FIELD GUIDE TO FEEDING FISH

IN CENTRAL AND EASTERN EUROPE, THE CAUCASUS AND CENTRAL ASIA

ALLER AQUA

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FOREWORDS

Aquaculture is the fastest-growing food sector in the world and now provides a source of income as well as precious nutrients for millions of households worldwide. It has the potential to close the increasing gap between the demand and supply of fish for human consumption. To date, roughly 300 fish species are professionally farmed worldwide, primarily dominated by only a few species. In combination with the diverse production systems and environmental conditions, aquaculture represents vast opportunities but also faces knowledge gaps, not only but mainly concerning feed use and feeding management. Considering the fact that expenses for fish feed are the most significant cost segment in most aquaculture operations, improvements in feed use and feeding management have the potential to professionalize fish farmers around the globe.

This field guide aims to compile comprehensive and holistic information about fish biology, culture systems, environment, feeds, and feeding management, emphasizing Central and Eastern Europe, the Caucasus, and Central Asia. This document is a joint effort between science and industry, merging the authors' vast knowledge with the commercial success in feed development and application of Aller Aqua in the last decades in the species and regions of interest. Therefore, this field guide provides invaluable information, knowledge, and experience for anyone interested in fish farming and feeding.

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CONTENT

ANNEXES AND APPENDIX

ABBREVIATIONS AND ACRONYMS

~	Approximately equal to
<	Less than
>	Greater than
≤	Less than or equal
≥	Greater than or equal
µ	micron
BOD*	Biochemical or biological oxygen demand
CA	Crude ash
CBF	Culture based fishery
CF	Crude fibre
CL	Crude lipid
COD*	Chemical oxygen demand
CP	Crude protein
CSC	Critical standing crop
DE	Digestible energy
DM	Dry matter
DO	Dissolved oxygen
EPA	United State Environmental Protection Agency
FAO	Food and Agriculture Organization of the United Nations
FCR	Feed conversion ratio
GE	Gross energy
n/a	Not applicable
NASA	National Aeronautics and Space Administration
NFE	Nitrogen free extract
Ng	nanogram (0.000 000 001 g)
P-FCR	In-pond feed conversion ratio
ppm	Part per million
ppt	Part per thousand
RAS	Recirculation aquaculture system
SAFA	Saturated fatty acid
SC	Standing crop
SL	Standard length
TAN	Total ammonia nitrogen
TDS	Total dissolved salt
TL	Total length
TSS	Total suspended solids
UFA	Unsaturated fatty acid
WHO	World Health Organization

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INTRODUCTION TO THIS FIELD GUIDE

Inland fishery and freshwater fish culture are both important sectors of the region. Environmentally friendly fishery management of *natural waters** guarantees a balanced aquatic life and facilitates commercial and/or recreational fisheries.

Nowadays, proper fishery management of natural waters cannot succeed without culturing fish as that ensures stocking material (i.e., fish seed) for differently utilized waters. Beyond *culture-based fishery** (CBF), freshwater fish culture also has the role to fill in the increasingly growing gap between the production of *capture fishery** and the increasing market demand for food fish. In addition to producing stocking material for natural waters and satisfying market demand for fish, the roles of fish culture also include the supply of good quality, contamination-free table fish.

1.1 PURPOSE

Innovation, improved feeding efficiency, reduced environmental impact, sustainable intensification, and diversification of fish production are the driving elements of fish culture development today, which cannot be expected without widely available field extension.

Natural conditions (native and introduced fish fauna, characteristics of natural waters, climate, etc.) and traditions in the region covered by this book strongly determine the dominant production system, which is carp pond polyculture. Even though conditions and traditions cannot be radically changed, there is still a huge potential for further development, provided that all information on intensification and diversification of fish production is readily available for interested farmers.
Consequently, the purpose of this field guide is to provide support in the form of technical information to help farmers:

- To review and take into consideration all important technical factors of fish production;
- To identify and exploit resources and opportunities;
- To intensify and diversify fish production in already existing fish farms and fishery management in natural waters;
- To identify new suitable water resources where one of the fish culture systems discussed in this book can be successfully practiced.

1.2 GEOGRAPHICAL AREA AND FISH SPECIES COVERED

The geographical area this book covers includes all countries of three sub-regions of Eurasia: Central and Eastern Europe (CEE), the Caucasus (CAC), and Central Asia (CA). Though the area made up of the listed three sub-regions is huge and divided by some of the world's largest rivers, it still has several common and similar features that determine fishery and fish production. These are, among others, climate, the range of native and introduced fish fauna, and a common history and traditions of the development of fish culture in the entire region (see details in Annex 1).

1.3 STRUCTURE AND CONTENTS

The structure of the book is simple; it consists of seven chapters. After the introduction in **Chapter 1**, the subsequent chapters discuss technical aspects which determine potential results relevant to the different fish culture systems.

Chapter 2, 'Elements of fish culture systems', inspects the three fundamental components of fish production that are essential for success.

Chapter 3, 'Key characteristics of fish culture systems practiced in the region' provides an inventory of and introduction to the three main culture systems and their variations practiced.

Chapter 4, 'Feeding, the food and feed spectrum of commercially important fish species' reviews environmental conditions influencing fish feeding and classifies commercially important fish species by their feeding.

Chapter 5, 'Characteristics of feeding fish and the attainable results in the different culture systems' describes both the culture system-specific principles of feeding fish and the suitable feeds to be used in them.

Chapter 6, 'Preconditions of proper feeding and verification of feeding efficiency and results' summarises and explains the prerequisites of fish feeding, including the verification of feeding efficiency and growth results.

Chapter 7, 'Feeding-related works in the fish farm' presents a concise review of all tasks and works linked to feeding.

According to the concept of this book, the chapters are short, informative, and focus on technical information that is directly and promptly required to remain efficient in practical fish farming. However, to supply readers with adequate background information for the topics discussed under the chapters, **ten annexes** listed in Table 1-1 were also elaborated. Each annex covers different topics that add to the technical knowledge and directly or indirectly support farmers' decisions.
An **appendix** with three tables is also included, as listed in Table1-1.

The authors aimed to use a technical language extensively spoken in the practice of fish farming. However, specific technical terms and explanations had to be introduced in some cases. At first use, such terms (italicized and asterisked) are explained in the **glossary**, where supplementary information is also provided for some entries.

Citing of sources follows a numeric style. Cited authors are listed and numbered in an alphabetic order under the chapter 'List of references'. Consequently, not the name and the date, but a relevant number before the name of a specific author in the List of references is indicated in the text within square brackets/crotchets.

Under the different chapters and annexes, recommendations can also be found on applying various techniques and materials to improve fish food productivity of pond water, restore and maintain water quality, and treat diseased fish. As the quality and concentration of the materials (i.e., organic/inorganic fertilizers, chemicals, and drugs) can vary even under the same brand name, testing before applying them to a larger stock or water area is always recommended.

TABLE 1-1: LIST OF ANNEXES AND TABLES OF THE APPENDIX

Annex 1
Conditions and resources of inland fisheries and fish culture in Central and Eastern Europe, the Caucasus, and Central Asia

Annex 2
Ingestion, digestion, and excretion of fish

Annex 3
Food spectrum, feeding habit, feeds and expectable growth of commercially important fish species in Central and Eastern Europe, the Caucasus, and Central Asia

Annex 4
Expectations towards and criteria of fish and fish feed qualities

Annex 5
Chemical composition and energy content of natural fish foods and feeds used in pond culture and intensive culture systems

Annex 6
Selection and adjustment of supplementary feeds for common carp in pond culture and the need to use nutritionally balanced and complete industrial feeds in ponds

Annex 7
Water quality criteria to maintain during production in the different culture systems

Annex 8
Impacts of fish feeding on the water quality of the different culture systems

Annex 9
Summary of primarily determining factors of fish production

Annex 10
Attainable production results

Appendix
Table A-1: Approximate composition of natural fish foods, feeds, and feed ingredients widely used in pond culture in the region

Table A-2: Selected Aller Aqua feeds of cold, warm, and tropical freshwater fish species used in the region

Table A-3: Planning figures on the use of Aller Aqua feeds listed in Annex 10

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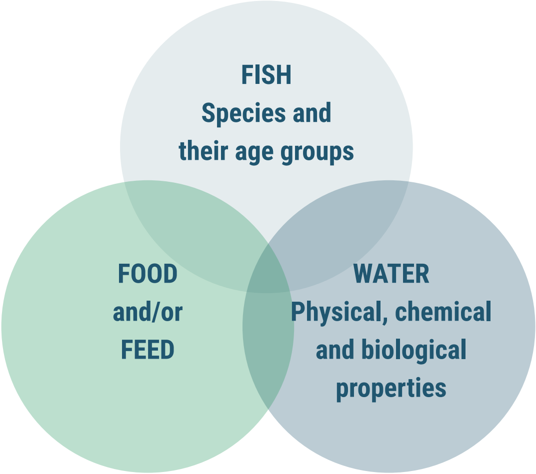
ELEMENTS OF FISH CULTURE SYSTEMS

A clear interpretation and uniform understanding of the principles and elements of fish culture are important requisites of sustainable results and success, both in the sense of production and finances. These elements include fish, water as a rearing environment, and food and/or feed, which ensure the healthy growth of fish.

2.1 FISH

FIGURE 2-1: MAIN ELEMENTS OF ALL FISH CULTURE SYSTEMS



When determining the suitability of a fish species for culturing, the following attributes are considered:

- Degree of domestication; the more a fish species is domesticated, the more it is adopted to artificial culture conditions, and the less stressful the fish is when handled and fed.
- Availability of stocking material. A precondition of culturing fish is a reliable propagation and fry-rearing production technology that supports a steady supply of different age groups of fish.
- The ability of a species to grow in available, quantitatively, and qualitatively acceptable water. It is especially important in regions where intensive salinization of surface waters reduces the amount of water tolerable by cultured species and strains.
- Ability to grow on natural food, which can be intensively produced in fish ponds.
- Capability to accept, ingest and utilize supplementary and/or nutritionally complete industrial feeds.

One of the most practical ways of grouping fish is when they are distinguished based on the water temperature preference where they live, feed, and propagate. Therefore, commercially important species presented and discussed in this book - listed below and presented in Annex 3 - are also grouped accordingly:

- **Cold freshwater species**: Arctic charr, Atlantic salmon (freshwater), brown trout, rainbow trout, and whitefish all belong to the Salmonidae family.
- **Warm freshwater species**: Sturgeons (Acipenseridae), pike (Esocidae), common carp, Chinese major carps and medium size carps: tench, bream, crucian and gibel carps (Cyprinidae), European catfish (Siluridae), eel (Anguillidae), bass (Centrarhidae), perch and pikeperch (Percidae).
- **Tropical freshwater species**: Tilapia (Cichlidae), African catfish (Clariidae), and pangasius (Pangasiidae).

TABLE 2-1: NAMES OF DIFFERENT AGE GROUPS OF FISH

Life/growth stage or size	Names used in coldwater fish culture	Names used in warmwater fish culture
Between hatching and *exogenous feeding**:	Larvae, alevin	Larvae (non-feeding larvae)
Period when larvae start feeding:	Swim-up fry, early fry	Feeding larvae
Period after starting exogenous feeding:	Fry	Fry
Growth stage (0.2-2 g):	Fry (advanced fry)	Advanced fry
Growth stage (2-100 g):	Juvenile (fingerling)	One-summer-old fish (fingerling)
Size of fish (100-250 g):	Grower	Two-summer-old fish, grower [1]
Size of fish (250-2500 g):	Depending on the market size of food fish: grower or table fish	

Observation: *[1] It is a suitable term for the same size of two-summer-old fish but produced in the first year of a two-year-long production cycle of carps*

The partly different nomenclature for life stages of coldwater and warmwater fish species might be confusing. Therefore, to support understanding and advance the development of common terminology, names of different age/size groups of fish used in fish culturing are reviewed in Table 2-1.

2.2 WATER

Water also needs distinctive attention with a focus on quality and quantity required to ensure successful fish culture. Inland waters, i.e., surface, spring, and underground waters determine either the location or the source of freshwater fish cultures. Table 2-2 summarizes the combination of water resources and producible fish species discussed in this book. The overall suitability of the different water sources listed in Table 2-2 is cardinal; therefore, details are found in Annexes 1, 7 and 9.

TABLE 2-2: COMBINATION OF WATER RESOURCES AND POTENTIAL SPECIES FOR CULTURING

Water source	Cold waters (below 20 °C)	Warming-up and warm waters[1] (2 – 33 °C)	Hot and thermal waters (≥ 25 °C)
Surface waters			
Lentic ecosystems: Natural lakes, water reservoirs, and ponds Lotic ecosystems: Streams, rivers, and canals	Arctic charr, Atlantic salmon, brown trout, rainbow trout, and whitefish	Sturgeons, common carp, Chinese major carps, tench, European catfish, eel, bass, perch, and pikeperch	-
Springs and underground waters			
Ground, karst, and artesian waters	Arctic charr, Atlantic salmon, brown trout, rainbow trout, and whitefish	Sturgeons, common carp, tench, European catfish, eel, bass, perch, and pikeperch	-
Hot and thermal waters	-	-	Common carp, tench, European catfish, eel, bass, perch, and pikeperch. Tilapia, African catfish, and pangasius

Observation: [1] *Depending on the length of summer and winter, seasonal production of trout, whitefish, and tropical species is also possible.*

2.3 FOOD AND/OR FEED

Proper feeding is both a precondition and a guarantee for fish growth. Therefore, regardless of whether the diet of a cultured fish is a combination of natural fish food and supplementary feeds, or it is a nutritionally complete industrial feed, the diet must cover both qualitatively and quantitatively the dietary requirements of growing fish.

Knowledge of the chemical composition and energy content of fish feeds detailed in Annex 5 facilitates the combination of different supplementary feeds and their adjustment to the natural food. In contrast, in the case of nutritionally complete industrial feeds, the same background information presented in Annex 5 supports the selection of the most suitable feeds by understanding and verifying the declared composition and nutrient content of products.

BOX 2-1: DEFINITIONS FOR FISH FOOD AND GROUPING OF FISH FEEDS

Natural fish food, or simply **fish food**, is the collective name for decaying, dead, and living organisms that fish consume as food. Consequently, as described in Annexes 5, 6, and 7, most of the natural waters have a wide range of fish food.

There are two distinct groups of **fish feeds**:

- Supplementary fish feeds are efficient only if consumed jointly with natural fish food. Such feeds are presented in detail in Annexes 5 and 6 and listed in Table A-1 of the Appendix.
- Nutritionally complete industrial fish feeds are professionally compiled and produced products that fully satisfy fish's dietary requirements. Such feeds are described in Annex 5 and 6 and listed in Tables A-2 and A-3 of the Appendix.

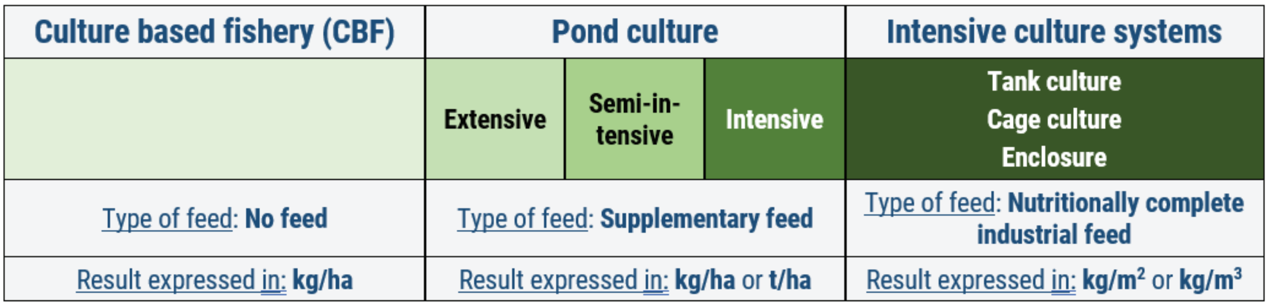
3

KEY CHARACTERISTICS OF FISH CULTURE SYSTEMS PRACTICED IN THE REGION

The term 'fish culture system' indicates the complexity of fish production. In most cases, they are classified and differentiated from one another by one of their most characteristic features, which is usually intensity. Based on this, pond culture is often considered and categorised as an extensive culture system, which is misleading and does not follow a technically sound and accurate classification compared to other fish production options practiced in the region.

For the above reasons, this book distinguishes, presents, and consistently identifies three basically different fish culture systems, which are differentiated according to food and/or feed available for fish. As Figure 3-1 shows, this classification indicates the chronological sequence of fish culture development and allows a technically correct characterization and comparison, as summarised later in this chapter.

FIGURE 3-1: DIFFERENT/MAJOR CULTURE SYSTEMS PRACTICED IN THE REGION



Culture based fishery (CBF)	**Pond culture**			**Intensive culture systems**
	Extensive	**Semi-intensive**	**Intensive**	**Tank culture** **Cage culture** **Enclosure**
Type of feed: **No feed**	Type of feed: **Supplementary feed**			Type of feed: **Nutritionally complete industrial feed**
Result expressed in: **kg/ha**	Result expressed in: **kg/ha** or **t/ha**			Result expressed in: **kg/m^2** or **kg/m^3**

3.1 CULTURE BASED FISHERY

Culture based fishery (CBF) is an increasingly practiced fish culture technique, where the entire aquatic ecosystem of surface water (natural water) is a culture space where stocked fish grow. Therefore, regular fishing of adult fish is also essential in addition to stocking young fish. In this fish culture system, neither feeding of fish nor organic/inorganic fertilization of water is practiced, only the natural productivity of the water body supports the growth of fish.

