Fishes of different age groups and sizes



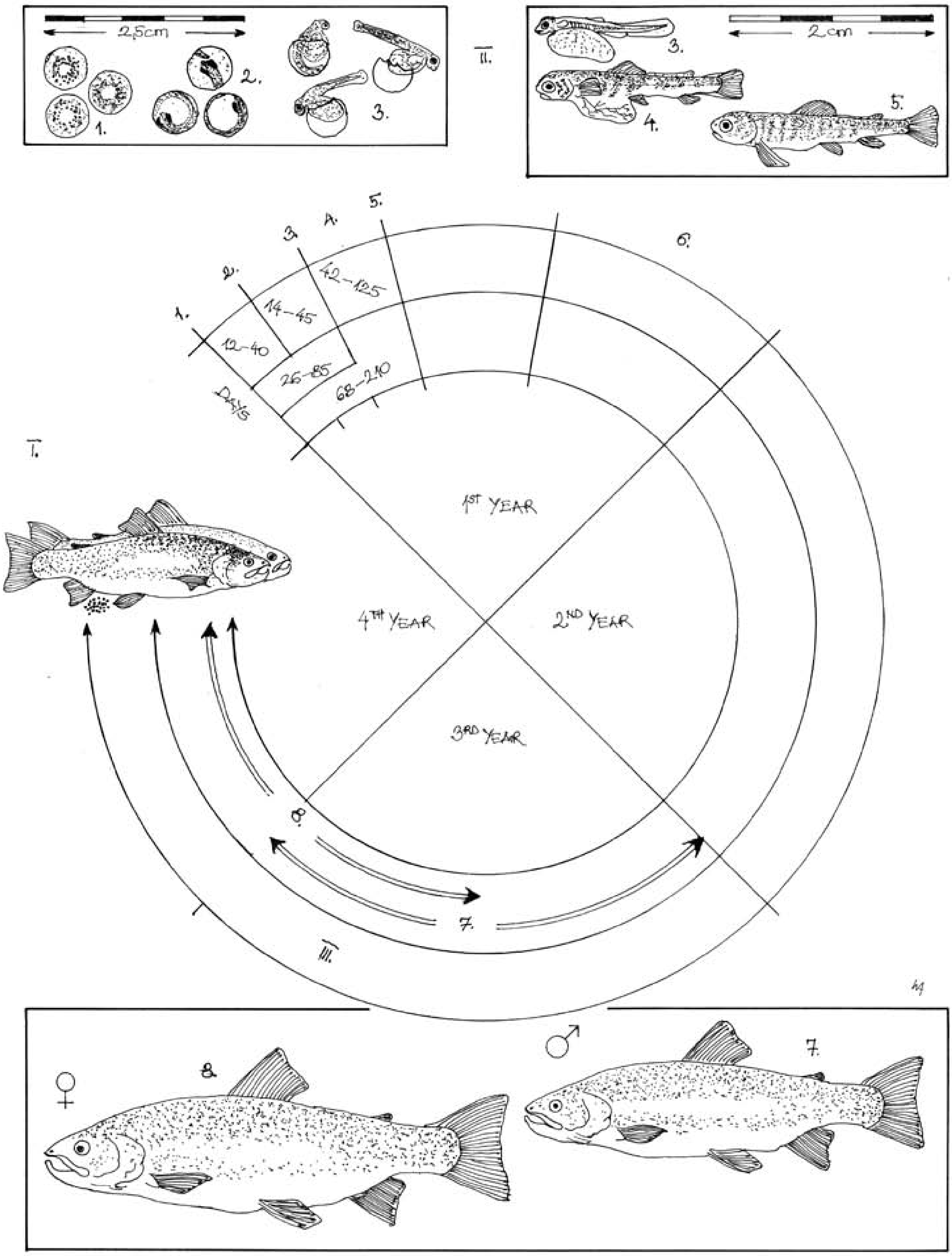
Offspring of reptiles, birds and mammals



3.3 LIFE CYCLE AND DEVELOPMENT STAGES IN THE WILD

Figure 13 shows the life cycle and development stages for rainbow trout in the wild.

FIGURE 13
Life cycle and development stages for rainbow trout in the wild



Development stages: 1. *Fertilized eggs**. **2.** *Eyed egg*.* **3.** Hatched *sac fry**. **4.** *Swim-up fry**. **5.** *Fry*.* **6.** One-summer fish. **7.** Sexually mature males (*symbol**: ♂) and **8.** females (*symbol**: ♀) are ready to spawn (after Huet, 1970).

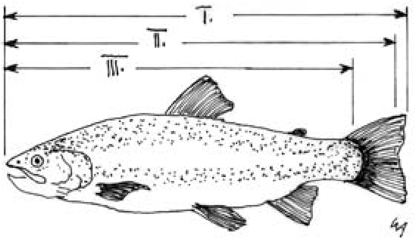
Development phases: I. Spawning. **II.** Development of fertilized eggs and sac fry. **III.** Development and sexual maturation of fish.

The actual start and duration of the different development phases depend on the water temperature, the genotype as well as the quantity and quality of available natural fish food.

3.4 MEASUREMENTS, BODY PARTS, ORGANS AND CORRELATIONS BETWEEN LENGTH AND WEIGHT

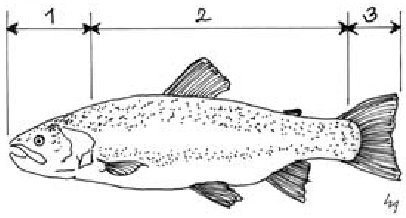
Figure 14 shows the standard measurements and body parts of a rainbow trout, while Figure 15 shows the correlation between its total length and weight.

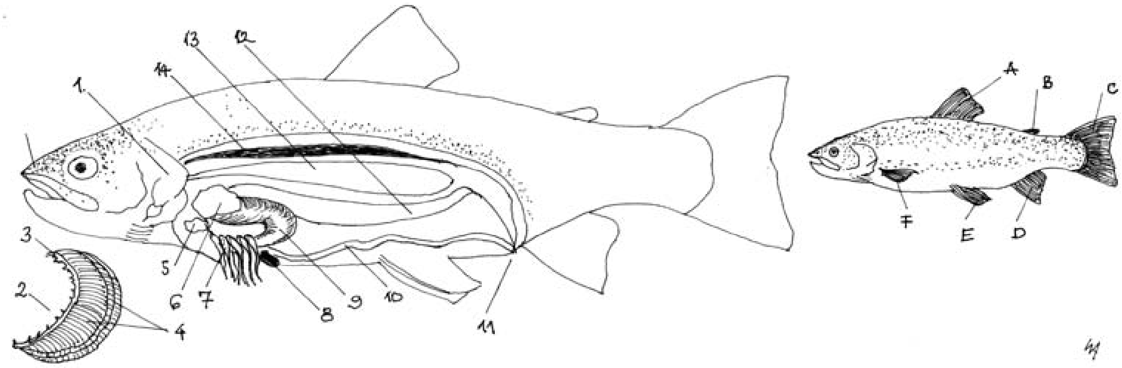
FIGURE 14
Standard measurements and body parts of rainbow trout



I. Total length (TL)
II. Fork length (FL)
III. Standard length (SL)
Depth of body is the "height" of fish measured between back and stomach.

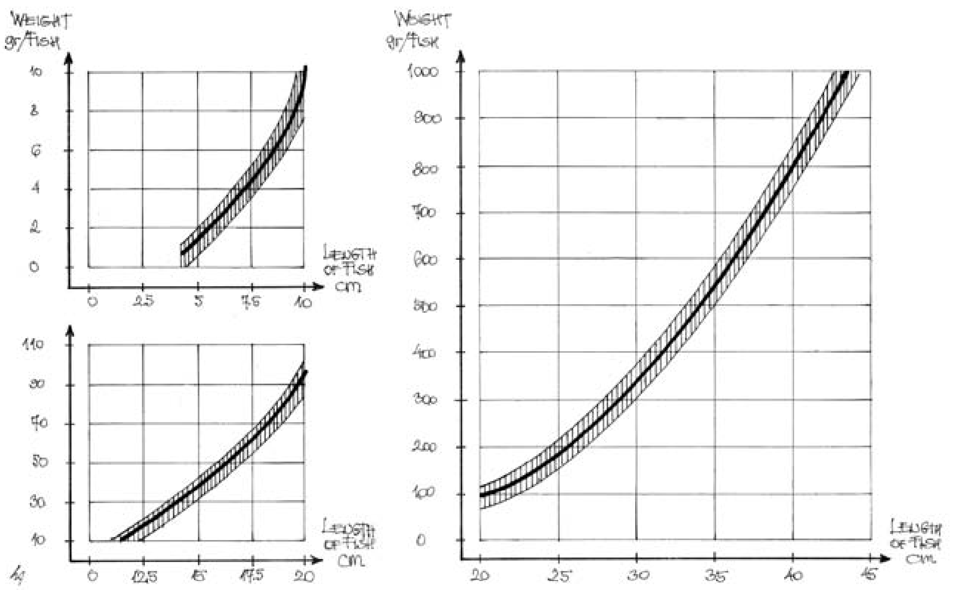
1. Head. **2.** Trunk. **3.** Tail.





1. Opercula (gill cover). **2.** Gill raker. **3.** Gill arch. **4.** Gill filaments. **5.** Heart. **6.** Liver. **7.** Pyloric caecae and pancreas. **8.** Spleen. **9.** Stomach. **10.** Intestine. **11.** Anus and urogenital papilla. **12.** Gonad. **13.** Swimming bladder. **14.** Kidney.
A. Dorsal fin. **B.** Adipose fin. **C.** Caudal fin. **D.** Anal fin. **E.** Pelvic fin. **F.** Pectoral fin.

FIGURE 15
Correlation between the total length and the weight of rainbow trout



Source: After Klontz (1991); Mills (2001); Hoitsy (2002).

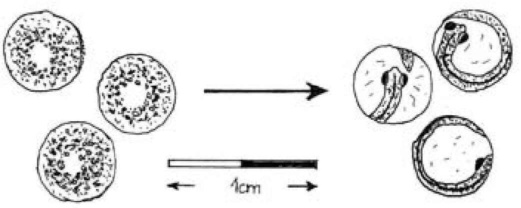
3.5 DURATION OF THE DEVELOPMENT STAGES

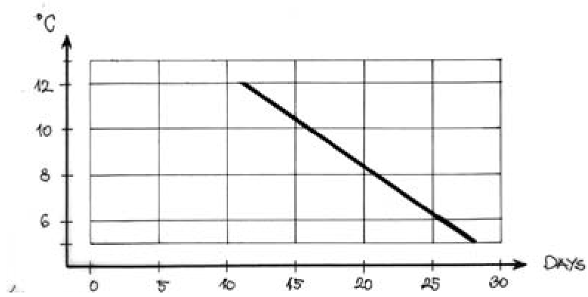
Water temperature is a determining factor of fish production. This is because the body temperature of *embryos**, fry and developing fish equalize their temperature to that of the water they are in. Along with the body temperature, the intensity of the *metabolism** also changes.

The developing embryos and fry feed from the *yolk sac** and receive oxygen through the entire body surface. When the water temperature is higher, the embryos and fry develop more rapidly, while at lower water temperatures the speed of development reduces (Figure 16). Outside of a certain range of water temperature (see Section 4.2), development stops.

FIGURE 16
Duration of the early development stages of rainbow trout

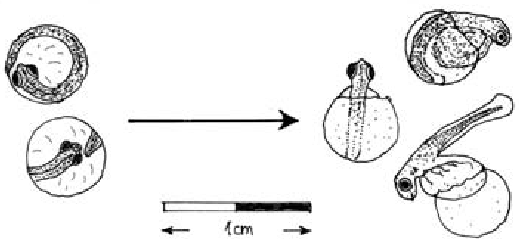
First phase of incubation: from fertilization of egg to eyed egg

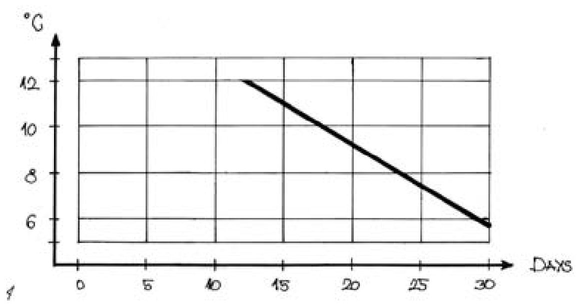




Length of the first phase of incubation at water temperature between 6 and 12 °C.

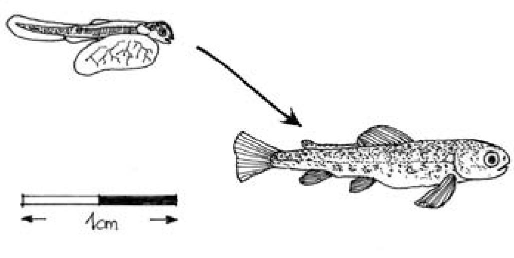
Last phase of incubation: from eyed egg to hatched sac fry

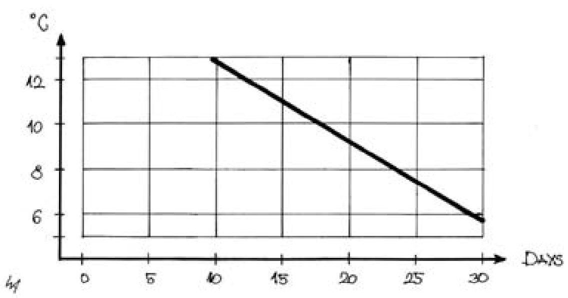




Length of the last phase of incubation at water temperature between 6 and 12 °C.

Development of sac fry: from hatched sac fry to swim-up fry





Length of the development of sac fry at water temperature between 6 and 12 °C.

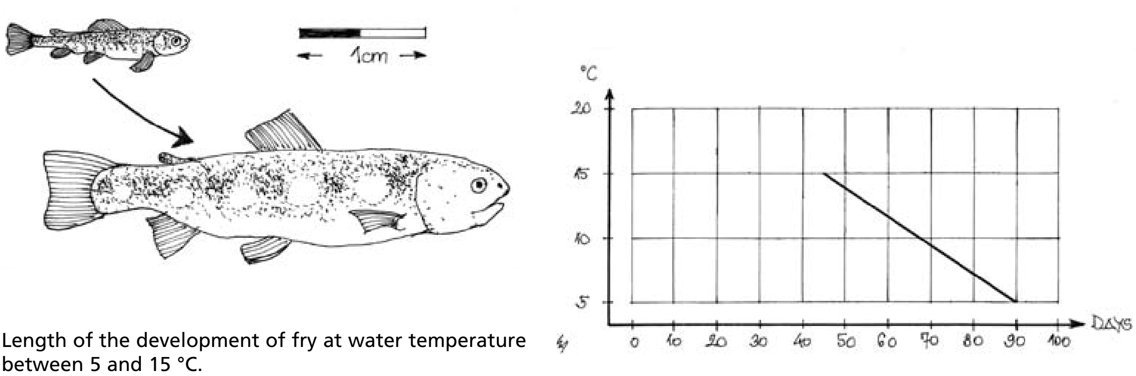
Source: After Huet (1970) and Hoitsy (2002).

The total length of the development of embryo and fry from fertilization to swim-up is about 37–83 days at water temperatures between 6 and 12 °C.

After starting *external feeding**, the actual length of the development of the different age groups depends not only on the temperature and oxygen content of water but also on the quality and quantity of consumed feed. In determining the following figures, it has been assumed that trout is adequately fed with commercial feeds, which are readily and widely available in the countries of Central and Eastern Europe[1] (CEE) and the Caucasus[2] and Central Asia[3] (CCA).

Development of fry from swim-up fry takes 1.5 –3 months (Figure 17). For the sake of clear understanding and simple calculations, "fry" in this technical paper refers to a total length of 5 cm and to an average body weight of 2 g.

FIGURE 17
Development of fry

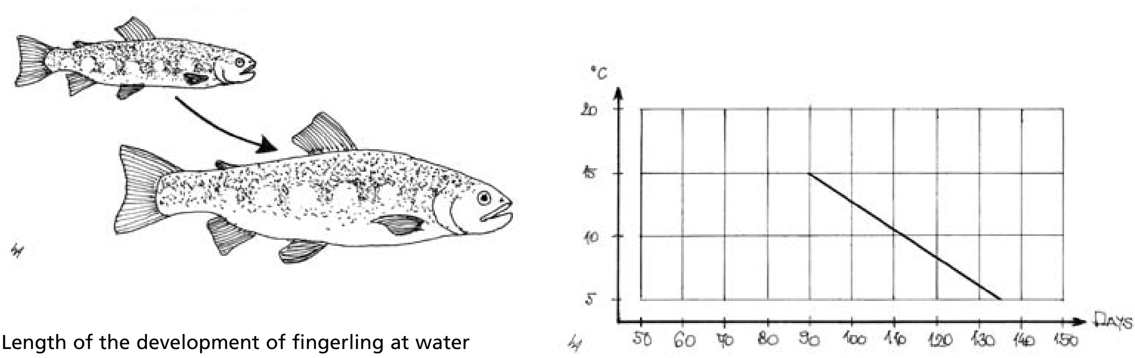


Length of the development of fry at water temperature between 5 and 15 °C.

Source: After Hoitsy (2002).

Development of *fingerlings** from fry takes 3–4.5 months (Figure 18). For the sake of clear understanding and simple calculations, "fingerling" in this technical paper refers to a total length of 12.5 cm and to an average body weight of 25 g.

FIGURE 18
Development of fingerlings



Length of the development of fingerling at water temperature between 5 and 15 °C.

Source: After Hoitsy (2002).

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[1] Albania, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Montenegro, Poland, Republic of Moldova, Romania, Russian Federation, Serbia, Slovakia, Slovenia and Ukraine.

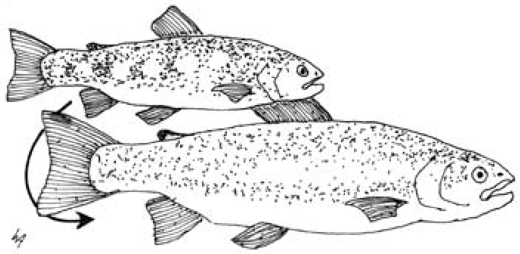
[2] Armenia, Azerbaijan and Georgia.

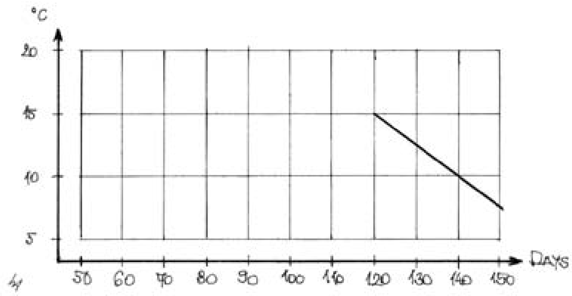
[3] Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan.

Development of *table fish** from fingerling takes 4–6.5 months (Figure 19). For the sake of clear understanding and simple calculations, “table fish” in this technical paper refers to the desired minimum body weight of 250 g.

Growth of large table fish from 250 g to 500 g takes a further 2.5–4.5 months (75–135 days) when the water temperature is between 5 and 15 °C.

FIGURE 19
Development of table fish





Length of the development of table fish at water temperature between 5 and 15 °C.

Source: After Hoitsy (2002).

4. Production conditions

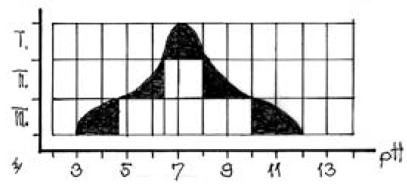
Optimal or near to optimal conditions should be ensured during production of the different age groups of rainbow trout. For this reason, the optimal production conditions – the actual requirements of fish – should be known.

4.1 PH OF WATER

Rainbow trout tolerates unfavourable *pH** conditions differently during the various development phases of the fish. The optimal and acceptable ranges of pH of rearing water also differ. For developing embryos and fry, the range of optimal pH is narrow, and varies between 6.5 and 8, but the range of acceptable pH is also narrow. For older fish, both the optimal and acceptable ranges of pH are wider, as demonstrated in Figure 20.

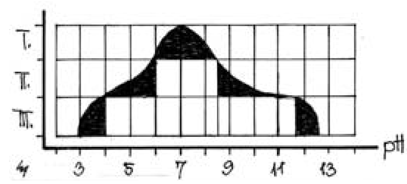
FIGURE 20

Optimal, acceptable and lethal ranges of water pH during development stages of rainbow trout



Development from fertilized egg to swim-up fry.

I. Optimal
II. Acceptable
III. Lethal



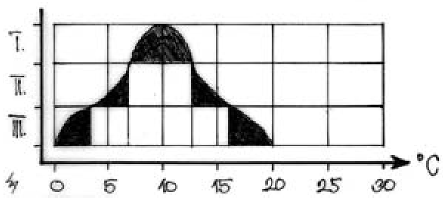
Development from swim-up fry to table fish.

4.2 TEMPERATURE OF WATER

The optimal, acceptable and lethal ranges of water temperature also vary according to the development stages of the fish, as demonstrated in Figure 21.

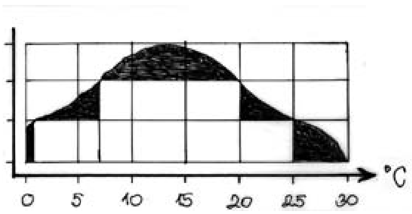
FIGURE 21

Optimal, acceptable and lethal ranges of water temperature during development stages of rainbow trout



Development from fertilized egg to swim-up fry.

I. Optimal
II. Acceptable
III. Lethal

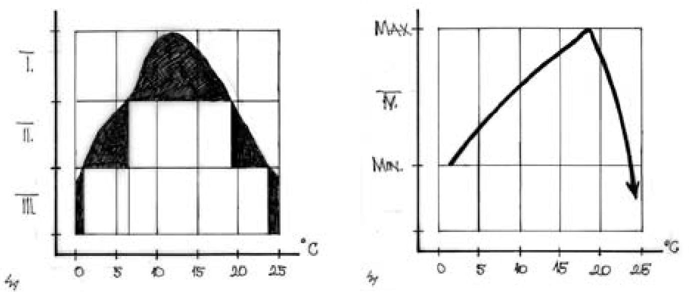


Development from swim-up fry to table fish.

There is a range of water temperature (about 7–18 °C), where the appetite of rainbow trout is optimal (Figure 22). Outside of this range, at lower and higher water temperature, fish lose appetite. Finally, at too low or too high water temperature, fish stop feeding.

Feeding (feed intake) of rainbow trout intensifies as the water temperature increases. However, this behaviour continues only up to about 18 °C. Above this temperature, the appetite of and feed intake by the fish sharply decreases and stops.

FIGURE 22
Water temperature and appetite of rainbow trout



I. Optimal range of appetite. **II.** Losing appetite. **III.** Feeding stops. **IV.** Intensity of feeding.

It is important to be aware that there is an inverse correlation between the intensity of feeding and the utilization of consumed feed. Thus, at about 18 °C, rainbow trout are willing to feed very intensively, but the digestion of consumed feed will be less complete at this temperature. The water temperature where the different trout species make the best growth out of the consumed feed varies from 13 °C (Baldwin, 1957) to 15 °C (Molony, 2001). Hence, the optimal utilization of feed and the maximum appetite of rainbow trout also fall within this range of water temperature.

4.3 DISSOLVED OXYGEN CONTENT OF WATER

Oxygen (O_2) dissolved in water ensures the respiration of the different aquatic plants and animals. Most frequently, the DO content of water is expressed in milligrams of oxygen per litre of water (mg/litre).

The maximum oxygen content of water depends on the actual water temperature. This is because water can dissolve only a certain quantity of oxygen, which is determined by the partial pressure of oxygen in the atmosphere.

Figure 23 shows the inverse correlation between temperature and DO content of water. At a higher temperature of water, the DO content is lower, and vice versa. At maximum oxygen content, water is 100 percent saturated with oxygen and the oxygen in excess soon leaves to the atmosphere.

The optimal and acceptable concentrations of oxygen in water vary according to the actual development stage of the fish. The optimum is when the oxygen content of rearing water is near to saturation (100 percent). The acceptable range of oxygen content of rearing water is lower. It ranges between 5 and 6 mg/litre during incubation of eggs and the first development stages of fry. For older age groups, the acceptable low oxygen content of water may be about 4–5 mg/litre.

It is important to know that the oxygen consumption of fish increases considerably during and after feeding. During these periods the demand for oxygen will temporarily increase.

FIGURE 23
Correlation between temperature and possible maximum saturation of oxygen in water

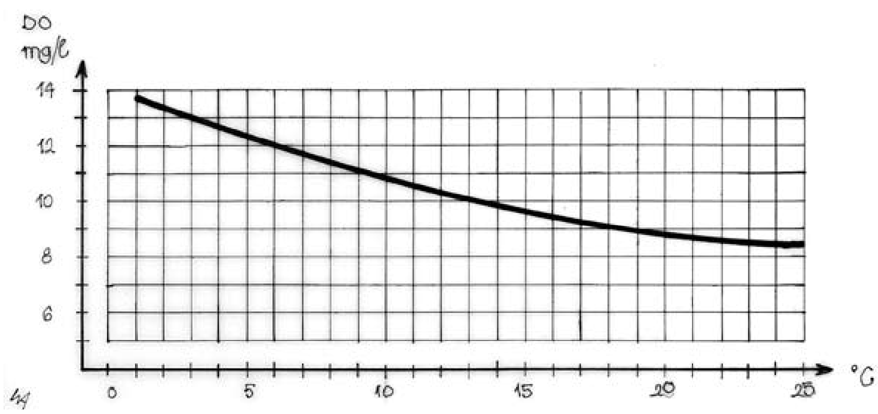


FIGURE 24
Water supply in tanks required according to development stage of fish

Water supply during incubation of eggs and developing fry

0.25–2.5 litres/min water is needed for incubation of 10 000 eggs and developing fry.

