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Carp polyculture in Central and Eastern Europe, the Caucasus and Central Asia

A manual

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Carp pond polyculture is the most widely practiced fish production system in Central and Eastern Europe[1] (CEE), the Caucasus[2] and Central Asia[3] (CCA). The total area of fish ponds, as well as water reservoirs smaller than 100 hectares, that is available for carp polyculture in these countries is almost 500 000 hectares[4]. This vast water area could, even under a conservative estimate, support about the double of the present yearly 170 000 to 200 000 tonnes of fish production which was given by the Food and Agriculture Organization of the United Nations (FAO) for the reporting years of the 2000s (FIGIS, 2009).

In CEE and CCA countries, the economic and social conditions changed profoundly in the early 1990s. The market economy was introduced and an overwhelming majority of the previously owned state or cooperative fish ponds and farms were privatized. The new owners and operators, often new to the aquaculture industry, had and still have to face many production-related technical problems. Field visits and consultations confirmed the lack of basic knowledge of farmers on identifying their own resources and selecting production technologies adaptable to their conditions.

Throughout the last decades, FAO has continuously supported the development of aquaculture by issuing technical papers, books and training materials. Though these have been very useful, specific concise technical publications, directly and fully applicable in the CEE and CCA regions, are still missing.

The reasons mentioned above called for the writing of this technical paper, which is a concise overview and inventory of the basic information on carp polyculture and its most applicable production patterns.

It is expected that this document will fill in the gap and will help not only with the realistic planning and successful realization of carp pond polyculture in CEE and CCA countries, but will also support the better and more efficient use of related publications of FAO.

Both the aim and the content of this publication are in line with the recommendations of the Rome Declaration on World Food Security and the World Food Summit Plan of Action (Tacon, 2001), directly supporting both the production of much needed affordable aquatic food and the generation of employment and income-earning opportunities.

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

2 Armenia, Azerbaijan and Georgia.

3 Kazakhstan, Tajikistan, Kyrgyzstan, Uzbekistan and Turkmenistan.

4 The total is about 350 000 hectares in CEE countries, about 100 000 hectares in the Russian Federation and approximately 50 000 hectares in the countries of the Caucasus and Central Asia.

Abstract

This technical paper is a basic guide to carp pond polyculture practicable in the Central and Eastern Europe (CEE) and the Caucasus and Central Asia (CCA) countries. It provides an overview on the guiding principles, aspects and tasks, and presents the most applicable production techniques and patterns of carp polyculture. For further reading and more in-depth information on the suggested techniques and technologies, it also includes a list of relevant FAO publications.

It is expected that this publication will help identify resources and contribute to the successful planning and realization of fish production by those fish pond owners and operators who need to strengthen and improve their knowledge on the subject.

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1. Introduction

In the last twenty years economic and social conditions profoundly changed in the countries of Central and Eastern Europe (CEE), the Caucasus and Central Asia (CCA). Therefore, earlier known and successfully practiced fish production technologies in these countries became unprofitable. The attitude of persons involved in aquaculture also changed as the previously exhibited typical willingness to exchange ideas and share experiences noticeably diminished. Obtaining technical information and knowledge became difficult. The lack of modern, market-economy-based extension services and reliable technical literature resulted in insufficient technical knowledge for the new fish pond owners and operators. These all contributed to the under exploitation of fish pond resources in the countries of CEE and CCA.

This paper is compiled to fill in the gap and equip fish pond owners and operators with basic knowledge on identifying their own resources and to select production techniques and technologies adaptable to their specific conditions. In order to satisfy interest for further details, a glossary is compiled and tables and annexes are attached to this paper. For the sake of finding additional information, asterisk symbols (*) are used after those words in italics and are explained in the glossary. The descriptions, explanations and related illustrations are short and informative in order to facilitate easy understanding. Still, it is suggested to consult with specialists in the subject in order to share ideas and discuss problems. This will help quicker perception of the technical and economic aspects of carp pond *polyculture** discussed in this paper.

Last, but not the least, a detailed list of carp production related FAO publications is attached as Annex 5. The objective of this list is to help find related further readings among FAO publications.

2. Pond fish culture

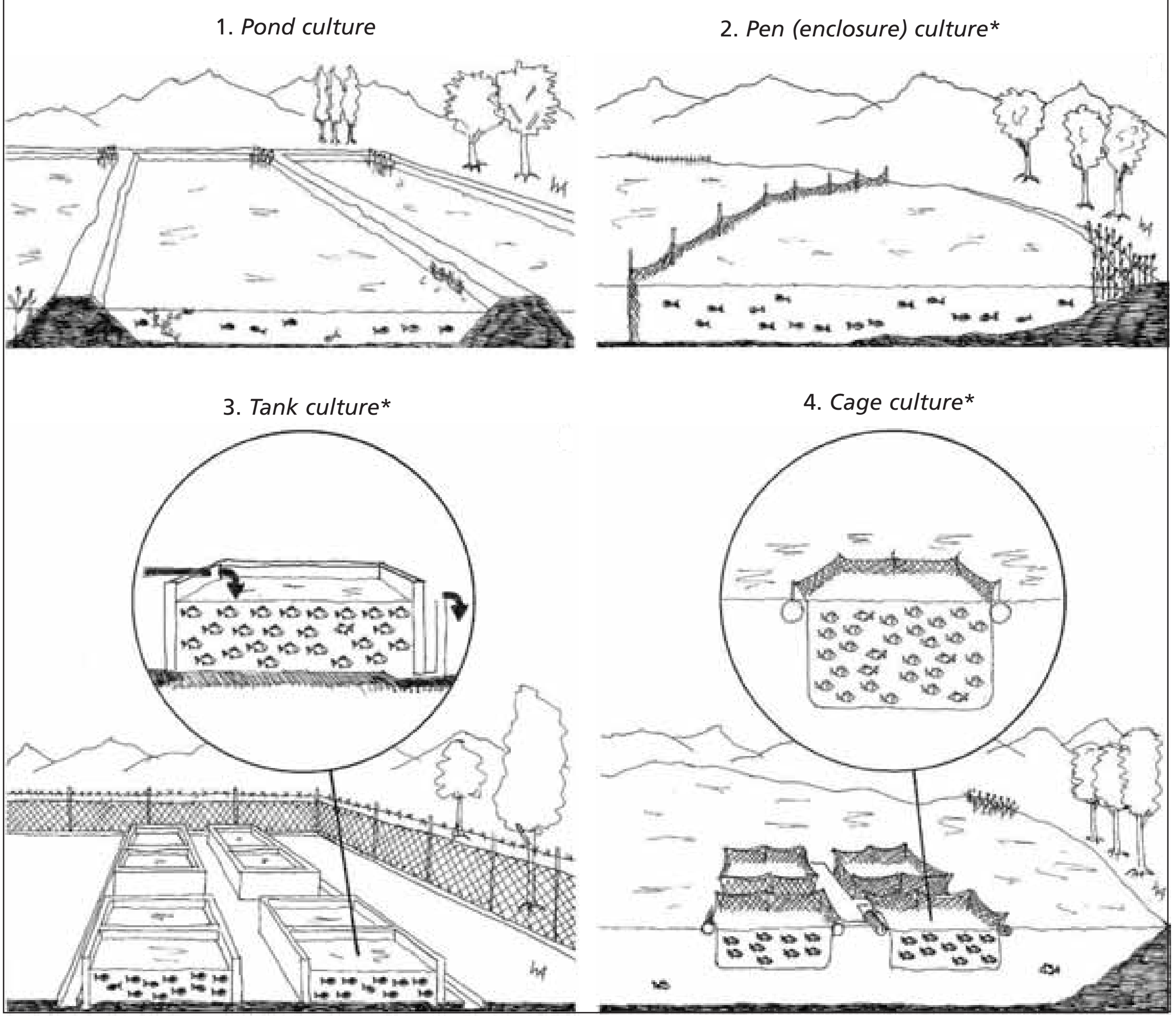
Pond fish culture is the most widely practiced fish production system. It facilitates the mass production of many different fish species all over the world.

2.1 TYPES OF PONDS

In the everyday English language a fairly small still water is called a pond, while a lake is described as a larger area of water surrounded by land. Many dictionaries distinguish between lake and pond simply by their size. In aquaculture literature, ponds are those earth structures which are built for storing water and/or for fish culture purposes, whereas lakes, regardless of their dimensions, are waterbodies of natural origin. Ponds are shallow. Their depth is usually around one metre and rarely exceeds a few metres. Water reservoirs are deeper. Most ponds are suitable for culturing fish.

Depending on the configuration of the terrain, different types of ponds can be constructed. Barrage ponds are built in hilly areas, while contour ponds are typical on

FIGURE 1
Different fish production systems



gently sloping or flat lands. The water supply of ponds can be rain and/or water from a nearby surface or underground water source. Depending on the formation of the surface, the water supply and drainage of ponds can be done partly or fully by gravity or pumping.

The actual size of a fish pond determines its fish rearing capacity and affects the profitability of production. The proportion of the surface of the bottom and dikes and the volume of water is more favourable (higher) in smaller ponds than in larger ones. Consequently, more insect larvae can develop in small ponds, and the nutrient transfer through the relatively large contact area between water and soil is more intensive. Moreover, the management of smaller ponds is easier. The disadvantage of smaller ponds is their relatively higher costs of construction and maintenance.

2.2 CHARACTERISTICS OF POND FISH CULTURE

Pond fish culture is the most ancient practice for producing fish under controlled conditions. The culture of carps developed simultaneously on different continents several centuries ago. Accordingly, Chinese, Indian and European carp polyculture can be distinguished from each other.

Carp polyculture was dramatically improved in the 1960s when *Chinese major carps** were widely introduced to most countries of Europe and Asia. Today, it is a widely practiced pond fish culture technique, not only in temperate but also in subtropical and tropical climates.

Recent country reviews of FAO (Hasan, *et al.*, 2007) support that the characteristics of pond fish culture make it very suitable to produce fish in an inexpensive integrated way.

The main feature and advantage of pond fish culture is that the *natural food** of fish can be produced in the same waterbody, i.e. in the pond where the fish are reared. The production of natural food organisms in ponds can be supported by applying *manure** and/or fertilizers. These materials increase the production of bacteria, plants and animals (worms, insects, etc.) which live in the water and in the bottom of ponds. By consuming these living organisms, fish can satisfy their protein requirements and, in order to maintain their optimal growth, they only need to be fed the relatively cheap, energy-rich supplementary feeds. Hence, one of the advantages of pond fish culture in comparison to the intensive fish production systems is that the protein requirement of fish is satisfied by the *natural fish food** instead of using expensive sources of *allocthonous** protein, i.e. fish meal.

Ponds can be stocked with one or with more than one fish species. The first stocking method is *monoculture,** while the second one is the polyculture. It is a general rule that more fish can be produced in the same waterbody if many fish species, different in their feeding habit and other biological features, are cultured together. This is because the utilization of natural food is much more efficient by a multispecies fish population. Furthermore, if the species composition of fish is properly established and maintained, the production of *plankton** is stimulated by the intensive consumption by the fish. Synergetic effects between some species may also support the higher fish production in polycultural ponds. For example, the production of common carp can be higher if reasonable quantities of silver carp and grass carps are in the same pond (Ruttkay, 1996).

Monoculture of fish can utilize natural fish food less effectively than polyculture. Consequently, unless very low stocking densities are applied, the production of fish in monoculture is much more feed dependent than in polyculture. Monoculture of common carp is widely practiced in many geographic regions of CEE and CCA. Nevertheless, the production figures of common carp are much lower in monoculture than in polyculture. The profitability of production is also less favourable in monoculture.

The water quality, the optimal growth of fish and their good health condition can be maintained with proper pond management. This means maintenance of carefully balanced fish stock, sufficient manuring/fertilization and rational supplementary feeding in accordance to the size of the *standing stock** of fish. As production intensifies, the improvement of water quality has to be ensured by *aeration** and/or the exchange of water.

The calculation of production in ponds is based on the unit area, such as the number of fish per unit area (fish/hectare) and/or weight of fish per unit area (kg/hectare, or tonne/hectare). However, for exact comparison of the technologies of the different production systems, only the produced fish per unit water volume (fish/m^3 and kg/m^3) is suitable.

2.3 ROLE OF POND FISH CULTURE IN LAND UTILIZATION AND ITS INTEGRATION WITH OTHER ACTIVITIES

In the distant past, fish ponds were built on agricultural lands which were not suitable for crop production. Even today good-quality arable lands are preserved, and only *water-affected areas and lands** are considered for building fish ponds or water reservoirs. This is even if fish ponds constructed on good quality soil are more productive than ponds constructed on swampy areas or unfertile lands.

In addition to the better utilization of land resources, fish ponds may contribute to the better management of water resources. They are suitable not only for the production of fish, but also to accumulate water which can be used for irrigation during dry periods. Moreover, ponds support the life of their surrounding *biotopes**.

Pond fish culture is suitable for the utilization of farm wastes such as manure from animal husbandry. These materials introduced in the water can support the development of natural fish food. Wastes from the milling industry and the by-products of crop, vegetable and fruit production can be used directly as fish feed. Consequently, agricultural activities which produce these by-products can be efficiently integrated with pond fish culture.

If pond fish culture is integrated with animal husbandry, the manure of the animals can be used for supporting the development of natural fish food. Therefore, pond fish culture is one of the most environmentally friendly and profitable tools for decomposition of huge quantities of animal wastes produced in agriculture. Most frequently, the production of poultry (chicken or duck) or pig, or husbandry of ruminants, is integrated with pond fish farming.

The integration of carp polyculture with irrigation is an option when water reservoirs are used for fish production. In these waterbodies, manuring and irrigation should be carefully balanced and done in accordance with the standing stock of fish and the actual quantity of water. Stock management in water reservoirs may differ greatly from the stock management performed in fish ponds. The applied fish production technology should be adapted to the length of the irrigation season and the quantity of the available water. For example, when water harmfully lowers in the reservoir, fish must be harvested way before the actual end of the production season.

In fish ponds, there is an intensive (0.5–1.0 cm/year) development of mud rich in nutrients and organic materials. From time to time, the mud should be dried and removed from the pond. If this material is distributed over less fertile land, the fertility of the soil will increase considerably. Consequently, this way of fish farming can support horticulture or the production of other terrestrial plants.

An increasingly popular way of pond utilization is the integration of fish culture with a recreational activity such as angling. Its advantage is that anglers pay for the fish and the fee for catching fish. They also pay for their accommodation, eat at the local restaurants and buy locally made products and souvenirs.

Carp polyculture can be integrated with intensive rearing of other fish such as trout or catfish. In this case, the flow-through tanks of the intensive system is constructed near the fish pond. The *effluent** of the intensive unit is discharged into the pond where the drifted-in fish faeces and other products of *metabolism** increase the natural fish food production in the same way as manure does. The unconsumed feed particles drifted from the intensive tanks into the pond are directly utilized as feed. If the ratio of the intensive unit and the pond area is determined properly, a high level of water purification can be achieved.

Integration of intensive and extensive fish culture practices in a traditional pond fish farm is also possible. The small wintering ponds can be used as the tanks of intensive production unit, whereas the large fish ponds can support the intensive unit as a mechanical and *biological filter**. Another way for integration of intensive fish culture with carp pond polyculture is the cage culture. If cages are placed in the fish pond during the production season, wastes from the cages will be utilized by the pond *ecosystem**, including by the fish that are produced there.

3. Background information on pond fish culture

For determining the most appropriate production technology and for taking day-to-day decisions, fish farmers and pond operators should be familiar with the principles of water quality, the life of pond habitat, and the role of manure, fertilizer and supplementary feeds.

3.1 CHARACTERISTICS OF POND WATER

The important *physical characteristics** of pond water have direct effects on fish production. For this reason they should be known and considered.

Temperature determines the growth, production and reproductive activity of all aquatic organisms. They are *poikilotherm**, so their metabolism is temperature dependent. All fish species have a range of *water temperature** optimal for their growth. When the water temperature is low during winter, fish stop feeding, they *hibernate** and remain dormant at the pond bottom.

Density or **specific weight** of water changes with the temperature. The specific weight of warm water is lower than that of cooler water. This physical characteristic is the reason why the calm or undisturbed water stratifies in layers. The cold water sinks down, while water of higher temperature stratifies on the surface. As a consequence, a diurnal vertical circulation can develop in ponds during the days when the wind does not create other currents. This process means that the upper layer of water contacting with relatively cold air at night cools down more quickly than the water at the pond bottom. The specific weight of this cooler water increases. Therefore, the surface water sinks to the bottom and the warmer and lighter water from the bottom rises to the surface. This circulation can transfer oxygen to the bottom but also ensures the exchange of nutrients between water and mud. Because of the chemical composition and molecular form of water, when water cools down in winter the specific weight increases only up to 4 °C. At this value the specific weight is the highest, which is 1 g/ml. At lower temperatures than 4 °C, the specific weight of water again decreases. This is the reason why ice floats on the surface. Consequently, under the ice, in deep, undisturbed waterbodies, the water temperature is always 4 °C at the bottom. If the water is deep enough, this phenomenon protects the fish from freezing.

Specific heat ensures waterbodies to warm up and to cool down slowly, much slower than the surrounding air temperature. This characteristic of water defends the aquatic organisms from quick and radical changes of water temperature.

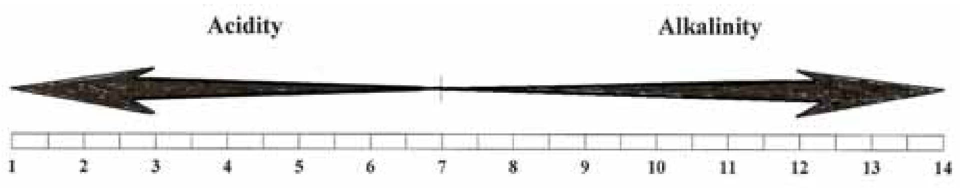
Surface stress is caused by the cohesion of water molecules. It allows insects (water cricket, pond scatter, etc.) to walk and others organisms (mosquito larvae) to float on the surface of the water.

Light conditions in pond water determine the intensity of the *photosynthesis**. Light conditions in a pond depend on the transparency of water, which is influenced by *turbidity**, *colour of water** and by biological factors such as density of plankton and the number and size of the different fish species. The transparency of water is measured with a *Secchi disk**, as described in Chapter 6.5. Transparent water allows an intense penetration of sun, which is unfavourable for *phytoplankton**. Moreover, the penetration of light supports the intensive growth of macrovegetation, which is less desirable in fish ponds.

Movement of pond water also has an important effect on the pond ecosystem. Wind, *thermal circulation of water**, currents developed by inflowing and outflowing waters create horizontal and vertical streams in ponds. These movements ensure healthy pond life through supporting the exchange of gases and dissolving nutrients to and from the pond bottom.

The **pH** value is an important figure of pond water. Fish farmers should know and regularly check the *pH** of pond water, because all chemical and biological processes which determine the production depend on this. Among others, pH influences the solubility of and accessibility to the different minerals.

FIGURE 2
Scale of pH



On the pH scale of 1–14, acidity of water increases from the neutral 7 towards the value of 1, while alkalinity increases gradually from the neutral 7 towards 14.

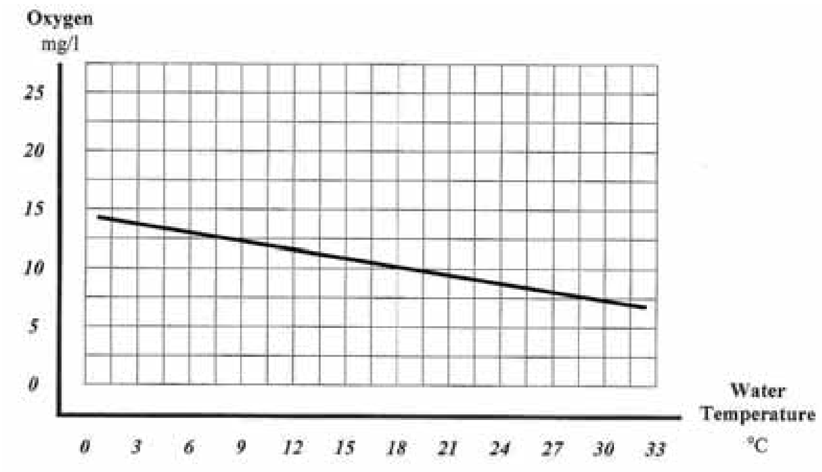
In fish ponds where the density of phytoplankton is high, the daily fluctuation of pH is considerable. This is because in the course of *assimilation** (photosynthesis) and *dissimilation** (respiration) phytoplankton reduces or increases the concentration of carbon dioxide (CO_2). During daytime, when phytoplankton assimilates, it consumes CO_2 therefore pH increases. At night, when the plants dissimilate, they consume oxygen and produce CO_2. This decreases the pH of the water.