The typical water temperatures and original fish fauna determine the range of stocked fish species, while the *trophity** of water is responsible for the actual and potential fish production capacity of a water body, as summarised in Table A1-3.

Annex 10 presents a concise summary of the steps of planning a CBF, even though each water body requires a specific fish stock management (i.e., stocking and fishing). The same annex also presents some typical examples, which show realistic results in a CBF.

FIGURE 3-2: STOCKING OF YOUNG FISH INTO LAKE BALATON

CBF is practically the only reliable option in inland waters today to sustainably maintain a balanced fish fauna.

3.2 POND CULTURE OF FISH

A most distinctive characteristic of pond culture is that fish and their natural food are grown in the same water, i.e., in the fish pond. This natural food is then supplemented with feeds to fulfil the demand of the dietary requirements of the fish in the pond. Fish and their natural food are produced under control, which is a challenge for pond culture production.

Pond culture can be mono-, bi-, and polyculture, depending on the number of fish species grown together.

Pond monoculture is a usual, traditional way of rearing fry. After the breakthrough of Horváth and Tamás [97], when they managed to develop a large-scale advanced fry rearing technology, the reliable supply of all pond cultured fish species became possible.

When there is no need to sort the produced advanced fry by species, biculture of fry can also be feasible. In this case, the stocked two species grow faster and larger than they would in a monoculture.

Pond polyculture is based on the concept that the more diverse the food spectrum and feeding habits of stocked species are, the utilization of natural fish food resources is better. This reduces competition for food/feed, increases the species' synergetic effect, and expands the exploitation of natural fish food resources in the pond.

Typically, one species is considered the main fish in a polyculture. Most frequently, these are common carp or silver carp (and its hybrid with bighead carp), but in some cases, when the aim is aquatic weed control, grass carp can also be the main fish species. Proportions of stocked species depend on many factors (original and improved productivity of a fish pond, earlier experiences, market demand, etc.), hence may vary on a wide scale.

In carp polyculture, common carp is the fish fed with supplementary feeds, as described in Annex 6.

Regarding the intensity, a pond culture can be extensive, semi-intensive, and intensive. Sometimes the term 'super-intensive pond culture' is also used, but to maintain simplicity, the term is not mentioned separately in this book. Still, it is discussed under the 'intensive' production level.

Certain factors basically determine the results of pond culture. These are the length of the production season, type and quality of fish ponds, quantity and quality of available water and cultured species, their size categories, and stocking densities of fish (see Annex 9). Other important information is the results, which are presented in Annex 10. Expectable results of both traditional three-year-long and recently spreading two-year-long production cycles of pond culture are discussed there. Some advantages of a two-year-long production cycle are presented in Table 3-1.

FIGURE 3-3: HARVESTING AND SORTING FISH PRODUCED IN POND CULTURE

The main fish species of a pond polyculture is uswually either common carp (above) or silver carp (below).

TABLE 3-1: ADVANTAGES OF THE TWO-YEAR-LONG PRODUCTION CYCLE OF COMMON CARP IN POND CULTURE

Key changes	Consequences
Length of production cycle	Production cycle is shorter by one year. Instead of two, only one wintering period, hence 50% less winter losses and significantly less risks.
Intensity	More intensive use of ponds combined with a high-quality feed for common carp to accelerate the growth rate of which using high quality feeds is a prerequisite.
Investment and return	The return period of expenses invested in production materials (water, fish seed, feeds, etc.) reduces by one year, i.e., by about 33%.

3.3 INTENSIVE FISH CULTURE SYSTEMS

Intensive fish culture systems embrace all fish production techniques, where feed is the only source of fish to cover dietary requirements. Contrary to pond culture, natural food is not required in intensive culture systems. Even its presence has no significant effect due to the high density of fish. Therefore, applied feed must be nutritionally complete, meaning that the feed must contain all macro- and micronutrients and energy required for fast and healthy growth.

As summarised in Annex 5 and 10, practically all commercially important fish species which accept and ingest feed can be safely produced in one of the intensive culture systems of the region by today.

In addition to the use of nutritionally complete industrial feeds, a common characteristic of all intensive culture systems is that a continuous water exchange through the culture space is mandatory. Water exchange ensures the supply of fresh, oxygen-rich water while also removing *metabolic wastes** produced by fish. The water exchange rate depends on the species, age (size), number, and fish biomass.

Similarly to pond culture, there are certain factors, such as the length of the production season when the water temperature is favourable for growth, type and quality of culture devices/space, quantity and quality of available water, as well as species, age (size) and stocking density, which on the whole determine achievable results in intensive culture systems (see Annex 9).
A key element of intensive culture systems is the availability of qualitatively and quantitatively appropriate feed.
The three basic types of intensive culture systems are tank, cage, and enclosure cultures. Differences between attainable results of tanks, cages, and enclosures presented in Annex 10 are due to the physical conditions that the various culture systems are able to ensure.

3.3.1 TANK CULTURE

In a tank culture, fish are kept and reared in smaller or larger tanks, including small earthen ponds (Figure 3-4 and Box 3-1), where water is continuously exchanged with an adequate speed to supply fresh, oxygen-rich water and carry away metabolic wastes produced by the fish.

Besides water exchange, aeration is also applied to maintain the required dissolved oxygen (DO) level and expel carbon dioxide from the water (Annex 9).

FIGURE 3-4: A TRADITIONAL TROUT FARM IN DENMARK

Though such traditional fish farms look like pond fish farms of the region, these culture systems are still different, as their production is based on high-quality, nutritionally complete industrial feeds.

FIGURE 3-5: WIDELY USED REARING TANKS IN THE REGION

Concrete raceways for trout (above) and a fish farm with tarpaulin tanks (below).

It is used an endless variation of materials (even altered shipping containers), shapes and sizes of tanks, troughs, and raceways in the region. They can even be earth ponds with or without pavements, linings, or tanks built from concrete or durable plastic, fiberglass, or tarpaulin.
When planning a tank fish farm, it is important to have each tank accessible from at least three sides, as it also happens with tween tanks. This facilitates proper feeding, observation, and catching of fish.

Finally, it is to note that the regular cleaning of tanks is an important element of securing proper rearing conditions and preventing outbreaks of fish diseases. However, as small earthen ponds with soil bottom used as tank culture cannot be cleaned properly when fish is there, hence the expectable results are lower.

BOX 3-1: USE OF EARTHEN WINTERING PONDS FOR INTENSIVE CULTURE OF SELECTED FISH SPECIES

Using smaller or larger earthen ponds for intensive culture of, among other trouts, common carp, European and African catfishes, pangasius, or tilapia is one of the widely followed intensive culture systems. It is a kind of tank culture where the use of nutritionally complete industrial feeds is mandatory [94]. In such ponds, the development of natural fish food (if any) is negligible and relatively insignificant. Because of the above reasons, this type of fish production cannot be compared with pond culture, not even with a very intensive one.

Regarding details the large-scale experiment of Egyed and his colleagues [33] proved the suitability of wintering ponds for intensive culturing of common carp during summer months. This, completed with Aller Aqua feeds aimed to shorten the three-year-long rearing cycle to two years, as well as to produce table fish during the summer months. There was no water exchange in the ponds of about 1.8 m average depth, only evaporated water was replaced with fresh one. Key water quality parameters were regularly checked. Stocking density of fish varied between 0.7-1 pcs/m². During the summer months fish grew from the size of 0.2-0.6 kg to 1.7-2.6 kg and obtained a result of 1.4-1.8 kg/m² net yield. It was observed that the growth of fish was especially fast when the water temperature was around 24-25 °C and DO content of water was above 5 mg/l, even at least 4 mg/l during nights and at dawns. To maintain this DO level aerators were used. Based on the explicit recommendation of Egyed, the fertile sludge from the wintering ponds should be removed (and utilized as organic fertilizer) and the pond bottom must be dried and disinfected before it is used again.

Naturally in the cases when higher yields are planned, exchange of water in the wintering pond proportional to the standing crop (SC) is inevitable.

3.3.2 CAGE AND ENCLOSURE CULTURES

Cage and enclosure cultures are alike in many aspects; fish are confined in a water body with durable materials like stiff grids or flexible nets. In many cases, setting, maintenance, cleaning, feeding, and handling fish in these cultures are done similarly.

Cage culture

The use of cages in fish culture has a long tradition: from spawning fish and rearing fry in hapas, through holding fish, up to fattening fish in smaller or larger cages set in a lentic (still waters) or lotic (flowing waters) water body.

Cages are grouped according to the material they are made of and the construction, i.e., whether they are fixed or floating.

Water exchange in cages is expected to be secured by the natural circulation (currents) and flow of water and the movements of fish in the cage. Therefore, aerators are used in critical periods of the day or when the size of the fish biomass requires.

Usually, cages are set in deep waters to keep enough distance – about 1-1.5 m, but a mini-mum of 0.6 m – between the cage and the water bottom where organic debris (fish scales, faeces, uneaten feed, etc.) accumulates.

Using a feeding frame that stops floating feed drifting out of the cage is beneficial, just like a feeding tray when sinking feed is applied; thus, fish can readily feed from the tray.

Enclosure culture

Rearing fish in large enclosures (also called fish pens) is somewhat similar to pond culture. In this culture system, a smaller or larger surface water section is confined either with a stiff, durable fence or flexible netting material. Fish are produced the same way as if the enclosure was an unfertilised, intensively fed fish pond.

FIGURE 3-6: FARM-MADE CAGES USED IN THE REGION

Cages are set in a river (above) and a water reservoir (below).

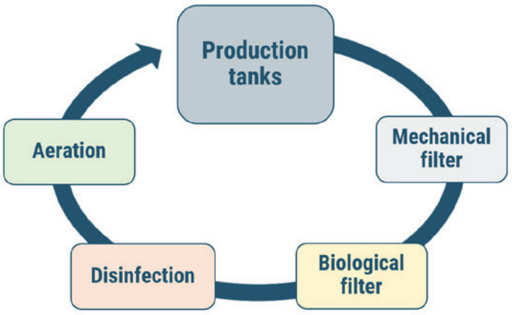
(Photo by courtesy of Andras Péteri)

As experiences with enclosure cultures accumulated and the use of nutritionally complete industrial feeds became widespread, sizes of enclosures reduced to a range that facilitates well manageable intensive culture of fish. In addition, cage-type encloses (enclosure with bottom) can be used to reduce fish escape [16].
Obtainable results may vary on a wide scale depending on the *trophic level** of the water where the enclosure is set or on the way of utilization, whether it is used as an unfertilised fish pond or (especially in smaller enclosures) fish are grown on nutritionally complete industrial feeds.

3.4 SPECIAL AND COMBINED FISH CULTURE SYSTEMS

On the contrary to pond culture, where the pond ecosystem itself balances and ensures a continuous renewal of required water qualities, in densely populated intensive culture systems this does not happen. Thus, in such systems, appropriate water exchange is indispensable.
The need for better utilization and reuse of water resources and increasing concern for reducing the impact of fish farm effluents has led to the development of recirculation aquaculture systems (RAS). There are indoor RAS and pond RAS. The concept and technique of recycled water purification are done differently in these systems.

FIGURE 3-7: FLOW CHART OF AN INDOOR RAS

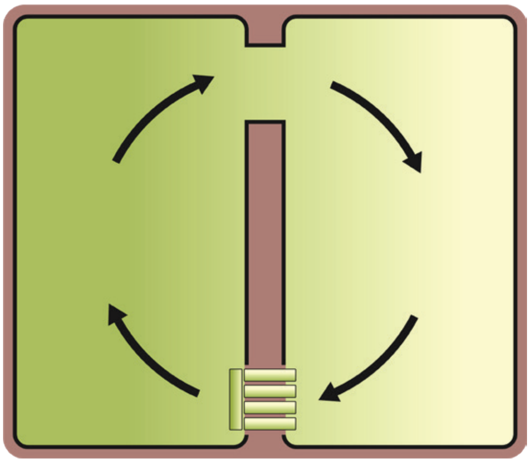


Indoor RAS
The design and operation of indoor RAS are based on the concept presented in Figure 3-7; the effluent from the rearing devices is first mechanically, then biologically filtered, appropriately treated (disinfected, aerated/oxygenised, etc.), and conducted back to the rearing devices for reuse. As production technologies, fish feed, and the efficiency of water purification units improved, the proportion between production and water purification units varies between 1:5 and 1:2 in the current RAS.

Pond RAS and in-pond RAS
The other type of RAS is developed for pond fish farmers who aimed to intensify and diversify beyond the option and results of a traditional pond culture system.
Pond RAS is a combined practice of pond culture and one of the three basic intensive culture systems discussed above (tank, cage, or enclosure).
The operation of such combined systems is based on the principle that in pond water, metabolic wastes produced in the intensive unit are *mineralised** in external pond water surrounding the intensive unit. The usual pond RAS and in-pond RAS consist of an intensive culture unit and an extensive unfed pond culture unit or pond section where water passes through and purifies. The most frequent combinations and variations are:

- The combination of a row of rearing tanks or smaller pond(s) at the side of a large pond, where effluents from the intensive unit flow through then from where purified water is pumped back into the intensive unit.Cages or enclosures are placed into an extensively managed unfed pond. To offer an easier setting, enclosures in ponds can be cage-type. This means that the enclosure is made with a bottom from an especially durable netting material laid on the hard pond ground.
- A row of tanks is placed into a large pond, and pond water is circulated through the tanks. This is called in-pond RAS (Figures 3-8 and 3-9).

FIGURE 3-8: THE SCHEMATIC LAYOUT OF AN IN-POND RAS WITH PROPER WATER CIRCULATION

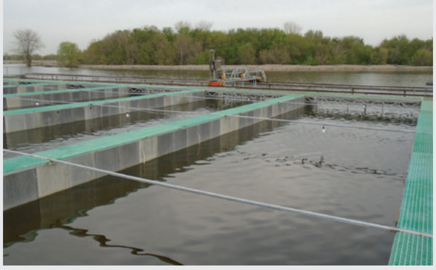


In-pond RAS raceways are built from concrete, plastic sheets, or fiberglass and are usually equipped with a unit at the end of tanks where solid wastes discharged from the tanks are settled and collected. This can considerably reduce the load of intensive units on pond water. Soluble wastes remain in the system and are processed by the pond ecosystem while water circulates around (Figure 3-8).

Regarding fish production capacities of pond RAS and in-pond RAS, it is important to emphasize that in combined fish production systems, when intensive and pond culture systems are linked, it is not possible to produce more fish than the amount of free-swimming fish in a pond of similar size and quality, if fed and managed (aeration, topping up pond water, etc.) on the same way. The reason for this is that a pond ecosystem's metabolic waste processing capacity does not improve by simply increasing the number of reared fish in it.

It must be emphasized that feeding, especially the quality of feed used in any RAS, is important. Only feeds with low FCR and reduced environmental impact are competitive in RAS regardless of whether it is an indoor or a pond/in-pond RAS. If the FCR of the feed is lower, less metabolic waste is produced by the fish stock; consequently, a higher number of fish can be grown within the same culture system, as highlighted in Chapter 6.

FIGURE 3-9: RACEWAYS OF AN IN-POND RAS



Intensive raceways facilitate diversification of fish production by growing different species and size categories of fish in the same pond.

3.5 COMPARISON AND SELECTION OF DIFFERENT CULTURE SYSTEMS

Comparison of different culture systems is a frequent subject of field discussions. This chapter aims to provide support in the form of some practical information to consider when needed. It is important to emphasise that no culture systems are better or worse; they only provide different solutions on how to exploit the available resources properly and gain the most out of the possible benefits a certain culture system offers (Tables 3-2 and 3-3).

However, selected aspects motivate and support comparative analysing of the considerable options. These are:
- Market demand, the price of fish in general, the seasonality of market demand/supply, and particularly fish price.
- Reduction of the production time and cycle to ensure faster financial returns.
- Intensification and diversification of fish production in existing waters and production facilities.

Information on expectable results of intensive culture systems is presented in Annexes 1, 3 and 10.

TABLE 3-2: A SIMPLE INVENTORY OF CULTURE SYSTEMS BY KEY INPUTS AND RESULTS OF TABLE FISH PRODUCTION

Key input items	**CBF**	**Pond wculture**			**Intensive culture systems**		
		Extensive	**Semi-intensive**	**Intensive**	**Tank culture**	**Cage culture**	**Enclosure**
Stocking material	√	√	√	√	√	√	√
Water	-	√	√	√	√	-	-
Fertilizers	-	√	√	√			
Cereal grains	-	√	√	√			
Simple feed mixes	-	√	√	√			
Farm-made compound feeds	-	-	√	√			
Nutritionally balanced industrial feeds	-	-	-	√			
Nutritionally complete industrial feeds	-	-	-		√	√	√
Expectable results relative to CBF (≤ 100 kg/ha)	1	10-fold	20-fold	30-fold	100-5000-fold		

TABLE 3-3: LINKS OF THE DIFFERENT CULTURE SYSTEMS TO THE WATER RESOURCES

Culture systems	**Water resources**		
	Location of fish culture activity	**Water received**	**Effluents discharged**
CBF	In surface inland waters (in natural waters)	-	-
Pond culture	In fish ponds	The farm needs a seasonal intake and regular top-up of evaporated and seeped water. Discharge of large quantities of water is often likely at the end of the season.	
Intensive culture systems			
Tank culture	In indoor and outdoor tanks	Continuous intake and discharge of the water increase during the entire production cycle.	
Cage culture	In cages and enclosures set in natural waters and ponds	-	-
Enclosures		-	-

4

FEEDING, THE FOOD AND FEED SPECTRUM OF COMMERCIALLY IMPORTANT FISH SPECIES

The feeding of different fish species is cardinally determined by the environmental conditions and feeding habits, together with the fish's food and feed spectrum.