Water supply during fry rearing

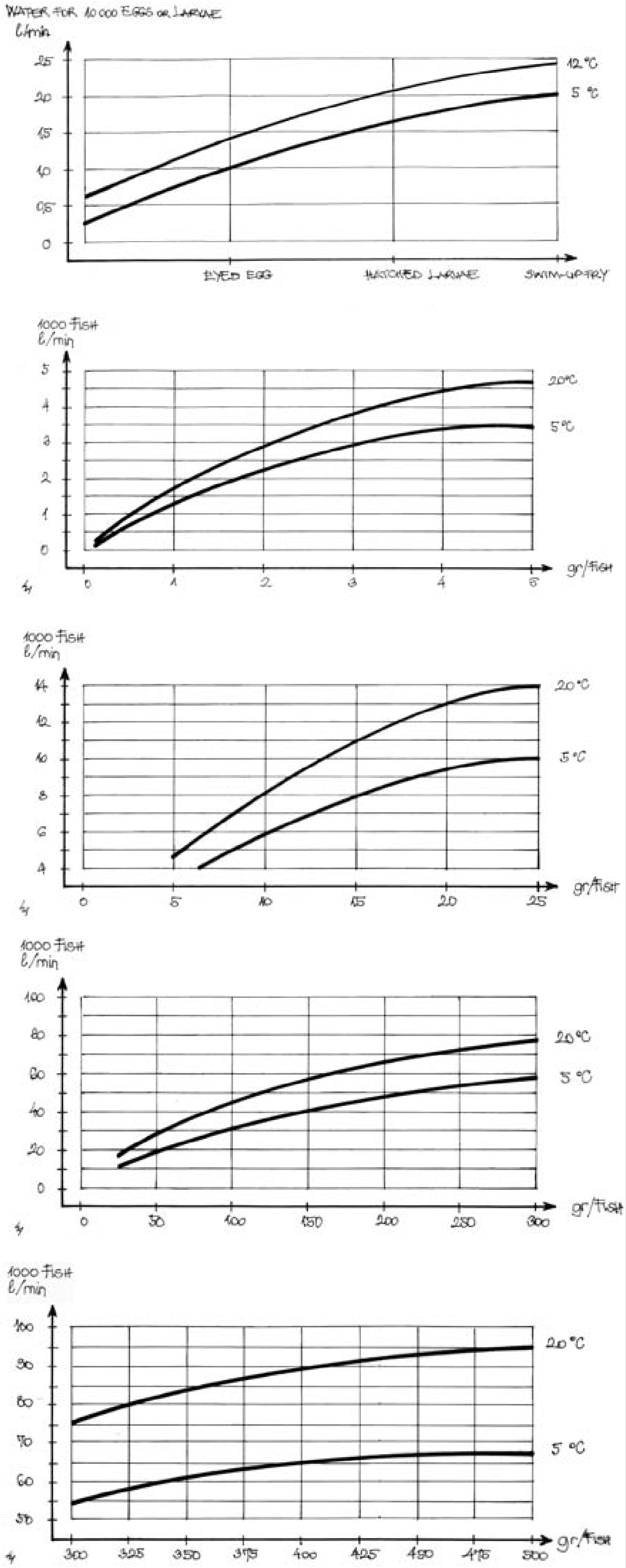
At start, about 0.25 litres/min; at the end, about 3.5–4.5 litres/min water is needed for rearing 1 000 fry.

Water supply during rearing of fingerlings

At start, about 3.5–4.5 litres/min; at the end, about 10–14 litres/min water is needed for rearing 1 000 fingerlings.

Water supply during rearing of table fish

At start, about 10–14 litres/min; at the end, about 67–95 litres/min water is needed for rearing 1 000 table fish.



Source: After Huet (1970) and Hoitsy (2002).

4.4 WATER SUPPLY[4]

In order to ensure the replacement of used water in the *rearing devices**, a continuous supply of fresh, clean and oxygen-rich water is essential. The necessary quantities of water supplied depend on the age and actual quantity of the developing fish.

The quantity of eggs, fry and growing fish per unit area of rearing device is determined by the oxygen content of supplied water. In colder water, the metabolism and, hence, respiration slows, while in warmer water they intensify. Accordingly, the actual quantity of water needed for the same number of developing embryos, fry and fish will be different. At low water temperature, the quantity of water supplied may be less but at higher water temperature it should be more.

Water supply is expressed by the flow rate, which is the quantity of water needed for 10 000 or 1 000 specimens of eggs, fry or fish. It is expressed either in litres per second (litre/s) or litres per minute (litres/min). See cross-calculations in Table A10.2.

Frequency of water exchange is another way to specify the quantity of supplied water. It is expressed by the *exchange rate** of water per hour or day. See cross-calculations in Table A10.3.

The water supply in concrete or lined *tanks** can be more intensive than in earth *ponds**, hence the density of fish can also be higher in these devices.

4.4.1 Water supply in tanks

In tanks, the water supply required varies according to the development stage of the fish (Figure 24).

4.4.2 Water supply in earth ponds

In earth ponds, water can be exchanged a maximum of 4–5 times/day, but typically it is done only 1–2 times/day.

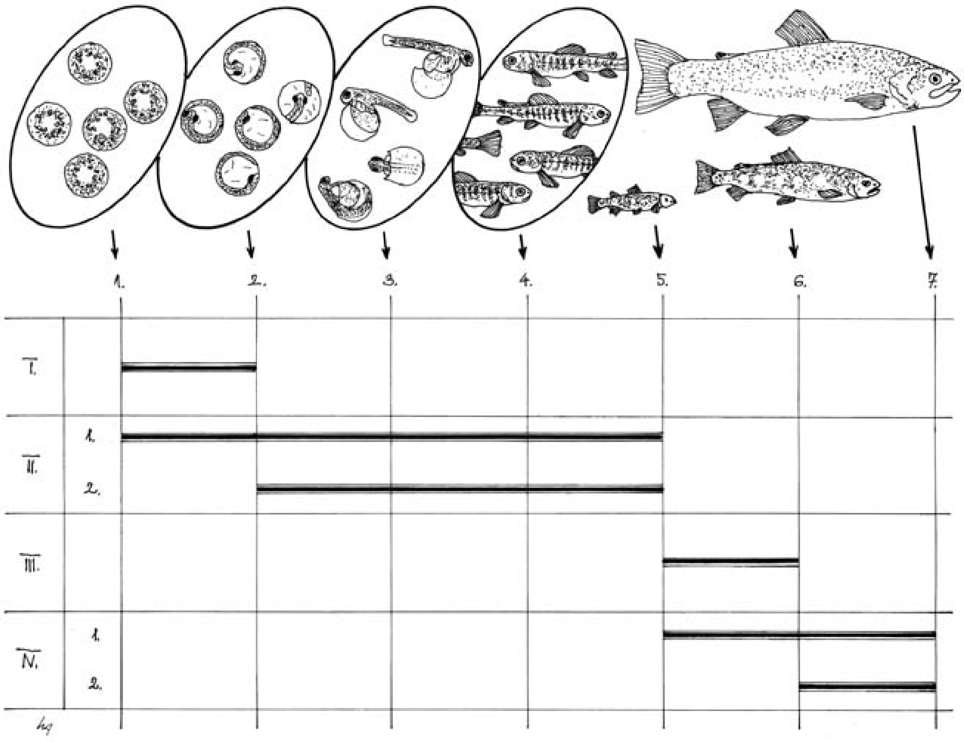
[4] When elaborating the graphs in this section, it was assumed that the water would be nearly 100 percent saturated with oxygen.

5. Production options, devices and capacities

5.1 PRODUCTION OPTIONS

Figure 25 shows the different production options, from which the most suitable one can be selected.

FIGURE 25
Chart of production options



Development stages: **1.** Fertilized eggs. **2.** Eyed eggs. **3.** Hatched sac fry. **4.** Swim-up fry. **5.** Fry. **6.** Fingerlings. **7.** Table fish.

Phases of production: **I.** Eyed egg production (90–95% survival). **II.** Fry production (90–95% survival). **III.** Fingerling production (90–95% survival). **IV.** Table fish production (95–98% survival).

Note: Survival rate between hatching and reaching the size of table fish is acceptable if it is about 75 percent.

I. Eyed egg production: This production option is not recommended for those who are about to start trout farming. The necessary quantity of eyed eggs can be purchased from *broodfish** farms, specialized on the production of high-quality eyed eggs. The reason why it is recommended not to start with eyed egg production is that even the basic management of broodfish stock and a hatchery requires specialized skills and extensive practice, which can only be gained through training. From specialized broodfish farms, the eyed eggs of *all female stock** can also be purchased.

II. Fry production: This option can be started either with fertilized eggs (suboption: **II-1**) or with the purchase of eyed eggs (suboption: **II-2**). The latter option is recommended.

III. Fingering production: This production has different options for practical reasons. There are circumstances where fry are too small to stock for the production facilities; therefore, farmers may need larger young fish. A fingerling production unit can be operated separately, but can also be one of the units of a fry or table-fish production farm.

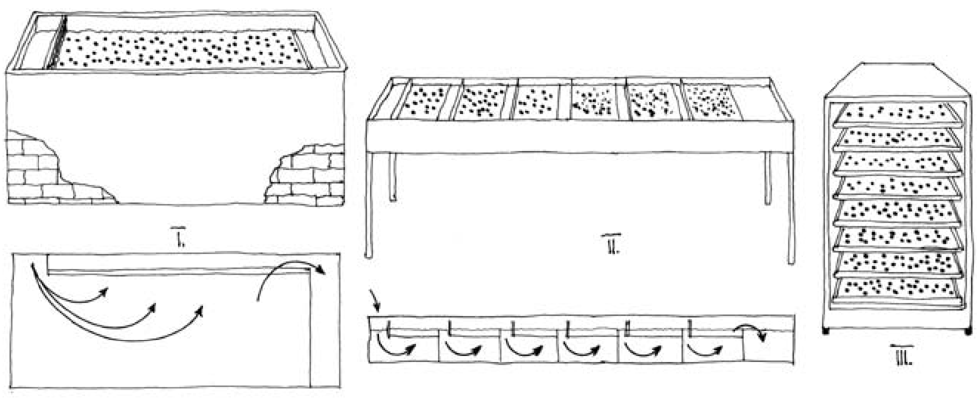
IV. Table fish production: There are two options. Accordingly, table fish can be reared either from fry (suboption: **IV-1**) or from fingerlings (suboption: **IV-2**).

5.2 PRODUCTION DEVICES AND THEIR CAPACITIES

Hatching trays, fibreglass or polypropylene rearing troughs and tanks, membrane tanks, concrete tanks, lined and unlined earth tanks are the production devices of fry, fingerlings and table fish.

Hatching trays are the devices for incubation of eggs and sac fry. The bottom of the trays is a sieve material, on which the eggs and sac fry rest. They receive freshwater through the sieve from under the tray, as illustrated in Figure 26. Although the material, shape and size of hatching trays may vary, the quantities of eggs and sac fry that can be incubated on them are similar. A hatching tray about 0.2 m^2 is needed for the incubation and hatching of 10 000 rainbow trout eggs. Later, the required space increases, because 10 000 swim-up fry need 5 times more space (about 1 m^2) with about 0.5 m depth. The required quantity of water in these devices should be ensured and adjusted as presented in the graphs of Section 4.4.

FIGURE 26
Hatching tray systems



I. Hatching tray placed in a concrete tank. After hatching, the tank serves as a rearing device for fry. **II.** Horizontal flow incubators have 4, 6 or 8 standard trays (size: 0.5 m × 0.4 m = 0.2 m^2). If hatching trays are removed, the same device can be used for rearing fry. **III.** Vertical flow incubators are used in order to save floor space. They are manufactured with 4, 6, 8 and 10 standard trays.

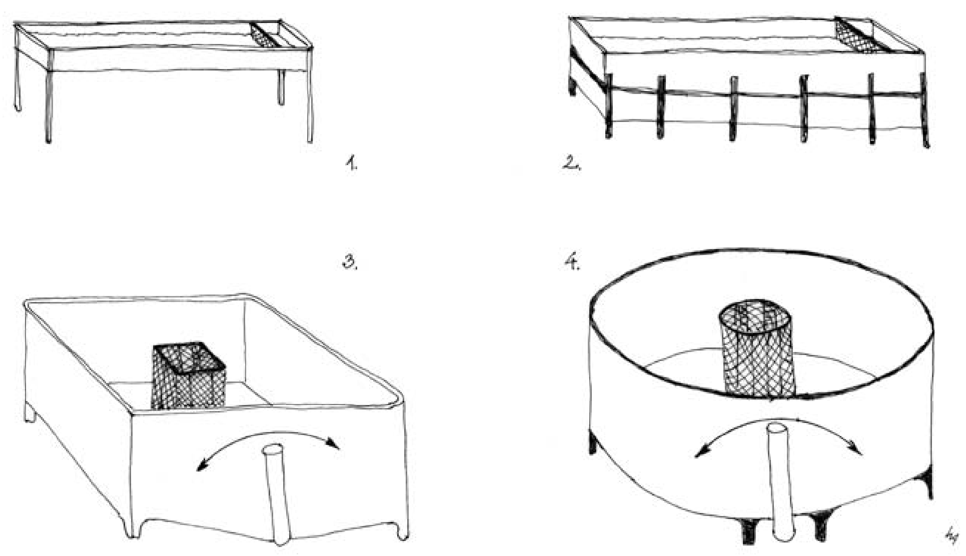
Fibreglass and polypropylene troughs and tanks are used for rearing fry, fingerlings or even table fish (Figure 27). Shallow troughs are usually used for rearing fry, while deeper ones serve for rearing fingerlings. Smaller tanks (0.5–5 m^3) are used for rearing younger fish (fry and fingerlings), while larger tanks (5–25 m^3) are used for growing table fish. There are fibreglass tanks that are mounted from panels on-site. Their sizes vary and they can be as large as 50–100 m^3.

Membrane tanks are also widely used in trout farming. Similarly to fibreglass and polypropylene tanks, they are also manufactured in many different sizes (Figure 28).

Lined earth tanks and ponds are the alternatives to large concrete rearing tanks or earth ponds paved with concrete and/or stone (Figure 29).

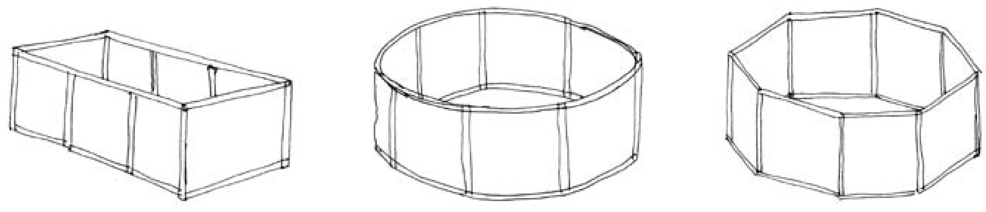
Concrete tanks come in indoor and outdoor versions (Figure 30). Smaller (a few cubic metres) concrete tanks are used for rearing small fish, and the larger (several hundred cubic metres) tanks are used for table fish production. Typically, they are rectangle or *raceway** type with a water depth of about 1 m.

FIGURE 27
Typical shapes of fibreglass and polypropylene rearing troughs and tanks



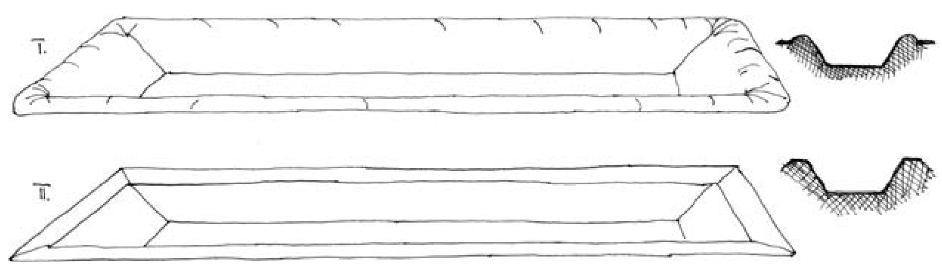
1. & **2.** Rearing troughs. **3.** & **4.** Rearing tanks.

FIGURE 28
Typical shapes of membrane tanks



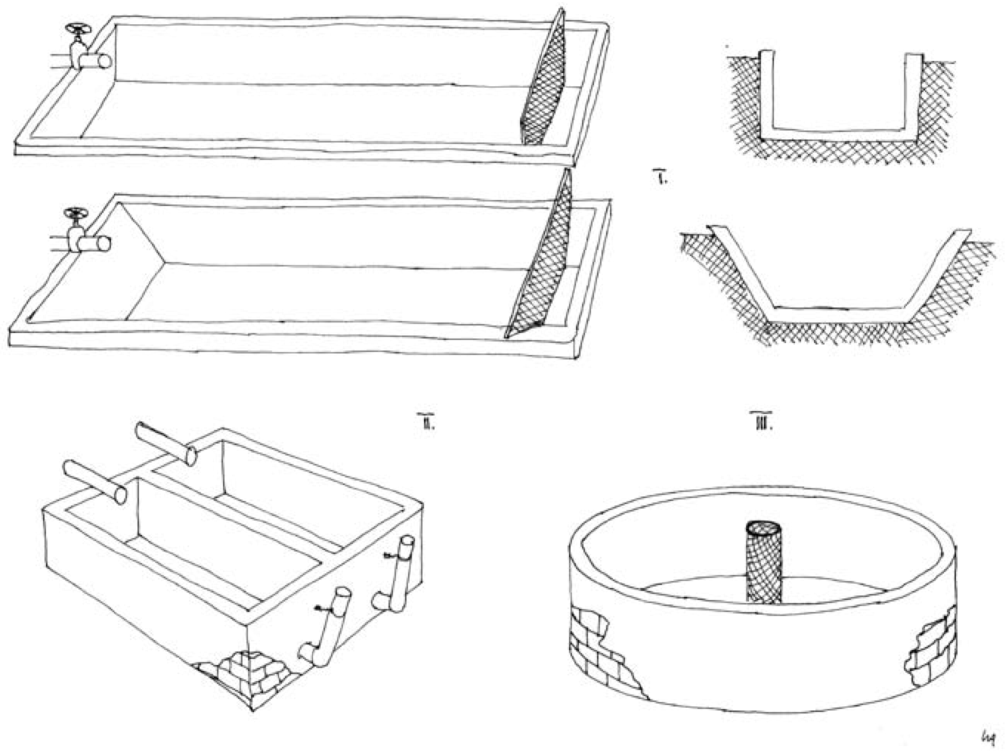
Membrane tanks need strong frames, which are made out of iron bars or planks. The shape of the frame/tank can be different.

FIGURE 29
Typical shapes of lined earth tanks



I. Lined with plastic sheet, which is widely used for greenhouses. **II.** Lined with geomembrane.

FIGURE 30
Typical shapes of concrete tanks



I. Open-air raceway tanks. **II. & III.** Indoor and outdoor tanks of different shapes. With twin arrangement of the tanks, the available space can be utilized better.

Rounded values in Table 1 show that the density of fish should be reduced as their individual size increases. As the size and the number of fish change in a tank, the quantity of water supplied should also be adjusted in line with the figures presented in Section 4.4.

TABLE 1
Key semi-intensive production figures of rainbow trout in lined and concrete tanks

Quantity of fish and water	Fry				Fingerling		Growing fish		Table fish			
	2 g/fish		5 g/fish		25 g/fish		100 g/fish		250 g/fish		500 g/fish	
	from	to	from	to	from	to	from	to	from	to	from	to
Weight of fish (~ kg fish/m^3)	2.5	5	5	10	10	20	10	25	15	25	15	25
Quantity of fish (fish/m^3)	1 250	2 500	1 000	2 000	400	800	100	250	60	100	30	50
Maximum quantity of water at 5 °C (~ litres/min/m^3)	3	6	4	7	4	8	3	8	3	6	2	3
Maximum quantity of water at 20 °C (~ litres/min/m^3)	4	8	5	10	6	11	5	11	5	8	3	5

Earth ponds are the traditional *structures** for trout production, but today as trout farming has intensified, they are less frequently used. Initially, earth ponds of any shape were used for rearing trout. Later, especially in Denmark, the shape of the ponds was adjusted to enable intensive trout rearing. These were built long (30–50 m), narrow (10–20 m) and deep (1.5 m), and the bottom was covered with pebbles. In such ponds, the flow of water is limited and cleaning is difficult. Today, therefore, most earth ponds on trout farms are lined with membrane or paved with stone or concrete.

The required quantities of water for 1 m^3 of a rectangular earth pond may vary between 0.7 and 1.4 litres/min where the exchange rate of water is about 1–2 per day. The usual densities of the different age groups of rainbow trout in earth ponds are presented in Table 2. With aeration of the water, the quantities of produced fish indicated below can cautiously be increased.

TABLE 2
Key semi-intensive production figures of rainbow trout in earth ponds

Quantity of fish and water	Fry				Fingerling		Growing fish		Table fish			
	2 g/fish		5 g/fish		25 g/fish		100 g/fish		250 g/fish		500 g/fish	
	from	to	from	to	from	to	from	to	from	to	from	to
Weight of fish (~ kg fish/m^3)	Not recommended				3	6	3	8	5	8	5	8
Quantity of fish (fish/m^3)	Not recommended				120	240	30	80	20	32	10	16

5.3 PLANNING THE NUMBER AND SIZE OF REARING DEVICES OF A NEW PRODUCTION UNIT

As fish grow, they need more and more rearing space. At the beginning, smaller tanks are enough, but later the fish stock has to be divided and restocked in reduced densities. Therefore, it is advantageous to have both smaller and larger rearing tanks on a fish farm.

Planning in fish farming is usually done in a reverse direction. First, the final result (number, total and individual weights of produced fish) is set/fixed, and from these planned figures all the required rearing spaces of the different age groups of fish are calculated backward, as demonstrated in Tables 3 and 4.

When planning for the number and size of rearing devices of a new rainbow trout production unit, the total quantity and the individual final size of fish should be taken into consideration, together with the fish density (intensity of production). The figures presented in Table 3 and 4 show the relative (1.) and absolute (2.) proportions of the required rearing spaces of the different age groups of rainbow trout.

The definition of a small-scale trout farm is rather subjective and may vary from country to country. In countries and regions where incomes equivalent to a few thousand United States dollars are attractive, a production of 2.5–5 tonnes of trout is already a considerable enterprise to start with.

TABLE 3
Proportions of estimated rearing spaces calculated from the planned number of produced table fish (size: 250 g/fish)

Proportions	Fry 2 g/fish	Fingerling 25 g/fish	Table fish	
			250 g/fish	500 g/fish
Production in different lined and concrete tanks				
1. Proportions of units as percent of table fish rearing space (100%)	6–8%	18–20%	100%	-
2. Proportions of units as percent of total rearing space (100%)	5%	15%	80%	-
Production in earth ponds				
1. Proportions of units as percent of table fish rearing space (100%)	Not recommended	18–20%	100%	-
2. Proportions of units as percent of total rearing space (100%)	Not recommended	15%	85%	-

Note: Sometimes, fish farmers should calculate the increased space needed for the growing fish stock. In this case, the starting point of calculations is the number of produced/received fry, which require more and more space as fish grow. Consequently, this table helps to estimate the required final space of the rearing devices needed for growing a given quantity of fry/young fish. In this case, the starting point of calculations (100 percent) is the fry rearing space.

TABLE 4
Proportions of estimated rearing spaces calculated from the planned number of produced table fish (size: 500 g/fish)

<table>
<tr><th rowspan="2">Proportions</th><th rowspan="2">Fry
2 g/fish</th><th rowspan="2">Fingerling
25 g/fish</th><th colspan="2">Table fish</th></tr>
<tr><th>250 g/fish</th><th>500 g/fish</th></tr>
<tr><td colspan="5">Production in different lined and concrete tanks</td></tr>
<tr><td rowspan="2">1. Proportions of units as percent of table fish rearing space (100%)</td><td rowspan="2">3–4%</td><td rowspan="2">9–10%</td><td>50%</td><td>50%</td></tr>
<tr><td colspan="2">100%</td></tr>
<tr><td rowspan="2">2. Proportions of units as percent of total rearing space (100%)</td><td rowspan="2">2–3%</td><td rowspan="2">7–8%</td><td>45%</td><td>45%</td></tr>
<tr><td colspan="2">90%</td></tr>
<tr><td colspan="5">Production in earth ponds</td></tr>
<tr><td rowspan="2">1. Proportions of units as percent of table fish rearing space (100%)</td><td rowspan="2">Not recommended</td><td rowspan="2">9–10%</td><td>50%</td><td>50%</td></tr>
<tr><td colspan="2">100%</td></tr>
<tr><td rowspan="2">2. Proportions of units as percent of total rearing space (100%)</td><td rowspan="2">Not recommended</td><td rowspan="2">7–8%</td><td>~ 46%</td><td>~ 46%</td></tr>
<tr><td colspan="2">92–93%</td></tr>
</table>

Note: Sometimes, fish farmers should calculate the increased space needed for the growing fish stock. In this case, the starting point of calculations is the number of produced/received fry, which require more and more space as fish grow. Consequently, this table helps to estimate the required final space of the rearing devices needed for growing a given quantity of fry/young fish. In this case, the starting point of calculations (100 percent) is the fry rearing space.

The required space for producing 2.5–5 tonnes of trout depends on the final size of fish and the intensity of production. Tables 1–4 show the basic figures that are needed to plan table fish production.

In order to help production planning, Tables A10.5–A10.8 summarize the different basic options of the yearly production of 2.5 and 5 tonnes of rainbow trout.

When elaborating Tables A10.5–A10.8, it was assumed that the production of trout would be semi-intensive. With increasing water supply, the intensity of fish production and the quantity of fish in the devices can easily be increased.

The fish produced on a rainbow trout farm can be doubled if the conditions are favourable and both autumn and spring fry are reared. This is because the same rearing devices can be used twice a year. In this case, not only can the fry production be doubled, but also the fingerling and table fish production if the water temperature is high enough and the feeding is adequate.