Water ranging in pH between 6.5 and 9.0 before dawn is considered the most suitable for pond fish culture. At pH 6.5–5.5, fish production will be less, either because of the direct effect on the fish and/or on the growth of fish food organisms. Acid water with pH 5.0–5.5 can be harmful to fish. Water with excessive alkalinity (above 10) can also be harmful to fish (Hepher and Pruginin, 1981).

Many gases and solid materials dissolve well in pond water, which is explained by the molecular structure of water. Gases dissolved in water derive either from the air, from the pond bottom, or they are produced during the metabolism of different living organisms. Oxygen, carbon dioxide, sulphur hydrogen, free ammonia and methane are the gases which can have both supportive and harmful effects on the aquatic life in general and on fish in particular.

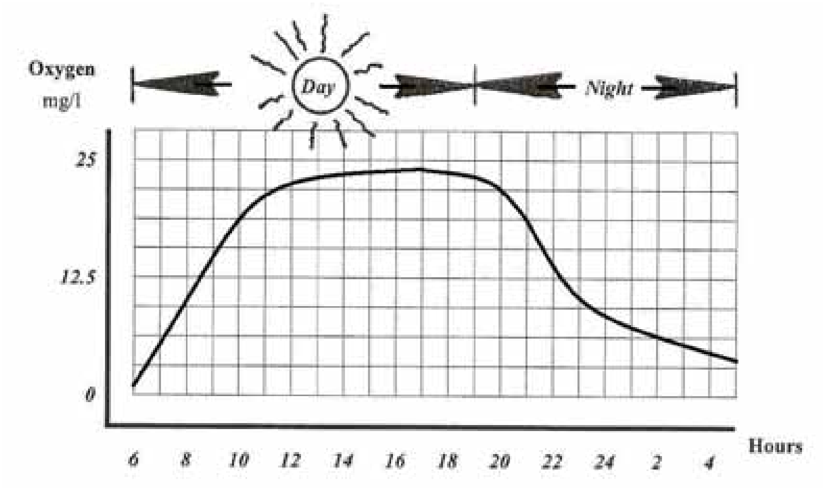
Oxygen (O_2) dissolves well in water. Dissolved oxygen (DO) in pond water ensures the respiration of fish. The oxygen content of water is expressed in mg/l or in percentage of saturation. Oxygen content of fully saturated water varies with temperatures as presented in Figure 3. Oxygen can penetrate into the water from the atmosphere, but the majority of DO in pond water is produced by phytoplankton in the course of photosynthesis. Because of intensive photosynthesis, water can be temporarily oversaturated by oxygen as demonstrated in Figure 4. The oxygen in excess is either consumed or it disappears into the atmosphere.

FIGURE 3
Oxygen content of fully saturated water at different temperatures



Water can dissolve only a certain quantity of oxygen at a certain temperature. The possible maximum oxygen content of water (100 percent saturation) depends on the actual water temperature and the partial pressure of oxygen in the atmosphere. Dissolved oxygen content changes slightly with the quality and quantity of dissolved materials. The altitude also modifies the oxygen content of the water.

FIGURE 4
Daily fluctuation of the oxygen content of pond water



In the light period, during photosynthesis, the algae produce the majority of the dissolved oxygen. No oxygen is produced in the dark period. All the organisms, including plants, consume the oxygen continuously, day and night. On sunny days less oxygen is consumed than produced. The excess quantity of oxygen which remains in the water is consumed by the organisms at night. As a result of these two processes there is a sinus-form curve which describes the fluctuation of the oxygen level in the pond water. The maximum of the oxygen content is in early afternoon and the minimum is at daybreak.

Free carbon dioxide (CO_2) is important for the photosynthesis of green plants because it is the source of carbon, which is one of the main components of all organic materials. A small quantity of CO_2 may penetrate from the atmosphere into the water. However, the majority of carbon dioxide is the result of the respiration of living organisms.

Ammonia is produced by different groups of living organisms as the end product of their metabolism. In the course of respiration, fish excrete through the gills about one-third of the consumed nitrogen in the form of ammonia. Free ammonia (NH_3) and ammonium ion (NH_4^+) together represent the *total ammonia** ($NH_3 + NH_4^+$) content of pond water.

Hydrogen sulphide (H_2S) is produced by anaerobic bacterial decomposition of *proteins**, degraded organic materials and sulphates in the mud of the pond bottom. Sulphur hydrogen dissolves very well in water. It is a strong poison especially when the pH of the water is acidic.

Methane (CH_4) is a colourless and odourless gas. It is produced under anaerobic conditions by bacteria. It is unlikely that methane develops in a fish pond.

Dissolved salts characterize the natural waters as they always contain some of the eight macro-ions of sodium (Na^+), potassium (K^+), calcium (Ca^{++}), magnesium (Mg^{++}), carbonate (CO_3^-), hydrogen-carbonate (HCO_3^-), chlorine (Cl^-) and sulphate (SO_4^-). The total *concentration of salts** is also an important parameter of waters. The salt concentration is expressed by weight (mg/l) or by percentage or is described by the electric conductivity of the water.

Different dissolved *nitrogen forms**, phosphorus and organic materials are also found in pond waters. All of the dissolved materials have an outstanding role in fish ponds because they can be either micronutrients and direct or indirect food sources of the aquatic organisms.

3.2 LIFE IN FISH POND HABITAT

Regardless of their size and shape, all fish pond *habitat** have four main biotopes where different organisms can live and develop. In ponds these organisms are, directly or indirectly, the natural food of the cultured fish. The biotopes of pond habitat are the water surface, the water column, the pond bottom and the *periphyton**.

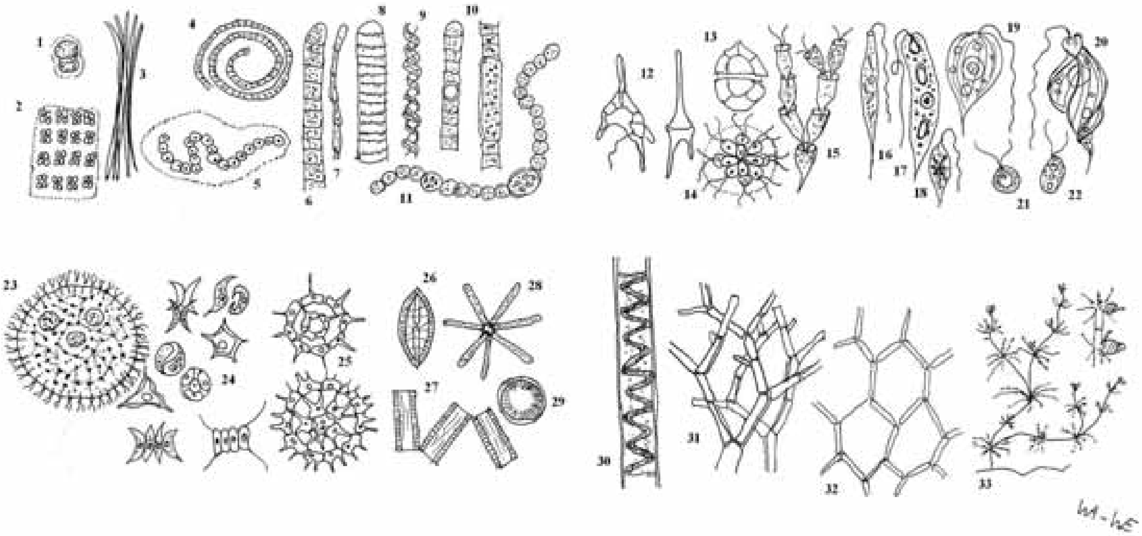
Pond water is connected to the atmosphere through the water surface. It offers limited quantity of natural fish food, discounting the invasive gradations of aquatic or terrestrial insects when they became abundant in this biotope of the pond.

The bulk of the natural fish food organisms in the water column of fish ponds are the plankton. The phytoplankton (Figure 5) and *zooplankton** (Figure 7) contribute directly to the diet of the different species of the polyculture. Besides phytoplankton and zooplankton, the role of the bacterioplankton is also important in fish ponds. This group of living organisms participates in the processes of both composition and decomposition. The bacterioplankton has a significant role in nitrogen fixation, nitrification, denitrification, remineralization, etc. The bacterioplankton serves directly as a food source of other planktonic organisms and their colonies are consumed directly by some of the fish.

The pond bottom is another important biotope in carp ponds, as different fish food organisms live and develop there (Figure 8). Moreover, the *detritus** and the bacteria, ciliate, etc., that develop in the detritus also serve as natural food for common carp, breams or tench. Water weeds which grow on the pond bottom serve as natural fish food for grass carp.

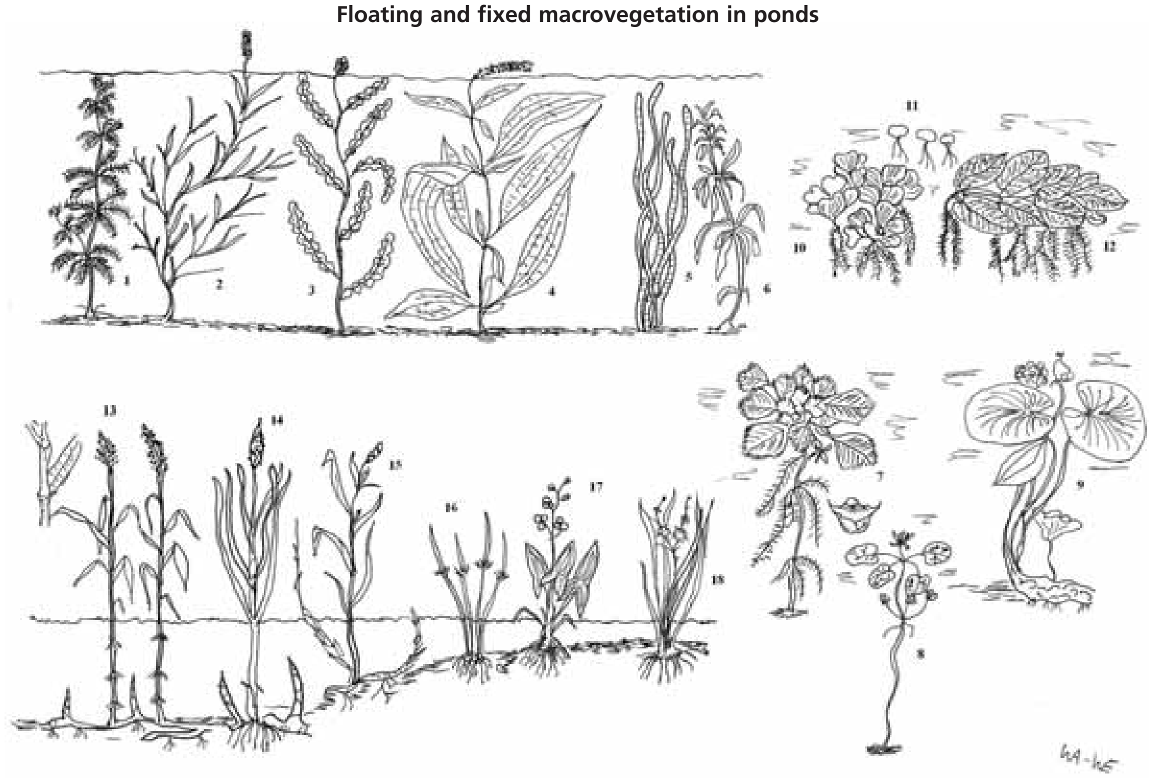
Periphyton or biological cover is the collective name of organisms which live on the surface of the submerged objects and macrovegetation in a pond (Figure 6). These

FIGURE 5
Members of phytoplankton in fish ponds



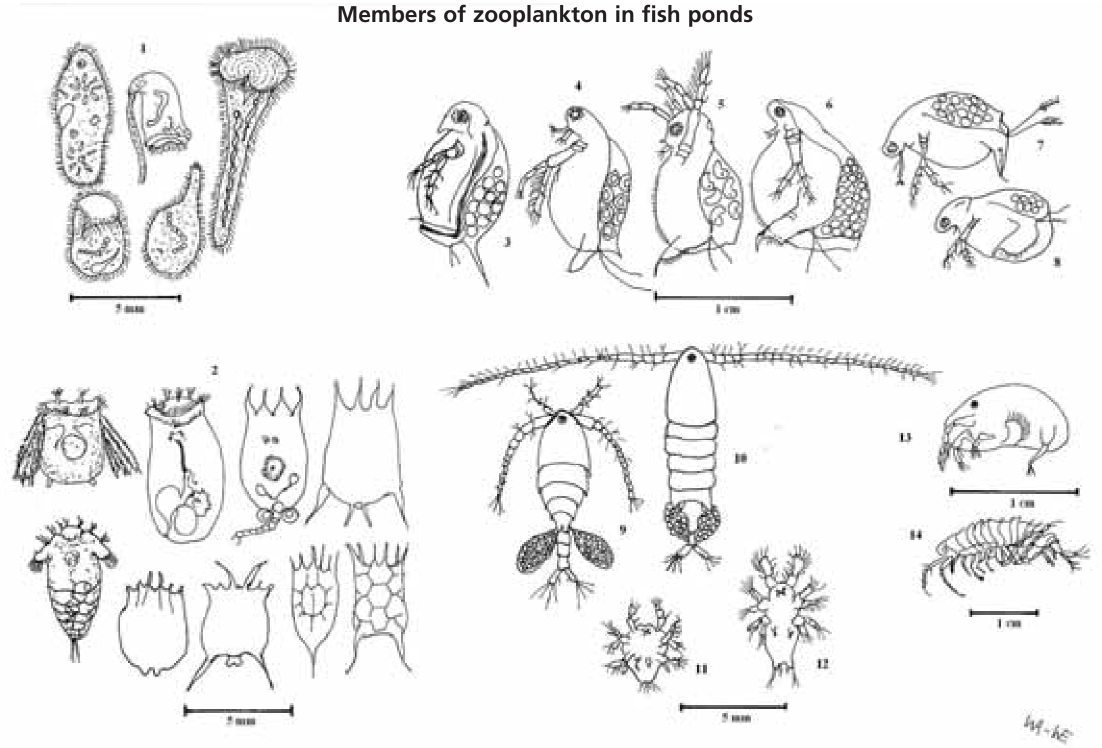
They are tiny, few ten microns size plants: **1.** Chroococcus, **2.** Merishmopedia, **3.** Aphhanisomenon, **4.** Lyngbia, **5.** Nostoc, **6–8.** Oscillatoria, **9.** Spirulina, **10.** Anabaena, **11.** Aphanisomenon, **12.** Ceratium, **13.** Peridinum, **14.** Syncrypta, **15.** Dynoprion, **16–18.** Euglena, **19–20.** Phacus, **21–22.** Chlamidomonas, **23.** Volvox, **24.** Chlorophyts, **25.** Pediastrum, **26.** Cymatopleura, **27.** Diatoma, **28.** Astorionella, **29.** Cyclotella, **30.** Spirogyra, **31.** Cladophora, **32.** Hydrodiction, **33.** Chara

FIGURE 6
Floating and fixed macrovegetation in ponds



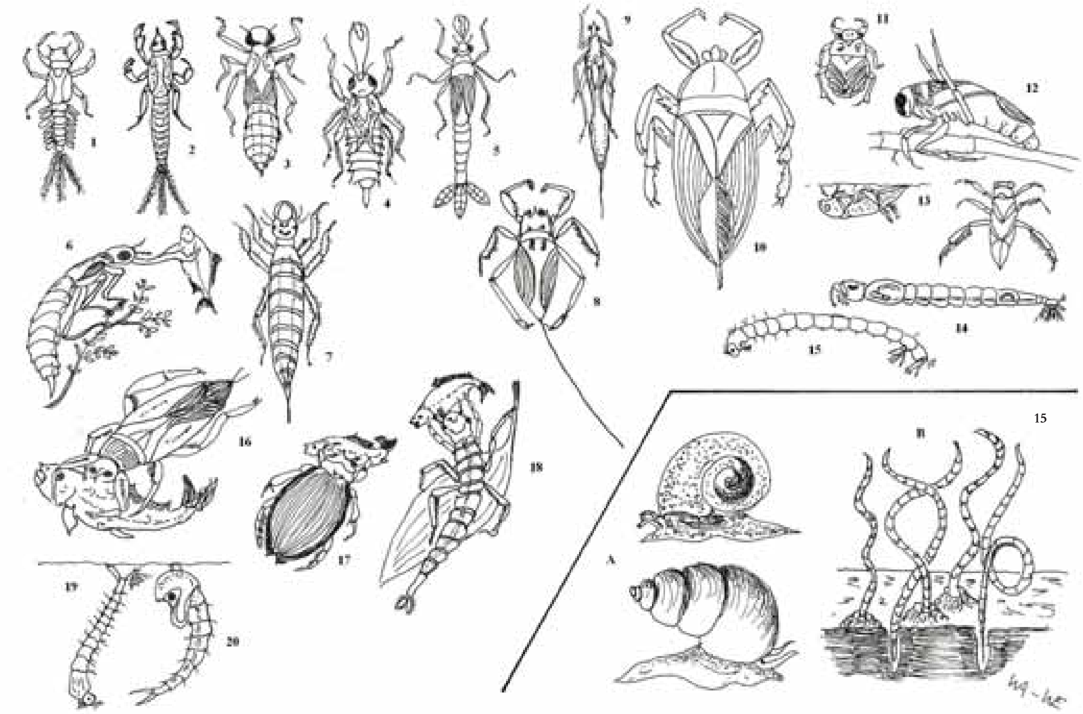
1. Miriophyllum, **2.** Potemogeton pectinatus, **3.** Potemogeton crispus, **4.** Potemogeton lucens, **5.** Vallisneria, **6.** Hydrilla, **7.** Trapa, **8.** Nymphoides, **9.** Nelumbo, **10.** Pistia, **11.** Lemna, **12.** Salvinia, **13.** Phragmites, **14.** Typha, **15.** Carex, **16.** Scirpus, **17.** Sagittaria, **18.** Sparganium

FIGURE 7
Members of zooplankton in fish ponds



1. Single-celled organisms, **2.** Rotifers, **3.** Daphnia sp., **4.** Diaphanosoma sp, **5.** Sida sp., **6.** Simocephalus sp., **7.** Moina, **8.** Ceriodaphnia, **9.** Cyclops sp., **10.** Diaptomus sp., **11.** Cyclops nauplius, **12.** Diaptomus larvae, **13.** Ostracoda, **14.** Amphipoda, **3–15.** Smaller crustaceans, **3–8.** Cladocera and **9–12.** Copepoda

FIGURE 8
Water insects and animals of *benthos**



1–2. Ephemeroptera (**1.** Plant living and **2.** Mud living), **3–6.** Dragonfly larvae, **7.** Ditiscus (larvae), **8.** Nepa, **9.** Ranatra, **10.** Belostoma, **11.** Naucoris, **12–13.** Notonecta, **14.** Chaoborus (larvae), **15.** Chironomus (larvae), **16.** Belostoma, **17–18.** Ditiscus beetle and larvae, **19.** Mosquito larvae, **20.** Mosquito pupa animals of benthos, **15.** Chironomus (larvae): A. Snails, B. Tubifex are bacteria, algae, moss and animals of different sizes. Though periphyton is less frequently mentioned as an important source of natural fish food, it may still provide a considerable quantity of food for some of the fish of pond polyculture.

3.3 BIOLOGICAL CYCLE AND FOOD CHAIN IN FISH PONDS

From a fish production point of view, fish is the final result of the complex biological cycle which takes place in a pond (Huet, 1972). This cycle in a fish pond includes production, consumption and decomposition of living or organic materials.

Primary production is the building of organic material from inorganic materials by autotrophic organisms when CO_2 is the single or main source of carbon. These organisms are the *autotrophic bacteria** and plants. In the case of plants, the production takes place in the course of photosynthesis. This is when plants (phytoplankton, algae and aquatic weeds) use mineral nutrients, CO_2 dissolved in the water and solar energy from which they build up their body.

Consumption is performed by both autotrophic and heterotrophic organisms. In the dark period plants consume and break down organic compounds which were produced by them in the light period to release energy for maintenance and growth. Heterotrophic organisms are mainly animals, fungi and bacteria. They cannot produce organic compounds from inorganic, but feed on living or dead organic materials which they break down to release energy or to use as building stones for growth, maintenance and reproduction. According to the size of consumer organisms, macroconsumers and microconsumers are distinguished.

Macroconsumers are mostly animals, both invertebrates (worms, insects, etc.) and vertebrates (fish, amphibians, reptiles, birds and mammals). On the basis of their typical food, they can be *herbivorous**, *carnivorous**, *detritivorous** or *omnivorous** (Allay, 1994). Microconsumers, mainly bacteria and fungi, break down complex organic compounds and release inorganic or relatively simple organic materials (Allay, 1994). Hence, microconsumers are decomposers and their performed process is the decomposition.