4.1 ENVIRONMENTAL CONDITIONS WHICH INFLUENCE THE FEEDING OF FISH

The term "environmental conditions" embraces a wide range of circumstances and situations, from which selected water properties and stress factors are reviewed here.

4.1.1 WATER PROPERTIES

Among the physical, chemical, and biological water properties discussed in Annex 7, water temperature and dissolved oxygen are especially important at feeding; consequently, these water properties require special attention among the ones listed in Table 4-1.

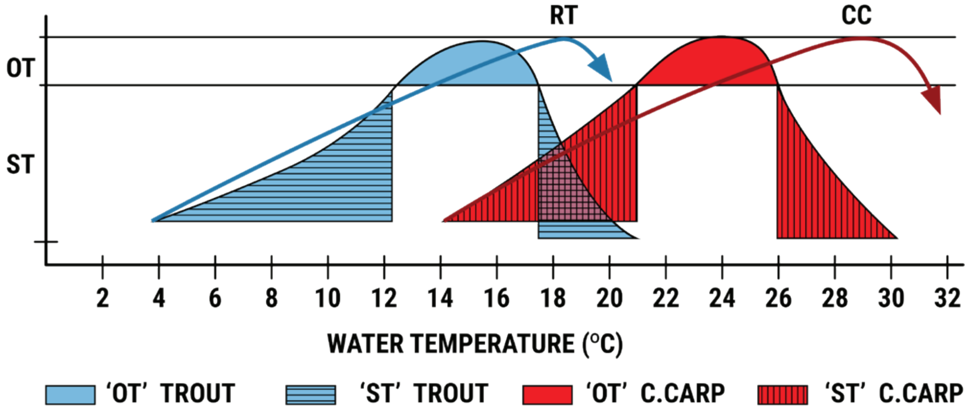
TABLE 4-1: DIRECT EFFECT OF SELECTED WATER PROPERTIES ON FISH FEEDING

Water quality parameters	Effects and required attention in practical fish culturing
Motion of water	In pond culture, the motion of water attracts fish; it is often used for fishing/harvesting in ponds. In intensive culture systems: Too fast currents unnecessarily tire fish and force them to consume energy for swimming, while too slow currents cannot ensure the required exchange of water in the rearing devices.
Transparency Light conditions Turbidity	Some of the cultured species are especially sensitive to these features. In pond culture: Influence on water temperature, DO content, plankton life. In intensive culture systems: Salmonids especially require transparent water when fed. Too strong light can be disturbing, and salmonids are also especially sensitive to turbid water.
Temperature	This water property has a vital role in all culture systems, hence discussed separately (see below sections).
Total dissolved salt (TDS)	TDS well below or above the specific ranges of the species reduce appetite.
pH	It influences chemical processes in waters, including the effects of dissolved toxic gasses; thus, it has an outstanding role in all types of culture systems. There are optimum, acceptable, and lethal pH ranges (see Annex 7), specific for species.
Dissolved oxygen (DO)	This water property is also vital in all culture systems, hence discussed separately (see below sections).
Trophity Saprobity	In pond culture: To keep control of changes in trophity and saprobity is a main challenge of fertilization. In intensive culture systems these are important water properties when pond RAS and in-pond RAS are practiced. The chemical properties of effluents discharged by intensive systems are in increasing focus due to the aim to reduce environmental impacts.
Toxicity	Even mild (higher than allowed) and sub-lethal toxicity (concentration of environmental toxicants) reduces appetite and overall ingested food/feed utilization.
Biological production	Its role is especially important in CBF and pond culture.
Presence of toxic organisms/algae and parasites	They are equally important in all types of culture systems. For example, they may reduce appetite and cause stress in fish, but more serious cases can even lead to mortality.
Presence of feed competitor	Feed competitors can be the larger specimens within the same culture device, another species, and aquatic or terrestrial animals like amphibians, birds and mammals. Unnecessary feed competition reduces feeding efficiency and develops stress in fish.
Presence of fish predators	The presence of predatory fish species, amphibians, birds, and mammals represent a direct threat to fish life and a serious stress factor. The latter one reduces feeding intention and efficiency.

Water temperature is by far the most significant condition that affects the life and feeding of fish, as temperature determines the current body temperature of poikilotherm aquatic organisms. These organisms cannot regulate their body temperature; therefore, it is practically the same as the ambient water temperature.

Fish and most of their natural food organisms are poikilotherm; thus, the intensity of their *metabolism** and movements depends on actual water temperature. The body temperature of fish is usually only 0.1–0.6 ºC higher than that of the surrounding water, which results from metabolic heat and the heat of muscle contractions [23].

FIGURE 4-1: SCHEMATIC PRESENTATION OF THE OPTIMUM AND SUITABLE RANGES OF WATER TEMPERATURE AND CHANGES IN THE INTENSITY OF APPETITE OF TROUT AND COMMON CARP



Curves of appetites of rainbow trout (RT) and common carp (CC) and ranges of optimum (OT) and suitable (ST) water temperatures for trout and common carp.

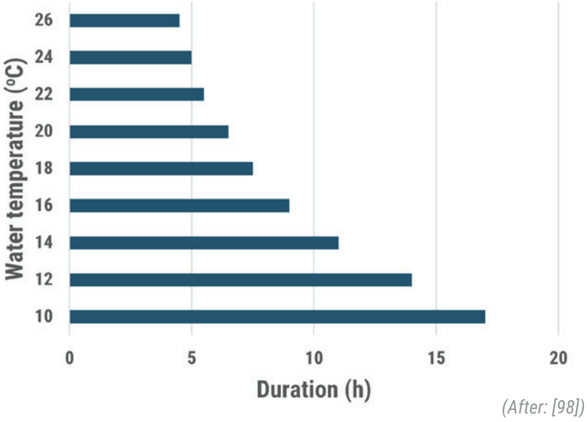
Appetite, transit time of feed particles in the gut, and digestion efficiency are temperature-dependent, those have species-specific characteristics, though there are similarities in their rate and tendency in all cold, warm and tropical freshwater fishes. Figure 4-1 demonstrates that the appetite of fish increases with the increase of water temperature, but only to a certain point. With further growth in temperature, the appetite of fish drastically drops, then stops, the fish falls into the state of complete anorexia. If this water temperature persists, it can lead to death. Such reactions of fish can also be observed at cool water temperatures. A drop in the temperature below the optimum of a species is also associated with the loss of appetite. Beyond a certain point, tropical fish die, while warmwater fish enter into a state like the hibernation of winter months and remain until the water warms up again.

It is important to remark that the increased ingestion of food/feed related to an increased appetite of fish due to higher water temperatures does not automatically result in better growth only in those cases when the food is in accordance with the fish nutrient requirement. Due to accelerated metabolism, the food passes through the digestive tract faster; thus, part of the ingested food/feed remains undigested. In cooler waters, ingested feed that is in excess relative to temperature will pass through too slowly, which may cause health problems. This relative overfeeding discussed in Annex 4 can even cause mortalities.

Figure 4-2 demonstrates the correlation between the water temperature and the digestion period through the example of common carp. Consequently, the rate of digestion is strongly temperature-dependent; it is an important physiological process of fish to know and observe in practical fish farming. It is especially true, as all modern feeding programs are strongly based on these processes.

In addition to water temperature, the dissolved oxygen content of water also primarily determines the appetite and food/feed intake of fish.

FIGURE 4-2: CORRELATION BETWEEN WATER TEMPERATURE AND DIGESTION PERIOD OF COMMON CARP



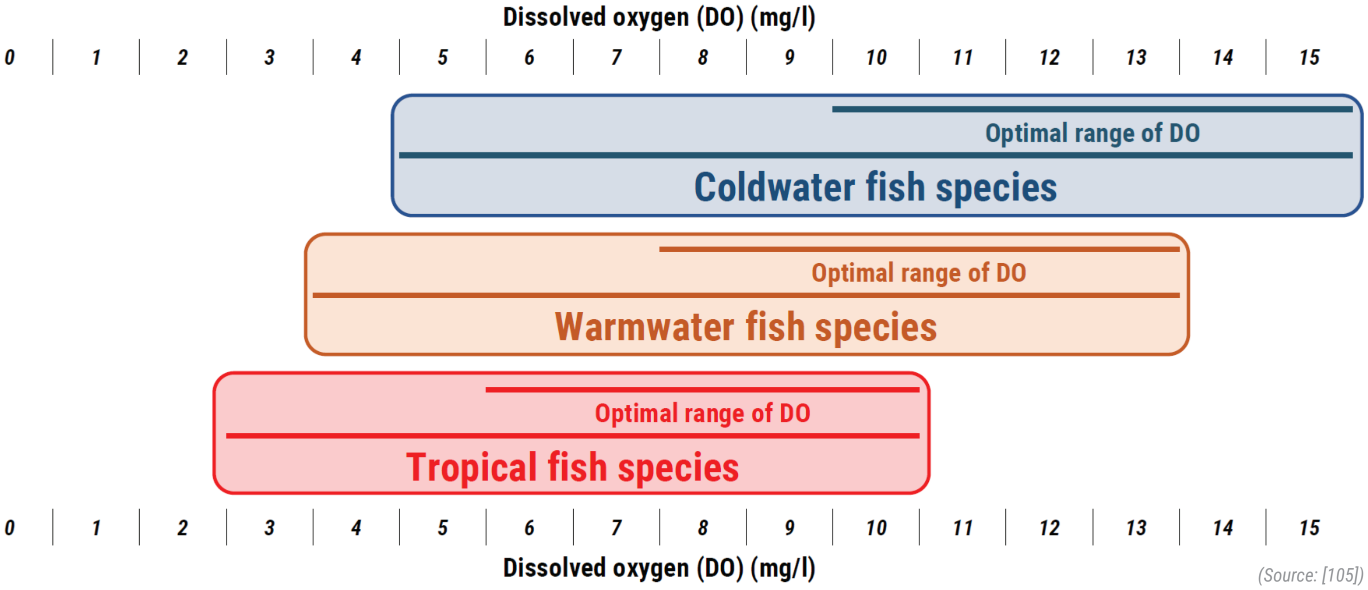
(After: [98])

In general, the dissolved oxygen demand of cold, warm, and tropical fish species is proportional to the oxygen dissolving capacity (DO retention capacity) of water where they live and are adapted to. This is demonstrated in Figure 4-3, which shows the basic differences of fish with different temperature requirements, optimum and tolerable ranges of DO content of water in intensive culture systems of different fish species. More detailed information on other important water quality parameters is available in Annex 7.

BOX 4-1: DISSOLVED OXYGEN DEMAND OF COMMON CARP IN POND CULTURE

For common carp in pond conditions, an oxygen content of 5-12 mg/l is adequate but becomes increasingly unfavourable if oxygen concentration goes under 5 mg/l and saturation is below 50% ([53] and [79]).

FIGURE 4-3: ACCEPTABLE AND OPTIMAL RANGES OF DISSOLVED OXYGEN CONTENTS FOR COLD, WARM, AND TROPICAL FRESHWATER FISH SPECIES



(Source: [105])

4.1.2 STRESS FACTORS

Unfavourable culture conditions and fish handling are the most evident stress factors of culturing fish. Among culture conditions, water quality parameters should remain within the optimum ranges, as shown in the tables of Annex 7. Any value constantly differing from the optimum range can and will cause stress in fish, along with susceptibility to diseases, exposition to predators, or competitions with larger specimens for feed.

A well-maintained diurnal routine of properly executed feeding will considerably reduce stress in fish. To avoid the disturbance of fish both in pond culture and intensive culture systems is a basic detail to consider. It should be noted that fish are sensitive to new, unknown noises, while the usual sounds of feed preparation and distribution, which are associated with food, develop positive *Pavlovian reflexes**.

Regular daily and diurnal inspections of fish should routinely be accomplished quietly. It is especially relevant in intensive fish farms. Defending fish stocks, scaring off feed competitors and predatory birds with bird guards is often inevitable. Selected solutions should be the least stressful for fish stocks, keeping in mind that water magnifies sounds and carries them well and far, which is very disturbing for fish.

Handling of fish, when captured, sorted, measured, stored, and transported, should be performed with care. During treatments, fish should be kept the shortest possible time out of water.

4.2 GROUPS OF COMMERCIALLY IMPORTANT FISH SPECIES BY THEIR NATURAL FOOD AND FEED CONSUMPTION

Being familiar with the similarities and differences of feeding and the food and feed spectrum of commercially important fish species is very important for understanding fish feeding. This knowledge also allows the selection of fish species for a pond polyculture, where stocked fish species should neither be food/feed competitors nor predators of each other.

During the *phylogeny**, fish have adapted to different environments with specific physical, chemical, and biological characteristics. Some species live on different aquatic organisms and decaying materials, organic debris, biotekton, phyto- and zooplankton, aquatic plants, worms, snails, insects, insect larvae, other fishes, etc. (see Annex 7). Accordingly, there are filter feeders, herbivores, omnivores, carnivores, mixed-feeders, and numerous combinations of them among fish. Thus, the food spectrum and fish diet are extremely diverse, almost completely covering all living, dead and decaying natural food sources in aquatic ecosystems. Hepher [49] summarized that fish had developed special morphological and physiological characteristics during phylogeny to adapt to a specific diet and establish the most efficient feeding habits for a specific environment. Adaptation is best reflected in the species-specific morphology of the organs involved in ingestion and digestion of nutrients. This difference can even be observed in species that otherwise have the same food spectrum. Thus, despite different morphological adaptations (position and size of the mouth, pharyngeal teeth, etc.), functional adaptations related to diet and eating habits generally remained similar. Identifying morphological and physiological characteristics of selection, ingestion, and digestion of different fish species (reviewed in Annex 2) supports the efficiency of feeding fish in practical fish culturing.

TABLE 4-2: GROUPS OF FISH SPECIES BY THEIR FOOD SPECTRUM

Groups	Role of food in the diet	Early fry	Advanced fry	Fingerling, grower, table fish, and brood fish
Filter feeders	Main/primary [1]	*Zooplankton**	*Phytoplankton** and all types of organisms and organic material in the size the fish are able to filtrate.	
	Occasional [1]	Phytoplankton	Small enough zooplankton	Floating organic detritus stirred by fish from the mud.
	Main/primary [2]	Zooplankton	Zooplankton and all types of organisms and organic material in the size the fish are able to filtrate.	
	Occasional [2]	Phytoplankton	Phytoplankton large enough	Filtrates floating feed particles that are in the filtrating range of fish.
Herbivores	Main/primary	Zooplankton	Zooplankton, filamentous algae	Water weeds with a preference for tender parts.
	Occasional	Phytoplankton		Grains, insects, insect larvae, and smaller fish.
Omnivores	Main/primary	Zooplankton	Zooplankton, insects, insect larvae, worms, different snails, smaller shells, tender parts of water weeds and decayed organic materials.	
	Occasional	Phytoplankton	Phytoplankton	Fish larvae, much smaller fish, and dead fish.
Predators	Main/primary	Zooplankton	Insects, insect larvae, fish, including smaller ones of the same species (cannibalism)	
	Occasional	Phytoplankton	Zooplankton	Insects, insect larvae, aquatic, and terrestrial animals in the range the fish can catch and swallow.

***Observation**: [1] Phytoplankton filtering fish species, [2] Zooplankton filtering fish species.*

(After: [106])

Considering the above, fish inhabiting surface waters have adapted their physical, chemical, and biological characteristics and the way to uptake and utilize food in various habitats filled up and formed by surface waters. In conclusion, the feeding habits, food, and feed spectrum of commercially important fishes are species-specific. Though they feed differently, they can still be categorised based on these attributes, as done in Table 4-2. Additional general and specific details of fish feeding are presented in Annexes 2, 3, 5 and 7.

5

CHARACTERISTICS OF FISH FEEDING AND ATTAINABLE RESULTS IN THE DIFFERENT CULTURE SYSTEMS

In CBF, no feed is provided. Instead, results are determined "simply" by the productivity of water and the type and age/size of stocked fish species. Annex 10 reviews the key aspects and principles of planning and executing fish stocking into surface waters. The relevant tables indicate some guiding figures of expectable results in CBF.

Because the success of CBF is based mainly on the quality of fish stocked, the fish produced in any of the culture systems should be in suitable condition to survive and grow in wild waters. Consequently, proper rearing and feeding before stocking are of significant importance.

In many CBFs, fish for stocking are reared in a cage or enclosure set in a water body where fish are planned to be released after reaching a certain size. In such systems, the proper development and growth of fish must be ensured by nutritionally complete industrial feeds.

FIGURE 5-1: AN ENCLOSURE WHERE STOCKING MATERIAL IS GROWN

(Photo by courtesy of Miklós Albel)

After reaching the expected size, fish are released from a tank-like enclosure to the same water body where the enclosure is set.