6. Structures and devices of water management

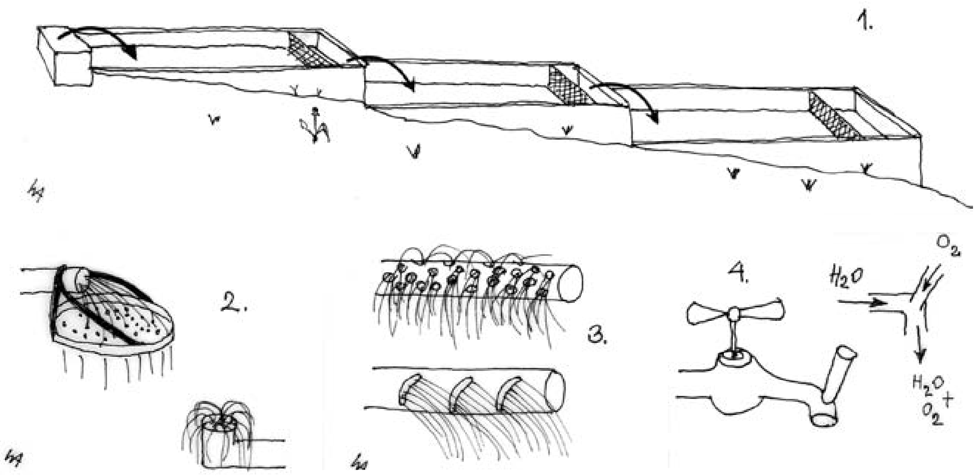
6.1 WATER SUPPLY AND DRAINAGE

Water supply by gravity to a fish farm and its rearing devices and structures is important. This saves energy and, consequently, large amounts in terms of production costs.

The water supply to rearing devices can be done in two different ways. The rearing devices can be supplied either in parallel (separately) or in series. If the rearing tanks are connected to the water supply in series, the freshwater should be used first in tanks/ponds of younger fish, from where water flows into the tanks or ponds of older age groups of fish. Although arranging tanks in series is rather frequent, construction of new tanks should prioritize parallel water supply.

Especially in the case of a *surface water** source, the construction of a water reservoir at the highest point of the fish farm will facilitate easy and efficient water management. The elevated central water reservoir will serve as a buffer, where water also settles. The water from the reservoir can be channelled to the rearing devices and structures through open canals, pipes or through a combination of these.

FIGURE 31
Simple aeration devices



A few practical alterations of the water supplying devices can ensure increased aeration of arriving and entering water: **1.** Cascade arrangement of canals and tanks. **2.** Plates and spouting fountains. **3.** Perforated pipes. **4.** Air-sucking Venturi tube if the water arrives with enough pressure from an elevated point.

The rearing water should contain as much DO as its temperature allows. *Aeration** ensures saturation of arriving water with air/oxygen. Aeration with a machine or the *injection of pure oxygen** are very efficient techniques, but they are expensive. However, there are simple solutions/devices (Figure 31) that can increase the DO of the arriving water.

Drainage of rearing devices and structures should also preferably be done by gravity in the simplest way possible.

At the point where water leaves rearing tanks and ponds, screens should be used. The mesh size of these screens should be dense enough to prevent fish not only from escaping but also from sticking into the screen or between the bars.

Inflowing and outflowing water can be controlled with different pipes, boards and monks (see Annex 5).

6.2 MECHANICAL AND BIOLOGICAL FILTERS

Intensive trout farming is a rather environment-polluting activity. In order to reduce or even avoid environmental pollution, trout farm *effluent** should be appropriately cleaned both mechanically and biologically. If the effluent of a trout farm is conducted into a carp pond or the mechanically filtered effluent is cleaned in a wetland or used for irrigation, full treatment of the effluent will be unnecessary. Cleaning of the effluent will only be necessary during the cold months, when carps *hibernate** and plant uptake of nutrients is low or when irrigation stops.

Mechanical water filtration removes the floating solid wastes (unconsumed feed particles and faeces) from the water. This process directly reduces the biological oxygen demand (*BOD**) of the water that is released back to the environment. Usual mechanical filters are different screens, settle tanks and cyclones (see Annex 6). Sludge accumulated in the mechanical filters is an excellent organic fertilizer.

Biological filtration of effluents should follow mechanical filtration. *Biological water* filters** or *biofilters** in fish culture are those that further reduce harmful BOD and remove toxic ammonia and nitrite. The mechanism of biofiltration is based on the metabolism of oxidizing nitrite and nitrate bacteria. These bacteria develop on the surface of objects found in or placed into the water. Therefore, the larger is the available surface, the more bacteria can develop, which is the precondition for significant biological filtration.

Built biofilters are efficient devices, but there are also natural, open-air filter systems such as fish ponds, wetlands and irrigated lands. Often, the different options are used in combination. Some typical models of biofilters are presented in Annex 6.

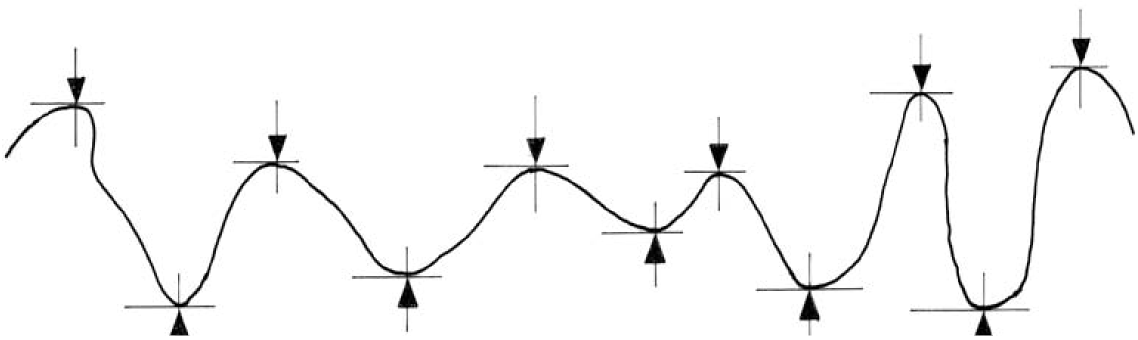
7. Site selection

When selecting the production site, it is important to check the quality and quantity (volume) of available water, as well as the suitability of the site where the new fish farm is planned to be constructed. A rule of thumb is that about 10 litres/sec (600 litres/min) of water source should be calculated for each 1 tonne of rainbow trout produced (Edwards, 1989 and 1990).

In general, both cold surface and underground waters are good for trout farming. In the case of surface water, the daily (day and night) fluctuation in temperature may be a few degrees (2–4 °C), while the seasonal (summer and winter) changes of water temperature may be as much as 5–15 °C. The temperature of springs and underground waters has no daily fluctuation and the differences between winter and summer are minimal if any. The quality of water should be consistent with those discussed in Chapter 4.

The availability (quantity) of water may change considerably according to seasons (Figure 32), especially in the case of surface waters and springs. In dry seasons, the water supply may drastically reduce while heavy rains often cause floods and sudden increases in the water quantity of springs.

FIGURE 32
Seasonal fluctuations in the quantity of available water

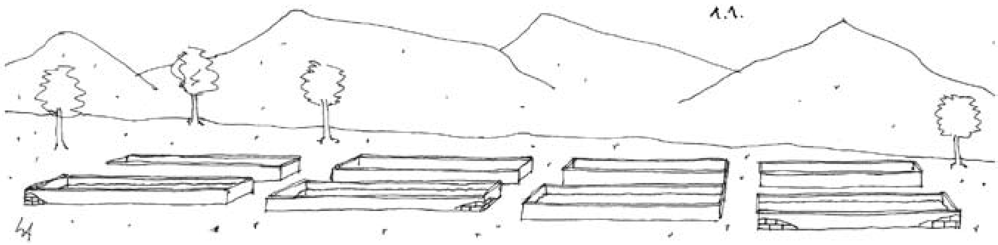


Note: The upper arrows indicate the levels of available maximum quantity of water and the lower arrows indicate the levels of available minimum quantity of water.

Therefore, the production capacity of a trout farm has to be planned according to the safe minimum quantity of water available. However, the protection of the farms against floods should be designed on the basis of the highest flood ever experienced. To reduce risk, a table of the seasonal fluctuation of the water source should be elaborated. In order to avoid flooding, the farm should be constructed in a location higher than the flood-affected areas. This can be done if water is taken and conveyed to the fish farm through a service canal.

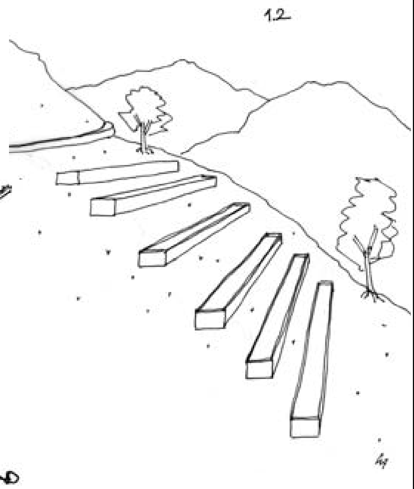
When determining the suitability of the site, the slope and soil quality should also be observed and checked as summarized in Figure 33.

FIGURE 33
Importance of slope and soil quality in site selection



1. Slope of the site and arrangement of tanks

It is important to select a site with substantial slopes. This will ensure the filling and drainage of the rearing tanks by gravity. **1.1** If a site has a gentle slope, the tanks can be arranged along it. **1.2** If the site has a steeper slope, the tanks should be arranged parallel to the slope.

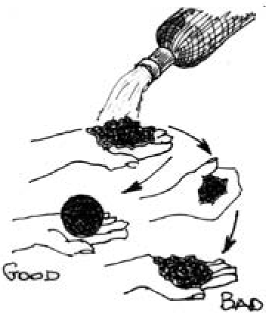


2. Soil quality

The requirements for building a fish farm depend on the type of buildings and earth/concrete structures planned.

For concrete tanks, the soil should be strong enough to hold the foundation of the tanks.

For earth ponds, the structure, *consistency** and *permeability** of the soil should be suitable for building strong dykes.



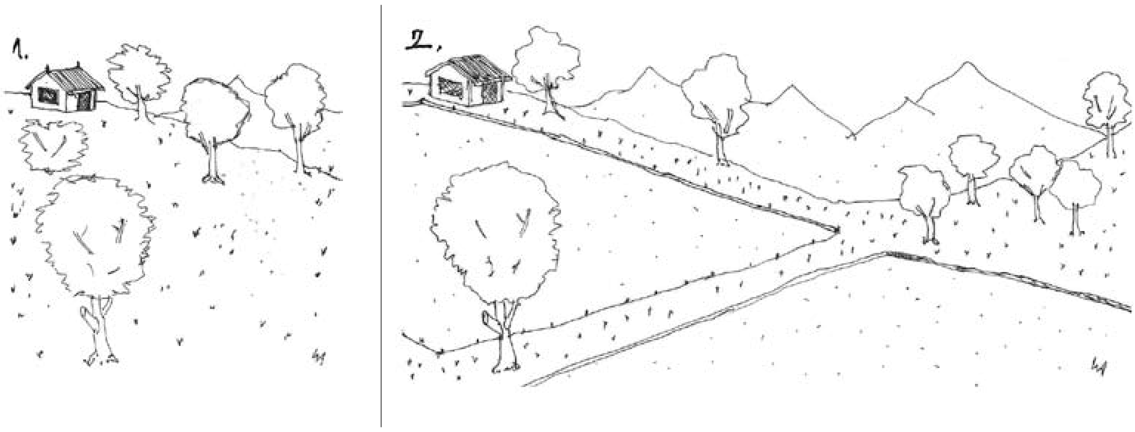
Sources: ADCP (1984); Coche (1988, 1989); Coche, Muir and Laughlin (1995).

8. Steps in the implementation of a new trout production unit or farm

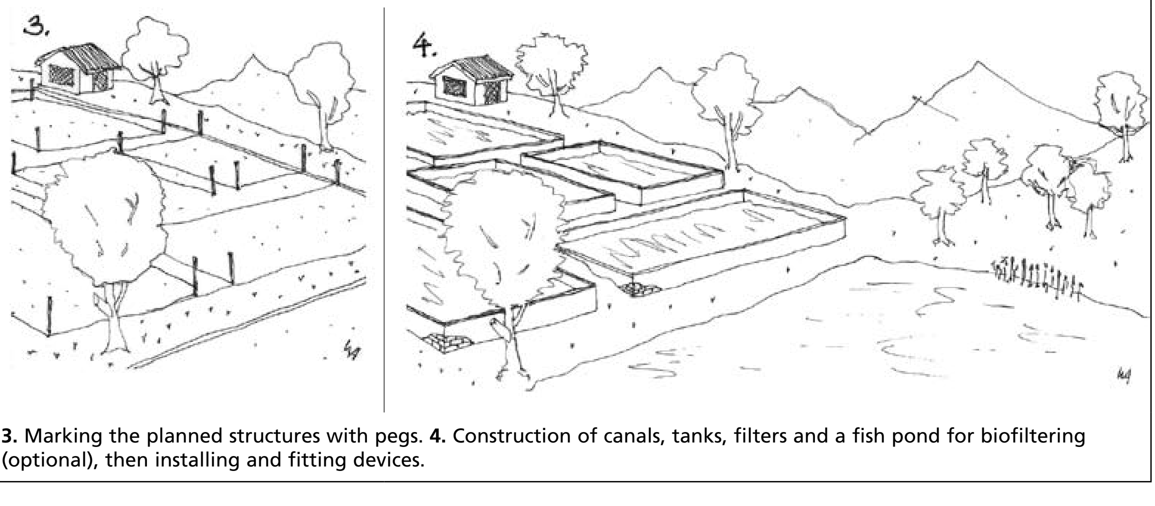
The entire future success of a new fish farm depends on how the different steps of construction are completed regardless of the size of the farm. If everything, including timing and budgeting, is well planned and prepared, considerable time and money can be saved.

Elaboration of engineering design and technical drawings is the first step after deciding to construct a new fish farm or production unit. Elaboration of the engineering plans is important and cannot be omitted. The benefits of a reliable engineering design are incomparably higher than the expenses of their elaboration, which is usually affordable.

FIGURE 34
Main steps in the construction of a new production unit or farm



The main steps of the construction of a new production unit or farm are: **1.** Building of a strong shed to store construction materials and tools (later: feeds, equipment and tools). **2.** Clearing the vegetation, removing objects from the site, as well as the topsoil where canals, tanks and ponds will be constructed.



3. Marking the planned structures with pegs. **4.** Construction of canals, tanks, filters and a fish pond for biofiltering (optional), then installing and fitting devices.

Acquisition of permissions is also important. Without the necessary permissions the construction should not start. The range of the permissions needed varies from country to country, or even from region to region within the same country. Especially in many mountainous regions, which are part of protected areas or national parks, obtaining permissions might be complicated.

Construction is the third step of the implementation (Figure 34). With a reliable engineering design, not only budgeting and programming but also the execution of the construction will be easier. Although much of the construction work can be done using one's own labour resources, it is recommended that a skilled bricklayer and plumber be contracted. They will ensure that the work is of the required quality.

There are many different ways and solutions for constructing concrete tanks and ponds and their water supply and drainage structures. Ideas can be gathered from the sections above and from Annexes 5 and 6.

Trial run is the last step in the implementation of a new trout production unit or farm. A trial run lasting a few days before starting fish production is important as this enables hidden defects and problems to be detected and remedied.

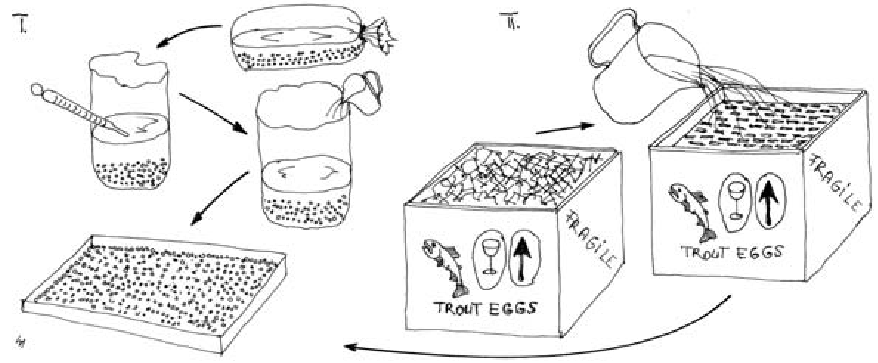
The trial period is also useful for observing the quality and quantity of the received water and practising its control and management.

9. Production work and tasks

9.1 RECEIVING EYED EGG, FRY, FINGERLINGS AND OLDER AGE GROUPS

On many trout farms, production starts when eyed eggs, fry or fingerlings arrive from another farm (Figures 35 and 36). Before the actual arrival of eggs, all of the rearing devices should be cleaned and disinfected. After the preparation of the devices, their water supply should also be checked.

FIGURE 35
Steps in receiving and unpacking eyed eggs

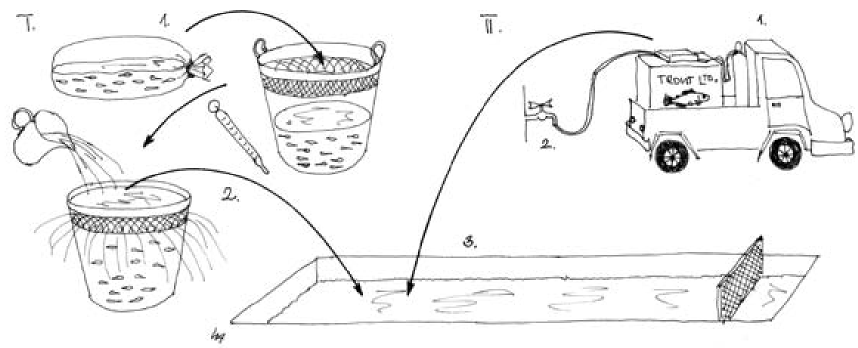


Eyed eggs are transported either: **I.** in plastic bags with water and oxygen; or **II.** hibernated in insulated box on trays with ice. The steps of *tempering** the eggs and unpacking are similar in both cases.

1. Measure both the temperature of the transport water and the hatchery water. Gradually adjust the temperature of the transport water to that of the hatchery water. As soon as the temperatures are equalized, the eyed eggs should be placed into the trays after disinfection, as prescribed by the supplier.

2. Gradually adjust the temperature of the eyed eggs in the transporting box by carefully adding hatchery water through the ice found on the top tray. As soon as the box is filled with hatchery water (the temperatures are equalized), the eyed eggs should be placed onto the hatching trays.

FIGURE 36
Steps in receiving and unpacking or unloading fry, fingerlings or older age groups of trout



Fry or fingerlings are transported either in plastic bags or in containers. The tempering procedure is the same in both cases.

1. Measure the temperature of the transport water and the receiving water. **2.** Gradually adjust the temperature of the transport water to the temperature of the receiving water. **3.** As soon as the temperatures are equalized, the fry or fingerlings may be transferred to their new place.

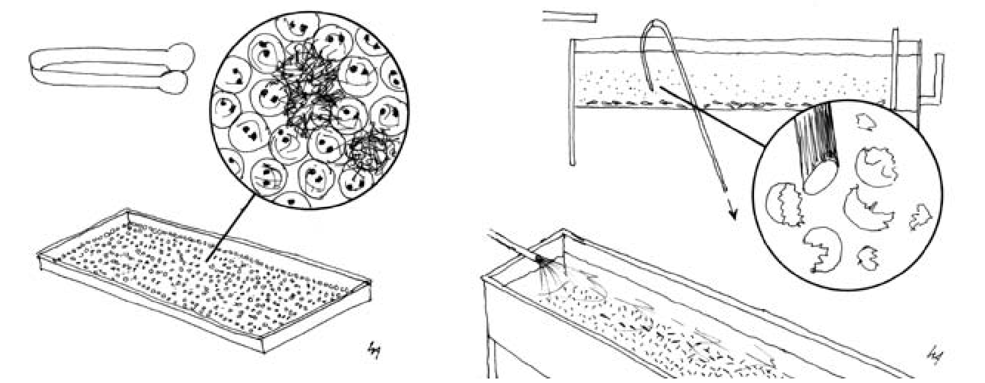
Trout are very sensitive to changes in water temperature, especially when it is from cold to warm. The smaller the fish, the more sensitive they are to *thermal shock** in general and to warm thermal shock in particular. Therefore, it is important to raise or lower the temperature of the transport water slowly, in steps of 0.5 °C/min in order to ensure safe adjusting (Molony, 2001).

9.2 HANDLING OF EGGS AND FISH OF DIFFERENT AGE GROUPS

The handling of eggs and fish of different age groups is a job that includes many diverse actions such as taking care of incubating eggs, removing dead eggs, fry and fish, as well as transferring and grading fish.

Cleaning of the rearing devices during incubation of eggs and after hatching is done with special egg-pincers and siphons (Figure 37).

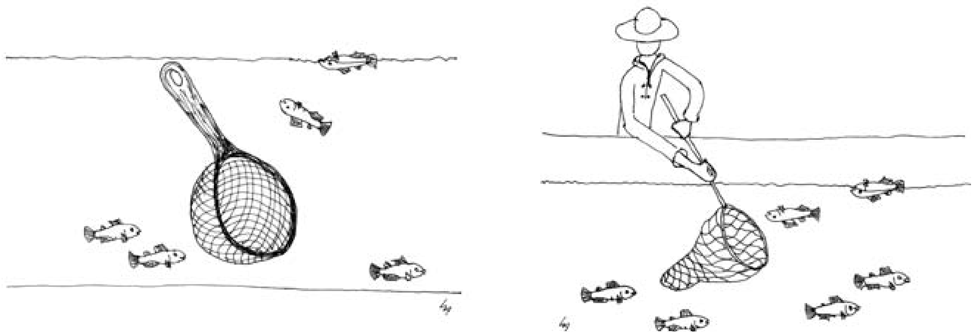
FIGURE 37
Cleaning of rearing devices



1. Eggs should not be disturbed before the stage of eyed egg. Dead eggs covered with fungus should be removed with special pincers. **2.** After hatching, the shells of eggs, dead eggs and the dead larvae should be siphoned from the rearing devices.

Removal of dead fish from the rearing devices and structures is a necessary daily task (Figure 38). The number and weight of collected dead fish should be entered into the fish stock and mortality register (see Section 9.6).

FIGURE 38
Removal of dead fish



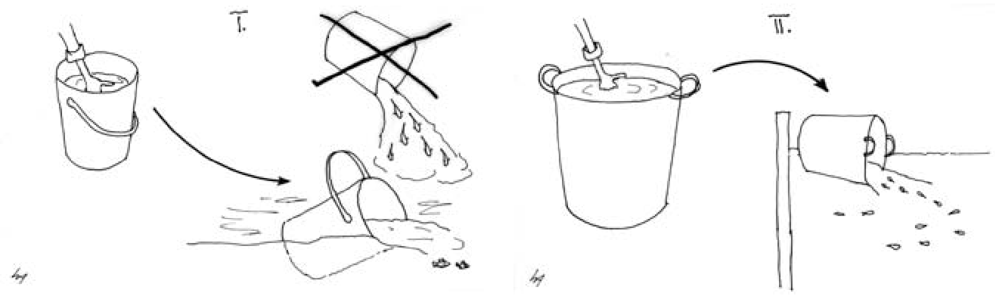
Removal of faeces from the rearing devices should also be part of the daily work routine. Especially in the case of smaller fish, the water current is not strong enough to wash out the solid waste from the rearing device. Therefore, the frequent removal of the faeces and the leftover (not consumed) feed particles is important. This is done with a siphon.

Fishing of fry, fingerlings and table fish needs different nets, netting materials and techniques. It is a general rule to use knotless netting materials, which do not damage the fish.

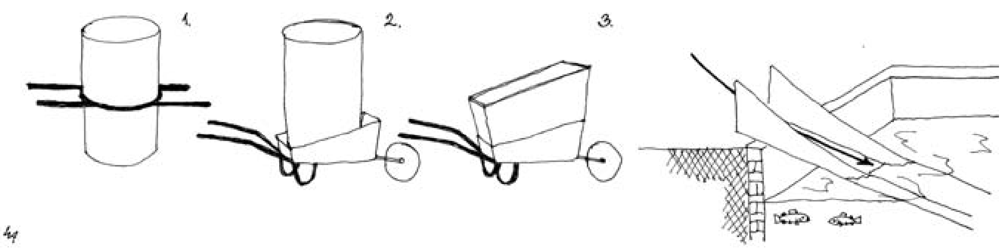
When netting the fish, trout should not be unnecessarily crowded in the net, especially the younger fish, which are more sensitive to being squeezed in a small space. Illustrations and short descriptions of the different nets are presented in Annex 7.

Relocation of fish must be done in water regardless of the size and age of fish (Figure 39). Trout carried without water cannot survive the shock. It is also important to release fish gently. Therefore, the bucket or basin in which fish are transferred should be submerged into the water where the fish are released. The gentle releasing into large concrete tanks and earth ponds should be done using a slip channel (slider).

FIGURE 39
How to relocate fish



Transferring fry **(I.)** and fingerlings **(II.)** should always be completed quickly in water. **Stocking procedure includes:** checking and equalizing the water temperatures if needed; releasing the fish gently into the new place.



Transfer of larger fish should also be completed quickly in water. **Stocking procedure includes:** checking and equalizing the water temperatures if needed; releasing the fish gently into the new location with the help of a fish-slider.

1.–3. Containers for carrying live fish.

Grading of growing fish is a basic job on trout farms. When grading, the entire stock of a tank or pond is screened and regrouped according to the size of the fish.

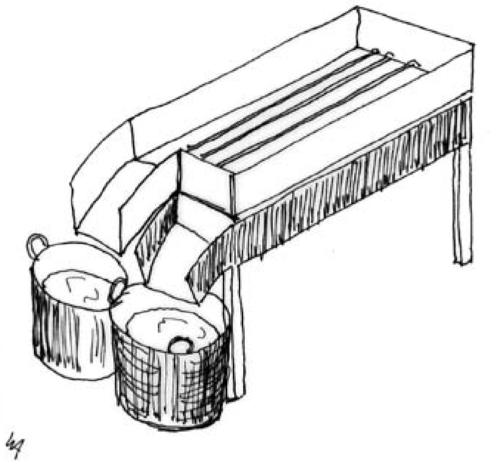
Without grading, the larger specimens attack the smaller ones, pinching/biting their tail and fins, and it can also end in cannibalism.