The success of pond fish culture depends on how the biological cycle is influenced and controlled. Its simplified illustration and description is presented in Figure 9.

In technical literature authors often describe and illustrate the natural food consumption of fish in the context of the food chain, which is the series of organisms that consume each other. The food chains of fish start with the primary production and finish with those organisms or organic materials on which they feed. Different fish species have partly or entirely different food chains as demonstrated in Figure 9. The food chains of fish which feed on phytoplankton or zooplankton are much shorter than the food chains of predator fish. The food web, which is the system of food chains, is a more scientific way to illustrate the complexity of how the different organisms feed on each other.

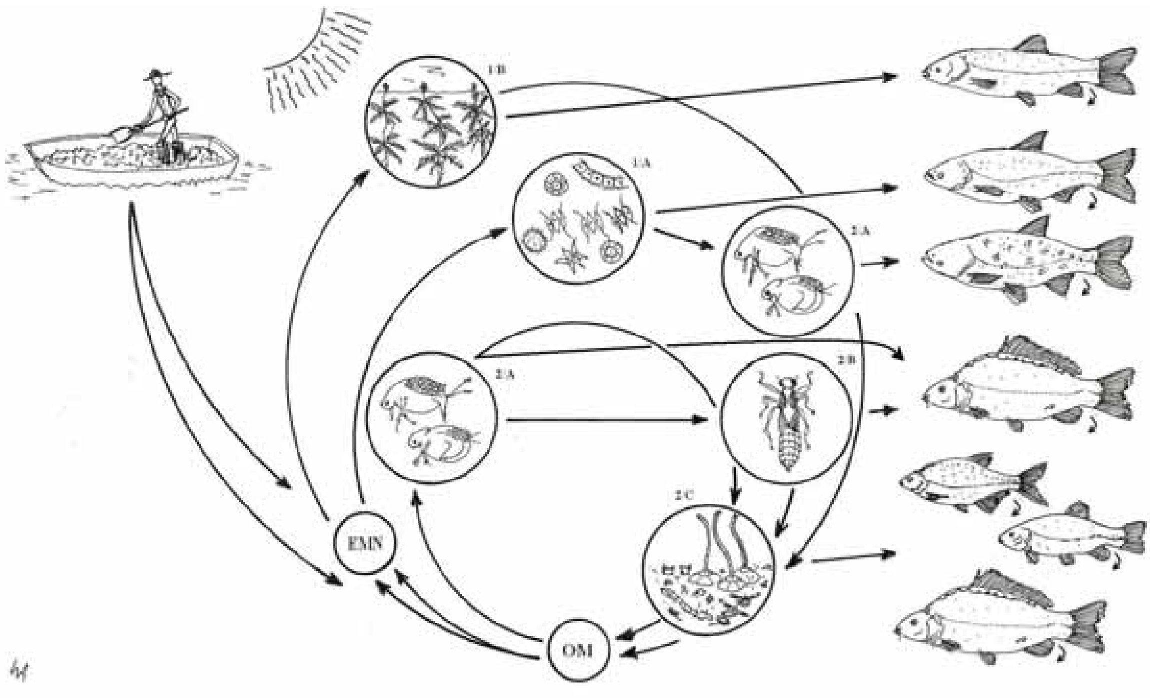
3.4 ROLE OF NATURAL FISH FOOD AND SUPPLEMENTARY FEEDS IN POND FISH CULTURE

In ponds, the detritus, the colonies of bacteria, the aquatic weeds, the plankton, the water and the terrestrial insects and their larvae are all natural food for the different fish species. In pond polyculture, the role of natural fish food is outstanding because it is the source of protein in the diet of fish which otherwise would only be supplied by expensive fish meal.

As the name indicates, feeding in pond fish culture is practiced mainly as a supplement to the natural fish food. Natural fish food organisms are rich in proteins but poor in carbohydrate. Widely applied supplementary feeds are the different cereals. They are relatively poor in protein but rich in energy. More protein-rich feeds, together with cereals, are also used to supplement the natural fish food when the standing stock of fish increases by the end of the production season.

FIGURE 9

Relationship between manuring/fertilization and fish production in ponds



The biological cycle in a fish pond is based on essential mineral nutrients (EMN), carbon dioxide (CO_2) and solar energy, from which organic materials are produced through photosynthesis. Most of the used mineral nutrients are the different forms of nitrogen (N) and phosphorus (P). Carbon (C) is obtained from CO_2. It is the result of bacterial decomposition of organic materials and the respiration of living organisms. The organic materials (OM) of the applied fresh manure, faeces of fish and the detritus are directly consumed by the zooplankton, insects and their larvae and by some fish species. Or they are broken down to essential mineral nutrients by bacteria and return in this form to the start of the cycle. Each fish species has its specific natural food from the food web. The materials needed for the establishment and maintenance of the food chains are supplied through manuring and/or fertilization. These ensure increased production of the natural fish food in the ponds.

The consumption and utilization of supplementary feeds depend on the species and the age of fish, as well as on the quantity and quality of the available natural fish food. Consequently, the *feed conversion ration (FCR)** of the supplementary feeds may vary within certain ranges as presented in Annex 2.

4. Species of carp polyculture and their practical classifications

One of the main characteristics of carp pond polyculture is rearing together fish species which have partly or entirely different *food spectrums** and *feeding habits**. This ensures that all kinds of natural fish food organisms which develop in different biotopes of a pond will be exploited properly. Fish species of a typical carp polyculture in CEE and CCA are presented in Figures 10, 11 and 12 and described in Annex 1.

Fish species can be classified according to many different aspects. Science uses the *taxonomy** of fishes, which arranges the species into genus, family, subfamily, order and class. Out of these, only the order, the family and the common and scientific names are widely quoted for the sake of exact identification of a fish. The scientific classification of selected species of fish ponds in CEE and CCA is presented in Table 1.

Besides the scientific classification, there are other practical groupings of fish which can be classified according to:

- temperature requirements (cold water, warm water and tropical fishes) (Edwards, 1989);
- behaviour (peaceful or predatory);
- food spectrum (herbivorous, carnivorous, detrivorous, omnivorous, etc.);
- feeding habit (filter-feeding, grazing, predatory, etc.);
- biotope of pond where fish typically consume feed (surface feeder, column feeder, bottom or periphyton feeder);
- proportion and position in the polyculture (main fish, additional fish, trash fish, fed fish, unfed fish);
- final use of fish (food fish, sport fish, ornamental fish, bait fish); and
- economic importance (expensive fish, cheap fish, high- and low-value fish).

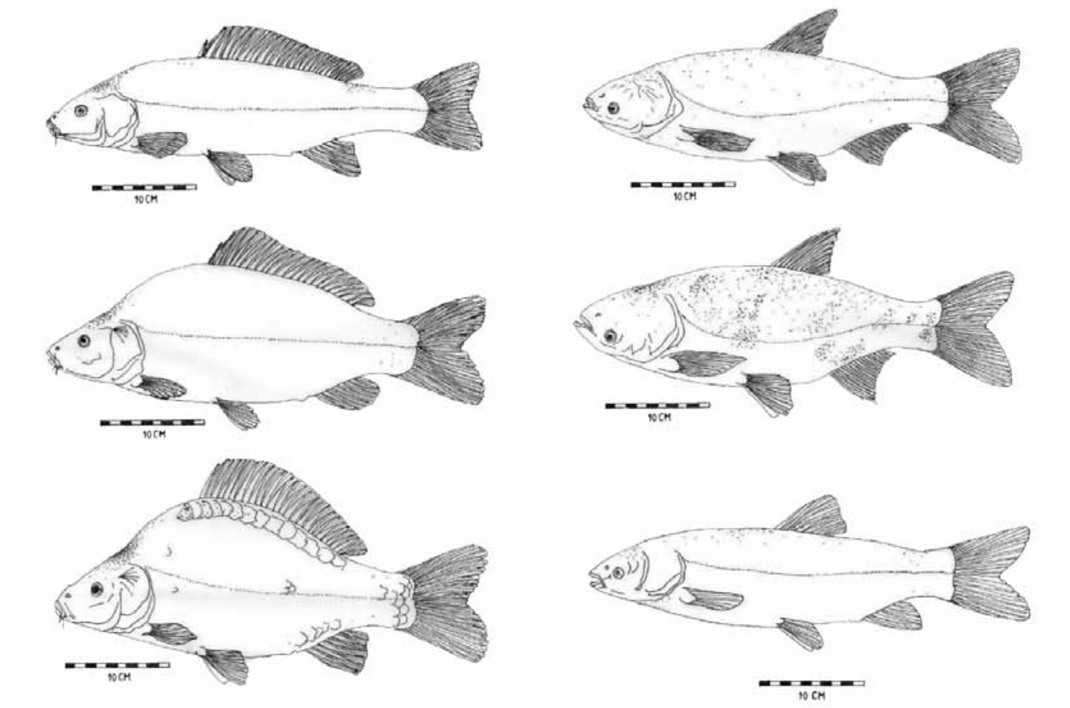
The economic importance is the most subjective aspect from the ones listed above as it varies considerably from region to region. The food spectrum, feeding habit or proportion and position in the polyculture are aspects of grouping which provide biological and/or technological information on the species.

TABLE 1
Scientific classification of selected species of fish ponds in CEE and CCA

Order [5]	Family	Common and scientific names
Sturgeons and paddlefishes (Acipenseriformes)	**Sturgeons** (Acipenseridae)	**Common sturgeon** (*Acipenser sturio*), **Sturgeon** (*Acipenser guldenstaedtii*), **Sterlet** (*Acipenser ruthenus*), **Paddlefish** (*Polyodon spathula*)
Pikes and mud minnows (Esociformes)	**Pikes** (Esocidae)	**Pike** or **Northern pike** (*Esox lucius*)
Carps (Cypriniformes)	**Minnows or carps** (Cyprinidae)	**Bighead carp** (*Aristichtis nobilis*), **Black carp** (*Mylopharyngodon piceus*), **Carp bream** (*Abramis brama*), **Common bream** (*Abramis brama orientalis*), **Common carp** (*Cyprinus carpio*), **Crucian carp** (*Carassius carassius*), **Khramuli** (*Varicorhinus capoeta*), **Prussian carp** (*Carassius auratus*), **Silver carp** (*Hypophthalmichthys molitrix*), **Tench** (*Tinca tinca*), **Asp** (*Aspius aspius*), **Rasbora** (*Pseudorasbora parva*)
Catfishes (Siluriformes)	**Sheatfishes** (Siluridae)	**Wels** or **European catfish** (*Silurus glanis*)
Perch-like (Perciformes)	**Perches** (Percidae)	**Perch or European perch** (*Parca fluviatilis*), **Pikeperch** or **Zander** (*Stizostedion lucioperca*)

[5] Froese and Pauly, 2009.

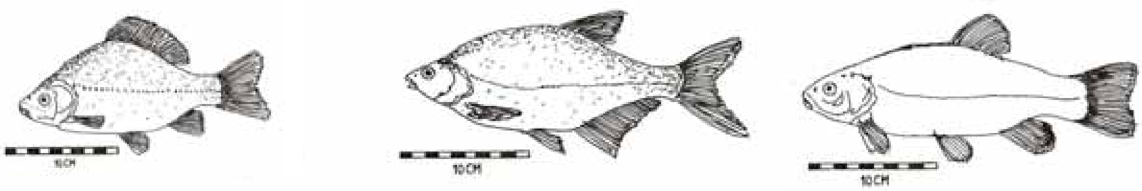
FIGURE 10
Important cyprinids of pond polyculture – 1



Different shapes of **common carp** (*Cyprinus carpio*)

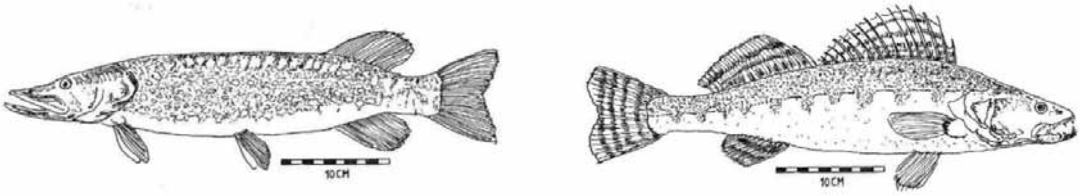
Chinese carps: **silver carp** (*Hypophthalmichthys molitrix*), **bighead carp** (*Aristichtis nobilis*), **grass carp** (*Ctenopharyngodon idella*)

FIGURE 11
Important cyprinids of pond polyculture – 2



Crucian carp (*Carassius auratus*) **Bream** (*Abramis* spp) **Tench** (*Tinca tinca*)

FIGURE 12
Predators produced in carp pond polyculture



Pike (*Esox lucius*)

Pikeperch (*Stizosteidon lucioperca*)

European catfish (*Silurus glanis*)

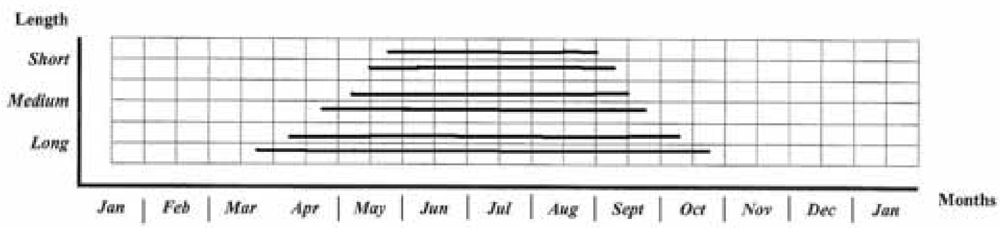
5. Culture practices and planning in carp polyculture

5.1 LENGTH OF FISH PRODUCTION SEASON

In carp polyculture, the production season begins when water temperature is constantly over 10 ºC. Apart from pike and pikeperch, the majority of species start intensive feeding above 15–20 ºC. The mentioned predators feed intensively in colder water, while the appetite of Chinese major carps increases when the water temperature is over 20 ºC.

Since the optimal range of water temperature required for the intensive growth of carps is between 20–25 ºC, the rearing period begins in spring and ends in autumn. In this period, the daily average water temperature permanently remains near to or over 20 ºC. This period is called production season. Its actual length depends on the number of warm months, which varies according to geographical regions and altitude (see Figure 13).

FIGURE 13
Length of fish production season under different climatic conditions



Because of climatic differences, the length of the production season is also different in the countries of CEE and CCA.

5.2 BASIC ELEMENTS OF CULTURE PRACTICES

There are three basic elements of carp polyculture which characterize its culture practices. They are the fish stock management, the use of manuring/fertilization and supplementary feeding. These elements are applied either separately or in combinations as summarized in Table 2.

TABLE 2
Combinations of basic elements of pond fish culture practices

Fish stock management	Manuring/ fertilization	Supplementary feeding	When and where to apply
✓	—	—	In ponds and reservoirs where the management of fish stock is the only possible and/or feasible option of increasing production.
✓	✓	—	There are options when only the use of manure/fertilizer is possible and/or feasible.
✓	—	✓	There are situations when the use of supplementary feeds is the only possible and/or feasible option.
✓	✓	✓	This option ensures the overall utilization of pond resources. It is recommended if economic calculations prove its feasibility.

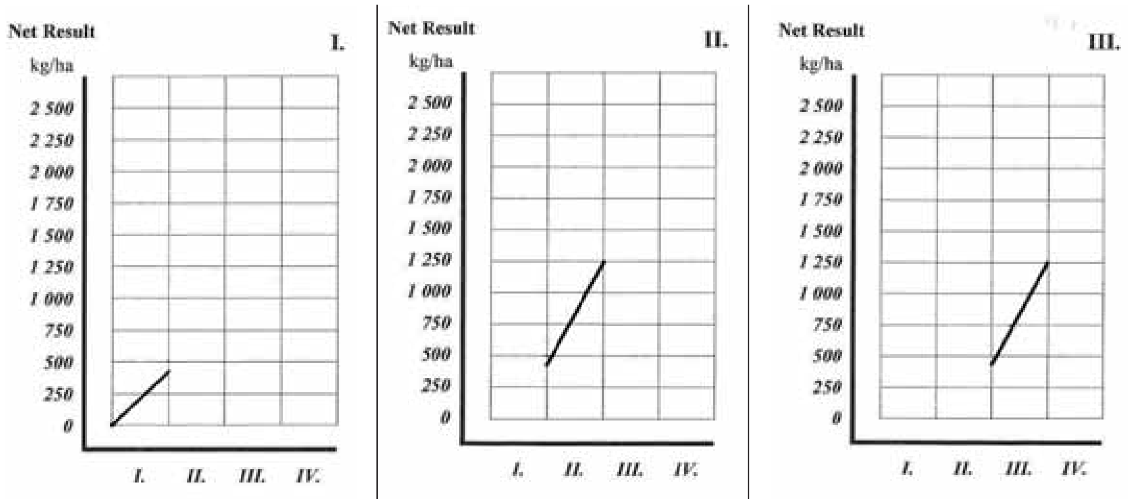
Expected results of the different management practices are presented and summarized in Figure 14. In the traditional supplementary feed-based common carp dominant polyculture, when only carbohydrate-rich cereals are fed, about 1 to 1.2 tonnes/hectare fish can be produced. If higher yield is expected, fish feed with protein content higher than cereals must be fed. It is especially true when the population of natural food organisms starts declining, both in relative and absolute terms. By adding more protein-rich feeds to cereals, the decline of natural food can be compensated. With aeration of water and/or with its exchange with fresh water (daily exchange rate of about 7 to 15 percent) in the second half of the production season, further increase of fish production can be achieved.

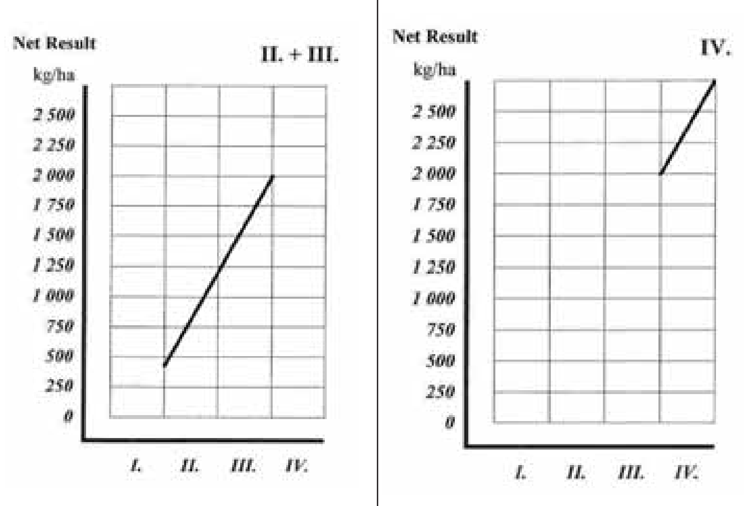
At planning production, the following steps should be undertaken:

1. All technical and financial conditions should be carefully surveyed and considered. A decision should be made whether supplementary feeding and manuring/fertilization are possible and feasible.
2. The combination of species as well as their age and stocking densities should be determined proportionally to the *natural productivity** of the pond, to the planned manuring/fertilization and to the planned supplementary feeding.

FIGURE 14

Range of expected results of table fish production according to the combinations of basic elements of culture practices





I. Considerable results can be achieved with fish stock management if the stocked fish species are well selected and balanced.

II. The result of fish production can be further increased with the use of manure/fertilizer.

III. Supplementary feeding is another way of increasing fish production.

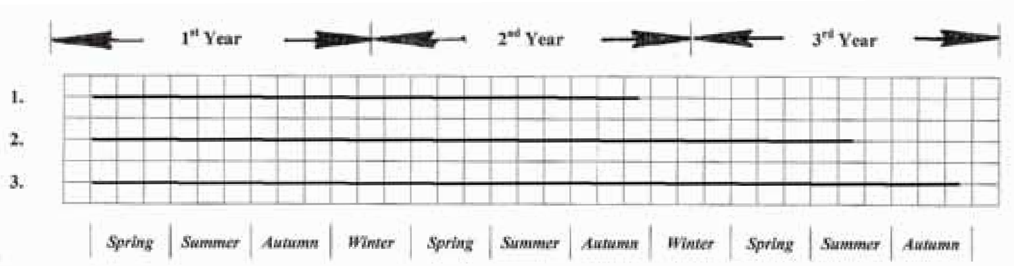
II. + III. Manuring/fertilization and feeding have complementary role in increasing production results.

IV. Aeration of water ensures safe and higher production results.

5.3 PHASES OF TABLE FISH PRODUCTION

Under the climatic conditions of CEE and CCA countries, table fish production can be completed within two or three years. In countries where the season is longer the production of table fish lasts for two years, while in countries where the season is shorter the production of table fish is completed during a three-year-long cycle. When the objective is to produce fish larger than 2.5 kilograms, farmers often rear their fish for an additional year. For supplying the market continuously with fish, the fish can be harvested during the usual autumn season, in late spring or summer. In this case, so-called summer fish are produced. They are reared only for 2.5 years (Figure 15).