5.1 FISH FEEDING AND ATTAINABLE RESULTS IN POND CULTURE

Critical factors and achievable results in pond culture, including the range and age/size groups of fish species, are presented in Annexes 9 and 10. The results indicated in Annex 10 are based on the combined use of fertilizers and supplementary feeds detailed in Annexes 6 and 8 and summarised in the subchapters below.

5.1.1 SELECTION AND USE OF ORGANIC AND INORGANIC FERTILIZERS

One of the most important factors of pond culture is using fertilizers. There are organic and inorganic fertilizers. Properly managed fresh organic fertilizers (i.e., different manures of farmed animals) have a more positive effect on zooplankton, which increases the production of natural fish food if dosed and distributed properly. In contrast, inorganic nitrogen and *phosphorus** fertilizers directly support the growth of phytoplankton and aquatic plants.

Organic and inorganic fertilizers listed in Annex 8 are selected based on suitability and efficiency determined by the composition and concentration of nitrogen (N) and phosphorus (P).

In addition to the description of the composition of different organic and inorganic fertilizers in Annex 8, there are also figures on frequently applied doses and the monthly programming of the distribution of organic/inorganic fertilizers throughout the production season.

BOX 5-1: SAMPLING AND EVALUATION OF ZOOPLANKTON IN POND CULTURE

It is recommended to take samples with a 60 µm plankton net. At least every two weeks, preferably every ten days during the production season, from several sampling spots proportional to pond size. It is enough to filter 20-50 litres of water in a fish pond rich in zooplankton. For a microscopic examination, a few drops of absolute alcohol or formalin should be added to the sample to stop the movement of planktonic organisms and settle them for measuring the total biomass of the sample.

A skilled farmer with a routine can determine the amount of zooplankton "by eye", even without filtering the recommended amount of water.

Production of natural fish food in pond culture depends on the soil of the pond and the properties of the water, as discussed in Annex 7. Therefore, the purpose of organic/inorganic fertilization is to improve plankton conditions further, i.e., to increase the production of natural fish food.

Over the years, many excellent publications have been produced on organic/inorganic fertilization and its effect on improving natural fish food production. Based on the publications, fertilization/manuring strategies should consider both the nutrient processing capacity of pond water and the concentration of different nutrients in the water. If their concentration is below the required values indicated in Table A7-5, the application of fertilizers should be considered.

TABLE 5-1: SAMPLING-BASED ESTIMATION OF ZOOPLANKTON PRODUCTION OF POND CULTURE

Quantity of settled zooplankton (ml/100 l)	The estimated mass of zooplankton in a fish pond with an average water depth of 0.8-1.4 m (kg/ha)		
	Live mass	DM	CP
0.1	8 – 14	0.8 – 1.4	0.5 – 0.8
0.5	40 – 70	4 – 7	2.4 – 4.1
1	80 – 140	8 – 14	4.7 – 8.3
5	400 – 700	40 – 70	23.6 – 41.3
10	800 – 1400	80 – 140	47.2 – 82.6

(Source: [98])

Several methods have been suggested to determine and monitor the effects and efficiency of fertilization. However, methods appropriate for farmers must be able to provide fast and reliable practical information. According to Horváth [52], pond fertility is best reflected by the quantity and quality of zooplankton, which depends on the efficiency of applied organic and inorganic fertilizers. Box 5-1 and Table 5-1 present a simple way of sampling and estimating zooplankton production of pond water. In addition to the recommended sampling procedure, the number, proportion, and developmental stage of the main groups of zooplankton (rotifers, cladocerans, and copepods) should also be monitored during the evaluation process. For example, the presence of a few but large sexual eggs in cladocerans indicates that the inorganic and organic nutrient supply in the water is exhausted [76].
Although benthos is among the main foods of common carp, chironomus larvae are generally not sampled in fish ponds. Their amount in fertilized, fish-free ponds can be around 7 900-21 500 specimens/m^2. In the same pond, the total DM (dry matter) of estimated zooplankton biomass is 330–420 kg/ha [50].

5.1.2 SELECTION AND USE OF SUPPLEMENTARY FEEDS

Another decisive characteristic of pond culture is the use of supplementary feeds. The type, size, and application of supplementary feeds are discussed in Annex 6. When traditional supplementary feeds are selected, like cereal grains, industrial by-products, ingredients of simple feed mixtures, and farm-made compound feeds, Table A-1 of the Appendix provides support.

The essence of pond culture is that natural food produced in the pond is supplemented by feeds in order to ensure the dietary requirements of fish fed. It is important to note that not only the quantity but also the quality and nutrient content of feed should be proportional to the fish biomass and the absolute and relative biomass of available natural food (see Annex 6).

5.1.3 FEED DEMAND CALCULATIONS OF SUPPLEMENTARY FEEDS

Calculations of supplementary feed demand for fry of carps and larger age groups of common carp are completed in two different ways. Rearing of advanced fry in ponds stars at stocking and lasts for at least 20-30 days until the fry reaches an individual size of about 0.5 g. The feeding procedure of fry of common carp and Chinese major carps is described in Box 5-2.

BOX 5-2: FEEDING FRY OF CARPS IN POND CULTURE

Based on the technology of rearing advanced fry of carps of about 0.5 g individual weight in pond culture, a very finely ground mixture of soybean (25%), wheatmeal (25%) fishmeal (25%) and blood (or meat) meal (25%) is used. At the beginning, the daily portion of this mixture is 1 litre per hundred thousand feeding larvae, which should gradually be increased to 5 litres per day. Application of the mixture should start immediately after stocking, as it not only feeds growing fry, but the zooplankton as well. In the first days the powdered mixture should be mixed with water before being distributed. Later, the distribution of the dry powder itself will also be applicable [54].

For growing common carp larger than 0.5 g in ponds, practical figures on the approximate proportion of supplementary feeds applied monthly during the production season are also available. These are presented in Table A8-4 and help to calculate the total and monthly feed demand. In addition, farmers should be able to calculate the quantities of feeds to be used daily.

Two aspects should determine daily quantities of traditional supplementary feeds:
- Size of fish (see Table 5-2).
- Speed of consumption of feed.

Table 5-2 demonstrates that for larger fish, proportionally less supplementary feed should be given.

Indicated figures in Table 5-2 should be carefully observed and followed up especially at the beginning of the season.
This explains the importance of time required for consuming the daily portion of supplementary feed, as it serves as reliable feedback on the fish's appetite. Thus, it is useful to be aware if fish have consumed all feed provided.

TABLE 5-2: DAILY PORTIONS OF TRADITIONAL SUPPLEMENTARY FEEDS AS PER THE WEIGHT OF FISH AND DIGESTIBLE ENERGY OF FEED

Growth category of fish (g)	Daily portion of feed as % of body weight of fish				
	9 MJ/kg	10 MJ/kg	11 MJ/kg	12 MJ/kg	13 MJ/kg
≤ 10	12	10.5	10	9	8
10 – 50	10 - 8	9 – 7	8 - 6.5	7.5 - 6	7 - 5.5
50 – 100	8 - 6.5	7 – 6	6.5 - 5.5	6 – 5	5.5 - 4.5
100 – 250	6.5 - 5.5	6 – 5	5.5 - 4.5	5 – 4	4.5 - 3.5
250 – 500	5.5 - 4.5	5 – 4	4.5 - 3.5	4 - 3.5	3.5 - 3
500 – 1000	4.5 - 4	4 - 3.5	3.5 - 3	3.5 - 3	3 - 2.5
1000 – 1500	4 - 3.5	3.5 – 3	3	3 - 2.5	2.5
1500 – 2000	3.5 - 3	3	3 - 2.5	2.5	2.5 – 2
≥ 2000	3	3	2.5	2.5	2

(Source: [43])

Ideally fish should not receive a larger amount of feed than 1-2% of the body weight per time. The advantages of frequent, smaller portions on production efficiency and nutritional value of fish feed are well known. However, some practical obstacles such as time, workforce, or increased feed distribution expenses limit the frequent feeding of fish in pond culture. In the case of fish smaller than 50 grams, an acceptable compromise is to provide daily quantities of supplementary feed in at least two portions. Each portion should be consumed within 0.5-1 hours, depending on the supplementary feed.
If it is possible and economically feasible to organize, distribution of supplementary feed twice per day should also be maintained with larger fish. When the feed is distributed in one portion, consumption time for traditional supplementary feed should not be longer than 1.5-2.5 hours. If feeding is done in two portions, consumption time should be shorter, about 1-1.5 hours. In the case of two portions, the second one should not be late afternoon, as this is the period when DO content in the water may start to reduce.
It is important to emphasize that after fish consume the offered feed, they will return to search and exploit the natural food provided by the pond. Therefore, planned distribution of supplementary feed is also a tool to "motivate" fish to search for food.
When the real feeding of common carp starts, water temperature is lower in late spring, so daily feed consumption should especially be checked. The same applies at the end of the production season when the decreasing water temperature reduces fish's appetite.
When planning daily feeding, it cannot be overemphasising that fish should be fed every day, even on the weekends. Regular feeding of fish on weekends will increase the growth of the individuals and the total biomass weight of fish.

5.1.4 ENVIRONMENTAL IMPACT OF FERTILIZERS AND SUPPLEMENTARY FEEDS IN POND CULTURE

The joint impact of organic and inorganic fertilizers and supplementary feeds on the pond water quality is evident in semi-intensive and intensive pond culture, especially in the second half of the production season, when the quantity of used feed, hence the quantity of metabolic wastes in the water also increases. To reduce water quality problems, Annex 8 presents the main technical information and aspects that are important to observe and calculate with:
- Strength and chemical composition of organic and inorganic fertilizers;
- Amount of metabolic waste when traditional fish feeds are used;
- Monthly programming of fertilization and supplementary feeding;
- Utilization of a simple formula to estimate the single and joint impacts of fertilization and supplementary feeding in pond culture.

Environmental impacts of effluents of different culture systems are increasingly monitored nowadays. Water release is seasonal in pond culture; it mainly happens at the end of the production season in autumn. By this period, properties of pond water are already restored to the same or similar status as were received in spring.

5.2 FISH FEEDING AND ATTAINABLE RESULTS IN INTENSIVE CULTURE SYSTEMS

Primarily determining factors and attainable results in intensive culture systems, including fish species and their age/size groups, are presented in Annexes 9 and 10. An intensive culture system has no feed-related limitations because nutritionally complete industrial feeds are used, ensuring proper fish growth.

5.2.1 SELECTION AND USE OF NUTRITIONALLY COMPLETE INDUSTRIAL FEEDS – THE ALLER AQUA CONCEPT

FIGURE 5-2: WEBSITE AND WEBPAGE ACCESS TO ALLER AQUA FEEDS BY FRESHWATER SPECIES CULTURED IN THE REGION

Species Sheets →	**Cold Freshwater Species →**	→ Arctic Charr
		→ Atlantic Salmon (Fw)
		→ Brown Trout
		→ Rainbow Trout
		→ Whitefish
	Warm Freshwater Species →	→ African Catfish
		→ Carp
		→ Eel
		→ European Catfish
		→ Pangasius
		→ Perch
		→ Pikeperch
		→ Sturgeon
		→ Tench
		→ Tilapia

Nutritionally complete industrial feeds of Aller Aqua cover all dietary requirements through the entire life cycle of all freshwater fish species produced in intensive culture systems in the region.

There is a wide range of species grown on Aller Aqua feeds, each of them with a separate description on their species sheets listed in Figure 5-2, where it is possible to select from fry, pre-grower, grower, and broodstock feeds produced for the given species.

The two main types of **Aller Aqua fry feeds**, granulates and micro-pellets, are presented in Figure 5-3.

- Granulates are real starter feeds for swim-up and early fry of different fish species listed in Figure 5-2. Their chemical composition, nutritional value, and size categories fully support fry growth. Granulates recommended for a specific fish species are accessible at the Aller Aqua website.
- Micro-pellet fry feeds are for rearing advanced fry until reaching pre-grower feed size.

The chemical composition and nutritional value of **Aller Aqua pre-grower feeds** are produced to support the growth stage between the size of 10 and 50 g of fish.

Aller Aqua grower feeds support fish to reach their market size. Like feeds used for smaller growth categories, grower feeds also aim to support and ensure optimal growth, which is about the right balance between growth and feed price, consequently supporting and ensuring economically optimal growth. Therefore, a wide range of feeds are offered for the same sizes of fish.

It is to notice that there is a methodical link between the size of Aller Aqua granulates and pellets and their chemical composition and nutritional value. Each size category is specified to a certain growth stage of fish rearing; thus, the feed size is not only a physical parameter of the product but also a quality indicator and a guide to define the growth stage of fish to feed. This link is illustrated in Figure 5-3. Consequently, when feed is selected for a species, feed size should be considered together with the growth stage of fish, as suggested on the datasheets of each feed found on Aller Aqua's website. This facilitates and ensures proper matching of dietary requirements of growing fish to the composition of feed used. Additional information on this topic is presented in Annex 10 and Table A-3 of the Appendix.

FIGURE 5-3: SIZES OF ALLER AQUA FEEDS AND GROWTH STAGES OF FISH SPECIES TO FED

Fry feeds									Pre-grower feeds	Grower and broodstock feeds			
Granulate size (mm)							Pellet size (mm)						
0.1	**0.2**	**0.4**	**0.5**	**0.5-1**	**0.9-1.6**	**1.3-2**	**1.3**	**1.5**	**2**	**3**	**4.5**	**6**	**8**
Growth stages - Initial and end weight of fish to be fed (g)													
Cold freshwater species													
0.05-0.15	0.1-0.25	0.2-0.5		0.5-2	2-7	7-15	2-7	7-15	15-40	40-100	100-400	400-1000	1000-2000 and above
Sturgeon													
	0.03-0.5	0.5-1		1-2	2-5	5-10	3-6	6-10	10-50	50-200	200-1500	1500-4000	4000-7000 and above
Common carp and tench													
< 0.2	0.2-0.5	0.5-2	0.5-2	2-5	5-8	8-10	5-8	8-10	10-50	50-100	100-300	300-1500	1500-2500 and above
Eel													
	0.2-0.5	0.5-1		1-5	5-15	15-30			30-80	80-120			
European catfish													
	0.05-0.1	0.1-0.3		0.3-1.5	1.5-4	4-10			10-50	50-150	150-500	500-1500	1500-2500 and above
Perch and pikeperch													
0.05-0.2	0.2-0.5	0.5-1		1-4	4-7	7-10			10-20	20-50	50-150	150-1000	
Tilapia													
< 0.1	0.1-0.3	0.3-0.5	0.3-0.5	0.5-1	1-6	6-10			10-70	70-200	200-800	800-1000	
African catfish and pangasius													
< 0.05	0.05-0.1	0.1-0.3		0.3-1.5	1.5-4	4-10	1.5-4	4-10	10-50	50-150	150-500	500-1500	1500-2500 and above

5.2.2 FEED DEMAND CALCULATIONS OF ALLER AQUA FEEDS

Aller Aqua recommends feed programs for the fish species on its website. This starts with feed selection based on performance, which is indicated on the webpages of species sheets listed in Figure 5-2, while details on a particular Aller Aqua feed can be found on datasheets for each product.

After selecting the suitable feed, the required total and daily quantities should be determined. This can also be done with the help of information found on the datasheets of the Aller Aqua feeds. At first the growth stages are matched to feed size categories, then the daily feed portions should be determined on the basis of current fish size and the measured water temperature.

In addition to the determination of daily portions, the total quantity of required feed for a given number of fish to grow should be calculated. The tables of Annex 10 and Table A-3 of the Appendix provide practical details to this, like (1) expectable total quantities of feed to be used for feeding thousand fish as per growth stages, and (2) the predictable length of growing periods at water temperature optimal to the species.

5.2.3 ENVIRONMENTAL IMPACT OF FEEDS IN INTENSIVE CULTURE SYSTEMS

There are two critical reasons to estimate and follow up on the environmental impacts of feeds and feeding in intensive fish culture systems:

- Discharge of effluents of flow-through systems and metabolic waste of fish in cages may represent a considerable environmental impact on the recipient water body and generate eutrophication or a considerable deterioration of water qualities in the recipient.
- Environmental impacts of feeds used in intensive culture systems determine the fish carrying capacity of a culture space. The less impact a feed has, the less water should be exchanged, and the more fish can be grown in a given culture unit.

Low environmental impacts of used feed in combined culture systems such as pond RAS and in-pond RAS are also important. The lower the impact is, the more fish can be grown in a system, as the load is less on the extensive (i.e., on the unfed) pond unit. Required technical consideration and details on the topic are presented in Annex 8.