There are mechanized and manual graders. Out of the manual graders, hand graders are used for small fish, while table graders are used for sorting large fish. Some typical manual graders are presented in Annex 7.

Younger fish should be graded every 15–60 days and larger fish at 30–90 day intervals, unless the fish stock becomes uneven within a shorter period than the time indicated above.

One of the practical solutions of grading is when the original fish stock is sorted into two groups. Accordingly, specimens above and below the average are separated into two groups. If the original fish stock is very uneven in size, three new groups should be formed instead of two.

FIGURE 40
Fish grader



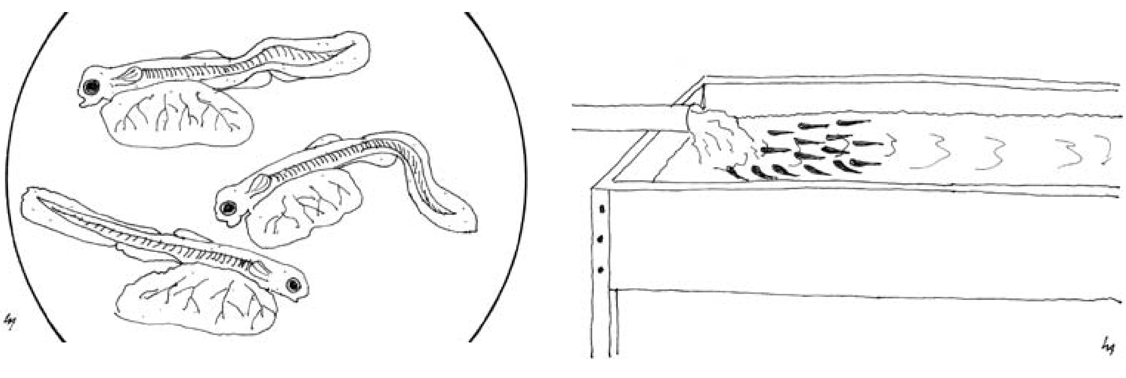
It is important to be aware that in the process of grading, fish should not remain without water unnecessarily. Therefore, the best solution is to grade fish, and especially the younger age groups, under water where possible. If fish have to pass a "dry" grading grid, they should arrive into water immediately after passing the grid (Figure 40).

9.3 WATER MANAGEMENT OF REARING DEVICES AND TANKS

If water flow is less than required, the development of eggs, fry and fish will be endangered. In a well-dimensioned rearing tank, the water current should carry enough freshwater to all fish, but should also be fast enough, more than 3 cm/sec (1.8 m/min) to wash out most of the floating waste materials from the trough or tank (Hoitsy, 2002). The water current should be proportional to the size and number of fish in the rearing troughs and tanks. If the water flow is too strong, fish will use additional energy to keep up with the current. Therefore, too strong a current is also disadvantageous. Consequently, it is crucial to ensure appropriate water supply and maintain the appropriate water flow needed to bring enough oxygen and carry away wastes, such as faeces and the unconsumed feed particles.

Signs of water shortage during incubation of eggs or development of sac fry are not obvious. Continuous low oxygen content of water will cause malformations, as well as mortality of the embryo and sac fry (Figure 41). In the case of fry, fingerlings and older age groups of trout, the obvious sign of water (oxygen) shortage is when fish gather at the inflow of water (Figure 41). Acute water shortage may cause mortality, while a less acute but permanent (chronic) shortage will cause loss of appetite.

FIGURE 41
Signs of water shortage

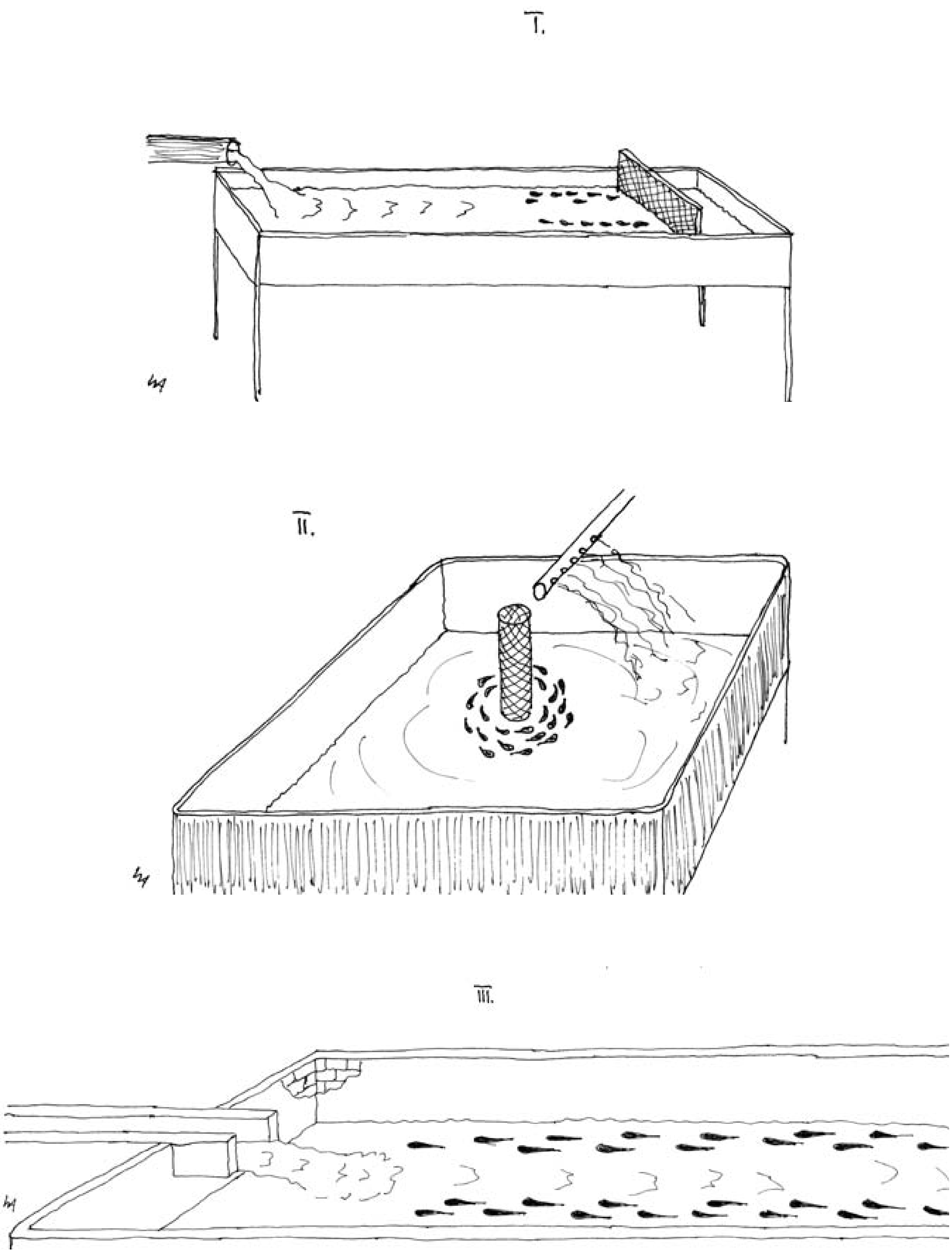


Insufficient water supply will result in crippled fish larvae.

If the water supply is insufficient, fish will concentrate at the inlet.

Signs of excess water and too strong water flow are different (Figure 42). Whirls of water, observed in the rearing troughs and tanks, are the most evident signs of strong water current. The other obvious sign is when fish visibly struggle against the current and the weaker or sick fish are taken by the current.

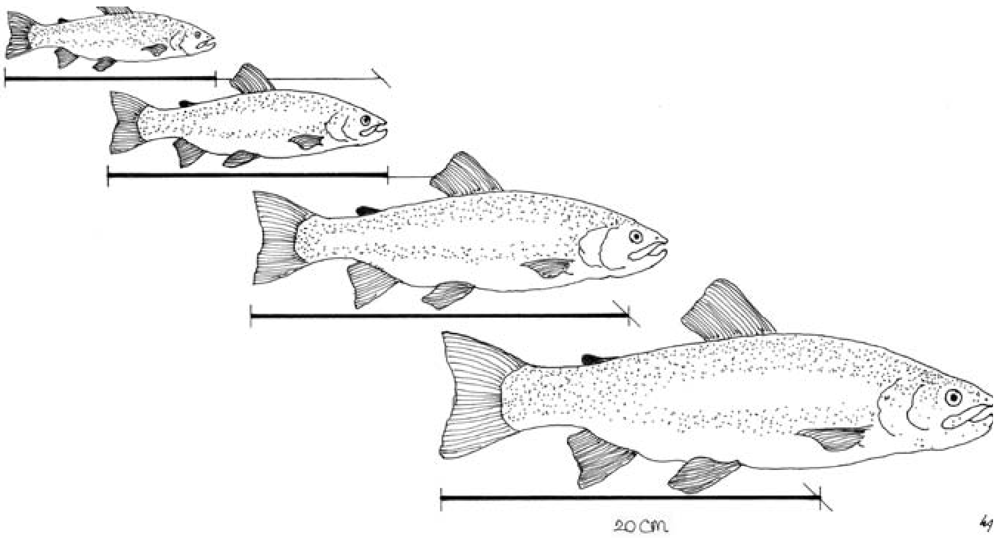
FIGURE 42
Effect of strong water flow on distribution of fish



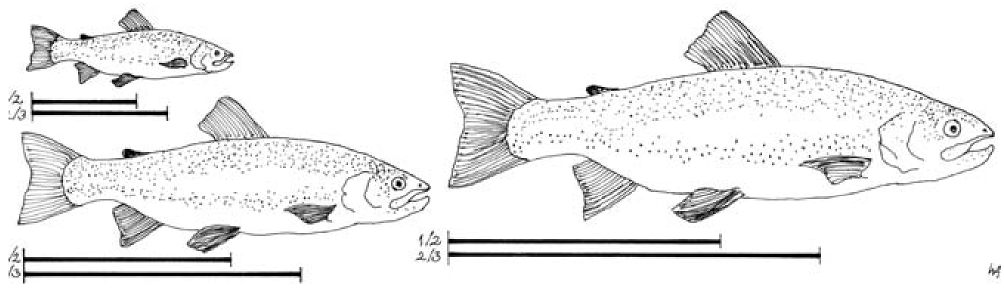
I. In fry rearing troughs, fish will gather at the walls far from the inlet. **II.** In rearing tanks where water flows in a circle, fish will concentrate in the middle of the tank, instead of occupying evenly the entire water volume of the tank. **III.** In large raceway tanks and rearing ponds, the fish will also try to find shelter at the side walls of the tank.

The velocity of water flow in troughs and tanks should be proportional to the size of reared fish (Figure 43; Hoitsy, 2002).

FIGURE 43
Water flow and fish size



I. Water should not flow faster within 1 second than the actual total length of the reared fish. However, the maximum velocity of water should not exceed 20 cm/sec (12 m/min) even if the fish is longer than 20 cm.



II. The optimal velocity of water is 2–3 cm/sec (1.2–1.8 m/min) for smaller fish and 4–10 cm/sec (2.4–6 m/min.) for larger ones. However, the actual speed of water per second should not be faster than from one-half to three-quarters of the length of the reared fish.

9.4 FEEDING

Feeding is the most expensive part of trout production.

In the past, trout were fed with trash fish and slaughterhouse by-products, offal and wastes. It is a widespread opinion that using the feeds for fattening listed in Table 5 is rather inconvenient and also very polluting both to the rearing tanks/ponds and to the surrounding environment.

The next period in the development of the trout farming industry was the formulation and use of different types of high *protein** feeds. Their *feed conversion ratio* (*FCR**) varied between 2 and 3.

TABLE 5
Traditional trout feeds

For fry		For fattening of 100–250 g fish	
Type of feed	**Feed conversion ratio**	**Type of feed and protein content (%)**	**Feed conversion ratio**
Daphnia sp.	6–7	Pig lung (18%)	7.9
Chironomids	4.2	Trash fish (16–21%)	4.6–4.9
Tubifex sp.	4.1	Chicken grinding (15–18%)	6.2–6.7
Cattle spleen	5.6–9.8	Cattle spleen (18–21%)	5–5.1
Pig liver (cooked)	7.9	Pig liver (17–19%)	6.5–6.8
Cooked blood	6.2–9.8	Cooked blood (16–21%)	5.2–9.8

Source: Hoitsy (2002).

In the modern trout farming industry, the traditional feeds have been definitively replaced with very efficient pelleted dry feeds (0.6–1.1 FCR).

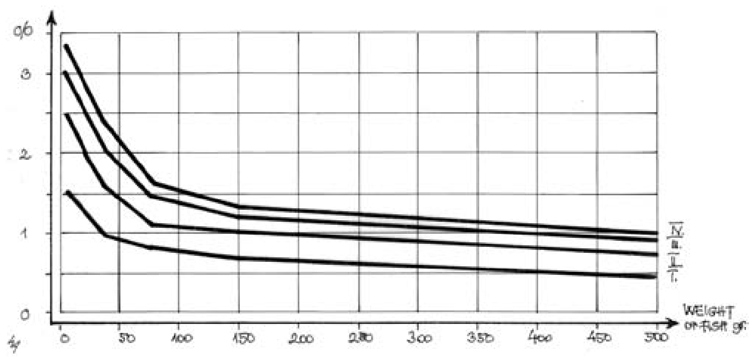
There are publications that advocate the use of home-made feeds, which may be feasible only with some reservations. Home-made feeds seem to be a good solution, especially where commercial trout feeds are not readily available. However, the ingredients of home-made feeds should be easily locally available, with continuous supply in the required quantity and quality and at competitive prices. In this case, one of the numerous recipes of formulated trout feeds should be selected and blended.

Extensive experience has proved that purchasing commercial feeds is often the only feasible and profitable option. In evaluating the commercial feeds, the expected FCR and the related price are those characteristics that should be considered at purchase and use. It is a general rule that the price of a feed is inversely related to its FCR – the lower the FCR, the higher the price of a feed will be. However, economic calculations may prove that a feed with a lower price but a higher FCR will be more expensive than an expensive feed with an outstandingly low FCR. For this reason, many farmers choose high-quality expensive feeds for the first stages, where little feed is used but where the fish are most vulnerable and sensitive.

Normally, commercial feed manufacturers determine the recommended daily quantities of their feeds. If not, Figures 44 and 45 provide guidance for adjusting the daily rations.

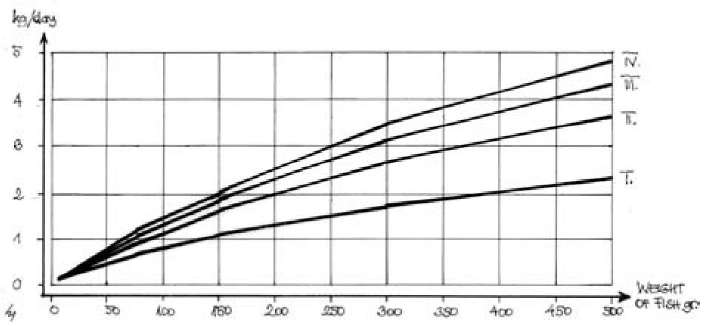
Daily feed rations should be given in 2–24 equal portions. It is a general rule that the younger fish should be fed more frequently than older ones (Figure 46). The frequency of feeding should also be increased with the temperature of the water. Concerning the size of feed particles, they should be small enough that fish can comfortably grab and swallow them.

FIGURE 44
Range of relative daily feed rations of trout (percentage)



Note: Water temperature: **I.** 5 °C, **II.** 10 °C, **III.** 15 °C and **IV.** 20 °C

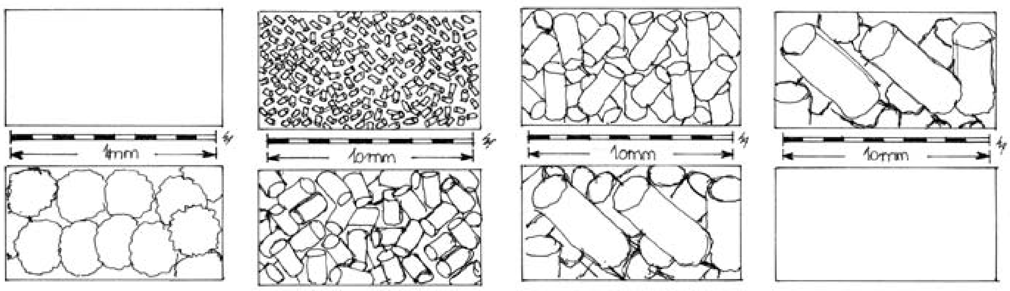
FIGURE 45
Range of absolute daily feed rations of trout (kilograms per 1 000 fish)



Note: Water temperature: **I.** 5 °C, **II.** 10 °C, **III.** 15 °C and **IV.** 20 °C

FIGURE 46
Frequency of feeding and feed size

Swimming fry*:	**Fry – Fingerling:**	**Growing fish:**	**Storage of table fish:**
24–48 times/day	6–8 times/day	4–6 times/day	3–4 times/day



9.4.1 Practical aspects of feeding and feeds

Hand-feeding techniques

Hand and mechanized feedings are the two widely practiced techniques. Of these, hand feeding is the recommended one.

Loss of appetite among fish is one of the most obvious symptoms of many different problems. It indicates, among others, insufficient oxygen content of water or a developing disease in fish. Therefore, regular daily feeding is an excellent opportunity to observe fish and detect problems and diagnose diseases.

Figure 47 shows that calibrated spoons and hand shovels should be used in order to ensure exact and uniform portions of feed.

Demand and automatic feeders

Demand feeders are those that release feed according to the appetite of fish. Because rainbow trout are very greedy fish, these feeders may allow unnecessary overfeeding of fish unless the portions are controlled.

The advantage of mechanized and automatic feeders is that they save on labour.

The most typical mechanized and automatic feeders are the demand bar feeder, used from fish size 50 g, and the clock-driven feeding belt (Figure 48).

Signs of feeding problems

Obvious signs of feeding problems are the increasing differences in individual sizes, growing aggressiveness and cannibalism (Figure 49). Lack of sufficient feed manifests itself in bitten/damaged fish and dead fish.

Storage of fish feeds

The quality of purchased dry feeds can be maintained only if they are stored properly. For this reason, dry store rooms or, in the case of smaller quantities, dry chests should be used.

During storage, feeds must also be safe from rodents (rats, mice, etc.) and insects (Figure 50).

FIGURE 47
Spoons and hand shovels used for feeding fish

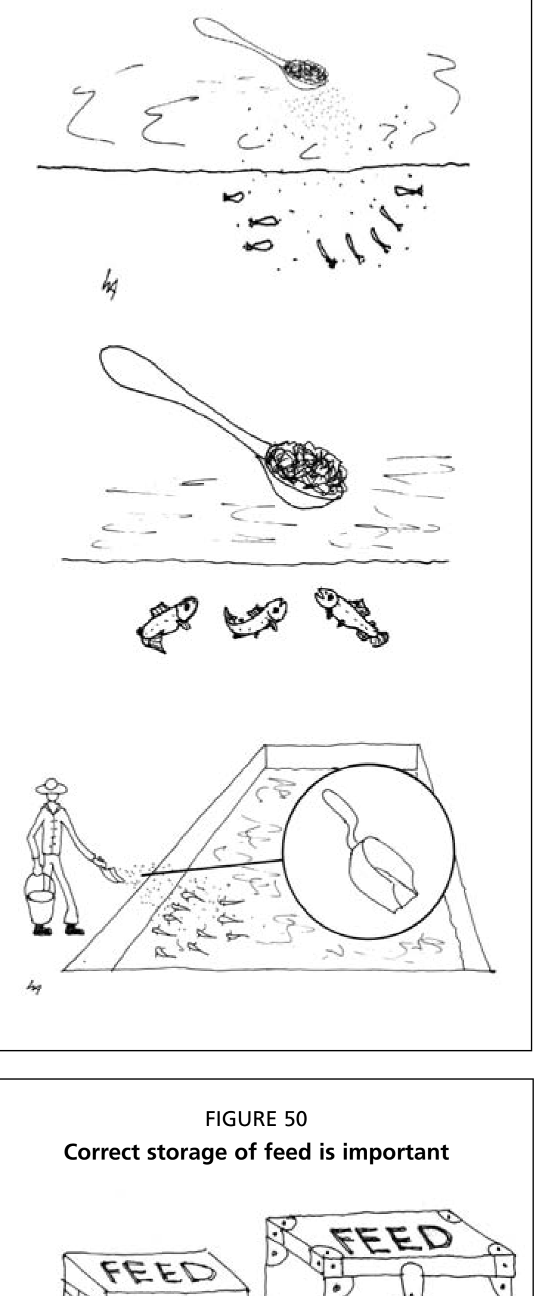


FIGURE 48
Examples of automatic feeders

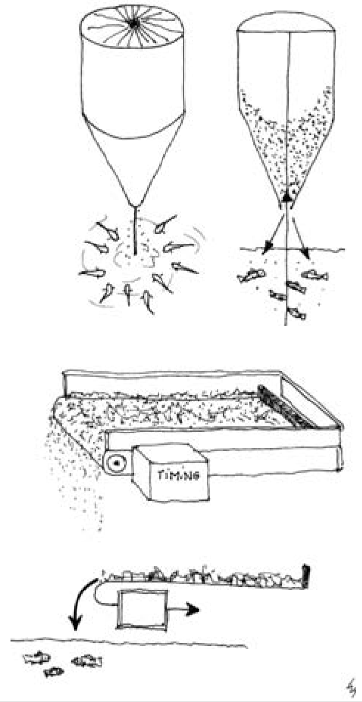


FIGURE 49
Obvious signs of feeding problems

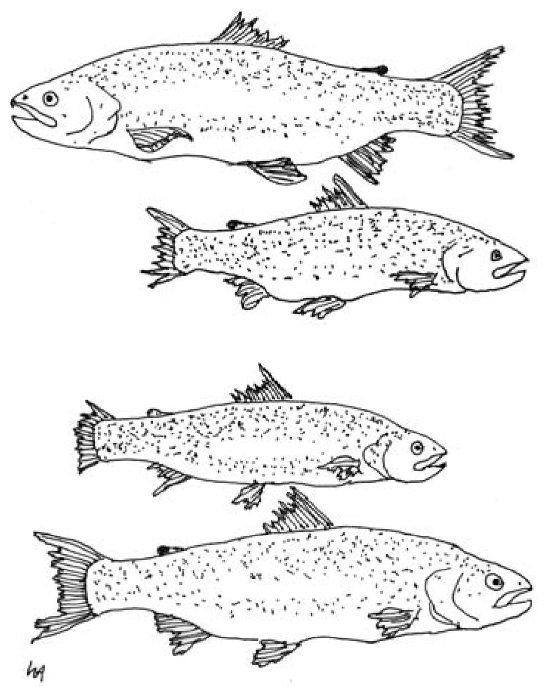
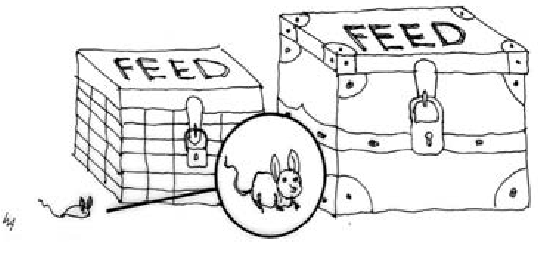


FIGURE 50
Correct storage of feed is important



9.5 FISH HEALTH

9.5.1 Prevention

The most efficient and economic way of avoiding health problems in fish is prevention. This means that all of the production conditions are properly established and maintained. This includes the maintenance of the quantitative and qualitative parameters of water, appropriate feeding and stress-free handling. Prevention also means keeping the equipment, rearing devices and structures clean, disinfected and dry when they are not used (Box 1).

BOX 1

Frequently used cleaning materials and disinfectants

Coarse/kitchen salt is used for cleaning the rearing devices of fry. After removing dead fish and siphoning off faeces, the walls of the rearing troughs and tanks should be cleaned with salt. This is done by rubbing the dirt with salt.

Formalin is used for disinfecting tanks and water pipes after or before they are used. About 1 percent formalin solution is used for washing equipment and rearing devices. A more concentrated solution (about 2–3 percent) is used for disinfecting the pipes used for water supply. Disinfection is done between two production cycles, when there are no fish in the system. Water pipes are filled with the formalin solution, where it should be kept for about 15–30 minutes. Then, the system should be drained and washed throughly with freshwater until no trace (smell) of formalin remains.

Lime is used outdoors in concrete tanks and earth ponds after they have been harvested and emptied. About 0.25 kg/m^2 of quick lime or 0.03–0.05 kg/m^2 of chlorinated lime evenly distributed serves the purpose. If the pH of the pond soil is higher than 8, the use of quick lime is not recommended. Instead, use chlorinated lime.

Domestic cleaning powders and liquids are widely used for cleaning equipment, devices, rearing troughs and tanks on trout farms.

9.5.2 Signs and types of rainbow trout diseases

The more intensive the trout production is, the more the reared fish are exposed to *stresses**, which increase the chances of falling prey to dangerous pathogens (viruses, bacteria, fungi or parasites) and contracting environmental or nutritional diseases. Therefore, it is important to observe the behaviour of fish. The most obvious signs of disease are unusual/abnormal behaviour, such as lost appetite, gathering at the water inflow, gasping for air at the surface, staggering, whirling or floating on the water surface with forced movements or trembling.

If fish are observed closely, the most common symptoms of disease are unreflecting, stiff eyes, wounds, blisters, lost scales, bloody or discoloured areas on the body, and reduced or excess quantity of mucous on the surface of the body.

Fish farmers may encounter a range of different diseases that will present the described signs and symptoms. In order to identify and cure diseases, they are grouped in pathogens and causes. Accordingly, there are viral, bacterial, fungal, parasitic, environmental and nutritional diseases. The most frequent diseases are summarized in Annex 9. In the event of health problems, consultation with a specialist is highly recommended.