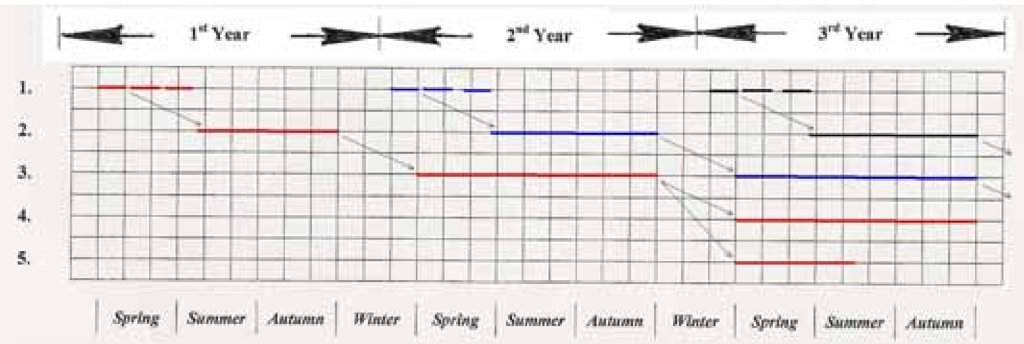
FIGURE 15
Options and lengths of table fish production cycle



1. Table fish production within two years. **2.** Summer fish production. **3.** Table fish production within three years.

As illustrated and explained in Figure 16 stocking material for the last phase of table fish production is produced in steps. First *advanced fry** is produced, which is stocked in the same summer in order to produce one-summer-old fish. This age group of fish is stocked for the next year for producing two-summer-old fish, which is the stocking material for producing table fish during the third year.

FIGURE 16
Consecutive steps of table fish production



1. Advanced fry can be produced from *feeding larvae** within 4–6 weeks (weight of fish: 0.25–2.5 grams). Because this is a brief period, the same pond can be used two or three times within one season. **2.** With one-summer-old fish production, either feeding larvae or advanced fry are stocked and reared within 10–12 weeks (weight of fish: 10–100 grams). **3.** Two-summer-old fish production lasts during the entire fish production season, when one-summer-old fish are stocked and reared up to the size of 200–800 grams. These carps are considered big enough for consumption in many CEE and CCA countries. Still the two-summer-old fish are usually reared to a larger size for an additional year because of the better price of bigger fish. **4.** Table fish production also lasts during the entire fish production season, when the objective is to produce fish with a weight of over 1–2 kilograms. **5.** Summer fish production is finished during the summer of the third year.

5.4 OPTIONS OF CULTURE PRACTICES

Fish can be produced in monoculture, *biculture** and polyculture. Only one species is stocked in monocultural ponds. Biculture is the joint rearing of two fish species, while polyculture is the combined rearing of three or more fish species.

In addition to the above-mentioned culture practices, mixed-age polyculture is also a frequently followed technique. In this case, not only different fish species but also different age groups of the same species are reared together in one pond. This ensures not only the better utilization of pond resources, but also the better supply of the market with different sizes of fish. This is because mixed-aged polyculture allows continuous production of table fish during the entire production season. The disadvantage of this practice is that sorting out the age groups of four to seven species is complicated and is labour demanding.

Advanced fry of predator species are reared in monoculture. During the rearing of the advanced fry of European catfish feeding larvae of carp is also stocked in order to ensure food fish. Rearing of the advanced fry of carps is usually done in monoculture, but their biculture or polyculture is also feasible.

One-summer-old, two-summer-old and table fish are produced in polyculture. Often four to seven different fish species are stocked together in order to utilize the natural fish production capacity of ponds.

5.5 GUIDE TO FISH PRODUCTION PATTERNS

The result of fish production depends on physical, human and economic conditions. These are conditions that should be taken into consideration when a production strategy is selected. In order to facilitate the selection of the strategy which suits best, a set of production patterns were elaborated. They are presented in Annex 4 and summarized in Table 3.

Patterns presented in Annex 4 reflect the basic rule of pond fish culture. There is negative correlation between number, growth and the final size of fish, i.e. under the same production conditions fish grow faster and will be bigger if the fish density is

TABLE 3
Summary figures of fish production patterns presented in Annex 4

1.	**Advanced fry production patterns**
	1.1. Pike (size: 0.25–1.5 g)
	1.2. Pikeperch (size: 0.25–1 g)
	1.3. European catfish (size: 0.5–2 g)
	1.4. Carps (common carp and Chinese major carps) (size: 0.5–2.5 g)
	1.5. Breams (size: 1–2 g)
	1.6. Tench (size: 0.25–0.5 g)
2.	**One-summer-old fish production patterns**
	2.1. Extensive production of medium one-summer-old fish (size: ~ 50 g)
	2.2. Semi-intensive production of small one-summer-old fish (size: ~ 25 g)
	2.3. Semi-intensive production of large one-summer-old fish (size: ~ 100 g)
3.	**Two-summer-old fish production patterns**
	3.1. Extensive production of two-summer-old fish (size: ~ 250 g)
	3.2. Semi-intensive production of two-summer-old fish (size: ~ 250 g)
	3.3. Semi-intensive production of large two-summer-old fish (size: 500–750 g)
4.	**Table fish production patterns**
	4.1. Semi-intensive production based on stocking large one-summer-old fish (size: ~ 1 250 g)
	4.2. Extensive production with stocking two-summer-old fish (size: ~ 1 250 g)
	4.3. Semi-intensive production with stocking two-summer-old fish (size: ~ 1 250 g)
	4.4. Summer fish production with stocking large two-summer-old fish (size: ~ 1 250 g)
5.	**Special table fish production patterns**
	5.1. Extensive production in water reservoirs (size: ~ 1 500 g)
	5.2. Fish production combined with biological control of water weeds (size: ~ 1 250 g)

lower and vice versa; fish stocked in a higher density will reach a smaller final size. This is visualized in Figures 17, 18, 19, 20 and 21.

The size and quality of the fish pond will also influence the final results. If a pond is deeper (up to a depth of about 2.5 metres), higher fish production can be expected. As far as the size of a pond is concerned, there is a certain inverse correlation between the intensity of applicable fish production technology and its actual size. A smaller pond is more favourable for intensive fish production because the fish stock management, feeding and control of unfavourable conditions, including protection of fish, is easier.

While planning production, an important aspect is to estimate the natural fish food production capacity of the pond. Ponds built on fertile land can expect much higher production than ponds built on a less fertile and acid land. Too low or too high water pH value also has a negative effect on the production.

During the selection, possible production patterns should be evaluated both technically and economically. The managerial practice and professional skill of the implementing staff should also be taken into consideration. The production patterns indicated as “extensive” in the tables in Annex 4 are applicable when experience and the financial resources are missing or limited. Production patterns, indicated as “semi-intensive”, is applicable if all of the conditions can be ensured.

In the production patterns presented in Annex 4 the common carp is the main fish. If there is a higher demand for other species the number of common carp can be reduced and the number of other carps can be increased, but it should not be done mechanically. Though the total number and the final size of the fish will not be modified considerably, such changes should be supported with matching management practices, i.e. with appropriate modification of the proportion of other species, manuring and/or feeding.

The presented production patterns show the expected final size of the different fish species. If during production one or two of the stocked species will grow faster than indicated in the production pattern, their number can be increased in the next production season. Regularly and properly maintained sampling can help to collect valuable related information.

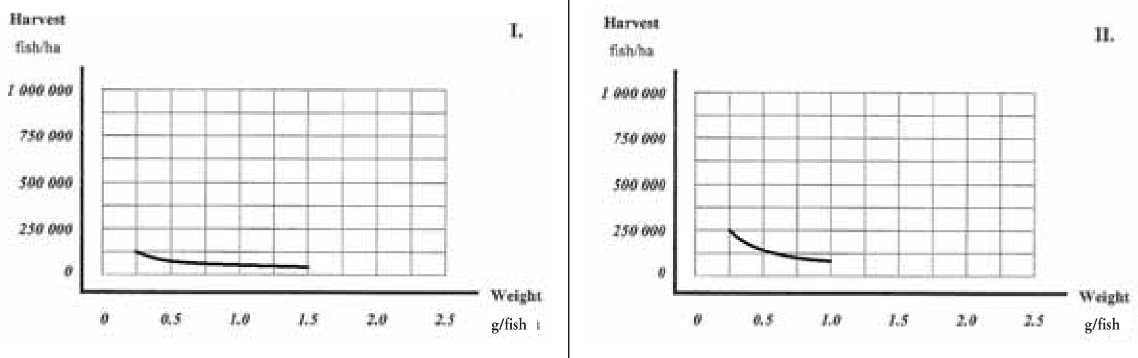
5.5.1 Advanced fry production

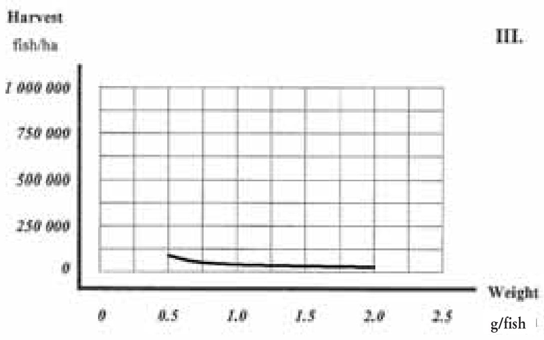
Advanced fry production technologies of predatory fishes (pike, pikeperch and European catfish) and carps (common carp, Chinese major carps, as well as breams and tench) are similar. All of them require similar manipulation of the zooplankton population based on the increased zooplankton production through manured pond water. Regardless of the species, the length of the production period of advanced fry varies between 4 and 6 weeks. Stocking and harvesting data of advanced fry production are detailed in Annex 4 and are summarized in Figures 17 and 18.

Production of advanced fry is usually carried out in monoculture. Nevertheless, it is possible to do the nursing in polyculture. All cyprinids of this age group consume zooplankton. In this respect there is no significant difference between the species. Consequently, the ratio of them in the polyculture should be in accordance with the required ratio of the one-summer-old fish. This will reduce the need for sorting fish later.

FIGURE 17

Relationship between the produced number and the individual size of advanced fry of predatory fish





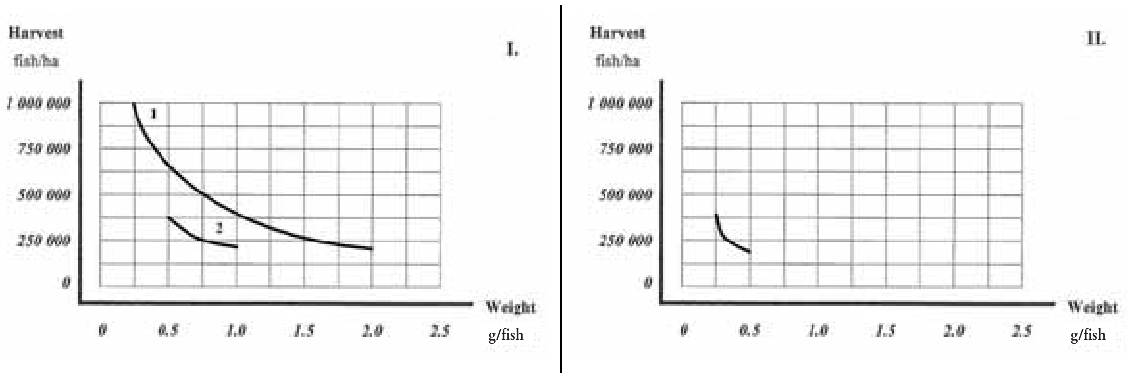
I. Production of the advanced fry of pike – well-prepared fish pond with abundant population of copepods and cladocerans is important. Artificial feeding of this species is not possible in ponds.

II. Production of the advanced fry of pikeperch – fish pond with abundant population of rotifers is essential. Later copepods and cladocerans are the main food organisms. Feeding of this species is not possible in ponds.

III. Production of the advanced fry of European catfish – fish pond with abundant zooplankton is a prerequisite. About 10–20 times more common carp fry than the number of catfish can be stocked as prey. Artificial feeding with dough type feeds of high protein content is possible and may be financially feasible.

FIGURE 18

Relationship between the produced number and the individual size of advanced fry of common carp, Chinese major carps, breams and tench



I. Larvae of common carp, Chinese major carps (1) and breams (2) are larger and they grow faster than **II.** Larvae of tench.

5.5.2 One-summer-old fish production

One-summer-old fish (yearling or *fingerling**) production is carried out mainly in polyculture because in this way the fish production capacity of ponds is utilized best. Out of the possible culture techniques, the extensive and semi-intensive patterns are presented in Annex 4, where the targeted final weight of fish are about 25, 50 and 100 grams. One-summer-old fish with 25 and 50 grams of final weight are usually used for stocking fish ponds where the table fish is produced in a three-year-long cycle. One-summer-old fish of 100 grams can be the stocking material of these ponds where table fish are produced during a two-year-long cycle.

One-summer-old fish can be produced either from fish larvae or from advanced fry. As production results are more predictable when advanced fry are stocked, the presented patterns refer to this option (Annex 4 and Figure 19).

5.5.3 Two-summer-old fish production

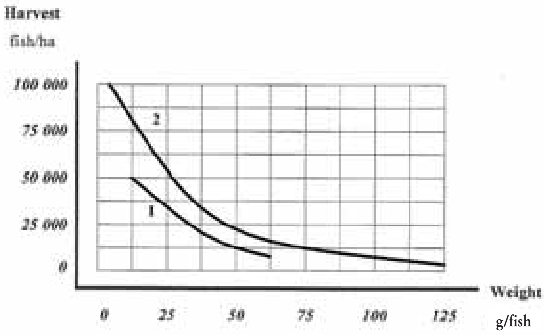
In the case of two-summer-old fish, the entire production season is available, since one-summer-old fish can be stocked either in autumn or in early spring. By the end of the season the fish become about ten times larger than their initial weight. There are countries where the produced 0.2–0.3 kg size two-summer-old fish are consumed as table fish. Otherwise, the harvested fish are stocked for the third/last phase of rearing in order to produce 1–2 kg table fish. Relevant information is presented in Annex 4 and in Figure 20.

5.5.4 Table fish production

As presented in Tables 4.4.1 to 4.4.4, there are three different ways of table fish production in carp polyculture: the first is the stocking of large one-summer-old fish (~ 100 g) to produce table fish by the end of the second year. The second method is the stocking of two-summer-old fish (~ 250 g) to produce table fish by the end of the third year. The third one is the stocking of large two-summer-old fish (500–750 g) to produce summer fish by the middle of the third production season. The relationship between the harvested number and the individual size of fish is illustrated in Figure 21.

FIGURE 19

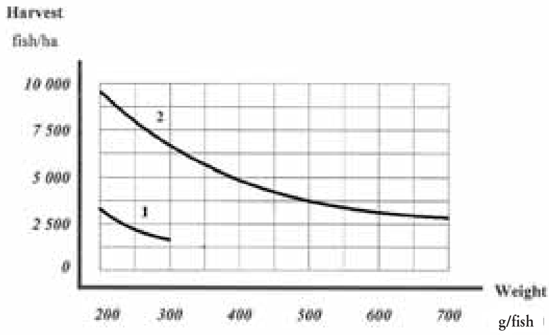
Relationship between the produced number and the individual size of one-summer-old fish in polyculture



The length of the production period is 10 to 12 weeks (2.5–3 months). If extensive (1) production practices are applied, the total harvest will be about 300–500 kg/ha. If semi-intensive (2) production technology is followed, the production can be 1 000–1 500 kg/ha.

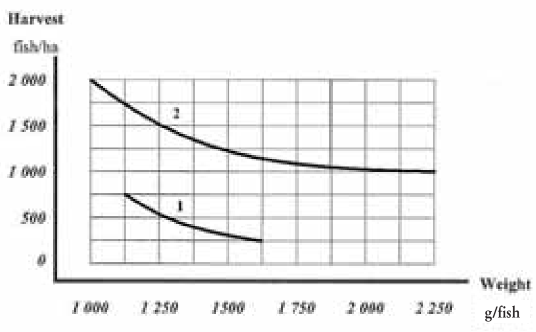
FIGURE 20

Relationship between the produced number and the individual size of two-summer-old fish in polyculture



The length of the production period may vary between 22 and 24 weeks (5–5.5 months). The expected net fish production will be around 500 kg/ha in extensive (1) and about 1 500 kg/ha in semi-intensive (2) ponds.

FIGURE 21
Relationship between the produced number and the individual size of table fish in polyculture



The length of the production period may vary between 22 and 24 weeks (5–5.5 months). The expected net fish production will be around 500–800 kg/ha in extensive (1) and about 1 500–2 000 kg/ha in semi-intensive (2) ponds.

5.5.5 Special fish production practices

Here production practices are considered special, when neither manure/fertilizer nor supplementary feeds are applied, because the circumstances only allow fish stock management. One option is presented in Table 4.5.1 in Annex 4.

Using grass carp for aquatic weed control (Table 4.5.2, Annex 4) is another widely practiced option. In this case it is important to observe and estimate the actual biomass of aquatic weeds and stock the fish accordingly. It has to be taken into account that grass carp can consume 60 to 120 percent and 30 to 60 percent of their actual body weight/day from soft and hard aquatic weeds, respectively, if the water temperature is above 20 °C (Antalfi and Tölg, 1972). In Annex 4, where the figures of this method are presented, it is assumed that at least half of the water surface is covered with vegetation.

Production of bait fish and ornamental fish (goldfish, koi, etc.) as main fish in the polyculture are also feasible options, but this publication does not provide details on the production of these fish.

6. Production-related works and tasks

There are production-related works and tasks which should be correctly done in order to achieve the planned results. These include pond preparation and maintenance, management of water, stocking of fish, application of manuring/fertilization, feeding, follow-up on fish growth, fishing, storing and transport of fish, as well as the follow-up on fish health and on the financial status/results of the production.

6.1 PREPARATION AND MAINTENANCE OF FISH PONDS

Fish ponds used for fry production should be kept dry when they are not used. Other ponds, which are used for rearing bigger fish, should also be kept dry whenever it is possible. When the mud dries the overall physical structure of the pond bottom improves. The developed aerobic conditions will remain for a long time after inundation. Moreover, this is also suitable for the elimination of remaining fish, the fish pathogens and predatory insects which otherwise would survive in the shallow pools left in the pond. The major repairs of dike and concrete structures can also be done while the ponds are dry.

Before a fish pond is inundated the unwanted vegetation should be cut and removed, and the pond bottom should be passed with a harrow or disk harrow.

Liming and manuring described in Chapter 6.4 are the last steps of pond preparation. The applicable quantities presented in Table 7 and 8 vary according to a wide range of conditions; they are also described in Chapter 6.4.

6.2 POND WATER MANAGEMENT

When a pond is prepared, it should be filled with water. The time requirement for filling and draining ponds of different sizes are shown in Table 4. However, these time frames can be achieved only if the dimensions/capacities of the water supply and draining structures are proportional to the size of pond and if their physical conditions are proper.

It is widespread practice to fill the pond gradually when rearing advanced fry. First the pond is filled with water up to 50–60 cm. Later, after stocking the larvae, the pond is fully filled within about five to ten days. This technique ensures higher initial concentration of rotifers.

To prevent the entering of unwanted fish (predators and trash fish) in the pond, the water should be filtered through a strong sieve/screen. The sieve mesh size depends on the size of fish planned to prevent entering the pond (see Table 5).

During the production cycle the level of the pond water should be checked regularly in order to replace losses due to seepage and evaporation.

When fish larvae of pikeperch or carps are stocked, a dense population of rotifers must be developed in the pond water. It can be done very effectively by application of *agricultural insecticides**. Permitted brands of suitable insecticides are widely used for this purpose in a concentration of about 0.5–1 ppm (0.5–1 ml/m^3). The actual concentration depends on the product, which should be tested before it is used.

TABLE 4
Recommended time for filling and draining ponds

Size of the pond (ha)	Length (days)
Smaller than 0.1	0.2–0.4
0.1–1	1–3
1–6	1–3
6–30	4–14
30–60	8–15
Larger than 60	15–30

Source: Antalfi and Tölg, 1971.

TABLE 5
Recommended mesh size of screen at filling and drainage of ponds

Age of stocked or harvested fish	Mesh size (cm)	
	Stocking	Harvest
Fish larvae	0.2	-
Advanced fry	1	2–3
One-summer-old fish	2–3	6
Two-summer-old fish	6	15
Table fish	15	20

Source: Horváth and Pékh, 1984.

The suitable insecticide, applied four to six days before the stocking of larvae, temporarily eliminates the population of planktonic crustaceans, which are feed competitors of the rotifers (cladocerans) or predate on them (copepods). Moreover, the water insects which also predate on developing fry can be eliminated with this method (Horváth and Tamás, 1981; Horváth, Tamás and Coche, 1985).