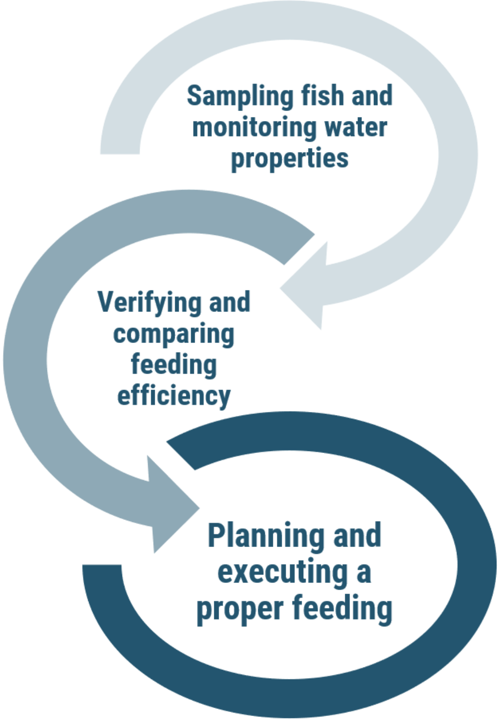
6

PRECONDITIONS OF PROPER FEEDING AND VERIFICATION OF FEEDING EFFICIENCY AND RESULTS

The most important preconditions of proper feeding are:
- Quantities and consumption of feeds should always be observed and followed up, with due attention to the behaviour and reactions of fish.
- Regular fish samplings, feed demand calculations, and verification of feed efficiency.
- Monitoring and verification of water properties, which determine the appetite of fish.

Verification of feeding efficiency and results are equally important and must be performed (Figure 6-1).

FIGURE 6-1: THE CYCLE OF PROPER FISH FEEDING



6.1 SAMPLING OF FISH

As detailed in the previous chapter, daily quantities of feed are calculated based on individual fish weight. In addition, it enables the verification of the gained weight of fish, which indicates the efficiency of feeding; thus, having information on fish weight is indispensable.

Though there are differences between the techniques and routines of fish sampling in pond culture and intensive culture systems, some general aspects and rules are uniformly relevant in all culture systems. These are:
- Regular inspection and monitoring of fish stocks should be a basic duty performed at least in the morning and late afternoon in pond culture and several times in intensive culture systems every day, including weekends and holidays.
- Observation of the behaviour, movement, and reactions of fish before and during feeding, regardless of the feeding method/technique.
- A frequent random and ad-hoc sampling of fish is usually combined with one of the daily inspections of ponds or rearing devices. The sampling can be done by a lift or a cast net in pond culture, while a suitable drag or scoop net in intensive culture systems can be used.

Large fish samplings when a significant number of fish are caught for recording the average body weight in pond culture are implemented at least once a month when fingerling is produced. A similar larger sampling of grow-out fish should happen in the first third, in the middle, and in the last third of the production season, keeping in mind that the more intensive the production is, the more frequently the sampling should be repeated. The last sampling is already used to plan the marketing and wintering of fish harvested in the autumn.

FIGURE 6-2: A FREQUENTLY USED EQUIPMENT FOR FISH SAMPLING IN POND FISH FARMS

Cast net is a basic tool in pond culture.

In intensive culture systems, the weight of smaller fish consuming fry and pre-grower feeds should be measured at least every five days. Fish receiving grower feed should be sampled every week, excluding larger specimens of sturgeons, where a monthly sampling should be sufficient.

Some benefits of a regular and accurate fish sampling are:

- Fish growth and feeding efficiency can be calculated for any specific period.
- Enables an early recognition of potential problems that may reduce feeding efficiency. In other words, unforeseen problems can be confronted in time.
- Allows effective, in time grading and separation of the fish by size.

The process of fish sampling summarized in Box 6-1 is simple and, after trying a few times, will become an easy routine work.

There is a wide range of different feed registers and ledgers recommended and used in fish farms. These vary from a simple exercise book to electronic forms, where data can be arranged in any required order/sequence.

These records are acceptable if all important data and information are accurately documented. From the different options, Figure 6-3 presents all the key data, which must be included and recorded in a feed register.

BOX 6-1: STEPS OF SAMPLING FISH

There are certain aspects and uniformly applicable rules for sampling fish:
Fish should be captured when they are gathering and waiting to be fed. This time a little amount of feed will attract and adequately concentrate fish in the sampling spot.
Fish sorting should be done quickly, and selected fish should be kept in well-aerated water until they are weighed and counted.

- The average weight of captured fish in the sample should correctly represent the entire stock:
  Less fish (about 20-30 specimens) need to be sampled when the sizes of fish are apparently uniform.
- A larger sample is needed when there are well observable differences in the size of the same species. Depending on size, captured fish should be sorted into two groups (sample's size: about 40-60 fish) or even three (sample's size: about 60-90 fish). The proportion of sorted groups also carries valuable information; therefore, the ratio of fish should be calculated, especially when the different size groups of fish are planned to be moved to separate rearing devices, which is a common practice in all intensive culture systems.

FIGURE 6-3: KEY DATA TO BE INCLUDED IN A FEED LEDGER OF A FISH FARM

Feed register													
Ponds or device (No.)	**Name of species**	**Feeding period**			**Number and weight of fish**						**Used feed**		
					Initials			**Final**					
		Date (from)	Date (to)	Days (No.)	No.	g/pc.	Total (kg)	No.	g/pc.	Total (kg)	Name	kg/day	kg/period

6.2 FOLLOW-UP ON KEY WATER PROPERTIES

From the different water quality parameters listed in Chapter 4 and detailed in Annex 7, water temperature and DO content are of major importance to be known and followed up. Consequently, water temperature should be closely known next to fish weight to calculate daily feed portions.

Water temperature is usually constant in indoor farms which receive underground water. In this case, seasonal, time-to-time temperature measurements provide enough information to calculate daily feed portions of fish.
In such systems, as well as in an intensive outdoor tank, cage, and enclosure farms, the high density of fish stirs up the water so that the temperature will be more or less the same within the entire device. Thus, measuring water temperature in a sample that is taken with a bowl or large cup from about 30-50 cm below the water surface should be enough.

In outdoor fish farms that are exposed to daily and seasonal changes of sun radiation, winds, air temperature, motion and thermal stratification of water, etc. (Annex 7), taking water samples near to the water surface is not enough, as the temperature of deeper water layers near to and at the pond bottom can be considerably different. For this purpose, simple equipment, shown in Figure 6-4, is recommended to be used.
A water thermometer, an accurate one produced for aquarists, or a simple but reliable baby bath thermometer can be successfully utilized.

In addition to temperature, the DO content of water is another essential water property, as fish only feed when oxygen conditions of the water are favourable. As soon as it is out of the acceptable range, fish lose appetite and stop feeding. Unless fish are stocked intensively, and mix water, the DO content of water stratifies similarly to water temperature. Too low DO content near the pond bottom deters common carp from the feeding ground.
The same equipment presented in Figure 6-4 is used for sampling water for DO content. It must be emphasized that excessive scientific precision is not required here. A reliable, accurate kit produced for aquarists serves well to measure DO.
Though the above recommendations (i.e., how and when water temperature and DO content should be sampled and measured) might seem time-consuming, but they are not. After a short period of regular diurnal measuring, reliable knowledge and skilled routine will develop on when (which period of the day) and how to perform these critical feeding-related tasks. After a while, when skills are developed, a close estimation of the temperature and DO will be possible.

6.3 VERIFICATION OF FEEDING EFFICIENCY

Verification of feeding efficiency is among the outstandingly important elements of fish production. It includes:

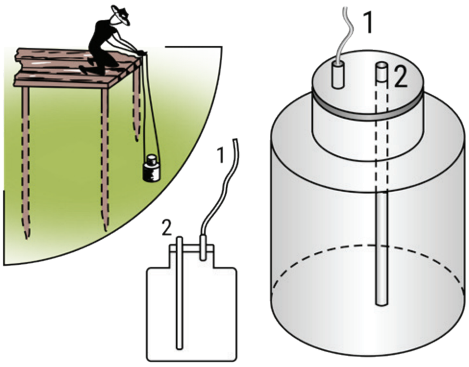
- FCR calculations.
- Individual growth of fish and also as biomass.
- Performance and quality of produced fish.
- Feed and feeding related economic calculations.

6.3.1 FEED CONVERSION RATIO (FCR) IN DIFFERENT CULTURE SYSTEMS

Feed Conversion Ratio (FCR) is a widely used parameter of feeding efficiency in animal husbandry. It is obtained by dividing the feed fed with the weight gained by fish (weight of used feed per weight gained due to the feed).

During the development of pond culture in the region, feeding efficiency has always been a prime aspect to observe and follow up. Therefore, similarly to other branches of animal husbandry, feed conversion ratio (FCR = feed applied [kg]/weight gained [kg]) is also used in pond culture, but with certain modifications summarised in Box 6-2. Table 6-1 shows the empirical FCR and P-FCR values of the most commonly applied supplementary fish feeds.

FIGURE 6-4: EQUIPMENT FOR BOTTOM WATER SAMPLING



A 0.3-0.5 litre bottle equipped with an outlet (1) and an inlet (2) pipe fixed to a measuring stick to take water samples from deeper waters.

BOX 6-2: CALCULATION OF FCR IN POND CULTURE – THE P-FCR

Traditional supplementary feeds such as cereal grains have a rather high FCR when fed without natural food. However, when the same feeds are applied in pond culture, obtained FCRs become considerably lower due to the synergy of a combined effect of natural food and supplementary feeds. For this reason, the terms' 'absolute' and 'relative' FCR were already suggested to be used in the early 1950s. However, they have not gained acceptance in practical pond culture, most probably as they are not compatible with the nutritional terminology of animal husbandry, where exclusively the term FCR is used, without any epithets.

Considering the need for exact terms which allow the distinction and comparison of feed efficiency applied in different fish culture systems, this book, besides FCR, also uses P-FCR (in-pond feed conversion ratio) as an exclusive term for characterizing the feed conversion ratio of all types of supplementary feeds used in pond culture.

The FCR of a specific supplementary feed in pond culture is not only efficient due to its composition and nutritional value but is also influenced by the age of the fish fed and the period of the production season:

- A supplementary feed with higher crude protein content usually ensures a lower P-FCR.
- In the case of younger age groups and less intensive pond culture, the P-FCR will usually be better; 1-2 at one-summer-old, 1.5-2.5 at two-summer-old, and 2-3.5 at tables fish.
- P-FCR varies according to the month of the production season, which is explained by the absolute and relative biomass of natural food. Accordingly, supplementary feed with an FCR of about 4-5 will reduce to 1.5 at the beginning, 2-2.5 in the middle, and about 3.5 P-FCR in the second half of the production season. Consequently, at the beginning of the season, P-FCR is very low (1-2), but at the end of the production season, it becomes rather high and almost reaches the original FCR of feeds (4-5) [107].

Seasonal changes of P-FCR prove the need to adjust both the amount and the nutritional value of supplementary feed to the availability of natural food, as explained in Annex 6.

It is important to emphasize that any type of feed, regardless of whether it is a mixture, farm-made compound feeds or a nutritionally balanced, even a nutritionally complete industrial feed with an excellent FCR, its P-FCR will be lower when natural food is also added to the diet.

It can be concluded that a distinction and calculation of P-FCR together with the original FCR facilitates a correct comparison of fish feeds applied in different culture systems.

TABLE 6-1: FCR AND P-FCR OF SOME TRADITIONAL SUPPLEMENTARY FEEDS USED PURELY OR IN SIMPLE FEED MIXTURES

Feed	FCR	P-FCR
Cereals		
Barley	4-5	1-3.5
Wheat	4-5	1-3.5
Corn	4-5	1-3.5
Rye	4-5	1-3.5
Oat	4-5	1-3.5
Mill by-products		
Barley bran	8-10	4-6
Wheat bran	8-10	4-6
Wheat (feed flour)	4-5	1-3.5
Foot flour	4.5-5.5	1-3.5
Rye bran	10-12	5-7
Rice bran	8-10	4-6

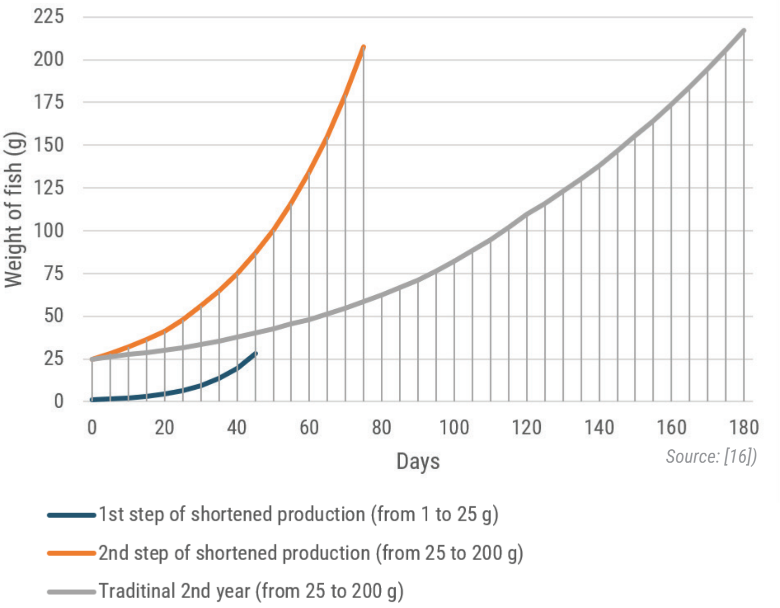
(After: [2] and [98])

6.3.2 INDIVIDUAL AND BIOMASS GROWTH OF FISH

The connection between the individual and biomass growth of fish is crucial. They show a negative correlation in traditional pond culture; the less fish is stocked, the quicker and larger they will grow, and vice versa. During the development of pond culture, empirical stocking figures have been established and are still applied (Annex 10).

The correlation between the total number of stocked fish and the individual and total weight of fish in a pond culture is related to the feeding principles of pond culture, detailed in Annex 6. With the development of quality fish feeds discussed in Annex 5 and 6, faster growth of the same or even bigger amounts of fish in the same production area became feasible, as demonstrated in Figure 6-5.

FIGURE 6-5: COMPARISON OF THE PRODUCTION LENGTH OF A TRADITIONAL THREE-YEAR-LONG AND AN INTENSIFIED FEEDING-BASED TWO-YEAR-LONG POND CULTURE

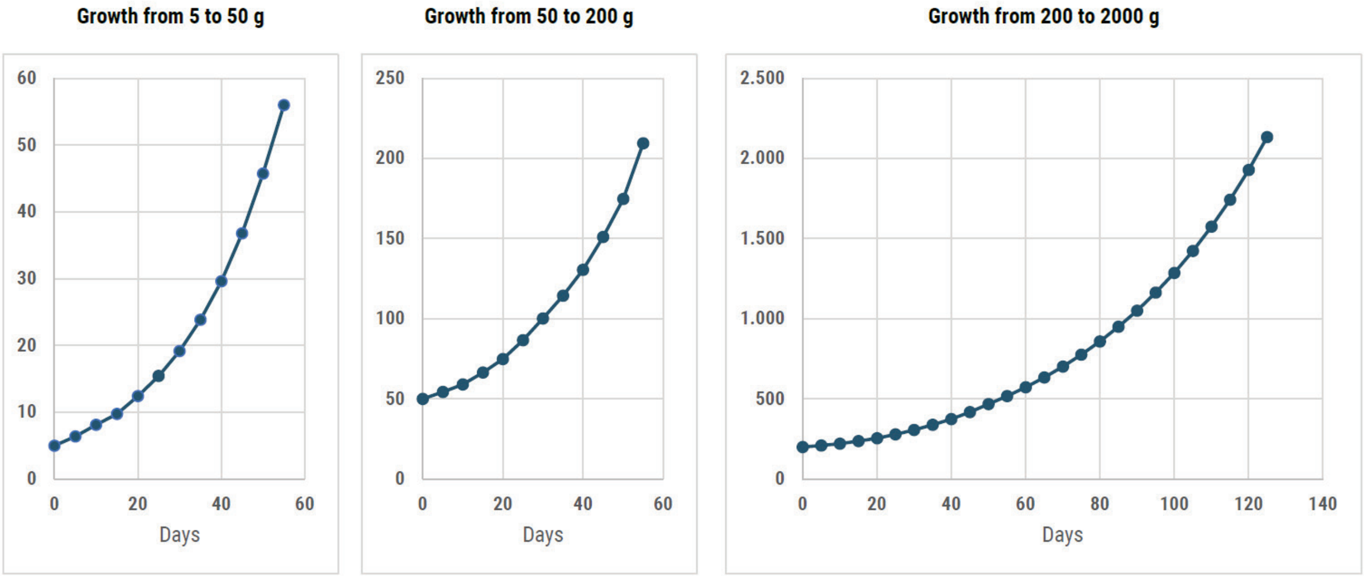


Source: [16]

Nutritionally complete industrial feeds of today are increasingly able to reveal and support the growth potential of fish species produced in intensive culture systems in the region. For example, Figure 6-6 demonstrates in the example of common carp that not more than a total of 110-120 days (3.5-4 months) and 120-130 days (4-4.5 months) are enough to reach the same size which requires three production seasons in a traditionally managed pond culture.

Tables of Annex 3 present growth results of cultured fish species achievable in outdoor fish farms. Tables of Annex 10 demonstrate growth results of the same species under ideal culture conditions, including constantly favourable water temperatures.

FIGURE 6-6: GROWTH CURVE OF COMMON CARP FED WITH ALLER CLASSIC BIOLOGICALLY COMPLETE INDUSTRIAL FEED



(Source: [16])

6.3.3 PERFORMANCE AND QUALITY OF PRODUCED FISH

In addition to the growth and egg/caviar production of brood fish, the fish performance also includes the efficiency of food and/or feed utilization, as well as body and health conditions and susceptibility to stress. These are qualities that can and should objectively be judged. Qualities of produced fry, advanced fry, fingerling, and stocking materials of larger sizes are also judged by listed performances.