9.6 FOLLOW-UP ON PRODUCTION FIGURES

Follow-up on production figures should be part of the daily routine. With a few minutes daily paperwork, all of the important information can be noted. This information consists of the starting and closing figures of the fish stock (number, individual size and total weight of fish) with details on mortalities, the quantities of purchased and applied feeds and other materials used during a given production period.

It is suggested that fish farmers have separate formats to register incoming and outgoing items and for the follow-up on the use of different items within the farm.

There are several suitable sets of formats and registers. In many CEE and CCA countries, some of the production data are compulsory, and some of them are recommended for being recorded and reported to higher/concerned authorities. If such official registration is not requested, the recommended formats are:

- farm register;
- fish stock and mortality register;
- feeding diary;
- store register; and
- monthly balance of production.

A **farm register** is similar to a cash register, in which incoming (eyed eggs, fish seed, feeds, chemicals, drugs and production materials) and outgoing items are recorded (Figure 51).

The use of this register allows farmers to follow up and analyse physical and financial data of production at the farm level.

A **fish stock and mortality register** facilitates the day-to-day recording and follow-up of changes in the fish stock (Figure 52). Each day should have a separate row unless nothing happened that day. There are summary columns, in which the daily figures are summed. This register also supports the elaboration of the monthly balance of production.

A **feeding diary** is to record and follow up the daily use of feeds (Figure 53). The register also supports the elaboration of the monthly balance of production. Different age groups of rainbow trout receive feeds of different types. Therefore, the daily applied quantities of each type of feed should be indexed or noted daily in separate rows.

A **store register** is suggested in order to monitor the use of production materials (Figure 54). It is especially useful if the ID numbers (where they are applied) of tanks/ponds are noted in the "Observation" column. This will allow the elaboration of useful summaries and analyses.

The **monthly balance of production** is the sheet that summarizes the monthly fish production results (Figure 55). Its format can vary. One option used by Hoitsy (2002) is a sheet that contains the figures of the transfer of fish within the fish farm (between the rearing tanks and/or ponds). In the rows headed "Stocking", items are recorded which arrive from outside or from

FIGURE 51
Simple farm register

Date	Item	Qty.	from or to	Amount	
				in	out
Total					

FIGURE 52
Simple fish stock and mortality register

Date	Qty.	Number of Tanks or Ponds													
		I.		II.		III.		IV.		V.		VI.		Total	
		in	out	in	out	in	out	in	out	in	out	in	out	in	out
	kg														
	pc.														
	kg														
	pc.														
	kg														
	pc.														
	kg														
	pc.														
Total	kg														
	pc.														

the hatchery and fry rearing units of the farm. Rows headed “Grading” are used to note the internal transfer of fish due to grading, while in the rows headed “Sold”, the quantity of fish that leaves the farm should be noted.

The registers recommended above facilitate not only detailed documentation, but also professional analysis of physical and financial aspects and consequences of the fish production. It is especially important at new fish farms, where owners and operators should learn from their own experiences.

Data recorded on the five sheets will support the calculation of the physical and financial figures of inputs and outputs, as well as the mortality rate (in percent), growth rate (in kilograms per unit of time), FCR (in kilograms of fish per kilogram of feed), production costs, unit prices and profit.

FIGURE 53
Simple feeding diary

Date	Number of Tanks or Ponds						
	I.	II.	III.	IV.	V.	VI.	Total
Total							

FIGURE 54
Simple store register

Date	Item	Qty.	Observation

FIGURE 55
Monthly balance of production

Lines		Number of Tanks or Ponds												Total	
		I.		II.		III.		IV.		V.		VI.			
		pc.	kg	pc.	kg	pc.	kg	pc.	kg	pc.	kg	pc.	kg	pc.	kg
Opening															
In	Stocking														
	Grading														
	Growth														
	Total														
Out	Mortality														
	Sold														
	Grading														
	Total														
Balance															

10. Basic economic calculations of investment and production

Economic calculations of investment are completed both before start (planning phase) and after completion of the implementation of a trout production unit or farm. The following calculations should usually be completed at the planning phase and by evaluation of investment:

- Total cost of investment: It is compiled from the costs of items listed in Table A10.9. Both the total costs and the proportions of the different items of investment should be observed in the analyses.
- Internal rate of return (IRR): It is the financial or economic indicator of the net benefits expected from a project or enterprise. It is expressed as a percentage. In a financial analysis, the IRR should be compared with the rate of interest prevailing in the market (Leopold, 1978).
- Net present value (NPV): The value of an enterprise at the present time, after applying the process of discounting to its costs or benefits (Leopold, 1978). This value is calculated for a period of ten years with the current applicable bank interest rate.
- Payback period: This indicator shows the needed time (in years) for the investment to pay back its expense.

Economic calculations of production are calculated in order to obtain exact information about the economic results of fish production. The production cost is calculated both before (in the planning phase) and after production. The calculations are:

- Total cost of production includes the cost of a wide range of items listed in Table A10.9. During the analyses, both the costs and the proportions of the different items of production should be observed.
- Unit price is calculated in order to establish profitable production. When planning, both *break-even** and expected unit prices should be calculated.
- Gross revenue expresses the total value of production that is realized on the market.
- Profit is the financial benefit of the production. Gross and net profits are distinguished. Taxes are paid on the basis of gross profit. Consequently, net profit is the amount that remains after paying taxes.

11. Cooperation among trout farmers

Cooperation among trout farmers can be ad hoc or regular, as well as informal or formal. The objective of the establishment of either form of cooperation should be mutual benefits. If the cooperation does not offer mutual benefits and does not remain advantageous for all of the cooperating partners, it will necessarily fail.

As failure in cooperation may create acute and severe tension among the cooperating partners, the correct, objective and impartial determination of the goals and physical and financial conditions of the cooperation are indispensible. It is especially important in the case of small-scale trout farmers, who are in the same or neighbouring communities.

For the reason mentioned above, it is crucial to consider thoroughly the reasons, objectives and benefits of the future cooperation before making final commitments. It is also important to set simple and transparent rules and terms for future cooperation. If the goals and conditions are clear and the benefits are obvious for all partners, the cooperation will last. Otherwise, it will create disappointment and tension among the partners.

The most frequent types of cooperation among small-scale trout farmers may be on joint purchasing, joint processing and joint marketing.

- Joint purchasing cooperation can be established in order to receive extension,[5] legal and veterinary services but can simply focus on joint purchase of supplies, such as equipment and production materials (fish seed, feeds, drugs, etc.). There are two main advantages of joint purchasing cooperation. The first is that the different services, which might be too expensive for one fish farm, will be divided among many of them. This will reduce the per-farm fees of the services considerably. The second advantage of joint purchasing cooperation is the increased negotiating and bargaining position on terms and prices of the delivery of services and goods. This sort of cooperation is very simple and can be practised on an ad hoc or a regular basis.
- Joint processing cooperation is specialized on increasing the marketability, as well as value, of the produced fish through primary and secondary processing. The simplest way of processing fish is chilling or deep-freezing whole or cleaned, gutted or filleted fish. Among the secondary processing practices, drying, salting, smoking, dressing/spicing and breading are the more frequent ones. The processing capacity depends on market demand, where national and regional tastes and expectations are important factors.

  The cooperation on a jointly operated processing plant can ensure more flexible supply to the markets. It is especially recommended the establishment of such cooperation be considered if the individual production capacities of trout farms justify the joint investment. It is important to know that this kind of processing plant is a cooperative enterprise that not only needs careful planning and preparations but also professional day-to-day transparent management.
- Joint marketing cooperation aims to ensure good and reliable market positions. It is especially important where the fish farms are far from the markets. This sort of cooperation needs specialized transport of live and/or processed fish, as well as reliable professionals for operating the enterprise. Without cooperation, the

[5] Extension services focus on technical and financial management of farms and businesses.

investment and operational costs of transport may be too high for the individual farms. A joint marketing cooperation can also ensure increased negotiating and bargaining positions in relation to wholesalers and retailers. If a fish stand or a shop is hired or owned, the profits from retail sales will also remain with the cooperating farmers.

In many countries all over the world, recreational fishing is very popular and generates huge incomes for local communities. This is particularly true for trout sport fishing. Selling fish from ponds and suitable local waterbodies through fee fishing ("put-and-take fishing") is an excellent way of generating income. For this reason, the creation and maintenance of recreational fishing tourism is a very profitable way of selling the produced fish. Moreover, it can generate additional incomes from services to local restaurants and hotels and from the sale of souvenirs.

In addition to informal and formal cooperation among trout farmers on purchasing, processing and marketing, farmers can also join together in order to establish organizations that represent their interests at the local, regional, national or international level. These organizations are different clubs, associations and federations of trout farmers. There are several thousand such farmers' organizations all over the world. They have very similar objectives and activities, which are listed in Box 2.

Local, regional, national and international organizations representing trout farmers are especially well established in Australia, Austria, Canada, Denmark, Germany, Canada, the United Kingdom and the United States of America. These organizations, and their experiences over several decades, may serve as an example and source of practical ideas and initiatives in the fields of representation, coordination and support of mutual interests of the members.

BOX 2

Frequently declared objectives and activities of trout farmers' organizations

- Enable a uniform voice.
- Act on the behalf of members.
- Liaise with governmental and non-governmental organizations.
- Protect, ensure and promote general, commercial and specific interests, including ensuring stable and good prices.
- Provide management, legal and veterinary assistance.
- Facilitate and promote the flow of technical, market and sector-related information.
- Promote economically feasible and environmentally friendly production practices.
- Support product traceability and labelling.

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Glossary

Acclimatization	A process which takes place when the temperature of the transport water is gradually adjusted to the temperature of water in which the arriving fish are released. When the temperature of the transport water is the same as the temperature of the receiving water, fish can be released without further acclimatization. The **thermal shock** can be particularly dangerous for young fish. Therefore, in the case of several degrees of difference, the adjustment process may take 30–40 minutes. Tempering is a practical United States term for acclimatization.
Aeration	The aeration of water allows for an increase in the number of fish per unit volume of the rearing water. The oxygen content of the water, which is a limiting factor, can be increased by mechanical agitators such as paddle wheels, or by ejectors, air diffusers or blowers. Aeration is a widespread technique for increasing the production capacity of fish ponds and tanks. An additional effect of aeration is that gases, such as carbon dioxide (CO_2) and ammonia (NH_3), are "driven/aerated out" from the water.
Alevin	See definition of **sac fry**.
All female stock	A stock where only females of the progeny are produced through pairing sex-reversed parent fish. In rainbow trout, female specimens grow faster. Another advantage of all female stock is that escaped fish will be less likely to propagate successfully in the wild. Therefore, all female progeny of sex-reversed males and normal females are produced and sold.
Anadromous	Fish that live in the seas but migrate upriver to spawn. Fish that migrate from the river to the sea to spawn are **catadromous** fish.
Annelids	Segmented worms of the **phylum** Annelida to which, among others, earthworms and leeches belong.
Ataxia	A disorder of partial or total inability to coordinate body movement (Guralnik, 1968).
Biofilter	See definition of **biological water filter**.
Biological water filter or **biofilter**	A device where bacteria oxidize the ammonium-N. These filters are used, among others, in intensive, industrial-type fish culture systems for removing the ammonia from the recirculated water by nitrifying bacteria. Materials that have a large surface/volume ratio for the settling of bacteria can be used as media for filling the biological water filters. These materials can be sand, stones, nets, plastic beads, lamellas, etc.
BOD	The abbreviation for **biological oxygen demand**. It is the quantity of the oxygen (in milligrams per litre) consumed by bacteria to decompose the organic materials in the water. For easy comparison, the length of the period during which the process takes place is standardized and indicated as a subscript index, e.g. BOD_5 means BOD in five days.

Break-even or **break-even point**	The point when costs and financial benefits are equal. At this point, the production turns from losses into profit or vice versa. In other words, the break-even point is when there is neither profit nor loss on the produced fish. Below the break-even point, fish farming produces a loss, and above the break-even point it produces a profit.
Broodfish (also spelled brood fish)	The carefully reared and selected sexually matured male and female specimens that are kept for propagation. Only from a professionally created and maintained stock of broodfish can good-quality and well-performing progeny be expected.
Carcinoma	Any of several kinds of cancerous growths made up of **epithelial** cells (Guralnik, 1968).
Catadromous	See definition of **anadromous**.
Chemicals	Often, dangerous poisons are frequently used as remedies in fish culture. Therefore, it is important to keep all these chemicals locked away from children. Although the chemicals are found in extremely small concentrations in the water of fish, it is important to emphasize that they can be very harmful for humans and other animals if they come in contact with or consume them.
COD	The abbreviation for **chemical oxygen demand**. The COD is an indicator that shows the oxygen consumption of the chemical process through which all organic and non-organic materials in the water can be oxidized.
Cold water fish	The body temperature of fish depends on the temperature of the water in which they live, because fish are **poikilotherm** animals. There are cold water fishes (e.g. trout) and warm water fishes (e.g. tilapia, African catfish). They do not tolerate water temperature out of their specific range of water temperature. There are also species (e.g. carps) that tolerate both mentioned ranges of water temperature.
Concentrated solution	A recommended quantity of the chemical to cure fish that is first dissolved in a small container (bucket or bowl) before it is diluted to the planned concentration in another larger container or rearing tank. It is a technique that is used to ensure the proper solution and even distribution of such chemicals.
Consistency	The quality of soil that indicates how suitable it is for building a dyke. The more consistent a soil is, the better it serves for building the dyke of a fish pond.
DO	The abbreviation for **dissolved oxygen,** which ensures the respiration of fish. The symbol of the oxygen molecule is O_2.
Duration of development stages	of fish depends not only on the species, but also on the temperature of the water in which they live, as well as on the quantity and quality of consumed food (in the wild) or feeds (in a fish farm).
Effluent	The water that flows out from fish ponds or tanks. It is the collective name of liquid waste and sewage discharged from a fish farm into the wild.
Embryo	of fish develops in the fertilized egg.
Epithelium	The cellular tissue covering surfaces, forming glands, and lining most cavities of the body. It consists of one or more layers of cells with only little intercellular material (Guralnik, 1968).

Exchange rate of water is the frequency with which water is fully replaced in the rearing device. It can be expressed on a per-day or per-hour basis as shown in Table A10.3.

Exophthalmia The abnormal protrusion of the eyeballs (Guralnik, 1968).

External feeding The term means taking natural food or feeds from the environment. External feeding starts when fish larvae/fry are about to finish the yolk sac.

Eyed egg The development stage of fish embryos when their eyes can first be seen well. The development of eyes takes place in the second half of the incubation period. In this stage, the egg can be safely transported even between countries and continents.

Family A principal **taxonomic** category below order and above **genus**.

Feeding larvae See definition of **swim-up fry**.

Fertilized egg Egg carrying the developing embryo of fish.

Fingerling A widely used term in fish culture. It refers to the size of a young fish, which is about 10–15 cm (10–35 g).

Fly fishing See definition of **natural food**.

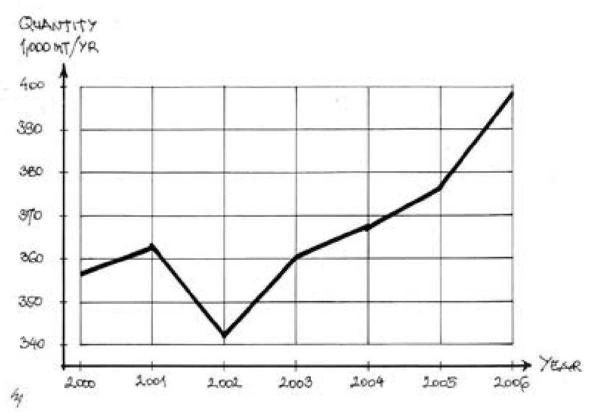
Feed conversion ratio (**FCR**) or **feed conversion rate** or **feed conversion efficiency (FCE)** The quantity of feed that produces 1 kg of live fish. Accordingly, the FCR or FCE is a very important indicator of the efficiency of feeding.

Fry The term for the development stage of fish that starts when young fish gulp air and finishes when the pre-adult form ends. By the end of this stage, all organs have developed including the reproductive organs (testes or ovary), which makes it possible to determine the sex of young fish. The size of young rainbow trout fry is about 3–7.5 cm and 0.5–5 g.

Genus (plural: **genera**) A principal taxonomic category that is below family and above species. The first part of the scientific (or Latin) name of species refers to the name of the genus, which always starts with a capital letter.

Global production of trout Among salmonids, trout are the most widely cultured species. Its total global yearly production summarized in the accompanying graph shows a steady increase (FISHSTAT, 2009).

Trend of global trout production



Habitat	The living place of an organism or community, characterized by its physical or biotic properties.
Haemorrhage	The escape of large quantities of blood from the ruptured blood vessel, heavy bleeding (Guralnik, 1968).
Harmful gases	Gases such as carbon dioxide (CO_2) and ammonia (NH_3) are the result of the respiration and metabolic processes of fish. These gases, released into the water through the gills of the fish, can easily accumulate in the water of rearing and transportation devices.
Harmful solid materials	Water of rearing tanks contain the uneaten and decaying feeds and faeces. They are harmful because they pollute the water in which fish are reared or transported. Bacterial decomposition of the faeces consumes oxygen and, in addition, harmful gases can be released during the process of decomposition. Their quantities are measured in terms of **BOD** or **COD**. Excess levels of suspended soils (first of all, clay colloids) can also be harmful to fish.
Hibernation	A process where the body temperature of a **poikilotherm** organism decreases and its **metabolism** reduces to a minimum. In the case of trout, this minimum is about 2 °C.
Injection of pure oxygen	Injecting pure oxygen into the rearing water is an expensive technique used in super-intensive farms where the total weight of trout in unit volume is extremely high (50–100 kg of fish per cubic metre).
Introduction	The introduction of rainbow trout makes it one of the most widely cultured fish species. It has been introduced to all continents (Welcomme, 1988).
Ion	An atom, or group of atoms, that has gained or lost one or more electrons and hence it carries a negative or positive charge (Sharp, 1990).
Lake trout	The common name of *Salvelinus namaycush* in North America, where it is native. It should not be confused with the lake form of brown trout (*Salmo trutta lacustris*), which is indigenous in Europe and also widely called lake trout.
Metabolism	The sum of life-maintaining physical, biological and biochemical processes carried out by living organisms. The organisms consume and digest certain materials in order to utilize their energy for maintaining their own activity and to deposit a part of the materials in different locations of their bodies. The discharge of used materials from the organism is the last phase of metabolism (Thain and Hickman, 1980).
Natural food	The collective name of those food items that can be found and consumed by fish in natural waters. In general, natural food either grows in the water or falls/drifts into it. In the case of salmonids, the fish also hunt for natural foods that touch the water surface or fly close to it. Dry **fly fishing** is based on this feeding habit of trout.
Non-feeding larvae	See definition of **sac fry**.
Pan fish (pan-size fish)	See definition of **table fish**.
Permeability	Permeability of soil indicates how fast water passes through it. Permeable soils allow water to pass, while impermeable soils do not.

Petechia	A small haemorrhagic spot on the skin, mucous membrane, etc. (Guralnik, 1968).
pH or H^+ ion concentration	Water molecules in nature dissociate to H^+ and OH^- **ions** according to the formula: $H_2O \leftrightarrow H^+$ and OH^-. pH is the negative logarithm of the H^+ ion concentration. This is that figure with which the hydrogen ion (H^+) concentration in the water is expressed. One litre of clean water contains 0.0000007 g H^+. In order to avoid calculations with extremely small numbers, the logarithmic scale is used for the determination of the H^+ concentration. This concentration is expressed on the pH scale of 1–14 (Dévai and Dévai, 1980).
Phylum	A taxonomic category above class and below kingdom.
Poikilotherm (i.e. such as fish or reptiles)	This is normally the state of being cold-blooded; more precisely, having a blood temperature that varies with the temperature of the surroundings.
Ponds	Large but shallow earth structures, which are typically constructed for rearing fish. The fish culture techniques for ponds are based on manuring/fertilization and/or supplementary feeding. In the case of trout farming, small raceway ponds, also called Danish ponds, are constructed and used.
Production capacities	The results of a rainbow trout farm can be doubled if both autumn and spring fry are reared because the same rearing devices can be used twice per year. In this case, not only fry production can be doubled, but also fingerling production. The production of autumn and spring fry is possible because there are some rainbow trout **strains** that spawn in autumn, while others spawn in spring.
Proteins	The prime organic constituents of the body of plants and animals. Only plants and a few bacteria are able to produce their own proteins from inorganic materials. Animals need the proteins of other living organisms in order to produce their body proteins. Many of the farmed animals need specific animal or even fish-origin proteins. There are animals that need less protein (15–20 percent) in their diets, but there are animals that require a high animal/fish-origin protein content (35–65 percent) in their diets. Trout, as they are a predator fish, belong to this latter group of animals. It is also very important to note that the younger age groups of trout require more protein (45–65 percent) in their diets than do older ones.
Raceways	Rectangular concrete or earth structures that are 5–10 times longer than they are wide. In raceways, a continuous water flow ensures the successful high-density rearing of fish.
Rearing devices	The different movable incubation and rearing trays, jars, troughs and tanks made out of a wide range of materials, such as planks, plastic, fibreglass, polypropylene, PVC, **tarpaulin**.
Remedy	See definition of **chemicals** used as remedy.
Sac fry (yolk-sac fry), **alevins** or **non-feeding larvae**	The terms used for the already hatched fish larvae that still carry the yolk sac. There is no **external feeding** because the developing larvae feed internally from the yolk sac.

Salmon Widely produced salmons belong to the **genera** of *Oncorhynchus* and *Salmo*. These are the seema salmon (*Oncorhynchus masou*), pink salmon (*Oncorhynchus gorbuscha*), chum salmon (*Oncorhynchus keta*), coho salmon (*Oncorhynchus kisutch*), cherry salmon (*Oncorhynchus masou masou*), sockeye salmon (*Oncorhynchus nerka*), chinook salmon (*Oncorhynchus tshawytscha*), Black Sea salmon (*Salmo labrax*) and Atlantic salmon (*Salmo salar*).

SI The abbreviation for the International System of Units. These units are weight (mass), length, area, volume, capacity, temperature, time, etc., detailed in Table A10.1.

SL The abbreviation for the standard length of fish, which is the length measured from the tip of the snout to the base of the caudal fin.

Strain A distinct variety or breed of a plant or animal.

Stress A term that has various definitions. The most appropriate one is related to the unfavourable environment of an organism. Accordingly, stresses are disturbing environmental forces that cause cerebral and physical strains and tensions in a living organism. Bad water quality, rough handling, low/poor quality of feed, presence of pathogens and some other factors, such as noise and vibration, are the most important stress factors for fish.

Structures The different tanks, ponds, canals and monks that are built out of concrete or earth.

Surface loading rate Indicates that quantity of water (Q) expressed in litres per second or cubic metres per minute or cubic metres per hour with which each square metre of a settling device can be loaded.

Surface loading rate of rectangular settling tanks (Q/A) can be calculated with the equation of $Q = L \times W \times V_S$ or $Q = A \times V_S$, in which Q is the water flow (in litres per second, cubic metres per minute or cubic metres per hour) that should pass through the settling tank, L is the length, W is the width and A is the surface area of the settling tank, and V_S indicates the sinking speed (velocity) of particles that should be removed from the water (Pálhidy, 1997). It is important in designing a rectangular settling tank that the water should flow evenly (without turbulence) through the tank within the same period of time that is equal to the time needed for the particles to settle. This ensures that the tank will retain/settle the floating particles. For this reason, the cross-section (height multiplied by width; $H \times$ W) of the settling tank should ensure the required even and slow speed of the passing water (V_W) equal to the settling speed (V_S) of the particles aimed to be removed from the system (Illés, Kelemen and Öllős, 1983; Pálhidy, 1997).

Surface waters Streams, rivers, canals, lakes, reservoirs and ponds are surface waters. Because they are exposed to the weather conditions, their water temperature fluctuates both daily and seasonally.

Swimming fry See definition of **swim-up fry**.

Swim-up fry or **swimming fry** or **feeding larvae** The term that indicates that development stage when the young fish gulp air from the atmosphere as well as starting to swim and feed externally from their environment.

Symbol ♀ International symbol for indicating the sex of female living organisms.

Symbol ♂ International symbol for indicating the sex of male living organisms.

Table fish or **pan fish** (pan-size fish) or **portion fish**	The term that covers the range of sizes of fish sold for human consumption. In the case of trout, this range varies from country to country. It can be as small as 115 g or as large as 340–450 g. However, the most frequent size of table fish varies between 200 g and 300 g.
Tank culture	One of the most widely used methods for intensive production of fish. Tanks, regardless of their size and material (earth, concrete, fibreglass, etc.), are suitable for keeping fish if the quality of water is good (rich in dissolved oxygen and free of metabolic products). The water quality in the tanks can be maintained by the exchange of water and supply of air or oxygen. Tanks can be supplied by flow-through water, or the water can be partially or fully recirculated after its mechanical and biological filtration. Biologically complete feed should be fed to fish reared in tanks. The production in tanks should be expressed as the quantity of fish produced per unit volume (number of fish per cubic metre or kilograms of fish per cubic metre).
Tarpaulin	A heavy-duty waterproof cloth. Originally, it was tarred canvas, but in modern times canvas is coated with plastic materials or it is made out of waterproof artificial fibres.
Taxonomy	The theory and practice of classifying and naming living organisms.
Tempering	See definition of **acclimatization**.
Thermal shock	The shock that is caused by sudden or rapid change of water temperature.
TL	The total length of fish. This measurement also includes the caudal fin of the fish.
Transport of eyed eggs in box	Eyed eggs are transported in closed boxes on trays with ice. In this case, the eyed eggs are hibernated during the transport. The ice is placed on the uppermost tray of the transporting box. From the tray, the melting ice provides for a continuous cool temperature as well as ensuring the necessary moistening of the eyed eggs. The water melted from the ice drops through the bottom perforations of the trays and accumulates at the bottom of the box.
Trout	Globally produced trout belong to the **genera** of *Salmo*, *Oncorhynchus* and *Salvelinus* of the Salmonidae family, like Adriatic trout (*Salmo obtusirostris*), brown trout (*Salmo trutta*), flathead trout (*Salmo platycephalus*), Soča trout (*Salmo trutta marmoratus*), Ohrid trout (*Salmo letnica*), Sevan trout (*Salmo ischchan*), Aral trout *(Salmo trutta aralensis*), Amu-Darya trout (*Salmo trutta oxianus*), Apache trout (*Oncorhynchus apache*), cutthroat trout (*Oncorhynchus clarki*), gila trout (*Oncorhynchus gilae*), golden trout (*Oncorhynchus aguabonita*), rainbow trout (*Oncorhynchus mykiss*), Mexican golden trout (*Oncorhynchus chrysogaster*) and Iwame trout (*Oncorhynchus iwame*), aurora trout (*Salvelinus fontinalis timagamiensis*), brook trout (*Salvelinus fontinalis*), bull trout (*Salvelinus confluentus*), Dolly Varden trout (*Salvelinus malma*) and **lake trout** (*Salvelinus namaycush*).
Water filter	See definition of **biological water filter**.
Yolk sac	The sac attached to the developing embryo and fry of fish provides for nourishment until fry swim up, gulp air and start external feeding. By the time the young fish are fit to feed from their environment, the yolk sac has been fully used.