If the use of insecticides is not permitted, or not available, the development of rotifers can be supported by quick inundation and immediate manuring of the pond water. Fixing of bundles of dry straw or hay in the pond water will further increase the population of small members of zooplankton such as ciliates, infusoria and rotifers.

Before stocking other older age groups of fish, it is not necessary to follow the above described special treatment of pond water. Still, the proper preparation and water management of the pond is very important.

6.3 STOCKING

When stocking fish larvae, the rule of thumb is to handle and release them with absolute care, which includes the selection of sheltered spots and *acclimatization** of the larvae in order to avoid *thermal shock**. Larvae of some species like pikeperch can be killed easily if they are released into a pond where the water is about 1–2 °C cooler than the water in which they were transported.

When stocking elder generations of fish, their careful transport and release is also very important. If fish are roughly handled, they will lose their scales and/or mucus covering their body. Their organs also will be injured. These wounds can easily be infected and will cause slower growth, retardation, or later, even death. The temperature of the water of transporting tanks and of the ponds should be the same when the fish are released into them. This is especially important in the case of younger age groups of fish. Different technical devices, such as flexible tubes or slides, should be used for releasing fish gently.

6.4 MANURING, FERTILIZATION AND LIMING

Application of fresh manure (also called organic fertilizer) ensures not only the needed essential mineral nutrients, but also the carbon which is often limited in fish ponds (Woynarovich, 1963). An additional advantage of using manure is that many fish food organisms consume the organic materials either directly or through a very short food chain. Manure, together with the bacteria which develop on their particles, is an ideal protein-rich microscopic food item for the zooplankton.

The chemical composition and the concentration of the mineral nutrients and organic materials of the manure determine the actual effect of them on the development of fish food organisms. Some of the farmed animals have less while others have more concentrated manure. Information presented in Table 6 facilitates the fine tuning of dosing manure.

The other option for supporting the production of natural food organisms is the application of fertilizers which provide the needed essential mineral nutrients in a different way than manure does. Fertilizers do not contain carbon, which could indirectly support the process of photosynthesis. The active ingredients from fertilizers arrive to the fish food organisms through a longer chain than manures. One of the advantages of their application is that fertilizers have standardized contents, while the contents of manures change according to the feeding and keeping of the animals.

TABLE 6
Chemical composition of the manures of different farmed animals

	Dairy cattle	Beef cattle	Ox	Pig	Chicken		Horse
					Layers	Broiler	
Dry matter as % of fresh manure	12.7	11.6	25.0	9.2	25.2	25.2	20.9
Dry matter (%)	100	100	100	100	100	100	100
Organic material (%)	82.5	85.0	85.0	80.0	70.0	70.0	80.0
Total nitrogen (%)	3.9	4.9	4.5	7.5	5.4	6.8	2.9
Total phosphorus (%)	0.7	1.6	0.7	2.5	2.1	1.5	0.5
Total potassium (%)	2.6	3.6	3.2	4.9	2.3	2.1	1.8
Biological oxygen demand *(BOD*)* $^{5\ days}$	16.5	23.0	9.0	33.0	27.0	-	-
Chemical oxygen demand *(COD*)*	88.0	95.0	11.8	95.0	90.0	-	-

Source: Miner and Smith, 1975.

Out of the different minerals, nitrogen (N) and phosphorus (P) are most often the limiting factors of the primary production in fish ponds. The recommended total quantity of soluble N and P should be about 100 to 200 kg/ha/season. Experience proved that in pond water, within the indicated total soluble quantity, the ideal proportion of N and P is about 6:1 (Pócsi, 1982). The quantity of potassium (K) is usually sufficient in ponds. Its application is not necessary. The manures and fertilizers are often used together because they complement each other.

It is important to find and select fertilizers which are suitable for the given pond's conditions. Use of those which contain too many carriers (gypsum, for example) may finally be more expensive because extra weight should be transported and distributed. Thus, the more concentrated fertilizers are better. Out of the nitrogen fertilizers, carbamide (urea) is one of the most concentrated as its nitrogen content is as high as 46 percent. Application of nitrogen fertilizers in alkaline waters should be done cautiously, especially if the pH is over 8–8.5 (Antalfi and Tölg, 1971). Fertilizers having basic effect (for example, the liquid form of NH_4OH) should not be used in ponds where the pH is too alkaline. Fertilizers containing acidic components should not be used in acid pond water. As for nitrogen fertilizers, the price of the P-fertilizer should reflect the true content of soluble phosphorous. Out of these fertilizers, superphosphate contains about 18 percent and triple-superphosphate around 46 percent soluble P content.

Manuring/fertilization should start when the temperature of water is around 10 °C. The positive effect of the increased nutrient concentration on the pond life can be observed within 10–15 days at this temperature, but at a higher water temperature the effect of the manure/fertilizer will appear within a much shorter period.

Manures and fertilizers are applied both during pond preparation and during the production season. At pond preparation they can be distributed either before the inundation of pond on the dry bottom or after inundation over the water surface. In the first case, the scattered manure should be mixed into the upper layer of the pond soil with a harrow or disk harrow. With the application of manure on the dry pond bottom, time, manpower and cost can be saved. The other option is to disperse fresh manure and fertilizers evenly over the water surface of the pond. This way of distribution ensures a much better effect (Woynarovich, 1963).

Normally a larger preparatory dose of manure/fertilizer is applied as a first treatment. After this, smaller doses are applied in regular intervals. Apart from the rearing of advanced fry, manure/fertilizer can be applied daily, weekly, biweekly or monthly. Treating the pond water with smaller but more frequent doses is considered better and much more effective because small but more frequent doses do not overload the pond ecosystem but keep all the organisms in an active production phase (Woynarovich, 1963). The most effective is the daily application of manure/fertilizers. In the case of daily application, the intervention into the biological cycle is the most even and the least radical. As the frequency of the application of manure/fertilizer decreases, the

TABLE 7
Recommended quantities of manure and fertilizers

Name	Total quantity (tonne/ha)	% of total quantity	
		Start	Later
Production of advanced fry			
Manure	1.5–2.5	100	0
Carbamide (urea)	0.1–0.2	100	0
Superphosphate	0.1	100	0
Production of elder age groups of fish			
Manure	3–5	25	75
Carbamide (urea)	0.4–0.5	25	75
Superphosphate	0.3–0.4	25	75

Source: Horváth and Pékh, 1984; Horváth, *et al*., 1985.

quantity of doses should be increased in order to maintain the same natural fish food production of pond water. However, this rule of thumb cannot be followed if manures/fertilizers are used only biweekly or monthly. The pond *biocoenosis** cannot digest doses that are too large. Consequently, if manuring/fertilization are carried out rarely, the productivity of the pond will be less than its actual potential. The recommended doses of manure and fertilizers are presented in Table 7.

When deciding for the right quantity of manure, the content of dry matter and organic materials should be considered, together with their biological oxygen demand and chemical oxygen demand. When these figures are higher (pig, poultry), the smaller doses should be applied within the values indicated in Table 7. If manures and fertilizers are soaked before distribution, the effect will be much better.

*Fish manure** is also effective and supports the increased production of natural fish food in ponds.

Lime raises the pH of the water. Most fish do best in water which has a pH between 7.0 and 8.5 (McLarney, 1984). Lime reduces the daily extreme fluctuation of pH, as well as supports useful chemical processes, such as decomposition and mineralization of organic materials (Woynarovich, 1963; McLarney, 1984). Lime is important not only for supporting pond life, but also for disinfecting the pond bottom and controlling phytoplankton blooms.

There are two types of lime which are frequently used in pond fish culture. They are the powdered limestone, or agricultural lime[6], and the quicklime[7]. The first one acts slowly, while the second one is a strong form of lime which reacts not only quickly but also aggressively. Therefore, the disinfecting effect of quicklime at pond preparation or at the treatment of water is outstanding. The quantities of lime should be calculated based on Table 8. Within the indicated ranges, higher doses should be given from agricultural lime, and the smaller ones from quicklime. If there is about a seven- to ten-day-long interval between the application of lime and manure/fertilizers, then the effect of both of them will increase.

During pond preparation, lime should be distributed evenly over the surface of the pond bottom. When wet patches or smaller pools remain in a pond, the lime – possibly quicklime – should be especially well distributed.

Except for advanced fry rearing, the application of lime during the production season is also necessary. The recommended quantities are presented in Table 8.

If the organic loading of the pond water is very high, or ulcers occur on the fish, an application of bleaching powder (chlorinated lime) is possible in the dose of 5–8 kg/ha and the treatments can be repeated after five to seven days (Molnár and Szakolczai, 1980).

Some of the essential nutrients may be trapped in the mud of the pond bottom. In order to recycle the nutrients, as well as to aerate the mud, its upper layer should be turned around. For this purpose a harrow or a heavy long chain dragged on the pond bottom should serve well. The use of a propeller near the pond bottom can also stir up and aerate the mud.

TABLE 8
Application of lime at pond preparation and during the production season

pH	Preparatory dose (kg/ha)	Monthly dose (kg/ha/month)
8	50–100	10–25
7.5	100–200	25–50
7	200–300	50–75
6	300–400	75–100
Less than 6	400–450	100–125

Source: Woynarovich, *et al*., 2003.

[6] Calcium carbonate ($CaCO_3$).
[7] Calcium oxide (CaO).

6.5 ESSENTIAL HYDROBIOLOGICAL INVESTIGATIONS

Water temperature, oxygen content of water, indicators of pond water productivity and the quantity of insect larvae in the mud should be followed up and checked regularly.

The temperature of pond water should never be measured at the surface because the water on the surface warms up or cools down quickly and hence it does not represent correctly the temperature of the water where fish stay. The water temperature should be measured in the water column near the bottom.

Most of the oxygen is produced by phytoplankton during photosynthesis in the light period of the day. Living organisms, as well as the biochemical processes, consume oxygen continuously, both in the light and the dark periods of the day. The actual balance of production and consumption of oxygen changes throughout the day. During cloudy days and in the second half of the production season when the standing stock of oxygen consumers is high but the oxygen production is low, oxygen shortage may develop by dawn. In these cases, fish come to the water surface to gulp for air. The usual way of overcoming the oxygen shortage is either aeration of the pond water or adding fresh water which is rich in oxygen. When the oxygen shortage at dawn becomes regular, the density of phytoplankton should be reduced with lime or chlorinated lime (about 5 kg/ha) distributed in strips across the pond (Molnár and Szakolczai, 1980). If the oxygen shortage remains, manuring/fertilization should be reduced or stopped. Feeding of fish should also be reduced for a few days. This type of oxygen shortage is very frequent in old ponds where the accumulated organic materials and the bacteria which develop on them consume large quantities of oxygen. Measuring of the oxygen content of water in the more critical second half of the season should be done in the afternoon, before sunset. If at this time the oxygen content of water is over 20–25 mg/l, serious oxygen shortage can be expected at dawn the following day. In earlier times, dissolved oxygen (DO) in water was determined with chemical components through *titration**. Today there are many different oxygen meters in use. Although they are expensive, they are very accurate instruments. A cheap alternative for quick determination of DO is the use of products made for hobby aquarists. These products are relatively cheap and rather reliable.

Plankton organisms are the best indicators of the natural fish food productivity of the water of fish ponds. This can be measured by the quantitative and qualitative assessment of phytoplankton and zooplankton.

Primary production of the pond is estimated through the quantitative and qualitative assessment of the phytoplankton. A very simple way of estimating the presence of phytoplankton is to observe the intensity of the greenness of water. Unfortunately this can be misleading because the colour of fertile or even very fertile pond water is not necessarily green. It may be greenish, brownish, yellowish (sometimes blackish or transparent) and all the combination of the listed colours. Still, these waters may have high productivity. The determination of planktonic algae species could improve the exactness of the indicator, but this is very difficult even for a well-equipped scientist.

Transparency measured with a Secchi disk may indicate how dense the phytoplankton is in the pond water. However, the importance of this indicator should not be overestimated (see Box 1). If the transparency is high, manure

BOX 1

Scientists' opinion about measuring transparency of pond water

"In most cases, turbidity measurement by Secchi disk may indicate the need for fertilization. Experienced experts are able to determine the quality of the turbid substance but this determination should be done carefully because misleading or wrong information may cause harm." (Rahman, 1992)

"In fish ponds, Secchi transparency shows correlation between the floating organic materials and the concentration of chlorophyll, which indicates the phytoplankton. However, a widely applicable pattern is nonexistent because the transparency, in addition to the phytoplankton, is also influenced by water turbidity and color." (Ördög, 2000) should be applied. However, it has to be noted that phytoplankton stratifies according to the strength of sunlight. If it is too strong, the phytoplankton sinks deeper, but if the light is weaker it lifts near the surface. In some cases, the density of zooplankton is so high that they filter the water clear. Therefore, the measuring of pond water transparency should be done parallel to zooplankton investigation. In order to receive reliable information, the transparency should be measured always at midday and in the middle of the pond. Following this practice, in time reliable skills of the fish pond owner will develop and eventually a Secchi disk will not always be needed to estimate the transparency of pond water.

Good production results can be obtained only if the level of zooplankton[8] and zoobentos remain high throughout the production cycle. The most simple and reliable way of measuring the efficiency of manuring is by measuring the growth of zooplankton (Horvath, 2000). Hence, there is no better way to estimate the productivity of the pond water than by checking the zooplankton, because it is both a direct and an indirect indicator. A conical hand net (diameter: about 15 cm; depth: about 20 cm) with a transparent vial fixed on its bottom that has a 60–70 micron mesh size serves well for sampling zooplankton. The larger algae, rotifers, cladocerans and copepods can be captured with this net. The sample can easily be observed with a hand loupe (10–20 fold magnifying force) in the vial, where the collected sample concentrates. Samples of plankton should be collected regularly, always from the same spots of the pond. It is also suggested to always filter the same quantity of water (50–100 litres) through the plankton net. This allows an accurate estimation of the quantity, size and development stages of the planktonic organisms. Moreover, from the number and type of their eggs important information can be obtained on the reproductive status of the plankton populations. In order to estimate the quantity of the collected plankton, a few drops of concentrated formalin is needed to kill the sample. The dead planktonic organisms will sediment within a few hours and the volume of the plankton can be measured. The water can be considered rich in plankton if the volume of the sedimented sample is about 5–10 ml/100 litres of pond water.

Observing the density of insects and insect larvae is important both in the ponds of advanced fry and in the elder generations of fish. Out of these two, the investigation in advanced fry rearing ponds is especially important. It will indicate the danger of the growing population of insect predators of the developing fry (see Figure 8). The invasion of predatory insects and their larvae happens usually in those advanced fry rearing ponds which were not kept dry and were not prepared properly.

Zoobentos in the bottom mud is the main natural food of common carp, breams and tench. The qualitative and quantitative estimation of worms, insects and insect larvae living on and in the mud of the pond bottom will show the actual productivity of the pond bottom. The bottom fauna examined together with the growth rate of bottom feeder fish supply useful information on the level of the exploitation of pond bottom resources.

6.6 FEEDING

Feeding is one of the most crucial technological elements of fish rearing, which largely determines the profitability of the production since even the prices of supplementary feeds are usually high. The principles and practice of feeding developing fry are rather different compared with the feeding of elder age groups.

Feed applied when rearing advanced fry of carps should have high protein content (30–35 percent) and it should be finely ground. Special manufactured feeds for rearing fry are available ready to use. If the use of manufactured feeds for fry is not possible or

[8] A rule of thumb is that about 100 kg of phytoplankton will produce 10 kg of zooplankton (crustaceans), which may produce 1 kg of fish meat.

feasible, farm-mixed feeds can also be used. The formula of a simple, easy-to-produce mixture for feeding fry of carps is presented in Table 9. At the start of production it should be flourlike (about 0.1–0.2 mm). Later, the size of the feed particles can be larger, proportional to the size of the mouth of the developing fry. Soaking of feed helps the digestion of the feed particles. Of the recommended mixture or a similar one, the quantity for 100 000 stocked feeding larvae should be about 1–1.5 kg/day. This ration must be increased gradually to 4–5 kg by the end of the production cycle.

TABLE 9
Simple mixture of supplementary feeds for rearing advanced fry of carps

Ingredients	%
Wheat or barley flour	25
Soya	25
Fish meal	25
Meat or blood meal	25

Source: Horváth and Tamás, 1981.

In the case of the elder age groups, only common carp, breams, tench and grass carp are fed with supplementary feeds. The daily quantity is recommended to be as much as is usually consumed by the fish within three to four hours. This will be about 1–5 percent of the standing stock of the common carp, depending on the actual consistency of the given feed, the size of fish and the water temperature. Feeding should be done in the morning hours at the same locations marked with sticks or small buoys. Whether the consumption of the supplementary feed occurred should be checked in late morning or during early afternoon.

Some of the frequently used supplementary feeds are listed in Annex 2. Grains are the best supplementary feeds because they are rich in energy. It is commonly believed that grains or other feeds that are not suitable for terrestrial animals because of their inferior quality are still suitable for fish. By-products of mills or broken grains are certainly suitable for feeding fish. Other feeds which are contaminated with fungi or are rotten or contain poisonous seeds of weeds should not be given to fish because they cause infection or inflammation of the digestive tract. Grains should be ground or at least crushed and soaked before they are applied as feeds. These preparations will improve the digestion and utilization of feeds.

Grass carp should be fed with fresh terrestrial plants. The widely available choices of green feeds are listed in Annex 2. Their daily portion should be consumed within 12–18 hours. To prevent grass carp from feeding on supplementary feeds, green feeding should be done first in the morning, even before common carp is fed. If the daily portions of green feeds are placed into simple floating frames, the follow-up of their consumption becomes easy.

The feed conversion ration (FCR) should be calculated each month, as well as at the end of the production season. It is a rule of thumb that the FCR will be less during the first half of the production season. In the second half of the production season it will be higher than its overall average. Another general rule, demonstrated in Table 10, is that the FCR of the same feed stuff of the younger fish will be lower than of the elder fish. This is because the proportion of protein-rich natural food is higher in the diet of younger fish; consequently, less supplementary feed is necessary to produce 1 kg of live weight.

TABLE 10
Expected FCR of grains at the different age groups of common carp

Age groups	FCR
Advanced fry	0.75–1.25
One-summer-old fish	1–2
Two-summer-old fish	1.5–2.5
Table fish	2–3.5

By the last third of the production season the populations of the natural fish food organisms in ponds may decline both in absolute and in relative terms. This is when the standing stock of common carp is over 1 tonne/hectare. In this case, feeds or mixture of feeds with higher protein content will supplement the missing protein of the natural fish food.

6.7 FOLLOW-UP OF FISH GROWTH

Checking the growth of fish should be done on a regular basis. During advanced fry rearing it must be done daily, while in the elder age groups it may be done weekly (one-summer-old fish) or biweekly (two-summer-old fish and table fish). Sampling of advanced fry can be done by using a lift net, while larger fish should be caught with a cast net. About September, still before the end of the production season, a large sample should be taken with a seine net. This will allow the accurate estimation of the actual fish stock as well as help plan the storing/wintering and sale of the produced fish.

6.8 FISHING

Many types of fishing equipment are used for catching fish in ponds. They can be lift nets, cast nets and seine/drag nets. Traps, fyke nets and gill nets are used for cropping (partial harvest of) table fish from the ponds and water reservoirs, where the use of a drag net is not possible because of the shape of the bottom or objects such as trees and trunks under the water surface. Traps set at or in the draining monks of ponds can also be used to catch advanced fry.

Catching of fish can be done for different purposes, such as sampling, cropping/selective fishing or harvesting.

When sampling, the objective is to catch that quantity of fish which represents the entire fish stock in a pond. For sampling advanced fry, a lift net can be used, while the elder age groups are sampled with a cast net or with a seine net. Sampling of fish is often done by attracting fish with feed. Sampling at the locations of feeding is also widely practiced.

Cropping (partial harvest) or selective fishing is done during the production season without lowering the water level of the pond. Fish are attracted with feed in order to congregate. However, the portion of feed used to attract fish should be much less than the usual feeding ration because fish captured and congested in a net may die if the fish have a full digestive tract.

The entire fish stock is captured from a pond during harvesting. It can be done only together with the partial or total drainage of water. For the sake of easier harvesting, internal or external fishing pits are constructed and used. The internal fishing pits are the lowest water drainage structures of the ponds. The bottom of the external harvesting pits should also be deeper than the other parts of the pond. As the water level decreases fish concentrate there and therefore can be captured quickly and easily.