Judging the quality of table fish for consumption is more complex. In addition to the general appearance of a fish (round, well-fed forms, no missing scales, wounds, signs of parasites, etc.), its taste is rather subjective. Very soft and loose flesh, rough odour, and strange taste discussed in Annex 4 are among problems that do not appear when a fish is properly fed. Consequently, the organoleptic qualities of produced fish can be improved or reduced by feeding; thus, the quality of used feeds is not indifferent.

6.3.4 FEED AND FEEDING RELATED ECONOMIC CALCULATIONS

In practical fish farming, direct production costs are investigated and calculated in planning and evaluating production. Calculations also include feed and feeding related expenses, as they cannot be excluded and observed on their own. Figure 6-7 presents a universal balance sheet that can be used for planning and evaluation of production costs. It must be emphasized that this is a model of a summary sheet; consequently, each item should be calculated in detail before the final figures are inserted here.

Production costs, feed and feeding related expenses are different in pond culture and intensive culture systems.

In the case of pond culture, the price and distribution of different fertilizers, preparation of cereal grains, simple feed mixtures, and farm-made compound feeds should also be considered when planning and evaluating feeds and feeding expenses of fish.

FIGURE 6-7: A BALANCE SHEET OF MAIN ITEMS OF PRODUCTION COSTS TO BE CONSIDERED IN PLANNING AND EVALUATION

Name of items with unit	INPUT			OUTPUT		
	Total (Qty.)	Costs		Total (Qty.)	Income	
		Unit price	Total price		Unit price	Total price
Fish (pcs.)						
Fish (kg)						
Subtotal - fish						
Water (m³)						
Feeds (kg)						
Organic fertilizers (t)						
Chemical fertilizers (t)						
Lime (t)						
Chemicals - solid (kg)						
Chemicals - liquid (l)						
Drugs - solid (kg)						
Drugs - liquid (l)						
Fuel (l)						
Electricity (kWh)						
Labour (md)						
Balance						
Result						

6.4 COMPARISON OF FEEDS USED IN DIFFERENT CULTURE SYSTEMS

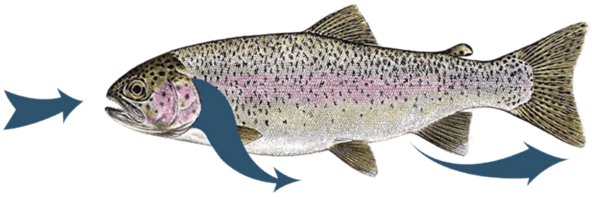
There are many different ways to compare feeds, which should also consider and focus on the technical and financial advantages of a specific feed. In addition, to **feed qualities** discussed in Annex 4, the following key properties of feeds should also be considered.

Suitability of feeds
For a certain fish species, together with growth stages, it is usually an evident aspect to observe. Still, there are cases in practical fish farming when less or no suitable feeds are used, resulting in fish receiving better or weaker feeds at a specific growth stage than the requirement of the species and age.

Physical performance of feeds
FCR in intensive culture systems and **P-FCR** in pond culture indicate both technical and economic qualities of feeds.

The required quantity of feed to produce one kilogram of growth is always less if the FCR is low, and vice versa. This correlation illustrated in Figure 6-8 supports the idea that a feed with low FCR will generate less metabolic waste per unit growth, than a feed with higher FCR. Consequently, the environmental impact of the same quantity of feed will be less if the FCR is lower. When effluent water has to be continuously discharged, or the feed is used in RAS, environmental impacts of the feed are especially not indifferent at all. This is also closely related to the FCR of the used feed.

FIGURE 6-8: A SCHEMATIC CORRELATION BETWEEN THE RELATIVE QUANTITY OF INGESTED FEED AND RELEASED METABOLIC WASTES



Feed with higher FCR will generate more metabolic wastes (above) than a feed with a low FCR (below).

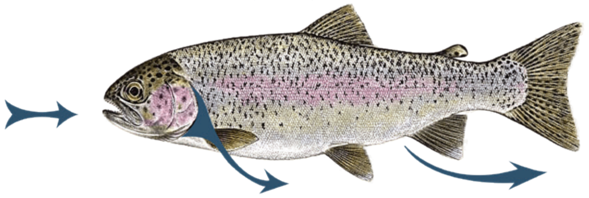


Table 6-2 demonstrates the example of common carp table fish that feeds with lower FCR and facilitates the production of more fish under the same culture conditions. It means that due to a lower FCR, the same size of culture space under the same exchange rate and/or water aeration can support the growth of more fish. However, the opposite is also true; as the value of FCR increases, the fish growing capacity of the same culture space and conditions decreases.

When fry of carps and fingerling of common carp are reared, nutritionally balanced and nutritionally complete industrial feeds are feasible to be used, especially when a fast, healthy growth is expected in an intensively stocked fish pond. In this case, particularly in the second half of the growing season, very good FCR and even better P-FCR can support profitable production.

TABLE 6-2: CORRELATION BETWEEN THE FCR OF FEED AND THE QUANTITY OF TABLE FISH PRODUCTION OF COMMON CARP WITHIN THE SAME PRODUCTION CONDITIONS IN INTENSIVE CULTURE SYSTEMS

FCR	Proportion of fish production relative to FCR	FCR	Proportion of fish production relative to FCR
0.5	300%	**1.5**	**100%**
0.6	250%	1.6	94%
0.7	214%	1.7	88%
0.8	188%	1.8	83%
0.9	167%	1.9	79%
1	150%	2	75%
1.1	136%	2.1	71%
1.2	125%	2.2	68%
1.3	115%	2.3	65%
1.4	107%	2.4	63%
1.5	**100%**	**2.5**	60%

Economic performance of feeds

Fish feeds should also be evaluated and compared by their economic performances. FCR of feed also plays a leading role in that. However, lower FCR feeds have higher absolute prices. Still, they must be considered together with the benefits they are able to offer, including declared quality, fast and healthy growth of fish with better predictability, which all support a high growth potential of cultured species.

This guarantees a **faster return of money** invested in fish feeds, as fish are quicker to reach the marketable size and can be sold earlier, even in a season when fish is missing in the market. Reducing the three-year-long production cycle of carp in pond polyculture to a two-year-long cycle with the help of nutritionally balanced and complete industrial feeds allows a one-year shorter return of money invested in production costs (fish, feed, water, etc.).

Finally, though the flesh quality of produced fish is rather subjective, the consistency of fish meat quality produced on these feeds can and should influence their selection and use.

7

FEEDING-RELATED WORKS IN FISH FARMS

Even the best quality feed will considerably loose its value, if it is improperly handled and used on a fish farm. Incorrect storage and preservation, improper preparation, and insufficient distribution of feeds are among the most frequent problems. To raise awareness, this last chapter reviews how to accomplish feeding-related tasks simply and correctly on fish farms.

7.1 STORAGE AND PRESERVATION OF FISH FEEDS

Annex 4 not only provides information on the expected and necessary quality of feed to be purchased and used but also on possible causes of deterioration that may occur during storage in a granary.

The feed can become contaminated, mouldy, or rancid; it can undergo chemical transformations, form *biogenic amines**, may become infected with bacteria, or accumulate *mycotoxins** due to the growth of mould. All of these can reduce the nutritional value of feeds, may cause nutritional deficiencies and health problems, and even lead to fish death.

It is evident that significant chemical and biological processes can occur in feeds during improper storage. The form and extent of chemical changes depend on environmental factors (humidity and temperature of the air, contact with water, exposure to excessive heat and light, etc.). At the same time, biological processes can be triggered by bacterial infections, or moulds, which may appear when grains are harvested or stored. Thus a clean, dry, well-aerated, insect- and rodent-free feed storage is essential for an efficient, free of losses feed utilization.

Consequently, the role of proper feed storage in preserving its qualities is outstanding. There are well established technologies to maintain required conditions in traditional agricultural granaries.

Pond fish farms built several decades ago usually have properly constructed settings to store feeds.

Modern and modernized pond and intensive fish farms increasingly use shipping containers to store feed, especially for less bulky but more expensive feeds, like farm-made compound and nutritionally balanced/complete industrial feeds. In larger fish farms, a set of containers can ensure safe storage. Silos are also suitable for storing feeds properly.

FIGURE 7-1: ELEMENTS OF A SUCCESSFUL FEEDING OF FISH

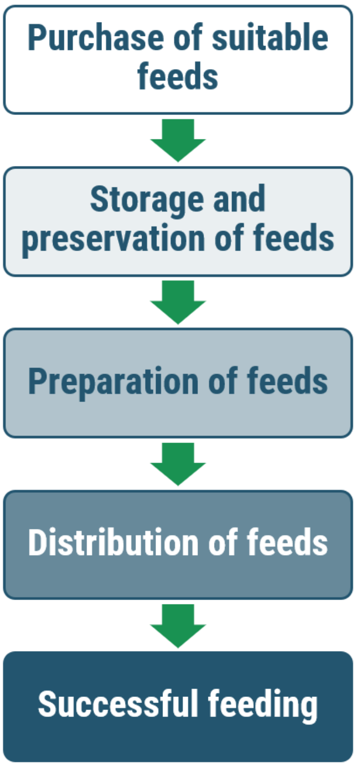


FIGURE 7-2: SHIPPING CONTAINER USED AS A FEED STORAGE

An inexpensive way of moist and rodent-free fish feed storage. A roof fixed on the top of the container provides shelter against excessive heat.

7.2 PREPARATION AND DISTRIBUTION OF FEEDS

There are certain tasks that should be completed before feeds are distributed, which are different for supplementary feeds and nutritionally complete industrial feeds.

7.2.1 PREPARATION OF FEEDS USED IN POND CULTURE

Preparation of supplementary feeds depends on the type of feed, whether they are grains, simple feed mixtures, farm-made compound feeds, or nutritionally balanced industrial feeds.

Grains and simple feed mixtures should more or less be prepared in the same way. However, depending on fish size, preparation means a coarser specific level of grinding, crushing, and mixing ingredients in the case of simple feed mixtures. Grinding of grains is especially important when fry and fingerlings are fed, but larger fish will also benefit from an improved rate of digestion when grains are appropriately ground. Experiments summarised in Table 7-1 demonstrate that grinding of grains facilitates better and more thorough digestion, so a more favourable P-FCR can be achieved.

TABLE 7-1: EFFECT OF GRINDING ON THE DIGESTIBILITY OF TRADITIONAL SUPPLEMENTARY FEED INGREDIENTS

Grinding level	Lupin (sweet)		Rye	
	Protein (%)	Carbohydrate (%)	Protein (%)	Carbohydrate (%)
Coarse	84.0	50.0	84.4	33.0
Fine	93.1	71.0	88.0	60-75

(Source: [49])

According to old-fashioned field practices of pond culture in the region, it was not considered absolutely necessary to pellet **farm-made compound feeds**. Usually, these were fed as dough. However, based on practical experiences later, it appeared that it was beneficial for the fish to receive the feed in pelleted form, which contained all ingredients in the desired proportions. As a result, farm-made compound feeds are pressed through a pelletizer. Water resistance of such feeds is rather limited, so farm pelleted feed should be fed in a way that allows the feed to be consumed entirely by fish before it disintegrates in the water.

Soaking grains, whether ground, crushed or whole, is a widely practiced technique to soften their consistency. However, finely ground grains, especially those for advanced fry and fingerlings, should only be soaked shortly before distribution, as prolonged soaking may reduce nutritional values presented in Table 7-2. In addition, increased leaching of nutrients will also happen if feeds remain unfed for a longer period.

TABLE 7-2: EFFECT OF SOAKING ON THE MASS AND COMPOSITION OF TRADITIONAL SUPPLEMENTARY FEED INGREDIENTS

Period of soaking	Lupin (sweet)				Rye			
	Mass (%)		Protein (%)		Mass (%)		Carbohydrate content (%)	
	Coarse grinding	Fine grinding	Coarse grinding	Fine grinding	Coarse grinding	Fine grinding	Coarse grinding	Fine grinding
10 minutes	100	95	100	100	100	100	100	66
20 minutes	95	83	93	90	92	86	88	58
120 minutes	80	80	90	82	90	80	80	33

(Source: [49])

In modern intensive pond culture, when the aim is to considerably increase the number of produced fish and/or to reduce the three-year-long production cycle to a two-year-long one, the use of **nutritionally balanced** or **nutritionally complete industrial feeds** becomes necessary, as natural food is reduced significantly or is exhausted in the pond (see Annex 6). These feeds do not need any preparation; and can be fed dry in the form supplied.

7.2.2 PREPARATION OF FEEDS USED IN INTENSIVE CULTURE SYSTEMS

Regarding feed preparation, the situation is similar as that described above. In intensive culture systems, where only nutritionally complete industrial feeds are used, consequently there is no need for preparation, as feeds are fed in the same form as purchased.

7.2.3 DISTRIBUTION OF FEEDS IN DIFFERENT CULTURE SYSTEMS

The feed can be distributed manually or with the help of demand or pre-programmable automatic feeders. Still, even then, the presence of a skilled worker is important to observe behaviour and reactions of fish.

In a traditional pond, cultured fish are fed at fixed places marked with poles or buoys across the fish pond. Feed is usually distributed from a boat. In large ponds, special metal boats with a slot in the bottom through which grain is washed out are used to distribute bulky supplementary feeds like maize, wheat, etc. The feed can also be distributed from a vehicle if there is a driveable dike around the pond.
It is important to mention that common carp feeding should always be scheduled after grass carp have received their daily green feed portion at a different location. Floating feeding rings are used for this purpose where fresh aquatic or terrestrial plants are deposited. This way, grass carp are the first to feed; thus, they will not consume the feed meant for common carp.

In intensified pond polyculture where pelleted feeds are used, and in intensive culture systems where nutritionally complete industrial feeds are applied, in most cases, demand and programmable automatic feeders are usually operated (see Figure 7-3). These feeders control the quantity of feed that fish should receive at a time, usually as much as they can consume quickly without loss.
Whether the feed is distributed from a boat or through demand or automatic feeder, birds and terrestrial animals also gather at the feeding spots where they compete with fish for food or predate on feeding fish. For example, water birds can learn quickly how to use a demand feeder while predator birds remain waiting on any suitable object, including poles, which mark feeding spots in a fish pond. These types of anomalies should also be detected and reduced/eliminated.

It is absolutely necessary to detect and verify how quickly the feed is consumed after feeding. Floating pellets can easily be observed if deposited on feeding frames, which stops them from drifting away.
If sinking pellets are used, the speed of fish to grab and swallow them should be faster than the sinking speed of pellets. Though it is no problem for common carp and sturgeon if the feed sinks to the bottom, it is still better to provide only as much feed as the fish can already ingest from the water column. When traditional grain-based supplementary feeds are used, it is recommended to check feed consumption with a roughly 30x30 cm feed searching hand net (Figure 7-4).

7.3 MACHINERY USED FOR PREPARING SUPPLEMENTARY FEED ON POND FISH FARMS

Worldwide field experiences prove that a basic set of machinery can be sufficient to prepare (grind, crush grains, mix, and pellet) the different types of supplementary feeds. It is important that the capacity should be proportional to the needs of the fish farm, and the set should include (1) a hammer mill with different screens, (2) a feed mixer (which is often a cement mixer), and (3) a pelletizer.

FIGURE 7-3: DEMAND AND AUTOMATIC FEEDERS

(Photo by courtesy of Megafish Kft.)

Pendulum demand feeder on a turning console allows loading from a dike (above). Programmable automatic feeder disperses pellets over a wide water area (below).

FIGURE 7-4: FEED SEARCHING HAND NET

BOX 7-1: EXTRUSION OF FEEDS AND THE NEED FOR AN EXTRUDER IN FISH FARMS

Extrusion changes the physical characteristics of fish feeds favourably (high water resistance, low specific gravity). In addition, the process improves the digestibility of the nutrients, breaks down substances that adversely affect metabolism, and kills bacteria and fungi. However, despite these advantages purchase and operation of the necessary machinery far exceeds the need for a fish farm.

GLOSSARY

A

Acetylcholine – is a compound in the nervous system which functions as a neurotransmitter. In addition, it is a stimulus transmitting substance.

Adipose – body tissue used for fat storage.

Aerobic organisms – are the ones that need molecular oxygen for their growth, multiplication, and energetic processes of metabolism. The presence of molecular oxygen is essential for most of their lives, though some are even able to grow under anaerobic conditions. In other words, organisms that require oxygen to maintain their characteristic structure of living matter and provide life phenomena.

Aerobic –processes and organisms that require oxygen.

Amino acids – are simple organic compounds both containing a carboxyl (—COOH) and an amino (—NH2) group.

Anabolic – relating to or promoting anabolism.

Anabolism – synthesis of complex molecules in living organisms from simple ones together with energy storage.

Anaerobic – processes and organisms which function in the absence of oxygen.

Antioxidant – compounds that reduce (per)oxidation processes in the fat content of feeds. Usually, they are organic compounds added to feeds. A most frequently used antioxidant is butyl-hydroxytoluene (BHT). Feeds of plant and animal origins contain antioxidant vitamins (e.g., vitamin E, vitamin C), flavonoids, and antioxidant peptides. They are also produced in animal and human bodies, including antioxidant enzymes and low molecular weight antioxidant compounds (e.g., glutathione, uric acid).