Annex 1

MEASUREMENT AND CALCULATION OF WATER FLOW

Frequently, the water flow from pipes or of streams, canals and raceway tanks should be measured. For accurate measurements, a stopwatch or at least a watch, with mechanical or digital second reading option, is indispensable.

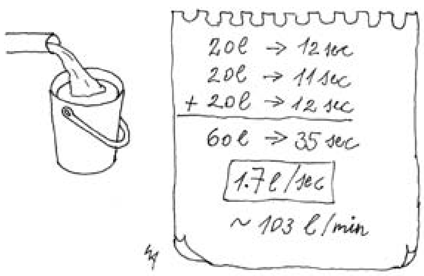


FIGURE A1.1

Measurement and calculation of water flow from a pipe

When water arrives from a pipe, the easiest way to measure and calculate the quantity of passing water is to put a 10–20 litre bucket under the water flow and measure the seconds it takes for the bucket to fill up.

For the sake of accuracy, do it 2–3 times.

Then, the quantity of measured water expressed in litres should be divided by the time taken (in seconds). This will be the quantity of water that arrives in one second (litres/sec).

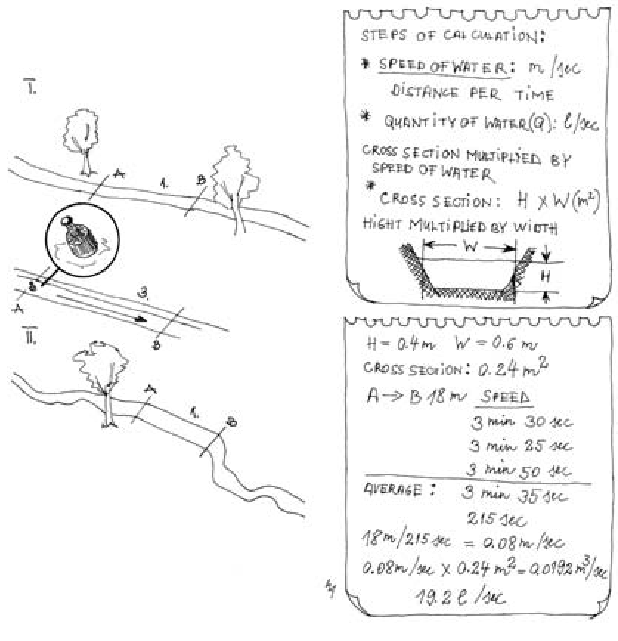
If you want to calculate the quantity of water that arrives in a minute, hour or day, you should multiply the result accordingly. See also Table A10.2.

FIGURE A1.2

Measurement and calculation of water flow in canals, raceway tanks and streams

I. Measurement and calculation of water flow in a canal or raceway tank with regular shapes is simple because the cross-sections are regular. Hence, the values can be read and calculated without estimations.

II. Measuring and calculation of water flow in a stream with irregular shapes needs the estimations of the cross-section where the banks of the stream are parallel. The values read should be arranged in an estimated shape to calculate the area.



Steps in calculations are:

1. Set the length of the section to be measured.
2. Measure the dimensions of the cross-section and calculate its area. This is the multiplication of width (W) by depth (D).
3. Measure the speed of the water with a small object that floats from point "A" to point "B". With 2–3 repetitions, the average speed of the object can be calculated.

Multiplication of the cross-section (in square metres) by the average speed (in metres per second) of the floating object will give the quantity (volume) of water (in cubic metres) that passes within the measured time. This quantity divided by the measured time will indicate how much water passes within one second. For calculating longer periods of time, use the exchange values presented in Table A10.2.

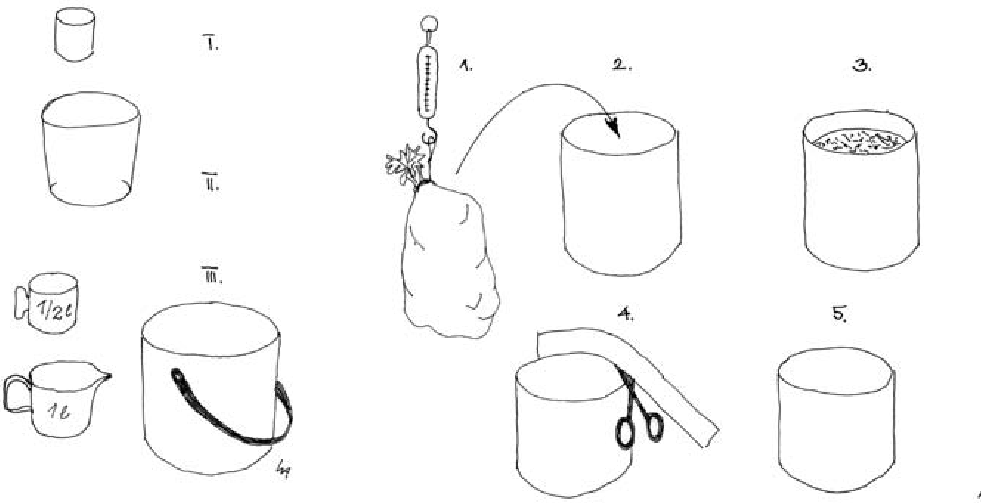
Annex 2

CALIBRATION OF FEED-MEASURING CONTAINERS

Although the use of different scales is important for weighing production materials such as feeds, the daily jobs need a quick solution. The answer is to use different measuring containers. The concept of the use of such tools is that the different feeds (or any other materials) can be quickly and accurately portioned by volume with a measuring container, which was calibrated earlier.

Some of the feed-producing companies supply measuring containers. However, fish farmers can select and calibrate their own. These containers can be buckets, bowls, cups or even tin cans.

FIGURE A2.1



Steps in the calibration of measuring containers

First, the containers should be selected according to the size of the different feeds. Plastic and aluminium kitchen measuring pots are ideal for this purpose. Select those that hold a round basic unit of the used feed; consequently, containers for: **I.** 10 g fry feed; **II.** 100 g fry feed; and larger ones for **III.** 0.5 kg, 1 kg and 5 kg of feed. If there is no such container, a new one should be calibrated.

The steps are:

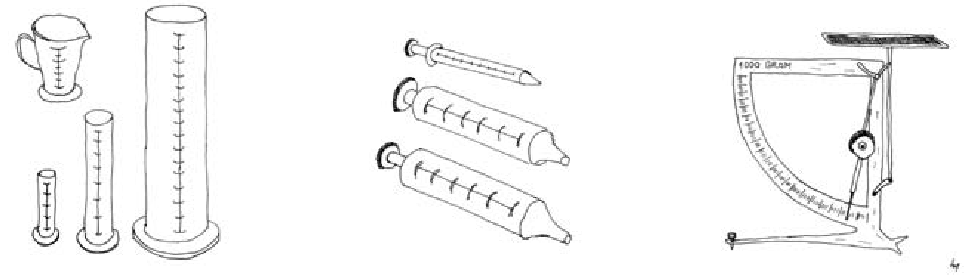
1. Weigh the planned round quantity of feed.
2. Place it into the container.
3. Mark the level. For the sake of accuracy, do it 2–3 times.
4. If the calibrated new measuring container remains strong, its edge can be cut. Trim the edge of the container. This will allow quicker portioning.
5. When it is sure that the measured and marked volume is correct, the container is ready to use.

Annex 3

MEASUREMENT AND USE OF CHEMICALS AND MEDICINES

*Chemicals** and medicines should be measured very accurately. Producers of chemicals and medicines usually provide the users with calibrated measuring cups. Where such devices are not supplied, ones similar to those pictured below can be used.

FIGURE A3.1

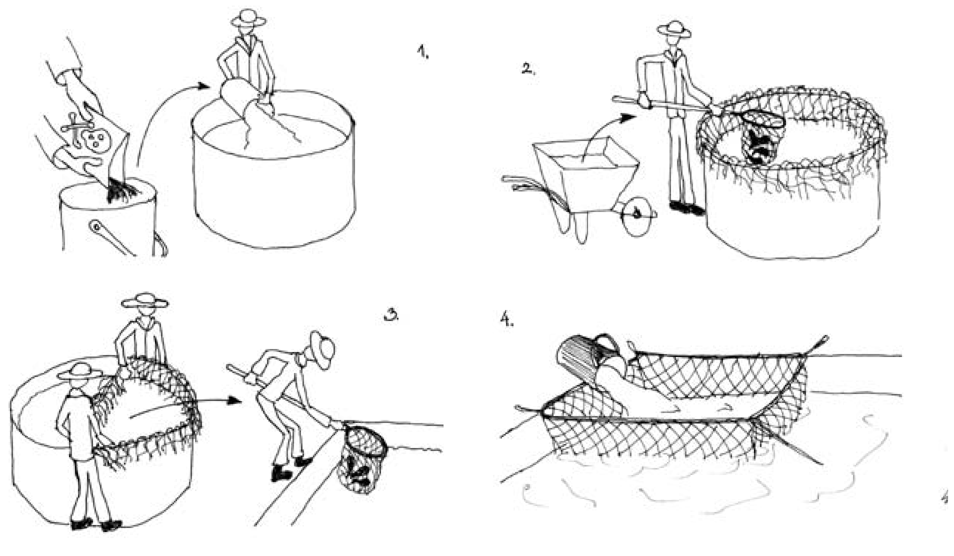


Measuring cups and cylinders are available in specialized shops.

For measuring very tiny volumes of liquids, use syringes of different sizes.

For weighing tiny quantities of powder or granulate, use a letter balance.

FIGURE A3.2



Dipping and bathing

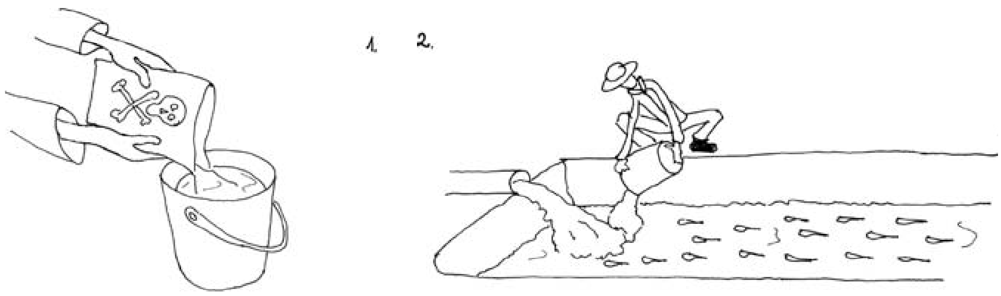
It is important to be sure that the temperature of the dipping water is equal to that of the water that fish are taken from.

The steps are:

1. Prepare a *concentrated solution** and dilute it to the exact final concentration in the bathing container.
2. Place the fish into the bathing container and leave them there as long as prescribed.
3. Remove the fish from the container into a chemical-free place where the fish can recover.
4. There are cases when fish are concentrated in a net, where the treatment is done. After treatment, the fish are released from the net. This type of treatment should be done only if the exchange of water is continuous in the tank and the final concentration of the chemical that remains in the tank is not harmful to the fish.

In fish culture, chemicals are used either for disinfection or for prevention or treatment of fish against parasites and diseases. In these cases, dangerous poisons are often used. For this reason, accurate concentrations and measurement of the duration while fish are exposed to the chemicals are the two aspects to be observed. The use of chemicals as a *remedy** in fish culture is done through bathing. Depending on the chemical applied, slow and quick bathing are distinguished. Often, they are called bathing and dipping, respectively.

FIGURE A3.3



Treatment of fish under continuous water flow

The steps are:

1. Prepare a concentrated solution.
2. Release the concentrated solution slowly and proportionally into the tank to ensure the even final concentration of the applied chemical.

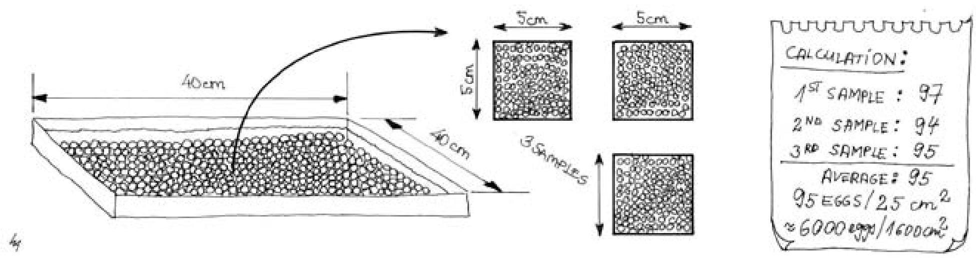
Use of medicines

Medicines are given to fish either blended in feed or through injection. In the case of feeding, medicines are mixed into the daily feed of fish in the required quantities recommended by a specialist veterinarian. In countries where the trout farming industry is advanced, the frequently needed medicines are premixed into industrial feeds. Injection of drugs or vaccination is expensive and labour-consuming but an efficient way to cure diseases. In the case of rainbow trout, injection of drugs or vaccination may be economically feasible.

Annex 4

COUNTING EYED EGGS, ADVANCED FRY AND OLDER AGE GROUPS OF FISH

FIGURE A4.1

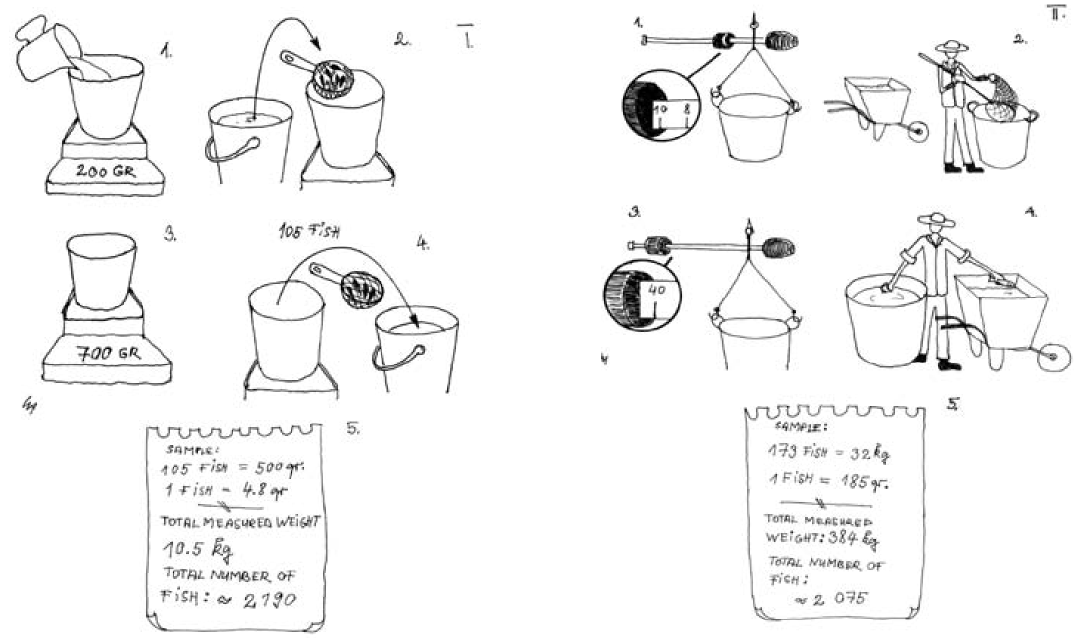


Counting eyed eggs

The steps are:

1. Count eggs on the sample frames.
2. Take the average of egg samples.
3. Calculate the total number of eggs.

FIGURE A4.2



Counting fish

The methods of counting the number of smaller (**I.**) and larger (**II.**) fish are similar. It is done by weighing 2–3 samples.

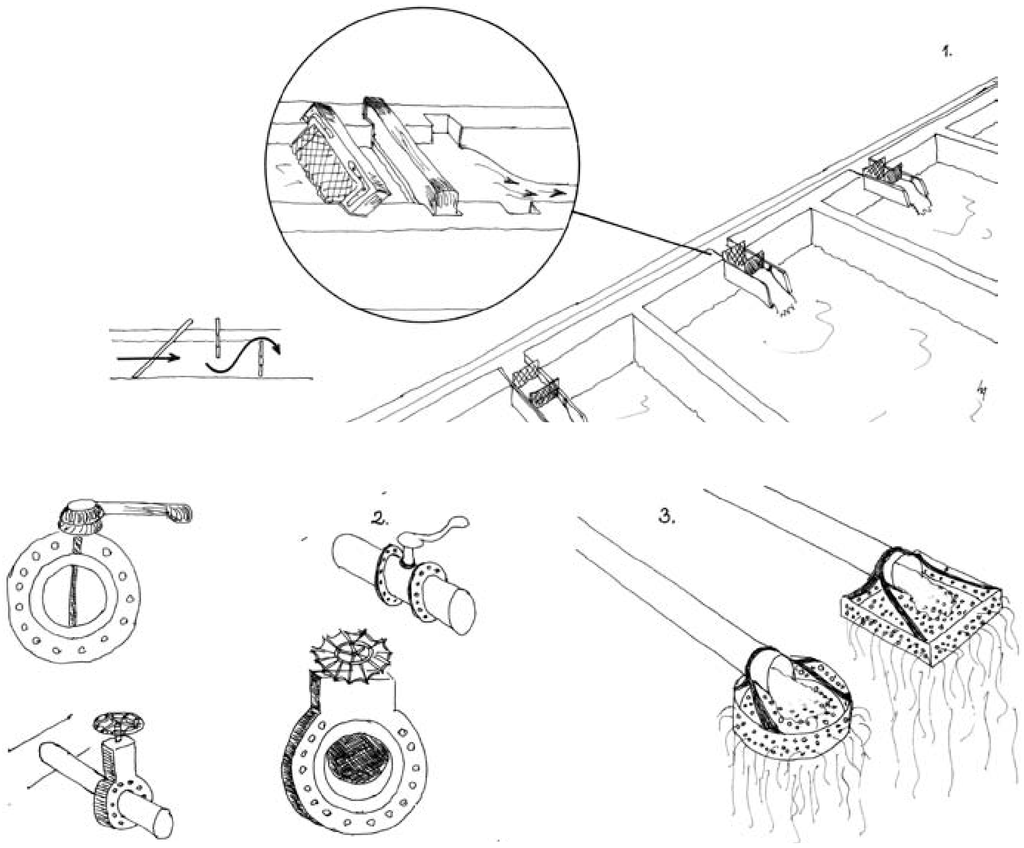
The steps are:

1. Fill 20–30 percent of a suitable container with water.
2. Fill with fish.
3. Weigh the entire container.
4. Count the fish in the samples.
5. Calculate the number of fish on the basis of the weight measured.

Annex 5

WATER SUPPLY AND DRAINAGE STRUCTURES

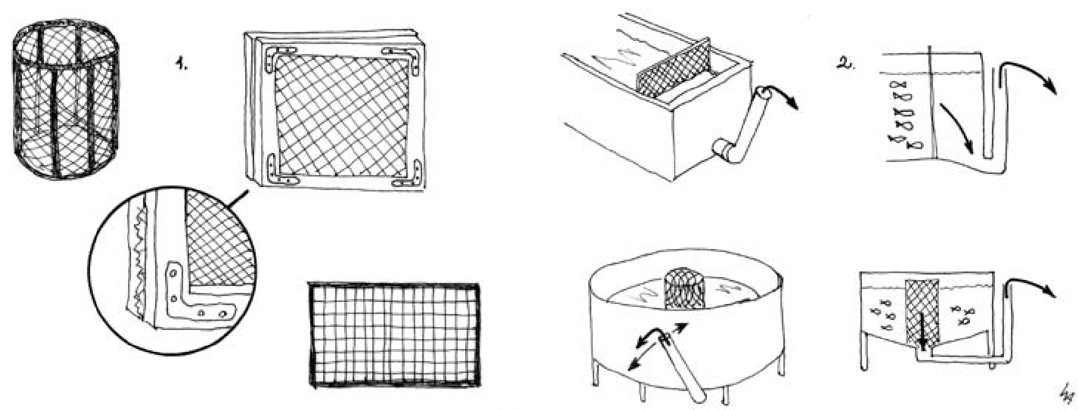
FIGURE A5.1



Water supply devices and structures

1. Water supply canals and boards. **2.** Valves and slide valves (D = 7.5–20 cm). **3.** Pipes (D = 7.5–20 cm).

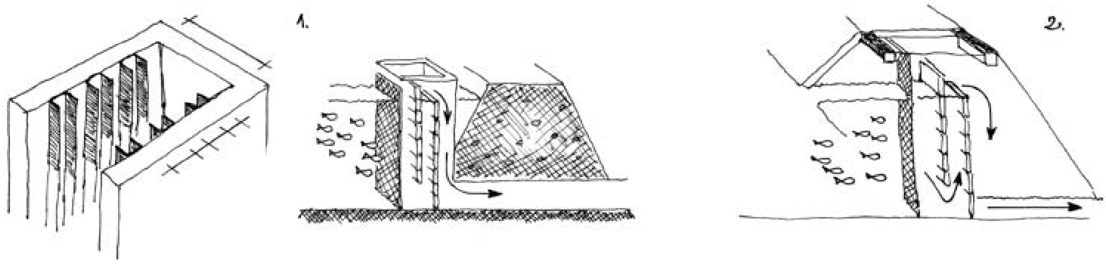
FIGURE A5.2



Water drainage devices and structures

1. Screens used to prevent escaping fish. **2.** In tanks, the turnable drainage pipes ensure that water is kept at the required level.

FIGURE A5.3



Monks with screens

1. Traditional monk. **2.** Open monk. In both cases, the parallel arrangement of the planks ensures that water is kept at the required level.

Annex 6

MECHANICAL AND BIOLOGICAL FILTERS

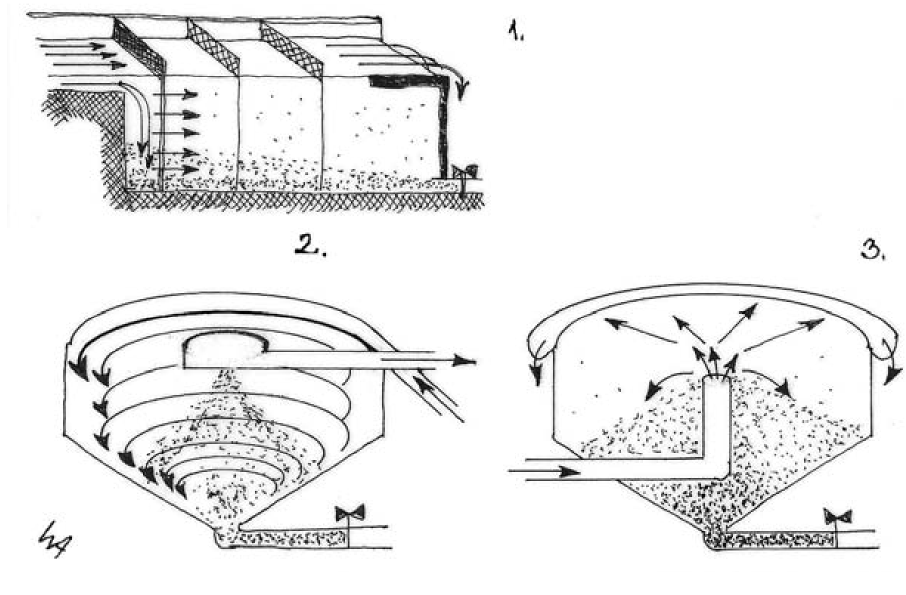
Mechanical filters

The simplest mechanical filters are the different screens that prevent floating particles from passing through them. The problem with such screens is that they soon become clogged. Therefore, they are rarely used unless the filter is continuously backwashed. Another way of removing floating particles is by settling them in special tanks.

In rectangular settling tanks, the speed of the water should slow to less than 3 cm/sec, because at this speed floating particles in the effluent of trout rearing tanks start to settle (Hoitsy, 2002). At this speed, the *surface loading rate** is about 30 litres/sec per square metre (1.8 m^3/sec per square metre), while at 2 cm/sec and 1 cm/sec, the surface loading rates will be 20 litres/sec per square metre (1.2 m^3/sec per square metre) and 10 litres/sec per square metre (0.6 m^3/sec per square metre), respectively. These values in a rectangular settling tank can already ensure the settlement of most of the floating particles. When screens, lamellas or tubes are placed in a rectangular settling tank, its efficiency increases.

Open hydrocyclones (also called swirl separator) and radial-flow settler are devices that remove floating particles in a different way from the way rectangular settling tanks do. They are more efficient gravity settling vessels than the rectangular settling tanks (Piggott, 2007). This greater efficiency can be as much as fourfold.