For partial or full harvesting of advanced fry, 10–20 metre long and 2.5–3.5 metre deep nets are used. They are made of light but strong water-resistant curtain material which have netlike patterns and a mesh size of about 2–4 mm. For catching the larger age groups, nets should be mounted from factory-made net materials. It is a general rule that the nets should be about 1.5 times deeper and 1.5 times wider than the actual depth and width of the pond. However, this is applicable only in small ponds, harvesting pits or wintering ponds. The length of drag nets for harvesting large ponds should not be more than 80–120 metres, and their depth should be about four times deeper than the depth of water. When a longer net is needed in larger ponds, two – sometimes three – seine nets should be fixed together temporarily. The type of the net material is also important. It should be knotless; otherwise, it will wound the skin and scales of captured fish. These wounds are potential entry points for later infections. The mesh size of nets necessary for catching fish of different sizes are given in Table 11.

TABLE 11
Recommended *mesh size of nets for catching fish**

Age groups	Full mesh (mm)
Advanced fry	2–3
One-summer-old fish	5–10
Two-summer-old fish	15–30
Table fish	30–50

Source: Horváth and Pékh, 1984.

6.9 WINTERING OF FISH

In the countries of CEE and CCA, the water temperature of ponds is low in winter and therefore the fish hibernate. There are three options for wintering fish. The first option is to leave the fish in the rearing pond for the winter and harvest them in spring; the second is to keep the fish in special wintering ponds; and the third is stocking the fish in the pond in autumn where they will be reared the next season.

When fish are stored in wintering ponds they should be selected by species and size. This facilitates easy handling and stocking or selling of stored fish.

The water surface area of wintering ponds varies between a few hundred and a few thousand square metres. The water depth in the wintering pond should be between 1.8–2.5 metres. It is suggested to keep the wintering ponds dry for at least a few months before they are used for storing fish in order to complete the mineralization of organic materials. The bottom of wintering ponds should be cleaned and disinfected using evenly distributed powder or a solution of lime. The suggested quantities of the different age groups of fish which can be kept per unit area during the winter are presented in Annex 3.

Wintering ponds should have a continuous supply of fresh oxygen-rich water in the rate of 60–120 litres/minute per 1 tonne of fish, as detailed in the tables of Annex 3. In order to avoid overhibernation of fish, the water of wintering ponds should not be changed at the bottom. The current of fresh water should run over the fish hibernating at the bottom. This can be done by opening the water outlet at a certain distance (at least 30–35 cm) from the bottom (Antalfi and Tölg, 1971). This ensures that the water temperature will remain around 4 °C at the bottom. The oxygen content of arriving water can be increased if water is trickled. When water is recycled in the wintering ponds, the oxygen content of the water must be checked daily.

If ice develops on the surface of pond water, it is important to clean it, as well as to cut large holes to ensure a way for light and air to enter into the water.

Fish lose weight during wintering. When the water temperature is over 5 °C, carefully monitored and well-dosed feeding with pellets may be tried in order to reduce these losses (Antalfi and Tölg, 1971; Horváth and Pékh, 1984).

It has to be ensured that predatory species receive enough food fish during wintering. For this reason, about 10 percent of their total weight in food fish should be stocked together with them.

6.10 TRANSPORT OF FISH

Fish are usually transported alive within a fish farm, between farms and to the market. Transport within the fish farm should be done just as carefully as the long-distance transport between farms, i.e. overloading of the transport tanks should be avoided, even if the duration of transport is short. This will reduce *stress** and suffocation of fish.

Clean, oxygen-rich water and enough space in the transport tanks have to be ensured. There is negative correlation between the temperature of transporting water and the number and total weight of fish transported in a unit volume of water. As the duration of transport increases, the number of the transported fish should be decreased. The transportable quantities of the different fish species are presented in Annex 3.

In order to reduce excess consumption of oxygen, stress and mortality, fish should be prepared for long-distance transport. Keeping them in cages or tanks supplied with current water for a period of about 12 to 24 hours ensures that the digestive tract of fish empties; therefore, they will not contaminate the water of the transport tank with metabolites (*harmful gases**) and faeces (*harmful materials**).

During transport, the state of fish and the oxygen diffusion should be checked frequently in order to discover and repair possible problems.

6.11 HEALTH MANAGEMENT

The health of fish in ponds depends mainly on the environmental conditions and the skills of those who maintain them. Accordingly, the water quality, feeding and the intensity of production are the factors which determine the actual health condition of fish.

Fish should have an overall healthy look and they should search actively for food, react vividly to the received stimuli and disappear quickly if disturbed. Sick fish can be

BOX 2

Reducing the risk of spreading fish diseases

Uncontrolled, unregulated and illegal movements of fish unnecessarily increase the risk of spreading fish diseases (Arthur and Subasinghe, 2004). Before moving live fish of any age groups, strict and professional checking of health should be completed regardless whether it is done between fish farms of a country or countries or even between continents. Fish health examination and its proper certification are not only an important part of transporting fish, but also the most worthy preventions against huge economic losses, which fish diseases may cause.

recognized mainly by their behaviour and the condition of their body. Sick fish usually lose appetite, may swim vaguely, stagger, whirl or float. They may concentrate by the inflowing fresh water or gulp for air. They are often thin, covered with wounds and patches, and the body covering mucus can be lost or extremely thick.

Fish diseases are grouped according to their pathogens. There are viral, bacterial, fungal and parasite infections. The environmental related diseases are also important, which also may cause, directly or indirectly, mortalities.

Viruses are microscopic infectious agents which can multiply only within the living cells of the host. They are obligate intracellular parasites. They utilize the machinery of the parasitized cell for their own reproduction. Their shapes are spherical or similar to the shape of a bullet. Eleven major groups of viruses are known in higher vertebrates. The most significant groups of viruses in fish are the herpes viruses, rhabdo viruses, retro viruses, irido viruses and reo viruses. There are two viral diseases which should be known and recognized by fish culturists:

- Spring viraemia of carp (SVC). Its pathogen is the *Rhabdoviris carpio* (RNS virus). The pathology and clinical signs are changed behaviour, reduced respiratory rate and loss of balance. Uncoordinated swimming and abdominal distension, as well as skin darkening and paleness of gills, are typical symptoms. The most susceptible species are the bighead carp, crucian carp, grass carp, silver carp, common carp, koi carp, European catfish and the tench.
- Koi herpes virus (KHV) is caused by a DNA virus, which was first described in 1998. It appears when the water temperature is higher than 22 °C. In case of infection, the mortality may be as much as 80 to 100 percent. Its most obvious symptoms are the necrotic white-spotted bleeding gills, sunken eyes, and pale patches and small blisters on the body. These symptoms are often accompanied with secondary bacterial infections. Mainly common and koi carps are infected; however, a majority of Cyprinidae are carriers.

Bacterial diseases are responsible for high mortalities in fish ponds. The bacteria are usually secondary pathogens. They invade the tissues of the host fish and cause infection. Stress factors and other diseases, such as parasites, make the fish more susceptible to bacterial infections. Water with a high organic load helps the multiplication of bacteria.

They cause typically septicaemic and ulcerative symptoms such as scattered haemorrhages and ulcers on the skin, petechial haemorrhages on the gills and on the peritoneum, abdominal swelling and scale losses. In chronic cases, focal lesions may occur in the kidneys and in the spleen as well as in the liver.

The majority of bacterial fish pathogens are Gram negative. The most frequent bacterial fish pathogens are the Flexibacter, Edwardsiella, Yersinia, Pseudomonas, Aeromonas, Flavobacterium and Mycobacterium.

Fungal infections, which frequently appear in carp polyculture, are:

- *Saprolegnia* develops very quickly on dying or dead tissue. It develops readily on lesions and appears in white patches which show its obvious presence.
- *Branchiomyces* infection is the fungal infection of the gills, which cause necrosis of the tissues in severe cases. Infection may be diagnosed by finding the hyphae

and the spores of the fungus in fresh preparations from gills. The fungus attacks the lumen of the blood vessels of the gills and causes blockage, haemostasis, thromboses and necrosis of the affected gill filaments.

There are three different groups of fish parasites.

- Protozoa – The most frequent protozoa are the flagellates, ciliates and sporozoan pathogens (*Ichthyobodo necator*, *Ichthyophthirius multifiliis*, *Trichodina* sp., *Chilodonella* sp., Myxosporea), which live on the surface of body and gills. They spread from fish to fish, but they die quickly in water without host fish. They can infect all fish species.
- Platyhelminthes – They can be *monogeneas** (*Gyrodactylus*, *Dactylogyrus*), *digeneas** (*Sanguinicola*, *Diplostomum*) and cestodas or tapeworms (*Khawia*, *Bothryocephalus*). Almost all of the monogeneas are ectoparasites on the skin, gills and fins of fish where they are hooked on the tissue and they dissolve it with their enzymes in order to make it consumable for them. Cestodas live on the mucous membrane of the intestines from where they suck the already digested food.
- Crustaceans – *Argulus*, *Ergasilus* and *Lernaea* are the most frequent crustacean parasites of fish. They are ectoparasites. They live and feed on the skin of fish.

Environment and management-related diseases may develop because of stress factors which make fish susceptible to clinical diseases. This happens after thermal shock, overcrowding and traumas occurring during handling and transport. Irregular or inadequate feeding can also stress fish.

The efficient measure for keeping fish healthy is through prevention, which includes the maintenance of a proper rearing environment, ensuring adequate feeding and fish friendly handling.

In carp polyculture vaccination against viral diseases is economically not feasible. For controlling bacterial diseases, different antibiotic therapies can be applied. There are a wide range of treatments against fungus and the different parasites. In order to overcome health problems of fish, aid of a specialized veterinarian is needed, who knows both the diseases and the suitable (efficient, feasible and permitted) treatments.

6.12 FOLLOW-UP AND EVALUATION OF PRODUCTION FIGURES

Follow-up of production figures should be the part of a daily routine. With a few minutes of daily paper work all of the important information can be noted and kept for future evaluation.

It is suggested to have separate formats for registering incoming and outgoing items and for the follow-up of the different items used within the farm. There are many options and formats. The best ones are simple ledgers with columns, just like the ones presented in Figures 22, 23, 24, 25 and 26.

FIGURE 22
Register of purchased and used materials and equipment

Date	Item	Qty.	kg	Price		Pond No.	Observation
				Purchased	Used		

Note: Qty. = Quantity.

FIGURE 23
Feed register

Date	Pond 1		Pond 2		Pond 3		Pond 4		Pond 5	
	Type of Feed	Qty.	Type of Feed	Qty.	Type of Feed	Qty.	Type of Feed	Qty.	Type of Feed	Qty.

FIGURE 24
Register of fish mortality

Date	Pond No.	Dead Fish			Observation
		Species	Qty.	kg	

FIGURE 25
Fish stock register

Date	Pond No.	Species	Stocked		Fished	
			Qty.	kg	Qty.	kg

The production of each fish pond should be planned and evaluated on separate forms, which are suggested to contain the columns in Figure 26.

FIGURE 26
Table of planning and evaluation of fish production

Species	Stocking				Surv. %	Fishing				
	Age Group	Size (g)	Qty.	Total kg		Age Group	Size (g)	Qty.	Total kg	Total Net kg
Total/Average										

Note: Surv. % = Survival rate.

The suggested forms, together with the list of employed persons, facilitate the registration, follow-up and calculation of the basic physical and financial data and information of fish production.

In most of the countries of CEE and CCA, there are regulations and registers/forms, which are compulsory to complete and to submit to government authorities. These documents often request data similar to the data shown in the figures above. In this case pond owners and fish operators should obviously observe and follow the government system.

However, whatever system is used, there are key calculations which are essential for pond owners and operators. These are:

- use of water (total quantity, quantity per months, m^3/ha, etc.);
- use of lime, manure and fertilizers (total quantity and kg/ha);
- fish stocking data (fish/ha and kg/ha);
- individual growth of fish (g/fish/day or g/fish/season, how many fold fish grew, etc.);
- gross and net fish production (fish/ha and kg/ha);
- consumption of feed and FCR (total quantities and kg/gained weight);
- number of man-days (total of auxiliary labour, total of skilled labour and management, etc.); and
- expenses, income, gross and net profit (total and per hectare, etc.).

As soon as the above data are available, the profitability of production can be calculated easily.

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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 into which the arriving fish is stocked. When the temperature of the transporting water is the same as the temperature of the receiving water, fish can be released without a longer acclimatization. The *thermal shock** can be particularly dangerous for young fish. In case of several grades of differences, the adjusting process may last 30 to 40 minutes.
Advanced fry	A term for the development stage of young fish when the pre-adult form ends. By this stage, all organs of fish are developed. At this stage, the initiatives of the reproductive organs (testis or ovary) already show the sex of the young fish, even if this can only be seen by microscopic examination. The size of young fish at this stage is about 3 to 5 cm (0.5–2.5 grams). Fish at this development stage is also called nursed fry.
Aeration	The oxygen content of the water can be increased by mechanical agitators such as peddle wheels, or by ejectors, air diffusers or blowers. Aeration is a widespread technique for increasing the carrying capacity of fish ponds. The additional effect of aeration is that gases, such as carbon dioxide, methane, etc., can be "driven/aerated out" from the water. Aeration is also suitable for reducing or stopping the stratification of pond water.
Agricultural insecticide	See definition of insecticide.
Allocthonous	Material that is formed, developed or purchased from somewhere other than the place it is used.
Assimilation	The incorporation of new materials acquired by the digestion of food or photosynthesis into the internal structure of an organism (Allaby, 1994).
Autotrophic bacteria	Bacteria that obtains energy either through *photosynthesis** or *chemosynthesis**.
Benthos	The collective name of organisms which live on and in the pond bottom.
Biculture	The culture method of rearing two fish species together in the same pond.
Biocoenosis	The association of different organisms forming a closely integrated community in a biotope (Thain and Hickman, 1980).
Biofilter	See definition of biological filter.

Biological filters Filters used in intensive, industrial type fish culture systems for removing the ammonia from the recirculated water by nitrifying bacteria. Materials which have a large surface/volume ratio for 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.

Biomass or standing stock The total weight of a group or stock of living organisms (e.g. fish, plankton, etc.) or of a defined fraction of it (e.g. spawners) in an area at a particular time (FAO Glossary, 2009).

Biotope An environmental region characterized by certain conditions and populated by characteristic plants and animals (Allaby, 1994).

BOD The abbreviation of biological oxygen demand. It is the quantity of the oxygen (mg/l) consumed by bacteria for decomposition of the organic materials in the water. For the sake of easy comparison, the length of the period where the process takes place is standardized and indicated as a subscript index. BOD_5 means BOD in five days.

Buffer capacity See definition of pH.

Cage culture The name of a method suitable for intensive production of fish in different floating compartments prepared from nets or grids. Cages are few metres deep and can be kept in rivers, lakes, reservoirs or even in fish ponds. Cage culture is based on the same principles as tank culture. The fish in cages should be fed with a biologically complete diet. The water quality is maintained by the continuous exchange of water in the cage. This exchange is naturally ensured by the stream of rivers and by the currents caused by winds or movement of fish in the cages located in confined waters. The production in cages is calculated in unit volume (number of fish/m^3 and kg/m^3). If cages are placed in fish ponds, the unused feed is utilized by fish out of the cages, while faeces are ideal manure for increasing the natural fish food production of the pond. However, long-term accumulation of faeces under the cages may cause oxygen depletion and deterioration of the water quality. Therefore, cages should not be fixed in the same place of the pond for a long period of time. It is a rule of thumb that the carrying capacity of the ponds where fish are kept in cages should not be bigger than the carrying capacity of the pond stocked with free swimming fish.

Carnivorous A kind of animal which feeds on flesh.

CCA The abbreviation of Caucasus and Central Asia.

CEE The abbreviation of Central and Eastern Europe.

Chemosynthesis A process in which the oxidation of a simple chemical material ensures the energy for the production of the organic compounds from nutrients, carbon dioxide and water. The chemical materials can be hydrogen, carbon monoxide, ammonia, reduced sulphur, iron or manganese compounds, methane, etc. (Thain and Hickman, 1980).

Chinese major carps	They are the silver carp, bighead carp, grass carp and black carp. The last one is much less often cultured in fish farms than the first three species.
COD	The abbreviation of chemical oxygen demand. It is an indicator which shows the oxygen consumption of the chemical process through which all organic materials in the water can be oxidized.
Colour of water	The different chemical components dissolved or suspended in the water and from the suspended materials. The colour of water can be determined by the colour of planktonic organisms which live in it. If water is full of phytoplankton its colour will likely be green, which to a certain extent shows the productivity of the pond water. See more information in Chapter 6.5.
Concentration of salt	The quantity of dissolved salts in the water. It is expressed in mg/l or in thousandth or in a percentage. On the basis of salt concentration the different waters of earth are classified to sweet water (50–500 mg salt/litre or 0.05–0.5‰), continental salt waters (500–20 000 mg salt/litre or 0.5–20‰) and sea salt waters (20 000–35 000 mg salt/litre or 20–35‰). Between special conditions, there are waters with salt concentration even higher than that of the sea water. The salt concentration is sometimes expressed as specific conductivity of the water.
Detritus	The collective name of fragments of dead/decaying material of plant or animal origin.
Detritivorous	The type of living organism which feeds on detritus.
Digeneas	A parasite that needs two or more hosts to complete its life cycle.
Dissimilation	The opposite process of assimilation. It is the freeing of energy through the decomposition of body molecules. In the course of dissimilation green plants use oxygen and produce carbon dioxide.
Ecosystem	A discrete unit that consists of living and non-living parts, in which the energy flows via food chains and food webs (Allaby, 1994).
Effluent	The water which flows out from fish ponds or tanks. It is the collective name of liquid waste and sewage discharged into nature.
Enclosure culture	See definition of pen culture.
Feed conversion ration (FCR)	Indicates that quantity of feed which is necessary to produce 1 kilogram of live weight of fish. Accordingly, FCR is an important indicator of the efficiency of feeding.
Feeding habit	A complex characteristic of fish, which summarizes where, when and how fish take their food.
Feeding larvae	The practical term which is used to denominate the development stage when the fish larvae gulp air from the atmosphere and start to swim horizontally and feed from its environment.

Fingerling	A widely used term in fish culture. It refers to the size of young fish, which are about 7–15 cm (10–35 grams), which is the size of a smaller one-summer-old fish.
Fish manure	The faeces of fish. According to an ancient Chinese saying one grass carp feeds four other fish in a pond, because the faeces of grass carp serves as manure and supports the development of plankton. Also, common carps and a few other fish species consume this manure directly. In such a way, the fresh terrestrial grass/plant fed by grass carps will increase the fish production. A modern interpretation of the saying is that the manure of those fish species which receive supplementary feeds boosts the fish production through increased production of natural fish food.
Food conversion efficiency (FCE)	See definition of Feed conversion ration.
Food conversion rate (FCR)	See definition of Feed conversion ration.
Food spectrum	The range of consumed natural food, which modifies or even changes in the course of the individual life of fish.
Habitat	The living place of an organism or community, characterized by its physical or biotic properties (Allaby, 1994).
Harmful gases	Gases such as carbon dioxide (CO_2) and ammonia (NH_3) are the result of the respiration and metabolic processes of fish and other organisms. These gases, which are released into the water through the gills of fish, can be accumulated in the water in transporting devices. Harmful gases (for example, H_2S) can be produced by bacterial activity in the mud from where it enters into the water column.
Harmful materials	The decaying faeces that may accumulate in the water of transport tanks. Bacterial decomposition of the faeces consumes oxygen, and in addition harmful gases can be released during the process of decomposition. Excess levels of suspended soils (first of all the clay colloids) can also be harmful for fish.
Hibernation	A process where the body temperature of a *poikilotherm** organism decreases and its metabolism reduces to a minimum.
Herbivorous	A living organism which feeds on plants.
Insecticides	Chemical substances used for the selective elimination of cladocerans and copepods at the preparation of advanced fry rearing ponds. Chemicals that contain either organophosphoric acid ester or trichlorfon are usually suitable for this purpose (Horváth, Tamás and Coche, 1985). Because rotifers are from another taxonomic group, they are not sensitive to these insecticides. Before using a new brand of insecticide, laboratory and field tests should prove its suitability. The list of chemical products permitted or banned varies from country to country. Therefore, the use of some otherwise suitable insecticides may be banned in one country but permitted in another one.