Assimilation – (1) A process by which living organisms convert inorganic matter to organic materials. (2) Absorption and digestion of food or nutrients by the body or any biological system with the help of macro and micro consumers in aquatic ecosystems. Assimilation and disintegration correspond to the building processes of biological production.

Autotrophic organisms – living organisms that build up their organic matter from inorganic substances engaged in their environment (carbon dioxide, water, minerals and ions) by using the energy of sun (photosynthesis) or chemical energy gained from the alteration of inorganic substances (chemosynthesis).

B

Beta-agonists – substances that open airways by relaxing the muscles around them, resulting in easier breathing.

Biogenic amines – low-molecular-weight organic bases formed by the degradation of amino acids, mainly by enzymes of microorganisms. They can also appear in many foods during processing operations. High levels of biogenic amines can cause poisoning.

Biosynthesis – is the process through which a living cell or organism builds more complex molecules from simple ones.

BOD – biochemical or biological oxygen demand of water expresses the content of its biodegradable organic matter. It means the consumption of oxygen required for the microbial (bacterial) decomposition of biodegradable organic substances in water, so by measuring it, the organic nutrient load of a certain water body can be assessed. The organic matter content of water is measured by the amount of oxygen consumed during 5 days of biodegradation. It is measured as mg O_2/l or g O_2/m^3.

Brown motion – irregular movement of tiny particles floating in gas and liquid (also in water) caused by the collision of molecules in the medium.

Buffer capacity – is responsible for reducing shock-like pH changes in water based on the CO_2-HCO_3-CO_3 system. It means that waters absorb a certain amount of acid or alkali without a significant change in their pH; thus, their acidity or alkalinity remains close to the original value. The process is the most important buffer mechanism in most freshwaters.

Buffer system – in chemistry, it concerns the resistance of a solution to have pH alterations when acids or bases are added to it.

C

Capture fishery – refers to all kinds of naturally occurring living resources harvested in marine and freshwater environments.

Catabolic – is to promote catabolism.

Catabolism – breaking down complex molecules in living organisms into simpler ones, which releases energy. It is also called destructive metabolism.

COD – Chemical oxygen demand is an indicator that shows the reducing capacity of substances in water. It is determined by measuring the oxygen consumption during the oxygenation of organic matter in a water sample. This is a standard method to determine the organic matter content of waters and thus their impurity (saprobity). It is measured as mg O_2/l or g O_2/m^3.

Collagen – insoluble fibrous protein that composes the main structural component of animal connective tissue.

Convectional current – a current in a fluid resulting from convection, i.e., transference of a mass of heat within a fluid caused by the tendency of warmer and less dense material to rise.

Culture-based fishery – stocking and restocking of freshwater lakes, reservoirs and floodplain fisheries management.

D

Diffusion – intermingling with another substance by the movement of particles.

Dioxins – (chemical name polychlorinated dibenzo-dioxins, PCDDs) are also called persistent organic pollutants (POPs), which means that it takes a long time for them to break down once they are in the environment. They are highly toxic and accumulate primarily in the adipose tissue of animals and humans. Due to their high fat solubility, they can quickly transfer through the food chain and cannot be naturally removed from the animal or human body.

E

Electrochemical – heterogeneous *redox** reactions where oxidation and reduction are constantly happening at the interface of liquid and solid.

Endothelial – the endothelium is a thin membrane that lines the inside of among others of the heart and blood vessels. Continuous endothelium is found in most arteries, veins and capillaries of the brain, skin, lung, heart and muscle.

Enzyme – a substance produced by a living organism acts as a catalyst to generate a specific biochemical reaction.

Epithelial – epithelial cells line body surfaces. They are found on the skin, blood vessels, organs, etc.

Erucic acid – is a monounsaturated omega-9 fatty acid present in oil-rich seeds of the Brassicaceae family of plants, particularly in rapeseed and mustard seeds. It mainly enters the food chain when rapeseed oil is used for industrial food processing and home cooking in certain countries.

Eurythermal – an organism that can tolerate a wide range of temperatures.

Exogenous feeding of fish larvae – means that larvae to start feeding from the environment.

F

Facial nerves – is the seventh pair of cranial nerves innervate the facial muscles and the tongue. The nerves travel from the brain stem through openings in the skull to the face and the tongue and send information between the brain and the muscles found there.

Fatty acids – important lipid components of a body. During digestion, the fat breaks down into fatty acids, which can then be absorbed into the blood.

Fusarium – one of the most common microscopic fungi that infect plants, especially cereals. The mycotoxins these moulds produce can cause severe production losses and are toxic. In addition, Fusarium mycotoxins cause reproductive disorders, developmental resilience, renal and hepatic degeneration, and, in severe cases, mass mortalities.

G

Generative growth – directs the energy of plants toward flower and seed production. Generative growth occurs in spring/summer-like conditions.

Glossopharyngeal – relating to the tongue and pharynx.

Gossypol – toxic crystalline compound present in cotton-seed oil and cottonseed meal.

GSM (Geosmin) – is characterized by its odour and taste and is found in drinking water and food ($C_{12}H_{22}O$). It is universal in nature. Geosmin is mainly produced by soil-dwelling bacteria and aquatic cyanobacteria. The human nose is susceptible to this substance and can detect it at an extremely low concentrations.

H

Haemoglobin – is a red protein responsible for transporting oxygen in the blood of vertebrates. The molecule comprises four subunits; each contains an iron atom bound to a haem group.

Heterotrophic organisms – consume plants or animals for energy and nutrients. Decomposing micro-organisms also belong to this group.

I

Immunoglobulin – also known as antibodies, are glycoprotein molecules in serum used by the immune system to recognise specific antigens.

Intermediate metabolism – is an intracellular process that converts nutritive material to cellular components.

L

Lupinine and lupanine – lupinine is a bicyclic quinolizidine alkaloid, whereas lupanine has a methylene-bridged dipyridodiazocine structure containing two quinolizidine systems. Both are quinolizidine alkaloids (QAs) produced by lupins and many members of the Fabaceae family. Alkaloids are secondary metabolites in plants, where their main function is a chemical defence against herbivores and microorganisms. They have bitter taste and are toxic to vertebrates and insects. Lupin alkaloids show moderate toxicity in vertebrates; thus, they must be debittered before consumption. Between 89 and 97% of the QAs present in seeds can be removed by soaking or boiling.

M

MCPD (chemically: 3-monochloropropane-1,2-diol or 3-chloropropane-1,2-diol) – is used in paint manufacture to reduce the freezing point of an intermediate, a solvent for cellulose acetate and dynamite. It is also registered as a rodenticide. Beyond the risk of cancer, 3-MCPD esters are likely genotoxic, causes male infertility. It can be present in drinking water, packaging materials, dairy, meat, and soya products.

Melamine and cyanuric acid – are widely used in chemistry and industry. Melamine (1,3,5-triazine-2,4,6-triamine) is a highly nitrogenous heterocyclic compound, a colourless or white crystalline powder with a water solubility of 3 g/l, and a wide range of applications. For example, they are used in the plastics industry, in manufacturing fertilizers, pesticides, and feed additives, and against ectoparasites. Falsification of the protein content of food and feed with melamine has also appeared.

Membrane transport – is a collection of mechanisms that maintains a continuous material transport through the two sides of the membrane. In passive transport, molecules move along the concentration gradient, while in the active one, they move against it, which requires energy.

Metabolic waste of fish includes faeces, carbon dioxide, ammonia and urea.

Metabolism – is a chemical process that occurs within a living organism to maintain life, converting nutrients into energy.

Methylmercury – is a highly toxic organic mercury compound formed from metal mercury by anaerobic bacterial activity. It can be present in water and integrated into fish through the food chain. Thus, it accumulates in older and larger fish both in marine and freshwater mercury-contaminated areas, especially in predatory ones (sharks, swordfish, etc.). Those regularly consuming such fish are particularly at risk, including pregnant mothers and young children. Methylmercury concentrations of 0.01 to 0.5 ppm are considered low, while 1 ppm is already a high level of contamination.

MIB (2-methylisoborneol) – is a volatile organic substance produced by blue-green algae and other microorganisms. Although not harmful to humans, it gives an unpleasant "puddle" taste to drinking water or fish, which can already be felt in the amount of 5-10 ng/l. It is produced by Oscillatoria spp., and some microorganisms fixed to a surface.

Microbiota – are microorganisms of a particular place (e.g., gut, water ecosystem).

Mineralization – is a process that fully or partly converts organic matter into a mineral, inorganic material, or structure.

Mycotoxins – products of the secondary metabolism of filamentous fungi. They often occur in the food chain and cause great economic losses to animal husbandry. They are also a threat to human health. Mycotoxin production is determined by the susceptibility of substrates (e.g., cereals, oilseeds, etc.) to mould infection, the presence of oxygen, and an appropriate temperature and moisture content. During production, the so-called field moulds may develop, requiring higher water content, while storage moulds may develop with lower moisture content. In addition, agrotechnical shortcomings, a lack of crop rotation, soil acidification, plant nutrition deficiencies, and plant protection anomalies may increase their presence. The growth of storage fungi and the production of mycotoxins almost exclusively indicate storage defects. Nevertheless, the different mycotoxins have common properties that deserve attention to prevent mycotoxicoses, reduce economic losses, and impact human health.

N

Natural waters – a collective name for all surface freshwater bodies, including lakes, water reservoirs, rivers, and canals.

Nekton – is the collective name for aquatic animals that are able to swim and move independently from water currents. It is often contrasted with plankton which floats/drifts in the water column.

Nitrates – are used on a larger scale (in millions of tonnes), mainly to produce nitrogen fertilizers to increase yields, but also for explosives, as an oxidant in the chemical industry, and as a preservative and colorant for the food industry. Besides nitrate, nitrite is also important in the food industry: it is a potent reducing agent with an antibacterial effect, so it is suitable for preservation food. Moreover, nitrate, along with phosphates, is one of the main causes of water eutrophication.

Nucleic acids – are macromolecules composed of nucleotide units. They are responsible for carrying genetic information. The most common nucleic acids are DNA (deoxyribonucleic acid) and RNA (ribonucleic acid).

O

Ontogenetic – related to ontogenesis.

Ontogeny (ontogenesis) – is the development of an individual organism, anatomical or behavioural feature from the earliest stage to maturity.

Oxygen-consuming gasses – are dissolved oxygen (DO) reducing gases, which extract DO from the water, such as hydrogen sulphide.

P

PAHs – or polyaromatic hydrocarbons – are mainly the result of incomplete combustion (pyrolysis) of organic materials and are generated during various industrial processes and waste burnings. Natural fires and volcanic eruptions can be natural sources. They usually occur as a mixture of hundreds of different substances. The main sources of human PAH intake are air, food, drinking water, and tobacco smoke. They can enter food in several ways: (1) as contaminants of environmental origin, (2) through certain packaging and wrappers contaminated with PAHs, and (3) as contaminants of technological origin of food processing. Food can be contaminated during smoking, heat treatments, and drying processes, which may have directly contacted with burnt products. They can also occur as environmental pollutants, especially in fish and fishery products.

Pavlovian reflexes – the method to induce a reflex response or behaviour by training with repetitive actions is called Pavlovian conditioning. For instance any stimulus positively associated with the food intake can develop a Pavlovian reflex.

PCBs – are polychlorinated biphenyls, stable fat-soluble compounds, and as such, are predominantly linked to vegetable and animal fats that can also accumulate. They are mainly fed with animal fat supplements. Fats and oils stored in PVC containers at higher temperature can potentially be a suitable environment for their appearance. They can also be formed during the collection of used oils from restaurants and technological processes of the food industry.

Phenological response – reflects the response of living systems to environmental cues. One example is flowering: it can show the correlation between the first flowering day of a year and seasonal temperature variations or changes in the mean first flowering day over multiple decades.

Phenophases – different stages of individual development of plants. Examples are the beginning of flowering, the start of fruit development, or the beginning of ripening.

Pheromones – are chemical substances produced and released into the environment by an animal, especially a mammal or an insect, which affect the behaviour or physiology of others of the same species.

Phosphorus (P) – is the most important element in the energy flow of aquatic living organisms. Although pure, “elemental” phosphorus (P) is rare in waters; it usually exists as part of a phosphate molecule (PO_4). Phosphorus in aquatic systems can occur in inorganic and organic phosphate forms. Animals can use both type of phosphates. Both forms can be dissolved or suspended in water (attached to particles in the water column). Orthophosphate is built into the organic compounds of plants. Organic phosphate consists of a phosphate molecule associated with a carbon-based molecule, as in plant or animal tissues. After the termination of life, organic phosphate is decomposed into orthophosphates with the help of bacteria.

Photosynthesis – is a basic life process where certain bacteria, algae, and plants use the energy of light (Sun) and special pigments (chloroplasts) to synthesize organic matter from carbon dioxide and water while releasing oxygen.

Phylogenic – relates to the evolutionary development and diversification of a species or a group of organisms.

Phylogeny (phylogenesis) – is the evaluation, development, and diversification of a species or a group of organisms.

Phytoplankton (algae plankton) – is the collective name of planktonic algae as a heterogeneous group of organisms belonging to the *microbiota**. Phytoplankton is mostly microscopic, single-cell photosynthetic organisms that live suspended in the water. Like terrestrial plants, they take up carbon dioxide, produce carbohydrates using ultraviolet light energy, and release oxygen. They are known as primary producers of water, organisms creating the base of a food chain. Phytoplankton lives near the surface, where a sufficient amount of sunlight can penetrate to enable photosynthesis.

Plankton – is a collective name and lifestyle of organisms floating and drifting in the water. They are microscopic organisms in sea and freshwaters, mainly consisting of diatoms, protozoans, small crustaceans, and eggs and larvae of larger animals. Many animals are adapted to feed on plankton, primarily by water filtering.

POPs (Persistent Organic Pollutants) – Most common POPs include organic pesticides, chlorinated hydrocarbons such as DDT, industrial chemicals like aldrin and dieldrin, polychlorinated biphenyls (PCBs), and by-products of several industrial processes, for instance polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs), commonly known as “dioxins”. In addition, due to their global impact, persistent organic pollutants (POPs) are considered hazardous chemicals.

Prions – are infectious protein agents. They are able to convert host cell proteins into an abnormal spatial structure similar to their own.

Protease inhibitors – are found in legume seeds that specifically inhibit trypsin and chymotrypsin enzymes. As a result, they reduce the digestibility of the protein.

Pyloric caeca – are finger-like appendages of the intestine at the end of the stomach (pylorus). They support digestion of nutrients.

R

Receptor – is a nerve ending that converts an external or internal stimulus into another signal that can be sensed by the cells of the nervous system.

Redox – oxidation and reduction are considered together as complementary processes.

S

Specific heat – is the heat required to raise the temperature of a unit mass of a certain substance by a certain amount, usually by one degree.

Stenothermal – ability to live in or tolerate only a small/narrow range of temperature.

Steroids – are hormones of the adrenal gland to fight stress or requires for osmoregulation and reproductive processes.

Surface tension – is the tension of the surface film of a liquid caused by the attraction of the particles beneath the surface layer by the bulk of the liquid, which tends to minimize surface area.

T

Taxa (singular: Taxon) – taxon is a group of organisms belonging to the same category and bearing a common collective name.

Thermal stratification – is the development of a relatively stable structure of warmer and colder layers within a water body. Thermal stratification is related to incoming heat, water depth, and the degree of mixing within the water column.

Thyrostatic action – reduces the production and release of thyroid hormones, like methimazole, carbimazole, or propylthiouracil. Thyroid hormones control basal metabolism.

Trophic levels – each of the several hierarchical levels of an ecosystem consisting of organisms sharing the same function in the food chain and the same nutritional relationship to the primary energy sources. The trophic level of an aquatic organism is determined by its place in the food pyramid (i.e., producer, primary, secondary, and tertiary consumer).

Trophity – the degree of the richness of water in inorganic nutrients that primary producers can utilize.

V

Vagus – each one of the ninth pair of cranial nerves negatively innervate the heart, lungs, upper digestive tract, and other organs of the chest and the abdomen.

Vegetative growth – the period of growth between germination and flowering is known as the vegetative phase of plant development. During this period, plants are active in photosynthesis and accumulating nutrients needed for flowering and reproduction.

Z

Zooplankton – is the collective name of tiny floating animals (protozoans, rotifers, cladocerans, copepods, etc.) that make up plankton.

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ANNEX 1

CONDITIONS AND RESOURCES OF INLAND FISHERIES AND FISH CULTURE IN CENTRAL AND EASTERN EUROPE, THE CAUCASUS AND CENTRAL ASIA

This annex presents region-specific aspects, which determine the characteristics and influence attainable results of the different fish culture systems practiced in the region.