FIGURE A6.1



Settling tanks

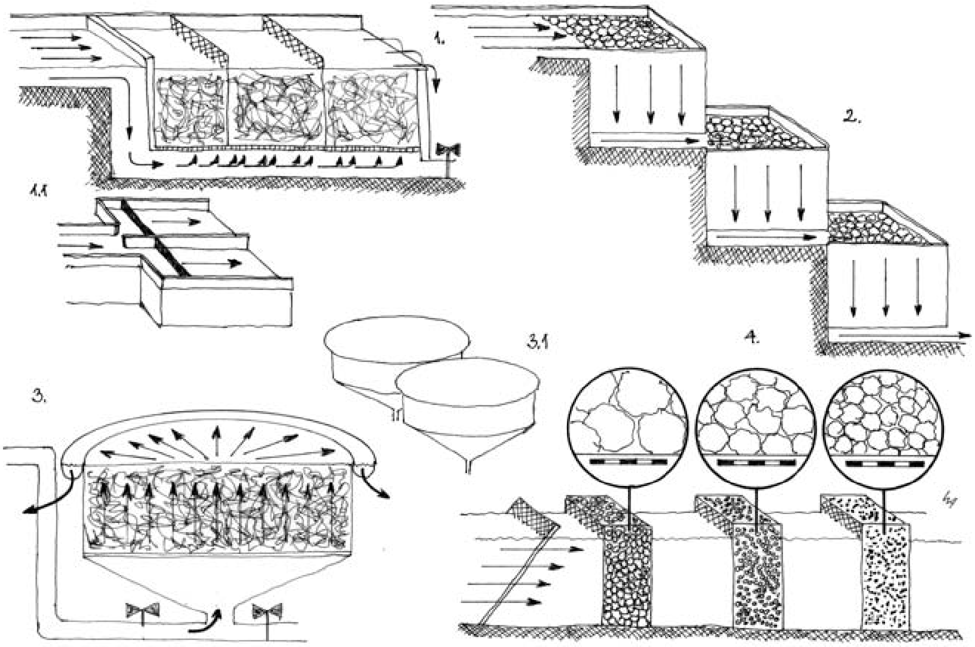
1. Rectangular settling tank. **2.** Open hydrocyclone or swirl separator. **3**. Radial-flow settler.

Biological filters

In order to ensure the development of efficient quantities of bacteria, a biofilter should have a large surface. The material of the media where bacteria can develop in a biofilter may be different. Gravel, pebbles, chips of stone, different plastics, shell of molluscs, etc., are all suitable for this purpose. Their suitability is compared on the basis of the total surfaces of one cubic metre volume (in terms of square metres per cubic metre). Biofilters can be submerged or of the trickling type, serving slightly different purposes. Water coming into contact with the submersible filters must be saturated with oxygen. In the case of a trickling filter, this is done automatically. The size of the biofilter should be proportional to the fish production, more precisely to the quantity of feed applied. The actual size of the biofilter is determined by the surface on which bacteria can develop. Accordingly, 1 kg of feed requires a biofilter surface of about 200 m^2.

Although practically anything that has a large surface may serve as media for biofilters, materials that cannot resist the bacteria or that are difficult to handle, move or clean should not be selected.

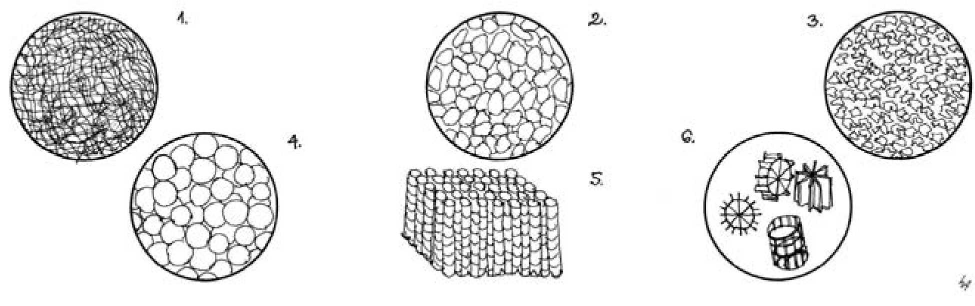
FIGURE A6.2



Biological filters

1. Biological filter placed in a tank. **1.1** Twin-arrangement facilitates cleaning. **2**. Trickling filter placed on slope. **3.** Cyclone-type biological filter. **3.1** Twin-arrangement facilitates cleaning. **4.** Stone chips are used as both mechanical and biological filters, although their cleaning is difficult.

FIGURE A6.3



Media of biological filters

Materials of biological filters for developing bacteria **1.** Netting material (~ 50–100 m^2/1 m^3). **2.** Stone chips or pebbles (~ 150 m^2/1 m^3). **3.** Plastic chips (~ 150–450 m^2/1 m^3). **4.** Polyphone balls "bead" (diameter 1.5 mm: 8 000 m^2/1 m^3). **5.** Lamella (250–350 m^2/1 m^3). **6.** Loose biomedia (~ 800 m^2/1 m^3).

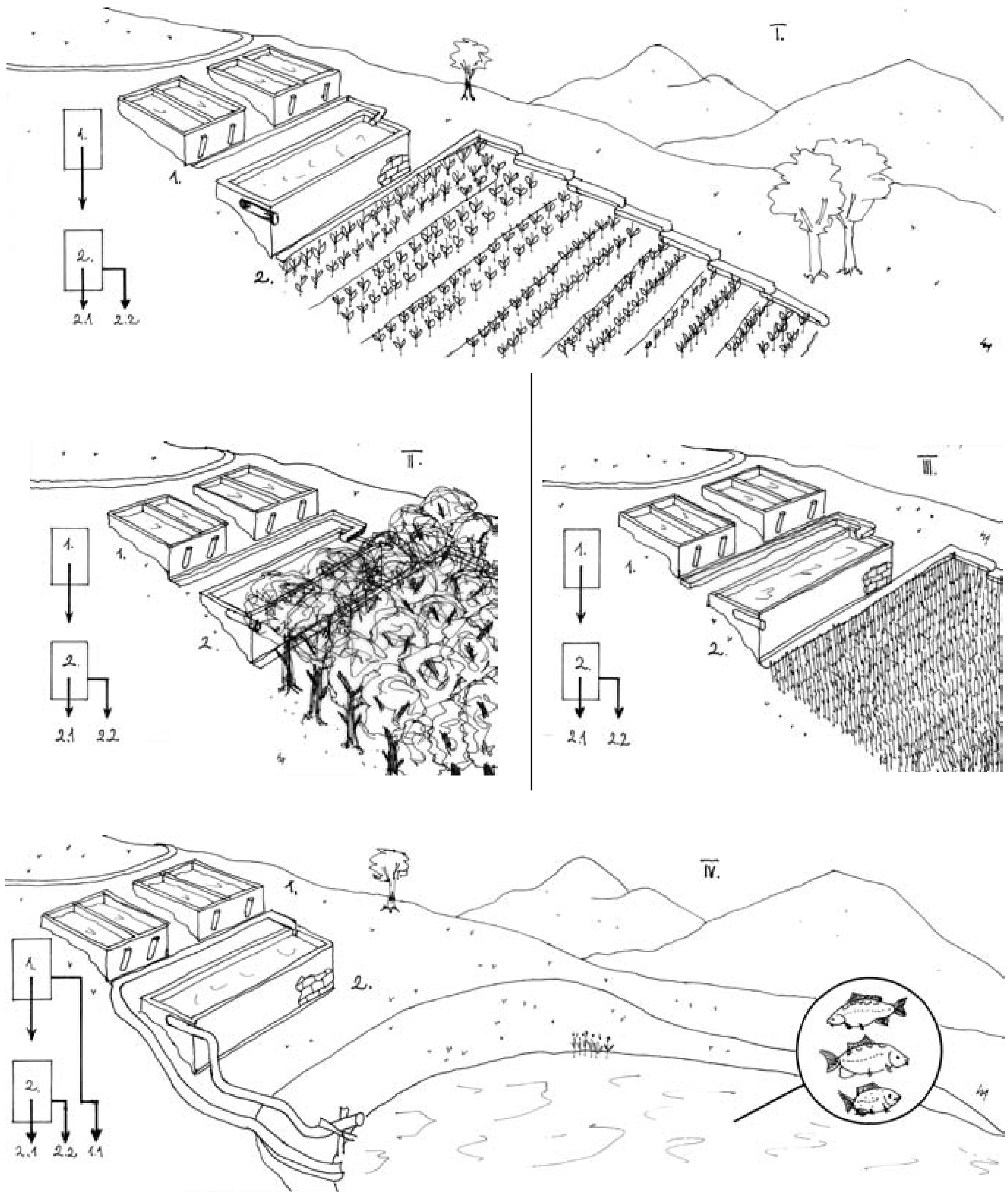
Open-air filter systems

Effluents of trout farms can be utilized for irrigation, wetlands or carp pond polyculture. Construction and use of a mechanical filter is recommended in all cases. After mechanical filtration, water and sludge can be used separately.

In the case of carp pond polyculture, effluents produced from spring to autumn can be used without mechanical filtration. The effluents of the production of 10 tonnes of trout can be utilized and absorbed by a pond of about 500 m^2 for common carp or/and bream. During the cold season, the appetite of these species reduces, at which time the effluent should be filtered and used as manure.

About 1 litre/sec of outflowing water is enough to irrigate 1 ha of land, while, according to specialists, the effluents of the production of 10 tonnes of fish can be treated and absorbed by 1 000–2 000 m^2 of wetland.

FIGURE A6.4



Types of large, open-air filter systems

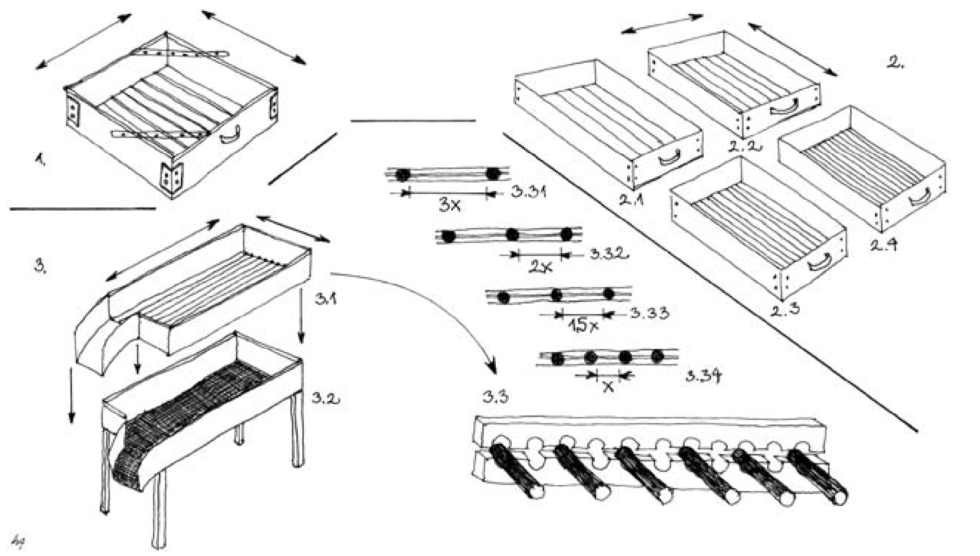
I. Irrigated land. **II.** Irrigated plantation of trees. **III.** Reed bed. **IV.** Fish pond.

Steps in filtering effluent: **1.** Trout production unit. **2.** Mechanical filter (**2.1** water; and **2.2** sludge).

Annex 7

EQUIPMENT, NETS AND HAND TOOLS

FIGURE A7.1



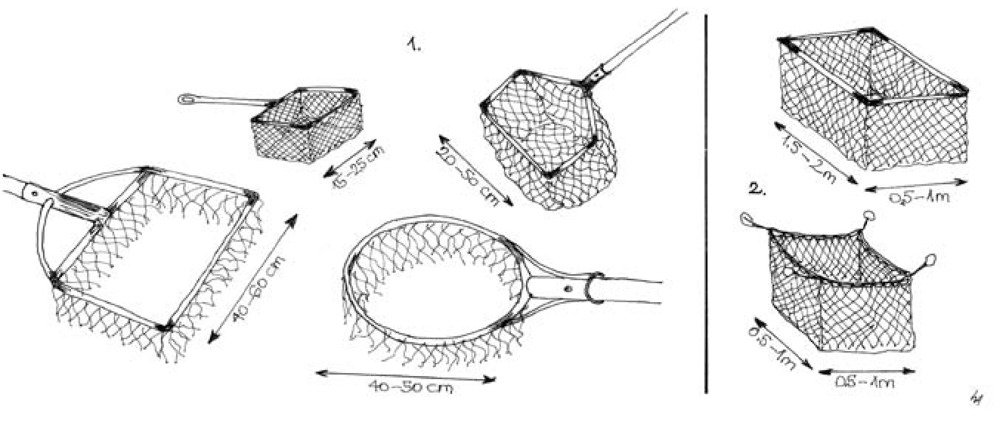
Equipment of fish grading

1. Adjustable hand grader. **2.** Set of hand graders. **3.** Sorting table with changeable bars (after Hoitsy).

Steps in hand grading: First the smallest, then through to the largest size is fixed on the grader.

Steps in grading on table: Place small quantities of fish on the grading bars, through which the smaller fish fall and slip into the collecting container, while the larger ones will slip into the other container.

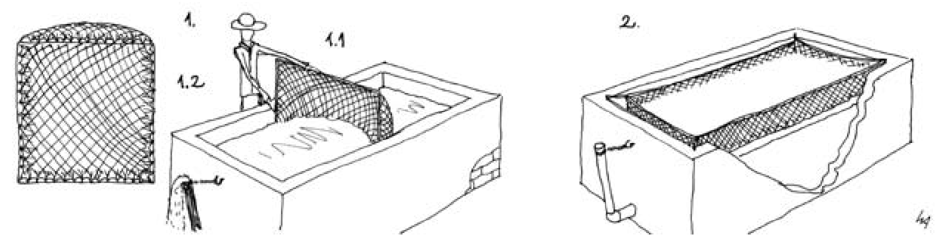
FIGURE A7.2



Hand and holding nets

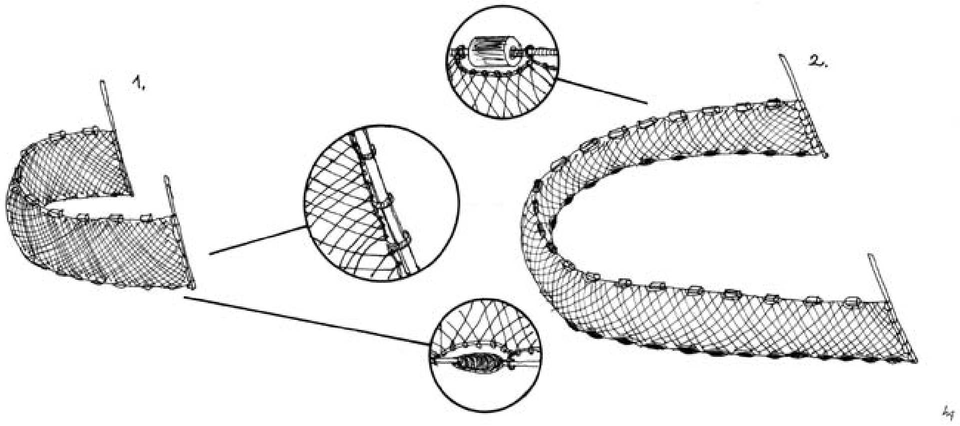
1. Hand nets of different sizes. **2.** Holding nets of different sizes.

FIGURE A7.3



1. Net mounted on a frame will facilitate its use. **2.** Holding net fixed in a concrete tank can help easy and quick removal of fish (after Woynarovich and Woynarovich [1998]).

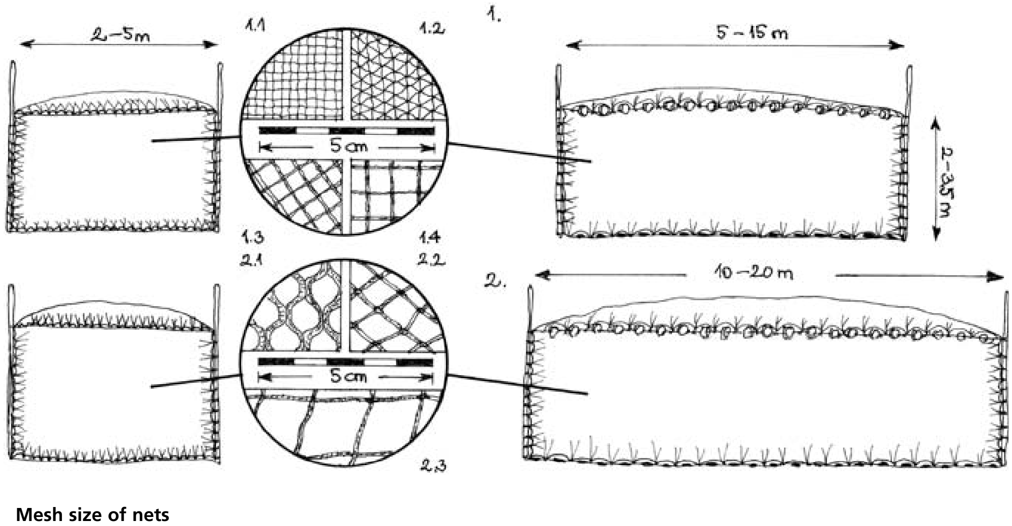
FIGURE A7.4



Seines

Seines mounted with floats and weights are used in tanks and ponds. These nets should be deep and wide enough. **1.** Smaller net for concrete tank. **2.** Drag net for earth pond. It is a general rule that such nets should be at least 50 percent times wider and deeper than the depth and the width of the tank or pond in which they are used.

FIGURE A7.5



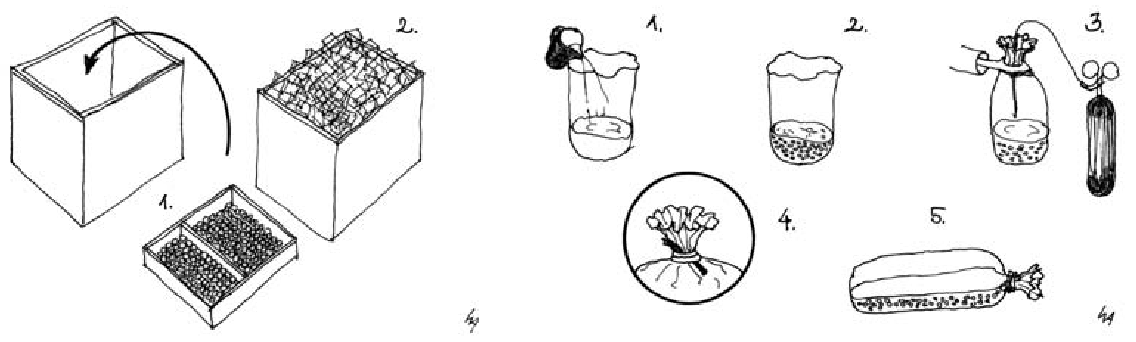
Mesh size of nets

Fish of any size should be captured with the suitable mesh size of the net (after Woynarovich and Woynarovich [1998]).

Annex 8

TRANSPORT OF EYED EGGS AND DIFFERENT AGE GROUPS OF RAINBOW TROUT

FIGURE A8.1



Transport of eyed eggs in box

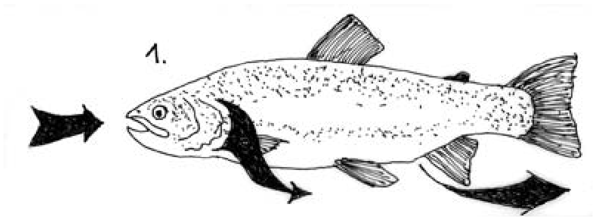
The steps are: **1.** Place eggs onto the trays of the carrying box. **2.** Place ice on the top tray.

Transport of eyed eggs in plastic bag

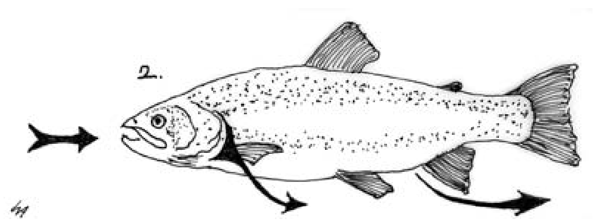
The steps are: **1.** Fill one-third of the bag with water. **2.** Place the eggs in the bag. **3.** Fill up the bag with oxygen. **4.** Close the bag with rubber band. **5.** Place in position for transport.

Preparation of fish for transport is important because fish, full of feed, consume more oxygen and release more harmful gases and faeces, and they are more stress sensitive. During preparation of fish for transport, the fish should be kept without feeding in running water in order to empty their digestive tracts.

FIGURE A8.2



Intensity of the metabolism of trout is intense before (**1.**) and reduces after (**2.**) the preparation of fish for transport.



Recommended length of the preparation of trout for transport

Temperature (°C)	Duration (hours)
12–18	12–18
9–10	24–26
5–6	36–40
2–3	72–80

Source: Hoitsy.

FIGURE A8.3

Transport of fish in plastic bag

A less equipment-demanding way of transporting fish is to use a 30 or 60 litre plastic bag in which the proportion of water and pure oxygen is 1:2 (one-third water and two-thirds oxygen). Accordingly, in such a bag, there will be about 10–20 litres of water.

The numbers of fish transported in 20 litres of water in a bag depends on the size of fish, the temperature of the transporting water and the duration of transport. Some reference figures for a few hours of transport are shown in the graphs (water temperature: 5–10 °C).

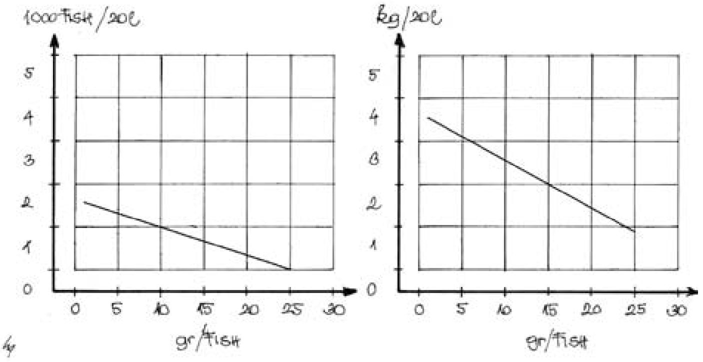
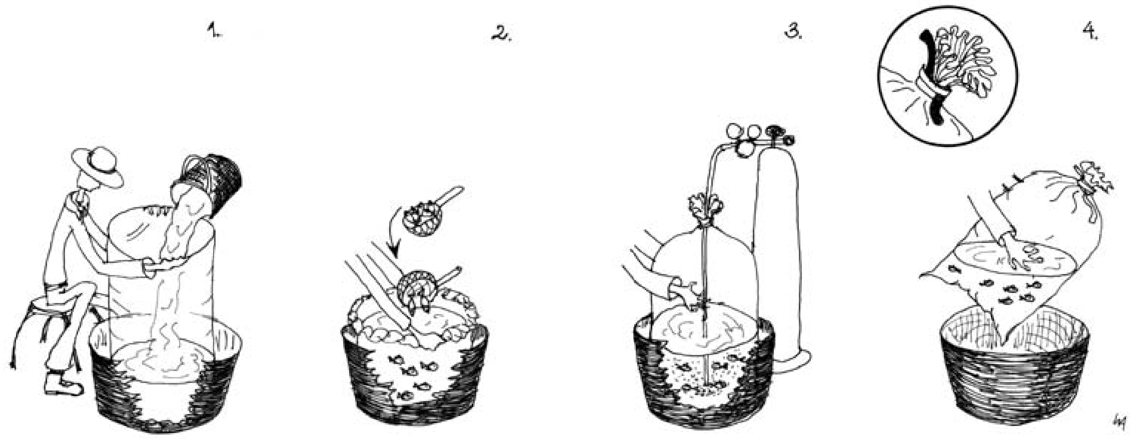


FIGURE A8.4



Packing fish into plastic bag

The steps are: **1.** Fill the bag with water. **2.** Place the fish into the bag. **3.** Fill the bag with oxygen. **4.** Close the bag with rubber band, made out of used tyre (Woynarovich and Woynarovich [1998]).

FIGURE A8.5

Transport of fish in tank

The transport of fish in a container with continuous oxygen supply is the usual way of moving large quantities of live trout.

The size of the container may vary from a few hundred litres up to few cubic metres. The usual size of transporting container for a smaller vehicle is about 500 or 1 000 litres.

The quantity of fish that can be transported per cubic metre of water at 5–10 °C with continuous diffusion of oxygen for about 4–8 hours is shown in the graphs (after Berka [1986]).

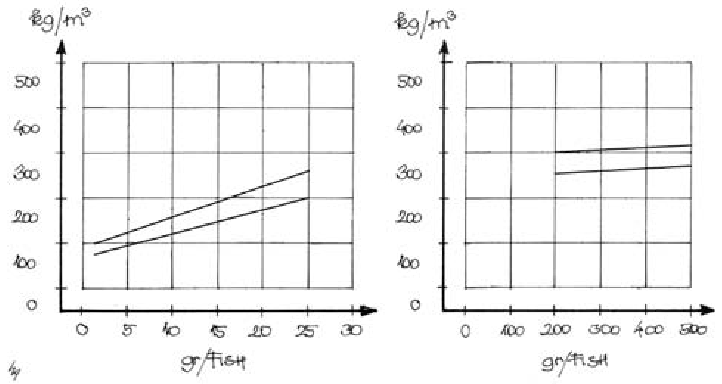
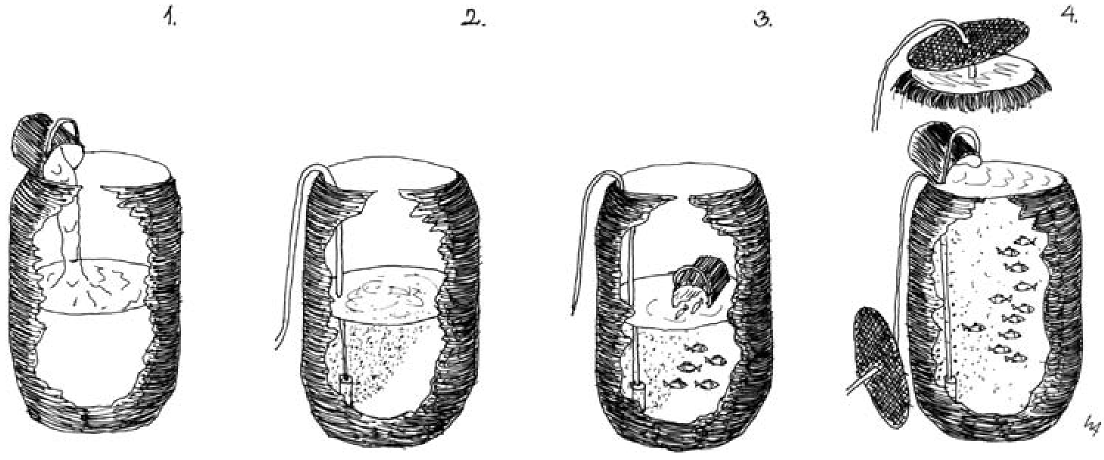


FIGURE A8.6



Preparation and loading of trout for transport

The steps are: **1.** Fill the container half full with water. **2.** Place and test the oxygen diffuser. **3.** Place the fish into the container. **4.** Fill up the container with water and close it (Woynarovich and Woynarovich [1998]).