Ion	An atom or group of atoms which has gained or lost one or more electrons and hence it carries a negative or positive charge (Sharp, 1990).
Manure	The faecal and urinary waste of animal husbandry.
Mesh size of net	The size of mesh opening in fishing nets (full mesh). The mesh size of the net is measured by two of the four sides of the mesh rhombus or square. Many manufacturers give the mesh size in half-mesh (or one bar) which equals only one of the four sides in the rhombus. It is therefore important to specify whether it is full-mesh or half-mesh.
Metabolism	The summary of life maintaining 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.
Monoculture	The stocking strategy in which only one fish species is reared in a fish pond.
Monogeneas	A parasite for which only one host is needed to complete its entire life cycle.
Natural fish food	The collective name of all those dead or living organisms and organic materials which grow/develop in ponds and which fish consume. Terrestrial plants given to grass carp, or the crushed snails and mussels used for feeding fish, are considered and called natural food incorrectly. These are supplementary feeds.
Natural food	See definition of natural fish food.
Natural productivity	A pond's capacity to produce natural fish food. It depends on the fertility of the water and the quality of the soil of the pond bottom and dikes.
Nitrogen forms	They are the atmospheric nitrogen (N_2), the nitrate (NO_3^-), nitrite (NO_2^-), ammonia in the form of free ammonia (NH_3), ammonium ion (NH_4^-), as well as nitrogen bound in organic materials. This latter explains its outstanding importance and role in plant production.
Omnivorous	The kind of living organisms which feed on both plants and animals.
Pen culture	Pen culture (or enclosure culture) is a special combination of fisheries management of natural waters and pond fish culture. Pens are small enclosures in natural waterbodies. They are fenced with nets or with other materials. In enclosures, the stocked fish are fed with supplementary feeds. The production in pens is calculated on the basis of unit area (fish/ha and/or kg/ha).
Periphyton	Water organisms attached or clung to the surface of submerged objects, such as stems or leaves of plants, stones, sticks, etc.

pH or H^+ ion concentration Derives from the fact that water molecule in nature dissociates to H^+ and OH^- *ions** according to the formula: $H_2O \leftrightarrow H^+$ and OH^- ions. pH is the negative logarithm (base 10) of the molar concentration of dissolved hydrogen ions (H^+). One litre of clean water consists of 0.0000007 grams of H^+ ion. The pH is used for expressing the H^+ ion concentration in the water. In order to avoid calculations with extremely small numbers, a logarithmical scale is used for the description of H^+ ion concentration. This concentration is expressed on the pH scale of 1–14 presented in Figure 2. There are different dissolved materials (gases and salts) in water. The positive and negative ions developing from the dissolved gases and salts can modify the ratio of these two ions in two directions. The pH of the water is determined by a very complex system of bicarbonates, carbonates, ammonia, different hydroxides, phosphates and silicates, as well as by calcium, magnesium and sodium ions and the carbon dioxide. The pH of pond waters are usually in the range of around neutral. If the soluble carbonates are abundant and the Ca, Mg and Na content of the water is also high, the pH is usually stable and the **buffer capacity** of pond water is high. It means that the fluctuation of pH will be less. Buffer capacity of pond water can be increased with liming.

Photosynthesis The process whereby green plants produce organic materials from inorganic plant nutrients, carbon dioxide and water with the energy/light of sun. In the course of photosynthesis plants produce oxygen.

Physical characteristics of water Water can be described with its physical conditions (ice, liquid and steam), temperature, specific heat, density, viscosity, surface tension, light conditions and its movements.

Physical condition of water The solid (ice), liquid (water) and gaseous (steam) forms. These forms change according to the temperature. Water is the only material which can be found widely and permanently in three different physical compositions in nature.

Phytoplankton The collective name of floating microscopic plants (see Figure 5).

Plankton The collective name of microscopic plants and animals, as well as bacteria, which float or drift in the water column. Accordingly, the plankton consists of bacterioplankton, phytoplankton and zooplankton (see Figures 5 and 7).

Poikilotherm See definition of temperature of water.

Polyculture The culture method when three or more fish species are reared together in the same pond.

Primary production The process where green plants produce organic materials and oxygen from inorganic materials.

Proteins One of the organic constituents of the body of plants and animals. Proteins always contain nitrogen. Only plants are able to produce their own proteins from inorganic materials. Animals need the proteins of other living organisms in order to produce their own proteins (body tissues).

Secchi disk A simple equipment to measure the transparency of pond water. Its diameter is about 20–25 cm. The opposite quarters of the disk are white and black. The disk is fixed on a line, which is marked at every 10 cm. The depth when the disc disappears is called Secchi disc visibility and used for evaluating the phytoplankton concentration of the pond water.

SL The abbreviation of the standard length of fish, which is the length measured between the tip of the snout and the base of the caudal fin.

Standing stock See definition of biomass.

Stress A term that has various definitions. Accordingly, the stress agents are those disturbing environmental forces which cause cerebral and physical strains and tensions in a living organism. Bad water quality, rough handling, bad quality of feed, presence of pathogens and some other factors, such as noise and vibration, are the most important stress factors.

Summer fish A term used for table fish, which reach its marketable size earlier than the end of the production season. The name derives from the fact that fish can be harvested during the summer.

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 to keep fish if the quality of water is good (rich in dissolved oxygen and free of metabolic products/faeces). The water quality in the tanks can be maintained by the exchange of water and supply of air. Tanks can be supplied by flow-through water, but the water can be partially or fully recirculated after its mechanical and biological filtration. Biologically complete feed should be fed to fish kept in tanks. The production in tanks should be expressed as the quantity of fish produced in unit volume (fish/m^3 and kg/m^3).

Taxonomy The theory and practice of classifying and naming living organisms.

Temperature of water A decisive environmental factor. Since fish are **poikilotherm**, they cannot regulate their body temperature. Therefore, the body temperature of fish follows the temperature of the ambient water. Along with the changing body temperature, the intensity of the metabolism increases or decreases. There are cold water (for example, trout) and warm water fish (for example, tilapia and African catfish). They do not tolerate water temperature out of their specific ranges. There are also species (for example, carps) which tolerate both mentioned ranges of water temperature.

Thermal circulation of water Daily changes of water temperature ensure the circulation between the pond surface and the bottom. The water is warmer at the surface than at the pond bottom during sunny days. At night when the air is cooler, the water at the surface also cools down, while the water temperature remains higher at the pond bottom. Since the specific weight of cooler water is higher than the warmer water, it sinks down to the bottom, pushing up the lighter warm water toward the surface. As the water gets to the surface it starts cooling down, so it sinks. This process maintains the water circulation and prevents the pond water from permanent stratification.

Thermal shock Reaction caused by sudden or rapid change of water temperature.

Titration A laboratory method when the unknown amount/ concentration of the substance in a solution is ascertained by measuring the volume of a standard reagent required to reach with it.

TL The total length of fish. This measurement also includes the caudal fin of the fish.

Total ammonia The sum of non-ionized ammonia (NH_3) and the ionized ammonia ($NH4^+$) dissolved in water. The quantity of total ammonia, which can be dangerous for the fish, depends on the pH, as summarized in Table 12 (Dévai, I. and Dévai, G., 1980).

TABLE 12
Dangerous quantity of total ammonia at different pH values

pH	12	11	10	9	8	7
$NH_3 + NH_4^+$ (mg/l)	1.00	1.05	1.54	5.55	33.3	100.0

Source: Dévai and Dévai, 1980.

Turbidity of water Determines the penetration of the light in water. Its cause can be mechanical (floating particles of different materials), chemical (colloids) or biological (plankton). The turbidity increases when currents are created in the ponds by wind or water flow or by the active movement of fish or other larger animals.

Water-affected areas and lands Temporary inland waters that remain after floods or rainy periods, or that develop because of the increasing level of the water table over land surface.

Water temperature See definition of temperature of water.

Zooplankton The collective name of tiny worms and insects swimming passively or actively in the water (see Figure 7). In other words it is the animal members of plankton (Thain and Hickman, 1980).

ANNEX 1

CONCISE DESCRIPTION OF FISH SPECIES USED IN CARP POLYCULTURE IN CEE AND CCA COUNTRIES

Fish species, such as common carp, breams, Chinese major carps and some predator species, are regularly stocked, while other fish species are only secondary members of the polyculture as they are stocked occasionally. Many smaller fish (rasbora, bleak, minnows, etc.) are found in natural waters and may enter the pond by water and become part of the polyculture by accident. They are called trash fish, which are often food competitors to the larger carps, but may also serve as food fish for the predatory species. Those which survive and remain in the pond can be harvested and sold as bait fish. This way these trash fish will also generate income. The actual and potential fish species of carp polyculture are:

1. Common carp (*Cyprinus carpio*)
2. Breams – Carp bream (*Abramis brama*), Common bream (*Abramis brama orientalis*) and Silver bream (*Abramis bjoerkna*)
3. Silver carp (*Hypophthalmichthys molitrix*) and Bighead carp (*Aristichtis nobilis*)
4. Grass carp (*Ctenopharyngodon idella*)
5. Black carp (*Mylopharyngodon piceus*)
6. Asp (*Aspius aspius*)
7. Tench (*Tinca tinca*)
8. Barbel (*Barbus sps.*)
9. Crucian carp (*Carassius carassius*) and Gibel (*Carassius auratus gibelio*)
10. Small Cyprinids
11. European eel (*Anguilla anguilla*)
12. Pike (*Esox lucius*)
13. Wels or European catfish (*Silurus glanis*)
14. European perch (*Perca fluviatilis*)
15. Pikeperch (*Stizostedion lucioperca*)
16. Volga pikeperch (*Stizostedion volgensis*)

1. Common carp (*Cyprinus carpio*)

Common carp is indigenous in the water systems of CEE and CCA. The maximum size, weight and age of common carp are about 120 cm *SL**, 40.1 kg and 38 years, respectively (Froese and Pauly, 2009).

Common carp is the most frequently produced freshwater fish species not only in CEE and CCA countries, but also worldwide. It was introduced to many regions out of its native range. It has several wild and improved strains and local forms. Most of the strains of common carp grow fast and reach the size of several kilograms within a few years.

This fish is a highly valued food and sport fish in CEE and CCA. In countries where people do not consume common carp, anglers still consider it a challenging sport fish, especially those specimens which are larger in size.

There are many different ways of catching common carp. Its population control is rather easy, even in bigger waterbodies. Since common carp is an excellent sport fish it can also be sold in the frame of angling tourism.

It is a hardy fish and tolerates a wide variety of environmental conditions. The species generally favours large waterbodies with slow flowing or standing water.

The optimum range of temperature, when common carp consume food intensively, is above 18 °C. During winter its metabolism slows down. If the water temperature is low enough (under 5–6 °C) the fish hibernate and stay at the bottom.

The common carp is omnivorous. A few weeks after hatching, young fish gradually switch from feeding on zooplankton to their species specific feeding habit and food range. Though zooplankton remains within the diet of the fish, its proportion reduces as fish grow bigger and other natural food items remain available. The main diet contains worms, snails, insects and their larvae, as well as soft particles of plants and decaying parts or bodies of plants and animals. Common carp is among the few fish species which dig on the pond bottom; therefore, it can utilize those natural food organisms of the benthos which are not accessible to other species. Common carp readily feeds on grains and balanced/pelleted feeds.

2. Breams

Breams such as carp bream (*Abramis brama*), common bream (*Abramis brama orientalis*) and silver bream (*Abramis bjoerkna*) may grow larger than a half metre in *TL** and several kilograms in weight, though this is exceptional. The largest individuals in a population are only 30–40 cm long. They can live longer than 10 years (Froese and Pauly, 2009).

Breams are important commercial species of the fisheries of the different natural and artificial waters of CEE and CCA. They are valued fish species. Therefore, they are part of carp polyculture in many countries. Breams are popular sport fishes.

The food spectrum and feeding habit of breams are similar to the common carp. They are strong food competitors, but common carp feeds more aggressively. Breams prefer insects and insect larvae but also prey on fish eggs and fish much smaller than them. Breams readily accept any type of grains or pelleted feeds.

3. Silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*Aristichtis nobilis*)

Out of the group of Chinese major carps, silver and bighead carps are very often discussed together because their feeding habit and reproductive biology are similar.

Their native range is the water system of Eastern Asia. Both of these species were introduced into the waters of many Asian, African, European, South and North American countries.

Both the silver and bighead carps grow fast and reach the size of several kilograms within a few years. They are "jumpy" fish when the water temperature is high. This suggests the use of suitable fishing gears selected in accordance with the season (water temperature).

Though they are warm-water fishes, they tolerate low water temperatures as well. Their metabolism slows down in winter, and they hibernate and stay at the bottom in groups, often according to species and age groups. The optimum range of temperature when they feed intensively is above 20 °C.

It is difficult to find genetically pure silver and bighead carps in some countries because the two species were crossbred both accidentally and intentionally.

A few weeks after hatching, the young fish gradually switch to their species specific feeding habit and food range. Both are filter feeders. They feed from the water column. Silver carp filtrates smaller, about 10–50 micron-size plankton, regardless whether it is phytoplankton or zooplankton. Bighead carp filtrates bigger, about 50–150 micron-size specimens of phytoplankton and zooplankton.

Both of these fish species take supplementary feeds if the size of floating particles is in the range which they can filter out of the water. Though they can filter feed particles, they are kept in pond polyculture because their main and practically only food is plankton.

4. Grass carp (*Ctenopharyngodon idella*)

The grass carp is the third species of the group of Chinese major carps. The largest specimen ever caught was about 1.5 metres long and 50 kilograms. It is a valuable member of carp polyculture and it is also a favoured sport fish. Still, it is considered as an invasive species in some countries.

Though grass carp is herbivorous, it feeds also on insects and their larvae, as well as on any small decaying or living organisms including fish fry. A few weeks after hatching, the young fish gradually switch from feeding on zooplankton to their species specific feeding habit and food range. In the beginning, they consume large algae and zooplankton, later they switch to leafs and tender stems of aquatic plants. As grass carp grows, it also consumes the harder parts of plants, especially when there is no other choice.

Grass carp readily accepts any fresh green terrestrial plants, especially leaves, but the bigger, more than 0.5 kilogram specimens, start to consume harder fibre-rich green stems with increased intensity if other more preferred food items are not available. Though it consumes grains and pelleted fish feed, these feeds may cause inflammation in the digestive track, as well as an unhealthy accumulation of fat in the liver.

5. Black carp (*Mylopharyngodon piceus*)

Black carp is the fourth species of the group of Chinese major carps. It feeds on worms, water snails and mussels. Even though the species was introduced to many countries, often accidently together with grass carp, it is much less widespread than grass carp.

6. Asp (*Aspius aspius*)

The published weight of the largest ever caught asp was 9 kilograms. Its maximum and common total length (TL) is 100 cm and 55 cm respectively (Froese and Pauly, 2009). It is a highly valued sport fish. It is often produced together with other carps in polyculture. Asp is a predator fish. It feeds on smaller fish and also consumes larger insects as well as frogs.

7. Tench (*Tinca tinca*)

It is a slow-growing fish that hardly reaches a size larger than 35–50 cm (Pintér, 1989). It is a popular sport fish and is considered a delicacy in many countries. Tench feeds on insects and insect larvae, as well on smaller snails and worms found in the benthos. It accepts and consumes feeds.

8. Barbel (*Barbus sps.*)

These fish grow slowly. Their common length is about 30–40 cm. It is a less frequent sport fish. It feeds from the benthos, mainly on insects and their larvae, as well as on worms. It accepts and consumes feeds.

9. Crucian carp (*Carassius carassius*) and Prussian carp (*Carassius auratus gibelio*)

Published maximum length and weight of crucian and Prussian carps is 64 cm TL (3 kg) and 45 cm TL (3 kg), respectively, but their common size do not exceed 25–30 cm. They are a good sport and bait fish. They may be both accidently and intentionally part of carp polyculture. They are strong food competitors to common carp, because large population of young fish can develop in the ponds which consume both natural and artificial food of common carp. In polyculture, they can serve as food fish for the predatory species.

10. Small cyprinids

There are a number of small cyprinids such as bleak (*Alburnus alburnus*), roach (*Rutilus rutilus*), souffie (*Leuciscus souffia*), dace (*Leuciscus leuciscus*), chub (*Leuciscus cephalus*), ide (*Leuciscus idus*), rudd (*Scardinius erythrophthalmus*) and minnow (*Phoxinus phoxinus*). They may enter accidently into a fish pond if it is filled/supplied with water without appropriate screening. Some of these species grow large while others remain small. They may serve as food for predatory fish species. The larger species and specimens are also used as sport fish while the smaller ones remain as bait fish.

Out of the small cyprinids, **rasbora (*Pseudorasbora parva*)** is the most frequently found species. It was introduced by accident to many of the CEE and CCA countries together with grass carp fingerlings. The final size of the rasbora is usually about 4–7 cm in the first year, if feeding conditions are favourable. During the subsequent years, it does not grow larger than 9–10 cm (Pintér, 1989). If rasbora reproduces in advanced fry and fingerling rearing ponds it may cause problems because it will prey on valuable fish larvae and it will remain a food competitor to the stocked carps. Though rasbora is considered as a pest, especially in fish seed producing ponds, it can still be useful as forage or bait fish.

11. European eel (*Anguilla anguilla*)

The eel is hardly stocked intentionally into fish ponds, but as a migratory fish it may enter into ponds with water. Therefore eel can be only found in fish ponds accidently.

12. Pike (*Esox lucius*)

The pike is a voracious cannibalistic predatory fish. It is a very popular sport fish in many countries. Its maximum size is 150 cm TL. The published maximum weight and age are 28.4 kg and 30 years (Froese and Pauly, 2009).

The advanced fry is reared in monoculture while the elder age groups are produced in carp polyculture. In pond conditions, the size of pike will be about 20–25 cm, 30–40 cm and 35–45 cm by the end of the first, second and third year, respectively (Pintér, 1989).

13. Wels or European catfish (*Silurus glanis*)

European catfish is one of the largest freshwater fish species. It may typically grow to the size of 1.5–2.5 metres in nature. According to FishBase, its maximum length is 500 cm TL. The maximum published weight and age of European catfish are 306 kg and 80 years (Froese and Pauly, 2009).

Under fish pond conditions, it can reach the size of 1.5–3 kg within three to four seasons. It is a widely produced commercial fish and is also a popular sport fish. European catfish is an important member of carp polyculture because it consumes intensively the unwanted fish and tadpoles, smaller birds, etc. As European catfish is a hardy fish its handling is easy.

The European catfish is increasingly produced in monoculture because it accepts and utilizes well the offered pelleted feeds.

14. European perch (*Perca fluviatilis*)

The common and maximum length of European perch is 25 cm (TL) and 60 cm (ST), respectively. The maximum published weight is 4.75 kg (Froese and Pauly, 2009). Its flesh is boneless. Sport fishing of perch is very popular in many countries. In fish ponds, it is a valuable species because it can be easily sold.

15. Pikeperch (*Stizosteidon lucioperca*)

Pikeperch may grow larger than one metre in length and 10–15 kg in weight (Pintér, 1989). Under fish pond conditions, it grows fast and reaches the size of 1 kg by the end of the third year. Pikeperch is one of the more valued freshwater fish. The flesh of pikeperch is a highly desirable delicacy. In addition, it is an exceptionally popular sport fish; therefore, it is widely produced in carp polyculture.

It is not hardy and less capable to adjusting to the low oxygen content of water, especially if it is paired with high water temperature. Pikeperch requires special treatment at harvesting. This means that the captured fish should be removed from the net immediately before other species.

Larvae of pikeperch start feeding on rotifers, then switches to feeding on bigger planktonic crustaceans. About one month after hatching, pikeperch starts predation on insect and fish larvae as well as on smaller fish.

The growing fish performs typical predatory behaviour. They hunt in packs when they collectively surround shoals of other but smaller freshwater species and then attack them. They also prey on each other. Later, at an older age they hunt alone near the bottom. They often hunt at night. Their eyes are large and have a reflective material behind the eyeball that helps them to see the maximum in low light conditions (Pénzes and Tölg, 1977).

16. Volga pikeperch (*Stizosteidon volgensis*)

The Volga pikeperch grows to a smaller size than pikeperch. It can also be part of carp polyculture.

Many other less or locally cultured fish species have not been mentioned or described in this book; however, they still may be part of carp pond polyculture. The FAO Web site of Cultured Aquatic Species[1] and the Web site of FAO supported FishBase[2] will help to find both orientations and details not only about the discussed but also about some additional fish species.

It is also suggested to refer to some additional FAO publications about the different fish species of carp pond polyculture, which are listed in Chapter 2 of Annex 5.

[1] www.fao.org/fishery/culturedspecies/search/en
[2] www.fishbase.org

ANNEX 2

FCR OF FEEDS USED IN CARP POLYCULTURE

(Antalfi and Tölg, 1971; Tasnádi, 1983; Horváth, 2000)

Name of Feed	Dry Matter (%)	Digestible Protein	Fat	FCR
		%		
Grains				
Wheat	87	10	1	4–5
Rye	87	9	1	4–5
Barley	87	8	2	4–5
Maize	87	8	4	4.5
Millet	87	8	4	4–5
Sorghum	87	6	3	4.5–5
Legumes				
Pea[1]	87	19	1	3–4
Bean[2]	87	20	1	3–4
Soybean[2]	90	28	16	2–3
Lupine (sweet)[3]	87	33	6	2.5–3
Lupine (bitter)[3]	87	30	5	2.5–3.5
By-products of milling and processing industry				
Wheat bran	87	10	2	8–10
Mill sweeping	87	10	-	5–15
Extruded sunflower	90	16	16	3–6
Raw fish[4]	20	16	-	6–10
Raw meat cuttings[4]	23	19	-	6–15
Protein-rich meals				
Fish meal	88	44	2	2–3
Meat meal	89	64	-	2–3
Green feeds				
Grass	30	2	4	20–30
Reed	28	1	-	20–70
Lucerne	24	3	-	15–25
Clover	18	3	-	20–30

More and additional information on fish feeding and feeds are presented in the FAO publications listed in Chapter 5 of Annex 5. Out of these publications, reference 5.21 (Tacon, Metian and Hasan, 2009) contains the average proximate compositions of all important actual and potential fish feeds.

[1] It should be ground or/and soaked well before use.
[2] It should be steamed, boiled or roasted before use.
[3] It should be ground and soaked well before use.
[4] Use of raw fish and meat in aquaculture is banned in the European Union. Therefore, they should be processed (steamed, boiled, etc.) before feeding them in ponds.

ANNEX 3

MAIN DATA ON WINTERING AND TRANSPORT OF FISH

The precondition of the successful wintering and transport of fish, beyond the good technical conditions of structures and devices, is the perfect physical condition and health of parasite-free fish.

There are well-established practice-based experiences on how much fish are usually wintered or transported in a shorter or longer period of time. The tables presented below contain these guiding figures, which can help to plan and perform both the wintering and the transport of fish. A wide range of options are presented in the tables. As a rule of thumb, beginners should follow the provided data with care. Within the indicated ranges they should select the lower quantities or the shorter periods in order to remain on the safe side. Selection of smaller stocking densities within the given ranges is also important if the wintering ponds are old.

TABLE 3.1
Practical figures of wintering fish

Age groups	kg/m^2	fish/m^2	Quantity of water (l/min./100 kg fish)	Source
One-summer-old fish	4–8	80–400	7–10	Horváth and Pékh, 1984
Two-summer-old fish	6–8	40–60	6–8	Horváth and Pékh, 1984
Table fish	8–12	7–10	6–7	Horváth and Pékh, 1984

Individual size of fish (gr.)	Fish species (kg/m^2)			Quantity of water (l/min./100 kg fish)	Source
	Grass carp	Common carp	Silver carp		
10–20	8–12	8–10	7–8	6–12	Antalfi and Tölg, 1971
20–50	12–14	10–12	8–10	6–12	Antalfi and Tölg, 1971
200–600	18–25	15–20	10–12	6–12	Antalfi and Tölg, 1971
1 000–3 000	20–30	18–22	12–15	6–12	Antalfi and Tölg, 1971

TABLE 3.2
Transport of larvae in plastic bag with pure oxygen (30 l water and 30 litre oxygen)

Species	Temperature of transporting water (duration of transport: 2–12 hours)			
	10 °C	15 °C	20 °C	25 °C
Pike	50 000–150 000	20 000–75 000	-	-
Common carp	-	200 000–400 000	100 000–200 000	60 000–120 000
Chinese major carps	-	-	80 000–150 000	30 000–80 000

Source: Antalfi and Tölg, 1971.

TABLE 3.3
Transport of advanced fry (2–3 cm) in plastic bag with pure oxygen (30 l water and 30 litre oxygen)

Species	Temperature of transporting water (duration of transport: 8–48 hours)			
	10 °C	15 °C	20 °C	25 °C
Pike	1 500–3 500	1 000–2 500	-	-
Pikeperch	-	500–2 000	300–1 000	-
Common carp	-	8 000–15 000	6 000–12 000	5 000–10 000
Chinese major carps	-	-	5 000–10 000	3 000–8 000
European catfish	-	-	4 000–8 000	2 000–3 000

Source: Antalfi and Tölg, 1971.

TABLE 3.4

Transport of the different age groups in 1 m^3 water under continuous oxygen diffusion

Species	Temperature of transporting water			
	4–15 °C		16–20 °C	
	Duration of transport (hours)			
	2–6	6–12	2–6	6–12
Advanced fry				
Common carp (No.)	-	-	150 000	100 000
Chinese major carps (No.)	-	-	120 000	80 000
European catfish (No.)	-	-	100 000	60 000
One-summer-old fish				
Common carp (kg)	120	80	70	50
Grass carp (kg)	130	90	80	60
Silver carp (kg)	50	30	30	25
Bighead carp (kg)	130	90	80	65
European catfish (kg)	140	100	80	65
Pikeperch (kg)	40	25	-	-
Tench (kg)	70	50	-	-
Two-summer-old fish				
Common carp (kg)	300	200	175	140
Grass carp (kg)	325	225	200	160
Silver carp (kg)	125	75	75	60
Bighead carp (kg)	325	225	200	160
European catfish (kg)	350	250	200	160
Pikeperch (kg)	100	60	-	-
Tench (kg)	175	125	-	-
Table fish				
Common carp (kg)	600	400	350	280
Grass carp (kg)	650	450	400	320
Silver carp (kg)	250	150	150	120
Bighead carp (kg)	650	450	400	320
European catfish (kg)	700	500	400	320
Pikeperch (kg)	200	120	-	-
Tench (kg)	350	250	-	-

Source: Horváth and Pékh, 1984.

TABLE 3.5

Transport of advanced fry (2–3 cm) in 0.1 m^3 water under continuous oxygen diffusion

Species	Temperature of transporting water (duration of transport: 2–12 hours)			
	10 °C	15 °C	20 °C	25 °C
Pike	3 000–8 000	2 500–5 000	-	-
Pikeperch	2 000–6 000	2 000–4 000	500–2 000	200–1 000
Common carp	-	13 000–30 000	5 000–15 000	2 000–5 000
Chinese major carps	-	-	6 000–18 000	3 000–7 000
European catfish	-	-	1 500–4 000	3 000–5 000

Source: Antalfi and Tölg, 1971.

ANNEX 4

APPLICABLE PRODUCTION PATTERNS OF CARP POLYCULTURE IN CEE AND CCA COUNTRIES

The production patterns presented in this annex are to demonstrate numbers, trends and ranges of stocking the different age groups of fish. They are also to show some typical practical figures of survival, hence the expected number and weight of fish produced under extensive, semi-intensive and intensive conditions.

It is a basic rule that rounded figures allow easy planning and evaluation of both stocking and harvesting. Therefore we also rounded the figures of the presented tables in the same way as it should be done by the fish producers.

TABLES 4.1: ADVANCED FRY PRODUCTION PATTERNS

4.1.1 Pike – Production period: 4–6 weeks

Intensity of stocking	Stocking per hectare				Expected survival rate (%)		Harvesting per hectare				
	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Low	High	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Net weight (kg)
Extensive	Feeding larvae	-	100 000	-	10	40	Advanced fry	1.50	25 000	40	40
Intensive			500 000	-				0.25	125 000	30	30

4.1.2 Pikeperch – Production period: 4–6 weeks

Intensity of stocking	Stocking per hectare				Expected survival rate (%)		Harvesting per hectare				
	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Low	High	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Net weight (kg)
Extensive	Eggs on nests	-	500 000	-	5	20	Advanced fry	1.00	65 000	65	65
Intensive			2 000 000	-				0.25	250 000	65	65

Intensity of stocking	Stocking per hectare				Expected survival rate (%)		Harvesting per hectare				
	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Low	High	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Net weight (kg)
Extensive	Feeding larvae	-	250 000	-	10	40	Advanced fry	1.00	65 000	65	65
Intensive			1 000 000	-				0.25	250 000	65	65

4.1.3 European catfish – Production period: 4–6 weeks

Intensity of stocking	Stocking per hectare				Expected survival rate (%)		Harvesting per hectare				
	Age Group	Avg. size (gr./fish)	Number	Total weight (kg)	Low	High	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Net weight (kg)
Extensive	Feeding larvae	-	50 000	-	20	40	Advanced fry	2.00	15 000	30	30
Intensive			250 000	-				0.50	75 000	40	40

4.1.4 Carps (common carp, silver carp and grass carp) – Production period: 3–6 weeks

Intensity of stocking	Stocking per hectare				Expected survival rate (%)		Harvesting per hectare				
	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Low	High	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Net weight (kg)
Extensive	Feeding larvae	-	500 000	-	30	40	Advanced fry	2.00	175 000	350	350
Intensive	Feeding larvae	-	2 000 000	-	30	40	Advanced fry	0.50	700 000	350	350

4.1.5 Breams – Production period: 4–6 weeks

Intensity of stocking	Stocking per hectare				Expected survival rate (%)		Harvesting per hectare				
	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Low	High	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Net weight (kg)
Extensive	Feeding larvae	-	500 000	-	30	40	Advanced fry	1.00	175 000	175	175
Intensive	Feeding larvae	-	1 000 000	-	30	40	Advanced fry	0.50	350 000	175	175

4.1.6 Tench – Production period: 4–6 weeks

Intensity of stocking	Stocking per hectare				Expected survival rate (%)		Harvesting per hectare				
	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Low	High	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Net weight (kg)
Extensive	Feeding larvae	-	500 000	-	30	40	Advanced fry	0.50	175 000	90	90
Intensive	Feeding larvae	-	1 000 000	-	30	40	Advanced fry	0.25	350 000	90	90

TABLES 4.2: ONE-SUMMER-OLD FISH PRODUCTION PATTERNS

4.2.1 Extensive production of medium-size one-summer-old fish: 10–12 weeks

Species	Stocking per hectare					Expected survival rate (%)		Harvesting per hectare				
	Age group	Avg. Size (gr./fish)	Number	%	Total weight (kg)	Low	High	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Net weight (kg)
Common carp	Fry	1.0	4 500	30	5	50	70	One-summer-old fish	50	2 700	135	130
Silver carp Bighead carp		1.0	4 500	30	5	50	70		50	2 700	135	130
Grass carp		1.0	4 500	30	5	50	70		50	2 700	135	130
Predators		0.5	1 500	10	-	50	70		50	900	45	45
Total	-	-	**15 000**	**100**	**15**	-	-	-	-	**9 000**	**450**	**435**

Observation: The ratio between silver and bighead carps should be 80–90% and 10–20%.

4.2.2 Semi-intensive production of small one-summer-old fish: 10–12 weeks

Species	Stocking per hectare					Expected survival rate (%)		Harvesting per hectare				
	Age group	Avg. size (gr./fish)	Number	%	Total weight (kg)	Low	High	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Net weight (kg)
Common carp	Fry	1.0	50 000	50	50	50	70	One-summer-old fish	25	30 000	750	700
Silver carp Bighead carp		1.0	35 000	35	35	50	70		25	21 000	530	495
Grass carp		1.0	10 000	10	10	50	70		25	6 000	150	140
Predators		0.5	5 000	5	-	50	70		25	3 000	80	80
Total	-	-	**100 000**	**100**	**95**	-	-	-	-	**60 000**	**1 510**	**1 415**

Observation: The ratio between silver and bighead carps should be 80–90% and 10–20%.

4.2.3 Semi-intensive production of large one-summer-old fish: 10–12 weeks

Species	Stocking per hectare					Expected survival rate (%)		Harvesting per hectare				
	Age group	Avg. size (gr./fish)	Number	%	Total weight (kg)	Low	High	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Net weight (kg)
Common carp	Fry	1.0	12 500	50	10	50	70	One-summer-old fish	100	7 500	750	740
Silver carp Bighead carp		1.0	9 000	36	10	50	70		100	5 400	540	530
Grass carp		1.0	2 500	10	-	50	70		100	1 500	150	150
Predators		0.5	1 000	4	-	50	70		100	600	60	60
Total	-	-	**25 000**	**100**	**20**	-	-	-	-	**15 000**	**1 500**	**1 480**

Observation: The ratio between silver and bighead carps should be 80–90% and 10–20%.

TABLES 4.3: TWO-SUMMER-OLD FISH PRODUCTION PATTERNS

4.3.1 Extensive production of two-summer-old fish: 22–24 weeks

Species	Stocking per hectare					Expected survival rate (%)		Harvesting per hectare				
	Age group	Avg. size (gr./fish)	Number	%	Total weight (kg)	Low	High	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Net weight (kg)
Common carp	One-summer-old fish	25	1 000	29	25	60	80	Two-summer-old fish	250	700	175	150
Silver carp Bighead carp		25	1 000	29	25	60	80		250	700	175	150
Grass carp		25	1 000	29	25	60	80		250	700	175	150
Predators		20	500	14	10	60	80		250	350	90	80
Total	-	-	**3 500**	**100**	**85**	-	-	-	-	**2 450**	**615**	**530**

Observation: The ratio between silver and bighead carps should be 80–90% and 10–20%.

4.3.2 Semi-intensive production of two-summer-old fish: 22–24 weeks

Species	Stocking per hectare					Expected survival rate (%)		Harvesting per hectare				
	Age group	Avg. size (gr./fish)	Number	%	Total weight (kg)	Low	High	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Net weight (kg)
Common carp	One-summer-old fish	25	5 000	50	125	60	80	Two-summer-old fish	250	3 500	875	750
Silver carp Bighead carp		25	3 500	35	90	60	80		250	2 450	610	520
Grass carp		25	1 000	10	25	60	80		250	700	175	150
Predators		20	500	5	10	60	80		250	350	90	80
Total	-	-	**10 000**	**100**	**250**	-	-	-	-	**7 000**	**1 750**	**1 500**

Observation: The ratio between silver and bighead carps should be 80–90% and 10–20%.

4.3.3 Semi-intensive production of large two-summer-old fish: 22–24 weeks

Species	Stocking per hectare					Expected survival rate (%)		Harvesting per hectare				
	Age group	Avg. size (gr./fish)	Number	%	Total weight (kg)	Low	High	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Net weight (kg)
Common carp	One-summer-old fish	100	1 500	50	150	80	90	Two-summer-old fish	750	1 280	960	810
Silver carp Bighead carp		100	1 000	33	100	80	90		750	850	640	540
Grass carp		100	350	12	35	80	90		750	300	225	190
Predators		75	150	5	10	80	90		750	130	100	90
Total	-	-	**3 000**	**100**	**295**	-	-	-	-	**2 560**	**1 925**	**1 630**

Observation: The ratio between silver and bighead carps should be 80–90% and 10–20%.

TABLES 4.4: TABLE FISH PRODUCTION PATTERNS

4.4.1 Semi-intensive production from large one-summer-old fish: 22–24 weeks

Species	Stocking per hectare					Expected survival rate (%)		Harvesting per hectare				
	Age group	Avg. size (gr./fish)	Number	%	Total weight (kg)	Low	High	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Net weight (kg)
Common carp	One-summer-old fish	100	750	50	75	80	90	Table fish	1 250	640	800	725
Silver carp Bighead carp		100	450	30	45	80	90		1 250	380	475	430
Grass carp		100	200	13	20	80	90		1 250	170	215	195
Predators		75	100	7	10	80	90		1 250	90	110	100
Total	-	-	**1 500**	**100**	**150**	-	-	-	-	**1 280**	**1 600**	**1 450**

Observation: The ratio between silver and bighead carps should be 80–90% and 10–20%.

4.4.2 Extensive production from two-summer-old fish: 22–24 weeks

Species	Stocking per hectare					Expected survival rate (%)		Harvesting per hectare				
	Age group	Avg. size (gr./fish)	Number	%	Total weight (kg)	Low	High	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Net weight (kg)
Common carp	Two-summer-old fish	250	210	30	50	80	90	Table fish	1 250	180	225	175
Silver carp Bighead carp		250	210	30	50	80	90		1 250	180	225	175
Grass carp		250	210	30	50	80	90		1 250	180	225	175
Predators		200	70	10	10	80	90		1 250	60	75	65
Total	-	-	**700**	**100**	**160**	-	-	-	-	**600**	**750**	**590**

Observation: The ratio between silver and bighead carps should be 80–90% and 10–20%.

4.4.3 Semi-intensive production from two-summer-old fish: 22–24 weeks

Species	Stocking per hectare					Expected survival rate (%)		Harvesting per hectare				
	Age group	Avg. size (gr./fish)	Number	%	Total weight (kg)	Low	High	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Net weight (kg)
Common carp	Two-summer-old fish	250	1 000	50	250	80	90	Table fish	1 250	850	1.065	815
Silver carp Bighead carp		250	700	35	175	80	90		1 250	600	750	575
Grass carp		250	200	10	50	80	90		1 250	170	215	165
Predators		200	100	5	20	80	90		1 250	80	100	80
Total	-	-	**2 000**	**100**	**495**	-	-	-	-	**1 700**	**2 130**	**1 635**

Observation: The ratio between silver and bighead carps should be 80–90% and 10–20%.

4.4.4 Summer fish production from large two-summer-old fish: 12–18 weeks

Species	Stocking per hectare					Expected survival rate (%)		Harvesting per hectare				
	Age group	Avg. size (gr./fish)	Number	%	Total weight (kg)	Low	High	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Net weight (kg)
Common carp	Two-summer-old fish	750	2 000	50	1 500	80	90	Table fish	1 250	1 700	2 125	625
Silver carp Bighead carp		750	1 250	31	935	80	90		1 250	1 060	1 325	390
Grass carp		750	500	13	375	80	90		1 250	430	540	165
Predators		600	250	6	150	80	90		1 250	210	260	110
Total	-	-	**4 000**	**100**	**2 960**	-	-	-	-	**3 400**	**4 250**	**1 290**

Observation: The ratio between silver and bighead carps should be 80–90% and 10–20%.

TABLES 4.5: SPECIAL TABLE FISH PRODUCTION PATTERNS

4.5.1 Extensive production in water reservoirs

Species	Stocking per hectare					Expected survival rate (%)		Harvesting per hectare				
	Age group	Avg. size (gr./fish)	Number	%	Total weight (kg)	Low	High	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Net weight (kg)
Common carp	Two-summer-old fish	250	150	30	40	50	70	Table fish	1 500	90	135	95
Silver carp Bighead carp		250	150	30	40	50	70		1 500	90	135	95
Grass carp		250	150	30	40	50	70		1 500	90	135	95
Predators		200	50	10	10	50	70		1 500	30	45	35
Total	-	-	**500**	**100**	**130**	-	-	-	-	**300**	**450**	**320**

Observation: The ratio between silver and bighead carps should be 80–90% and 10–20%.

4.5.2 Biological control of water weeds

Species	Stocking per hectare					Expected survival rate (%)		Harvesting per hectare				
	Age group	Avg. size (gr./fish)	Number	%	Total weight (kg)	Low	High	Age group	Avg. size (gr./fish)	Number	Total weight (kg)	Net weight (kg)
Common carp	One-summer-old fish	25	50	2	-	50	70	Two-summer-old fish	750	30	20	20
Silver carp Bighead carp	One-summer-old fish	25	100	3	-	50	70	Two-summer-old fish	750	60	50	50
Grass carp	One-summer-old fish (S)	25	1 250	42	30	50	70	Two-summer-old fish	750	750	560	530
	One-summer-old fish (L)	100	1 000	33	100	60	80	Two-summer-old fish	750	700	530	430
	Two-summer-old fish (S)	250	500	17	130	80	90	Table fish	1 250	430	540	410
	Two-summer-old fish (L)	750	50	2	40	80	90	Table fish	2 500	40	100	60
	Grass carp total	-	**2 800**	**93**	**300**	-	-	-	-	**1 920**	**1 730**	**1 430**
Predators	One-summer-old fish	20	50	2	-	50	70	Two-summer-old fish	500	30	20	20
Total	-	-	**3 000**	**100**	**300**	-	-	-	-	**2 040**	**1 820**	**1 520**

Observation: The ratio between silver and bighead carps should be 80–90% and 10–20%; (S) means small and (L) means large.

ANNEX 5

LIST OF RECOMMENDED FURTHER READINGS OF RELATED LITERATURE PUBLISHED BY FAO

The Fisheries and Aquaculture Department of FAO has been supporting the development of aquaculture since the 1960s. For this reason numerous useful documents were elaborated and published between 1960 and 2009. The following selection of technical papers and reports are recommended to refer to, if useful, additional carp polyculture related information is needed. The recommended publications are grouped in 11 chapters. Many of these publications can be found and downloaded from the Internet by using one of the search engines.

1. **Bibliographies and index lists of FAO publications**
2. **Fish species**
3. **Fish propagation and fish seed production**
4. **Production, management and marketing**
5. **Fish feeds and feeding**
6. **Transport of fish**
7. **Fish health, welfare and quality**
8. **Environment and water quality**
9. **Civil engineering (construction of hatchery and ponds)**
10. **Research**
11. **Regional and country-related general and technical reviews and papers**

1. BIBLIOGRAPHIES AND INDEX LISTS OF FAO PUBLICATIONS

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This technical paper is a basic guide to carp pond polyculture practicable in the countries of Central and Eastern Europe, the Caucasus and Central Asia. It provides an overview on the guiding principles, aspects and tasks, and presents the most applicable production techniques and patterns of carp polyculture. For further reading and more in-depth information on the suggested techniques and technologies, it also includes a list of relevant FAO publications. The manual aims to help identify resources and contribute to the successful planning and realization of fish production by those fish pond owners and operators who need to strengthen and improve their knowledge on the subject.

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