Annex 9

FREQUENT DISEASES OF RAINBOW TROUT

There are a range of different diseases of rainbow trout that are caused by viruses, bacteria, fungi and parasites, but the environment- and nutrition-related diseases are also rather frequent if the production conditions deteriorate. For the diseases listed below, where measurements cannot be given,[1] consultation with a veterinarian specialized in this field is not only suggested but explicitly recommended.

Frequent **diseases caused by virus** are:

- **Viral haemorrhagic septicaemia (VHS)**, which is a very serious viral disease of farmed rainbow trout.
  Symptoms: Darkened skin, swim erratically, absence of feed in the gut, fluid in the abdomen, *exophthalmia**, internal *haemorrhages** (liver, muscle), swollen kidney, pale or yellow-grey liver.
  Causes: Rhabdovirus.

- **Infectious pancreatic necrosis (IPN)**, which causes high mortalities in young salmonid fishes.
  Symptoms: Behavioural changes (swim unsteadily, *ataxia**) and gross external and internal lesions, as well as anorexia. Other external signs are hyperpigmentation, exophthalmia, haemorrhagic patches on the ventral surfaces. Other internal signs are visceral *petechia**, empty gut with yellow exudates, as well as necrosis of the pancreas and of the kidney.
  Causes: Birnavirus.

- **Infectious haematopoietic necrosis (IHN)** – In acute disease, there is a sudden increase in fish mortality, but the fish may not show clinical signs.
  Symptoms: Changing behaviour with lethargic and hyperactive phases, dark coloration, distended abdomen, exophthalmia, pale gills, liver and kidney, petechial haemorrhages of the fins, gills, mouth, skin and muscle. The stomach is filled with milky fluid.
  Causes: Rhabdovirus.

Frequent **diseases caused by bacterium** are:

- **Furunculousis**
  Symptoms: Exophtalmus, hemorrhagic patches along the side or on the dorsal body surfaces, bloody anal vents and furuncles on the body surface.
  Causes: *Aeromonas salmonicida.*

- **Enteric Red-mouth Disease (ERM)**
  Symptoms: Reddening of the throat and mouth, erosion of the jaw, haemorrhage on the body surface, at the gill tips, at the base of the fins, congestion of the blood vessels, petechial haemorrhages on the liver, pancreas, swim-bladder. The kidney and the spleen are swollen.
  Causes: *Yersinia ruckeri.*

---

[1] The applicable rules and regulations and the permitted chemicals and medicines in fish farming may differ from country to country in the countries of CEE and CCA. Therefore, the applicable measurements for many common fish diseases may be different.

- **Columnaris disease**
  Symptoms: It starts with greyish-white spots on the body of the fish, often on the head, lips or fin. The initial lesions are small and circular with greyish-blue centres and red margins surrounded by a ring of inflamed skin.
  Causes: *Flavobacterium columnare.*

- **Flavobacterium septicaemia (cold water disease)**
  Symptoms: Exophthalmia, abdominal swelling, reddening of the vent, enlarged spleen, hemorrhagic necrosis in muscle and viscera. In acute cases, haemorrhages may be seen in the heart, liver, swim-bladder.
  Causes: *Flavobacterium psychrophilum.*

A frequent **disease caused by fungi** is:

- **Saprolegnia** – The fungi responsible for saprolegniasis are secondary pathogens, which appear and develop after handling or after any traumatic damage to the skin of the fish.
  Symptoms: Grey-white patches on the skin, which under the water have a cotton-wool-like appearance.
  Causes: *Saprolegnia* spp.

Diseases can be caused by parasites such as:
Protozoa (e.g. *Ichthyobodo necator*, *Ichthyophthyrius multifiliis*, *Trichodina* sp., *Chilodonella* sp.) – Protozoa are single-celled eukaryotic organisms that range from being microscopic to being just visible with the eye. Most of them have a direct life cycle with no intermediate host involved. Others have indirect life cycles that involve several aquatic organisms. Protozoan infections occur in intensive culture systems.

A frequent **disease caused by parasites** is:

- **Whirling disease**
  Symptoms: The parasite destroys the cartilage in the head and in the vertebral column. The first signs are dark pigmentation; because of lesions in the cartilage, which exert pressure on the nerves, after about two months the abnormal tail-chasing behaviour (whirling) becomes noticeable. There are also deformations of the head and the spine.
  Causes: *Myxobolus cerebralis* (its alternate host, the free-living nematode *Tubifex tubifex*).

Frequent **environment-related diseases** are:

- **Acute and permanent oxygen shortage**
  Symptoms: When oxygen levels fall quickly to critically low levels, the fish can rapidly develop respiratory stress and may die. The respiratory problems manifest in increased gill beat and, in severe cases, the fish may gulp for air on the water surface. Chronic hypoxia is not necessarily lethal to the fish, but may cause stunted growth, reduced feeding and increased susceptibility to infections.
  Causes: The fish stock is not supplied with enough oxygen.
  Measures: The actual oxygen content of the water in the rearing tank should be checked not only at the inlet but also at the outlet (Bregnballe, 2010). This can be done with an oxygen kit or with an oxygen meter. Increase the water flow or/and the oxygen content of the water with aeration. Where these measures cannot be taken, the density of fish in the rearing device should be reduced.

- **Gas bubble disease** – Under certain conditions, water may become supersaturated with one or more gases, most frequently with nitrogen. In this situation, fish can develop gas emboli.
  Symptoms: Bubbles of gas appear in the edges of the body fins, in blood vessels, in all chambers of the eye, skin and gills.
  Causes: This disease is often associated with the supersaturation of the water with nitrogen or oxygen. This may occur in the wild, near to electrical water plants, or in fish farms, where powerful air or oxygen injection systems are used or where water from deep boreholes is used.

- **Poisoning –** It can be an environmental disease caused by natural events (rapid change in water quality) or caused by human activities (intensive use of agricultural chemicals, urbanization, industrialization, etc.). The water quality parameters applicable for fish farming are set by all countries. In European Union countries, the "Freshwater Fish" Directive (EEC 1978) is the applicable one.
  Symptoms: These vary, being poison-specific, but all of them cause mass mortality.
  Causes: Among others, nitrogenous wastes (ammonia, nitrite, nitrate), extreme pH, pesticides, heavy metals.
  Measures: Exchange of freshwater.

- **Stress** is related to the unfavourable environment and handling of fish. Stresses can be reduced easily with observation and application of the correct fish production technology.

Frequent **nutrition-related diseases** are:

- **Fusariosis**
  Symptoms: Focal (localized) hepatic necrosis, oedema, generalized haemorrhagic syndrome, infection of digestive track and hepatic *carcinoma**.
  Causes: Mycotoxins.
  Measures: Changing of feeds.

- **Vitamin and mineral deficiency –** Vitamins are complex organic substances that are essential to a wide variety of metabolic processes. Approximately 15 different vitamins are known to be important for fish. Fish also require minerals for different metabolic processes, such as haemoglobin synthesis, as well as for enzyme/hormone functions.
  Symptoms: These vary, but normally cause reduced growth or deformation. Measurements: Changing of feeds.

- **Fatty feed**
  Symptoms: Damage and deformation of liver and bile.
  Causes: There is too much fat in the feed of the fish.
  Measures: Reduction of the fat content of the feed.

Annex 10

TABLES

TABLE A10.1
Measurements

SI* unit	Multiples and submultiples: Name	Value	Symbol	Observation
Weight (mass)				
	tonne	1 000	t or mt	
kilogram		***1***	***kg***	
	dekagram	*0.01*	*dkg*	*Not official SI submultiple*
	gram	0.001	g	
	milligram	0.000001	mg	
	microgram	0.000000001	µg	
Length				
	kilometre	1 000	km	
	decametre	*10*	*dam or dkm*	*Not official SI multiple*
metre		***1***	***m***	
	decimetre	*0.1*	*dm*	*Not official SI submultiple*
	centimetre	0.01	cm	
	millimetre	0.001	mm	
	micrometre	0.000001	µm	
Area				
	square kilometre	1 000 000	km^2 or sq km	
	hectare	10 000	ha	Approved and used unit
	are	100	a or are	Approved and used unit
square metre		***1***	$\boldsymbol{m^2}$	***1 m × 1 m***
	square decimetre	0.01	dm^2 or sq dm	
	square centimetre	0.0001	cm^2 or sq cm	
	square millimetre	0.000001	mm^2 or sq mm	
Volume				
cubic metre		***1***	$\boldsymbol{m^3}$	***1 m × 1 m × 1 m***
	cubic decimetre	0.001	dm^3 or cu dm	10 cm × 10 cm × 10 cm
	or litre		l or litre	
	cubic centimetre	0.000001	cm^3 or cu cm	
	or millilitre		ml	
	cubic millimetre	0.000000001	mm^3 or cu mm	
Capacity				
	cubic metre	1 000	m^3	
litre		***1***	***l or litre***	***10 cm × 10 cm × 10 cm***
	millilitre	0.001	ml	
	microlitre	0.000001	µl	
Speed				
	kilometre/hour		km/h	
	metre/minute		m/min	
metre/second			***m/s or m/sec***	
	millimetre/second		mm/s or mm/sec	
Time				
	day	86 400	day or d	24 × 60 × 60
	hour	3 600	hour or h	60 × 60
	minute	60	min	1 × 60
second		***1***	***sec***	
Speed of water flow				
	litres/day		litres/day	
	litres/hour		litres/hour	
	litres/minute		litres/min	
	litres/second		litres/sec	

TABLE A10.2
Water flow

litres/second	litres/minute	litres/hour	litres/day
0.02	1	60	1 440
0.03	2	120	2 880
0.05	3	180	4 320
0.07	4	240	5 760
0.08	5	300	7 200
0.10	6	360	8 640
0.12	7	420	10 080
0.13	8	480	11 520
0.15	9	540	12 960
0.17	10	600	14 400
0.18	11	660	15 840
0.20	12	720	17 280
0.22	13	780	18 720
0.23	14	840	20 160
0.25	15	900	21 600
0.27	16	960	23 040
0.28	17	1 020	24 480
0.30	18	1 080	25 920
0.32	19	1 140	27 360
0.33	20	1 200	28 800
0.35	21	1 260	30 240
0.37	22	1 320	31 680
0.38	23	1 380	33 120
0.40	24	1 440	34 560
0.42	25	1 500	36 000
0.43	26	1 560	37 440
0.45	27	1 620	38 880
0.47	28	1 680	40 320
0.48	29	1 740	41 760
0.50	30	1 800	43 200
0.52	31	1 860	44 640
0.53	32	1 920	46 080
0.55	33	1 980	47 520
0.57	34	2 040	48 960
0.58	35	2 100	50 400
0.60	36	2 160	51 840
0.62	37	2 220	53 280
0.63	38	2 280	54 720
0.65	39	2 340	56 160
0.67	40	2 400	57 600
0.68	41	2 460	59 040
0.70	42	2 520	60 480
0.72	43	2 580	61 920
0.73	44	2 640	63 360
0.75	45	2 700	64 800
0.77	46	2 760	66 240
0.78	47	2 820	67 680
0.80	48	2 880	69 120
0.82	49	2 940	70 560
0.83	50	3 000	72 000
0.85	51	3 060	73 440
0.87	52	3 120	74 880
0.88	53	3 180	76 320
0.90	54	3 240	77 760
0.92	55	3 300	79 200
0.93	56	3 360	80 640
0.95	57	3 420	82 080
0.97	58	3 480	83 520
0.98	59	3 540	84 960
1.00	60	3 600	86 400
1.02	61	3 660	87 840
1.03	62	3 720	89 280
1.05	63	3 780	90 720
1.07	64	3 840	92 160
1.08	65	3 900	93 600
1.10	66	3 960	95 040
1.12	67	4 020	96 480
1.13	68	4 080	97 920
1.15	69	4 140	99 360
1.17	70	4 200	100 800
1.18	71	4 260	102 240
1.20	72	4 320	103 680
1.22	73	4 380	105 120
1.23	74	4 440	106 560
1.25	75	4 500	108 000
1.27	76	4 560	109 440
1.28	77	4 620	110 880
1.30	78	4 680	112 320
1.32	79	4 740	113 760
1.33	80	4 800	115 200
1.35	81	4 860	116 640
1.37	82	4 920	118 080
1.38	83	4 980	119 520
1.40	84	5 040	120 960
1.42	85	5 100	122 400
1.43	86	5 160	123 840
1.45	87	5 220	125 280
1.47	88	5 280	126 720
1.48	89	5 340	128 160
1.50	90	5 400	129 600
1.52	91	5 460	131 040
1.53	92	5 520	132 480
1.55	93	5 580	133 920
1.57	94	5 640	135 360
1.58	95	5 700	136 800
1.60	96	5 760	138 240
1.62	97	5 820	139 680
1.63	98	5 880	141 120
1.65	99	5 940	142 560
1.67	100	6 000	144 000
3.33	200	12 000	288 000
5.00	300	18 000	432 000
6.67	400	24 000	576 000
8.33	500	30 000	720 000
10.00	600	36 000	864 000
11.67	700	42 000	1 008 000
13.33	800	48 000	1 152 000
15.00	900	54 000	1 296 000
16.67	1 000	60 000	1 440 000

TABLE A10.3
Correlation between the quantity of water and daily and hourly exchange rates

Daily exchange rate	Hourly exchange rate	litres/min to supply 1 m^3 tank	litres/sec to supply 1 m^3 tank
1	0.0	0.7	0.01
2	0.1	1.4	0.02
3	0.1	2.1	0.03
4	0.2	2.8	0.05
5	0.2	3.5	0.06
6	0.3	4.2	0.07
7	0.3	4.9	0.08
8	0.3	5.6	0.09
9	0.4	6.3	0.10
10	0.4	6.9	0.12
11	0.5	7.6	0.13
12	0.5	8.3	0.14
13	0.5	9.0	0.15
14	0.6	9.7	0.16
15	0.6	10.4	0.17
16	0.7	11.1	0.19
17	0.7	11.8	0.20
18	0.8	12.5	0.21
19	0.8	13.2	0.22
20	0.8	13.9	0.23
21	0.9	14.6	0.24
22	0.9	15.3	0.25
23	0.96	16.0	0.27
24	1.00	16.7	0.28
25	1.0	17.4	0.29
26	1.1	18.1	0.30
27	1.1	18.8	0.31
28	1.2	19.4	0.32
29	1.2	20.1	0.34
30	1.3	20.8	0.35
31	1.3	21.5	0.36
32	1.3	22.2	0.37
33	1.4	22.9	0.38
34	1.4	23.6	0.39
35	1.5	24.3	0.41
36	1.5	25.0	0.42
37	1.5	25.7	0.43
38	1.6	26.4	0.44
39	1.6	27.1	0.45
40	1.7	27.8	0.46
41	1.7	28.5	0.47
42	1.8	29.2	0.49
43	1.8	29.9	0.50
44	1.8	30.6	0.51
45	1.9	31.3	0.52
46	1.9	31.9	0.53
47	2.0	32.6	0.54
48	2.0	33.3	0.56
49	2.0	34.0	0.57
50	2.1	34.7	0.58
51	2.1	35.4	0.59
52	2.2	36.1	0.60
53	2.2	36.8	0.61
54	2.3	37.5	0.63
55	2.3	38.2	0.64
56	2.3	38.9	0.65
57	2.4	39.6	0.66
58	2.4	40.3	0.67
59	2.5	41.0	0.68
60	2.5	41.7	0.69
61	2.5	42.4	0.71
62	2.6	43.1	0.72
63	2.6	43.8	0.73
64	2.7	44.4	0.74
65	2.71	45.1	0.75
66	2.75	45.8	0.76
67	2.8	46.5	0.78
68	2.8	47.2	0.79
69	2.9	47.9	0.80
70	2.9	48.6	0.81
71	3.0	49.3	0.82
72	3.0	50.0	0.83
73	3.0	50.7	0.84
74	3.1	51.4	0.86
75	3.1	52.1	0.87

TABLE A10.4
Correlation between individual weight, length and number of rainbow trout in one kilogram*

Total length of fish (cm)	Rounded weight of fish (g/fish)			Rounded number of fish in 1 kg		
	Minimum	Average	Maximum	Minimum	Average	Maximum
1	–	0.1	–	–	10 000	–
2	–	0.2	–	–	5 000	–
3	0.2	0.4	0.5	5 600	2 600	2 000
4	0.6	0.7	0.8	1 600	1 500	1 300
5	1.0	1.5	2.0	1 000	650	500
6	1.5	1.8	2.2	670	540	460
7	3.5	4.3	5.0	280	230	200
8	–	5.2	5.4	–	190	190
9	–	7.8	–	–	130	–
10	10.0	11	12.0	100	91	83
11	12.0	13	14.6	83	78	69
12	13.5	16	19.2	74	61	52
13	17.0	22	25.0	59	46	40
14	–	31	31.1	–	32	–
14	–	30	30.0	–	33	–
15	35.0	37	38.5	29	27	26
16	35.0	41	47.2	29	24	21
17	50.0	53	56.8	20	19	18
18	62.5	68	75.0	16	15	13
19	–	81	80.6	–	12	–
20	–	92	94.3	–	11	–
21	–	110	110.0	–	9	–
22	–	128	–	–	8	–
23	125.0	134	147.1	8	7	7
24	–	167	–	–	6	–
25	166.7	185	200.0	6	5	5
26	200.0	209	217.4	5	5	5
27	–	244	243.9	–	4	–
28	250.0	282	300.0	4	4	3
29	–	303	–	–	3	–
30	–	333	–	–	3	–
31	–	370	–	–	3	–
32	–	417	–	–	2	–
33	–	455	–	–	2	–
34	–	500	–	–	2	–
35	–	556	–	–	2	–
36	–	588	–	–	2	–
37	–	667	–	–	2	–
38	–	714	–	–	1	–
39	–	769	–	–	1	–
40	–	833	–	–	1	–
41	–	909	–	–	1	–

* Figures calculated on the basis of the publications of Klontz (1991), Mills (2001) and Hoitsy (2002).

Key data of different types and sizes of table fish production units of rainbow trout

TABLE A10.5
Production unit of 2.5 tonnes per year in tanks

Age groups	1st option						2nd option					
	Fish production		Rearing devices				Fish production		Rearing devices			
	No.	Weight (kg)	Total space		No. of devices	Size per device (m^3)	No.	Weight (kg)	Total space		No. of devices	Size per device (m^3)
			m^2	m^3					m^2	m^3		
Eyed eggs	14 000	–	0.5	–	2	–	7 000	–	0.25	–	2	–
Swim-up fry	13 000	–	2	1	2	0.5	6 500	–	1	0.5	2	0.25
Advanced fry (2 g/fish)	12 000	24	20	7	5	1.4	6 000	12	10	3.5	5	0.7
Subtotal	–	–	**22.5**	**8**	–	–	–	–	**11.25**	**4**	–	–
Fingerlings (25 g/fish)	11 000	280	30	20	5	4	5 500	140	15	10	5	2
Subtotal	–	–	**30**	**20**	–	–	–	–	**15**	**10**	–	–
Small table fish (250 g/fish)	10 000	**2 500**	125	125	5	25	5 000	1 250	62.5	62.5	–	–
Large table fish (500 g/fish)	–	–	–	–	–	–	5 000	**2 500**	62.5	62.5	–	–
Subtotal	–	–	**125**	**125**	**5**	**25**	–	–	**125**	**125**	**5**	**25**
Total (rounded)	–	–	**180**	**150**	–	–	–	–	**150**	**140**	–	–

TABLE A10.6
Production unit of 5 tonnes per year in tanks

Age groups	1st option						2nd option					
	Fish production		Rearing devices				Fish production		Rearing devices			
	No.	Weight (kg)	Total space		No. of devices	Size per device (m^3)	No.	Weight (kg)	Total space		No. of devices	Size per device (m^3)
			m^2	m^3					m^2	m^3		
Eyed eggs	28 000	–	1	–	2	–	14 000	–	0.5	–	2	–
Swim-up fry	26 000	–	4	2	2	1.0	13 000	–	2	1.0	2	0.50
Advanced fry (2 g/fish)	24 000	48	40	14	5	2.8	12 000	24	20	7.0	5	1.4
Subtotal	–	–	**45**	**16**	–	–	–	–	**22.5**	**8**	–	–
Fingerlings (25 g/fish)	22 000	560	60	40	5	8	11 000	280	30	20	5	4
Subtotal	–	–	60	40	–	–	–	–	30	20	–	–
Small table fish (250 g/fish)	20 000	5 000	250	250	–	–	10 000	2 500	125.0	125.0	–	–
Large table fish (500 g/fish)	–	–	–	–	–	–	10 000	5 000	125.0	125.0	–	–
Subtotal	–	–	**250**	**250**	**5**	**50**	–	–	**250**	**250**	**5**	**50**
Total (rounded)	–	–	**360**	**310**	–	–	–	–	**300**	**280**	–	–

TABLE A10.7
Production unit of 2.5 tonnes per year in fish ponds

Age groups	**1st option**						**2nd option**					
	Fish production		**Rearing devices**				**Fish production**		**Rearing devices**			
	No.	Weight (kg)	Total space		No. of devices	Size per device (m^3)	No.	Weight (kg)	Total space		No. of devices	Size per device (m^3)
			m^2	m^3					m^2	m^3		
IN TANKS												
Eyed eggs	14 000	–	0.5	–	2	–	7 000	–	0.25	–	2	–
Swim-up fry	13 000	–	2	1	2	0.5	6 500	–	1	0.5	2	0.25
Advanced fry (2 g/fish)	12 000	24	20	7	5	1.4	6 000	12	10	3.5	5	0.7
Total	–	–	**22.5**	**8**	–	–	–	–	**11.25**	**4**	–	–
IN PONDS												
Fingerlings (25 g/fish)	11 000	280	56	70	5	14	5 500	140	28	35	5	7
Subtotal	–	–	**56**	**70**	–	–	–	–	**28**	**35**	–	–
Small table fish (250 g/fish)	10 000	2 500	400	400	–	–	5 000	1 250	160	200	–	–
Large table fish (500 g/fish)	–	–	–	–	–	–	5 000	2 500	160	200	–	–
Subtotal	–	–	**400**	**400**	**4**	**100**	–	–	**320**	**400**	**4**	**100**
Total (rounded)	–	–	**460**	**470**	–	–	–	–	**350**	**440**	–	–

TABLE A10.8
Production unit of 5 tonnes per year in fish ponds

Age groups	1st option						2nd option					
	Fish production		Rearing devices				Fish production		Rearing devices			
	No.	Weight (kg)	Total space		No. of devices	Size per device (m^3)	No.	Weight (kg)	Total space		No. of devices	Size per device (m^3)
			m^2	m^3					m^2	m^3		
IN TANKS												
Eyed eggs	28 000	–	1	–	2	–	14 000	–	0.5	–	2	–
Swim-up fry	26 000	–	4	2	2	1.0	13 000	–	2	1	2	0.50
Advanced fry (2 g/fish)	24 000	48	40	14	5	2.8	12 000	24	20	7	5	1.4
Total	**–**	**–**	**45**	**16**	**–**	**–**	**–**	**–**	**22.5**	**8**	**–**	**–**
IN PONDS												
Fingerlings (25 g/fish)	22 000	560	112	140	5	28	11 000	280	56	70	5	14
Subtotal	**–**	**–**	**112**	**140**	**–**	**–**	**–**	**–**	**56**	**70**	**–**	**–**
Small table fish (250 g/fish)	20 000	5 000	800	800	–	–	10 000	2 500	400	400	–	–
Large table fish (500 g/fish)	–	–	–	–	–	–	10 000	5 000	400	400	–	–
Subtotal	**–**	**–**	**800**	**800**	**4**	**200**	**–**	**–**	**800**	**800**	**4**	**200**
Total (rounded)	**–**	**–**	**910**	**940**	**–**	**–**	**–**	**–**	**860**	**870**	**–**	**–**

TABLE A10.9
Checklists for planning and evaluation of investment and production

1	Engineering design
2	Technological design
3	Land
4	Permissions
5	Taxes
6	Earthworks
7	Tanks
8	Concrete structures
9	Buildings
10	Roads
11	Fences
12	Machines
13	Vehicles
14	Fittings and devices
15	Apparatus
16	Equipment
17	Tools
18	Furniture
19	Broodfish
20	Miscellaneous

Items of production costs

1	Fish (eggs, fry, fingerling)
2	Feeds
3	Materials
4	Energy (electricity, fuel, etc.)
5	Labour
6	Maintenance
7	Miscellaneous
8	Bank fees
9	Insurance

Production-related expenses

1	Depreciation
2	Taxes

This paper is a basic guide to starting and successfully practicing small-scale rainbow trout farming, summarizing all essential technical information important for small-scale trout production. It includes general information on efficient treatment of trout farm effluents, taking into consideration the need to protect mountainous regions where water resources could support profitable trout farming. The aim is to guide the reader through the necessary technical information, related practical solutions and the steps of preparation of both investment in and day-to-day operation of a small-scale rainbow trout farm. It includes a glossary and illustrations for easy understanding.

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