CONTENT

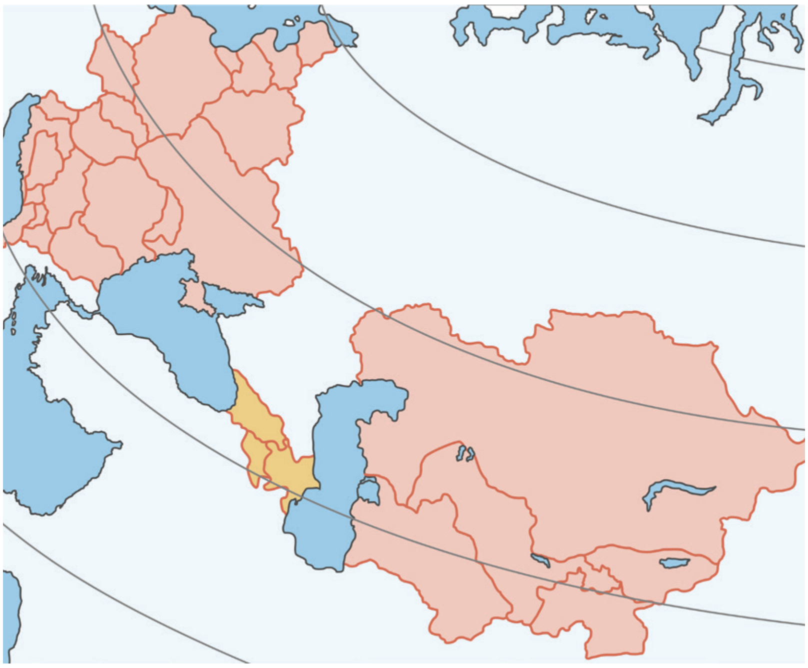
1. GEOGRAPHY AND CLIMATE

The region covered by this field guide includes three sub-regions: Central and Eastern Europe (CEE), the Caucasus (CAC), and Central Asia (CA).

Geographical position determines climate, weather, and hydrology, which influence the spectrum of selectable fish species and accessible physical and financial results. Despite the huge size of the region the climatic and hydrological conditions are similar enough to determine, support, and generate fish culture techniques, which are uniformly adaptable and extensively applicable.

The region and its sub-regions lay within the North Temperate Zone, well between the Arctic Circle (66o33’48.7” N) and the Tropic of Cancer (23o26’11.3” N). The four seasons and the climate are determined by the latitude, altitude, and humidity of a location within the region. These three determining factors provide a wide range of combinations characterizing the climate.

FIGURE A1-1: MAP OF REGIONS AND COUNTRIES COVERED



Central and Eastern Europe: *Albania, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Kosovo, Latvia, Lithuania, Republic of North Macedonia, Moldova, Montenegro, Poland, Romania, Serbia, Slovakia, Slovenia, and Ukraine.* ***Caucasus:*** *Armenia, Azerbaijan and Georgia,* ***Central Asia:*** *Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan*

When latitudinal distribution and annual precipitation are considered a desert, steppe, humid and dry forests may equally be found under cool and warm temperate zones, while altitudinal zonation results in humid and dry alpine, subalpine and mountain climates.

As climate basically determines agriculture, agro-climatic zones have been defined and established throughout the continents. Based on the principles of such zones, a similar monthly average air temperature-based division of fish culture zones was created in the 1980s. As the climate is one of the most decisive factors of fish production, the principles of this fish culture zonation are discussed together with climate change related issues under Annex 9.

2. SUITABILITY OF WATERS FOR FISH CULTURE

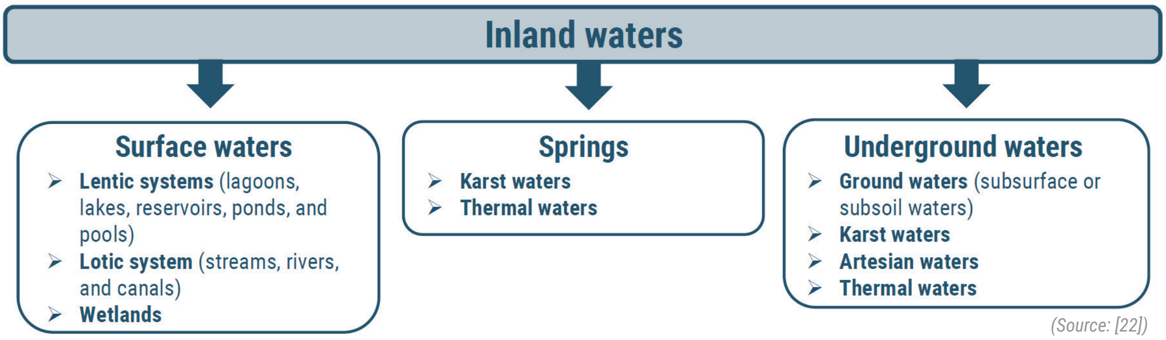
Freshwaters can be classified into three groups based on their origin and location: precipitation, surface, and underground waters. Precipitation ensures the filling and refilling of surface and underground water resources summarized in Figure A1-2. Though underground cold and thermal water resources are important for the intensive culture systems of cold, warm, and tropical fish species, the qualities of surface waters still dominate the physical and economic results of both fisheries and fish cultures in the region. From the huge total inland water resources, each group of surface waters presented in Figure A1-2 can be used for producing fish with different efficiency.

TABLE A1-1: APPROXIMATE AREAS OF SURFACE WATERS IN THE REGION

Sub-region	Inland surface waters (ha)			
	Total[1]	Rivers and canals[2]	Large lakes and reservoirs[2]	Small lakes, reservoirs and ponds[2]
CEE	4 183 000	693 000	1 262 000	577 000
CAC	593 000	216 000	511 000	7 000
CA	7 611 000	381 000	5 964 000	1 340 000
Total	**12 387 000**	**1 290 000**	**7 737 000**	**1 924 000**

(Source: [1] [12], [2] [38] and [72])

FIGURE A1-2: MAIN GROUPS OF INLAND WATERS



Inland waters

Surface waters
- **Lentic systems** (lagoons, lakes, reservoirs, ponds, and pools)
- **Lotic system** (streams, rivers, and canals)
- **Wetlands**

Springs
- **Karst waters**
- **Thermal waters**

Underground waters
- **Ground waters** (subsurface or subsoil waters)
- **Karst waters**
- **Artesian waters**
- **Thermal waters**

(Source: [22])

Springs and underground (subsurface) waters

Karst and artesian waters are usually ideal for intensive fish cultures, especially as their temperature remains practically unchanged during the entire year.

Thermal waters are used either directly or indirectly through a heat exchanger for supplying water (heat) for intensive cultures of tropical species, which would not be able to survive over a year under the climatic conditions of the region.

Rivers and canals

Water utilization from the upper sections of rivers in the mountainous regions for intensive production of coldwater species is already practiced in many countries of the region. However, an important disadvantage when surface water is considered for fish farming is that the water temperature falls during the winter months and may rise during the summer.

Middle and lower courses of rivers may also provide water for fish farms.

In theory, irrigation canals are also suitable to supply water for fish farms, supposing reliable water access throughout the entire fish production season.

Rivers, including the upper reaches and irrigation canals, are also suitable for culture-based fishery (CBF), which is widely practiced in many countries of the region.

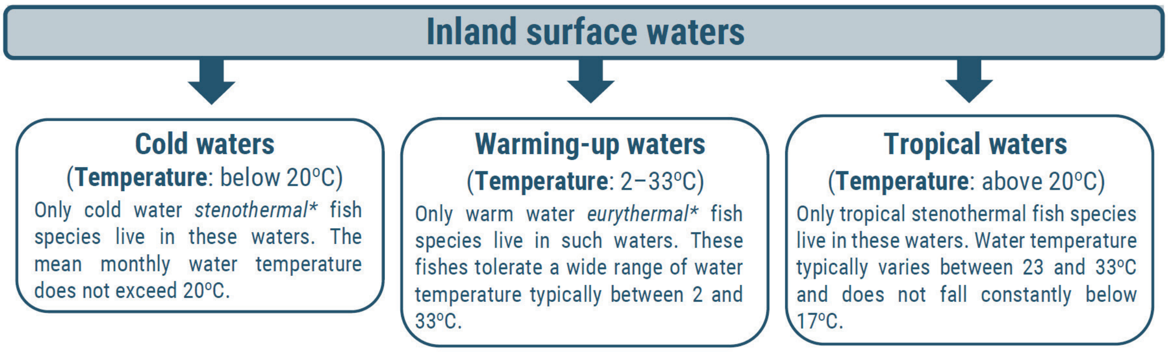
FIGURE A1-3: A TYPICAL MOUNTAIN RIVER IS A POTENTIAL WATER SOURCE FOR TROUT FARMING

FIGURE A1-4: A SMALL WATER RESERVOIR IS IDEAL FOR GROWING FISH

Lakes and reservoirs

Lakes and reservoirs are not only distinguished by their size but also by the physical, chemical, and biological qualities of the water. Water temperature is a critical parameter for fish, so surface waters can also be classified accordingly (Figure A1-5). In addition to water temperature, the fish production capacity of surface waters is also an important characteristic to consider when culture-based fisheries (CBF) are planned (Table A1-2).

FIGURE A1-5: CLASSIFICATION OF SURFACE WATERS AND THEIR FISH FAUNA BY TYPICAL TEMPERATURE



Inland surface waters

Cold waters
(**Temperature**: below 20°C)
Only cold water *stenothermal** fish species live in these waters. The mean monthly water temperature does not exceed 20°C.

Warming-up waters
(**Temperature**: 2–33°C)
Only warm water *eurythermal** fish species live in such waters. These fishes tolerate a wide range of water temperature typically between 2 and 33°C.

Tropical waters
(**Temperature**: above 20°C)
Only tropical stenothermal fish species live in these waters. Water temperature typically varies between 23 and 33°C and does not fall constantly below 17°C.

(After: [41] and [83])

TABLE A1-2: TROPHITY OF INLAND SURFACE WATERS UNDER TEMPERATE CLIMATE AND THEIR POTENTIAL FISH PRODUCTION CAPACITIES

Main categories of waters	Description	Potential fish production [1] (kg/ha/y)
Brown acidic (dystrophic) waters	Poor in natural fish food and oxygen.	-
Less productive (oligotrophic) waters	Cold waters which do not warm above 14–15 °C are poor in natural fish food, rich in oxygen. Transparency: above 8–4 m.	1–15
Medium productive (mesotrophic) waters	Waters that are warming up less, medium in natural fish food, well supplied with oxygen. Transparency: between 4 and 2 m.	15–50
Productive (eutrophic) waters and unmanaged fish ponds	These waters warm up in summer. Seasonal and daily problems of oxygen content may appear. Transparency: between 2 – 0.5 m	50–200
Very productive (hypertrophic) waters and extensive fish ponds	These waters warm up in summer. Seasonal and daily problems of oxygen content appear. Transparency: low 0.5–0.25 m	above 200

Observation: *[1] Figures concluded on the basis of published fish biomass estimations and fisheries statistics throughout the region.* *(After [5])*

There is an increasing focus in many countries on the restoration and maintenance of native fish fauna when fishery management of natural lakes is being considered. Thus, the role of restocking programs within fishery management measures is outstanding.

The nature and extent of fishery management in water reservoirs are determined by the primary utilization of the water body. Among others, these include irrigation, public water supply, flood control, hydroelectricity, navigation, recreation, pollution control, livestock rearing, etc. In many cases and locations, the fishery is subordinate to the primary use of a reservoir. Still, CBF can be feasible and sustainable in such waters if it is proportionally planned and harmonised with the primary purpose. This is often manifested in massive seasonal, periodical, or even daily fluctuations of water levels.

During the last decades, cages were set to produce fish in many of such waters. However, today establishment of cages on public waters is increasingly regulated and becomes conditional as fish production must comply with strict environmental regulations.

Small, natural lakes are extensively leased in the region with the condition that the leaseholder undertakes proper fishery management of the water body, which includes planned restocking and fishing. Small water reservoirs are managed either by farmers' irrigation associations, sport fishers' associations or are leased to other users. Their duty also includes maintaining proper fishery management, i.e., stocking and fishing.

Fish ponds

There is no consensus on a uniform nomenclature of ponds in the region. In some countries, barrage ponds are called fish ponds, while in others, these are considered to be water reservoirs, regardless they are used for fish cultures. To overcome this anomaly, the type of water bodies that are used for pond culture are called ponds or fish ponds in this book.

3. CHARACTERISTICS OF NATIVE FISH FAUNA AND INTRODUCED FISH SPECIES

The region and sub-regions lay within the river basins of many large Eurasian rivers, presented in Figure A1-6.

The native fish fauna of these rivers established and determined the taste, priorities, and acceptance of fish species consumed in the region. According to Froese and Pauly [46], editors of FishBase, most of the commercially important fish species are native all over the region and sub-regions.

In the waters of northern countries and at higher elevations in the southern ones, native and introduced salmonids are economically important species. However, in lower sections of rivers and in lakes found on the plains, dominant commercial species are warmwater cyprinids, sturgeons, and predator species such as pike, pikeperch, and catfish [36].

During the last century, mainly native species were domesticated and produced on fish farms. In the 1950's and 1960's different economically valuable cold and warmwater fish species were introduced both for fishing and fish farming to areas out of their native distribution. Tropical species, which cannot survive over a year, should not be considered as introduced ones, not like the species that can survive and propagate, as these are integral parts of the fish fauna of surface waters all over the region.

4. OVERVIEW OF FEASIBLE FISH CULTURE SYSTEMS

Already from the beginning of the last century, two distinct directions of fish culture practices existed, which developed in parallel in the region:

- Salmonids were produced in intensive culture systems, mainly in small earth ponds, later in tanks and cages.
- Cyprinids were produced in pond culture of different intensities, first exclusively common carp, and predator fishes, later together with Chinese major carps in pond polycultures.

FIGURE A1-6: MAIN RIVER BASINS TO REFER TO THE REGION

CEE: *(1) Oder, (2) Vistula, (3) Danube, (4) Dniester, (5) Dnieper, (6) Don and (7) Volga,* **CAC:** *Arax (Aras), Alazani, Aragvi, Enguri, Kura (Kur), and Rioni rivers,* **CA:** *(8) Ural, (9) Ob-Irtysh, (10) Balkhash-Alakol, (11) Syr Darya and (12) Amu Darya*

The comparison of the waste area of inland water resources (Table A1-1) and the statistics of actual fish production (Table A1-3) in the region suggests that there is a huge potential for future growth. Today a wide range of reliable culture techniques is available for all age groups of commercially important cold, warm, and tropical fish species cultured in the region. The role of the two culture systems developed in parallel is not only to produce table fish but also to support the success of CBF, which guarantees a planned, environment and ecosystem-friendly, sustainable fishery exploitation of inland waters. It must be mentioned here that advanced fry and fingerlings of many coregonid and salmonid species, including some endemic ones like Ohrid and Sevan trout are produced in intensive culture systems especially for restocking purposes.Table A1-4 presents feasible combinations of culture systems and the purpose of production, while Table A1-5 introduces the fish production potentials of different surface water resources as per culture systems.

TABLE A1-3: NATIONAL AND REGIONAL AQUACULTURE PRODUCTION OF THE MAIN GROUPS OF COMMERCIAL FISH SPECIES IN 2019

Sub-regions and countries	Carps, barbels, and other cyprinids (t)	Miscellaneous freshwater fishes (t)	Salmons, trout, smelts (t)	Sturgeons and paddlefishes (t)	Grand Total (t)
CEE	**124 221**	**13 005**	**37 093**	**2 023**	**176 396**
Albania			1 759		1 759
Belarus	8 926	145	373	148	9 591
Bosnia and Herzegovina	249	30	3 503		3 782
Bulgaria	8 254	600	4 238	476	13 571
Croatia	3 057	123	335	5	3 520
Czech Republic	19 182	864	939		20 986
Estonia	30	63	722	41	856
Hungary	12 810	4 309	76	87	17 283
Latvia	520	16	50	22	609
Lithuania	3 362	491	182	166	4 202
Republic of Moldova	12 510	60		80	12 650
Montenegro			695		695
Poland	23 730	2 818	17 365	805	44 718
Romania	9 877	258	2 618	96	12 848
Serbia	4 654	82	2 071		6 807
Slovakia	754	934	999	0	2 688
Slovenia	124	115	942		1 230
Ukraine	16 182	2 099	226	97	18 604
CAC	**3 320**	**285**	**12 734**	**4 097**	**20 436**
Armenia	1 880	270	11 410	4 000	17 560
Azerbaijan	429		102		531
Georgia	1 011	15	1 222	97	2 345
CA	**72 244**	**17 290**	**2 224**	**394**	**92 151**
Kazakhstan	4 063	1 685	1 007	179	6 933
Kyrgyzstan	1 650	0	1 000	25	2 675
Tajikistan	688	31	17		736
Turkmenistan	65			25	90
Uzbekistan	65 778	15 574	200	165	81 717
Grand Total	**199 785**	**30 580**	**52 051**	**6 515**	**288 984**
Proportion (%)	**69**	**11**	**18**	**2**	**100**

(Source: [37])

TABLE A1-4: FEASIBLE COMBINATIONS OF FISH SPECIES, CULTURE SYSTEMS, AND THE PURPOSE OF PRODUCTION

Species	Culture-based fisheries (CBF)		Pond culture		Intensive culture systems	
	Production of stocking material	Production of table fish	Production of stocking material	Production of table fish	Production of stocking material	Production of table fish
Coldwater species						
Salmonidae	Not relevant	√	-	-	√	√
Coregonidae		√	-	-	√	√
Warmwater species						
Acipenseridae	Not relevant	√	√	√	√	√
Common carp		√	√	√	√	√
Chinese major carps		√	√	√	-[1, 2]	-[1, 2]
Small carps		√	√	√	√	√
Pike		√	√	√	√	-[2]
European catfish		√	√	√	√	√
Eel		√	-	-	√	√
Perch, pikeperch		√	√	√	√	√
Paddlefish		-	√	√	-	-
Tropical species						
Tilapia, African catfish and pangasius	Not relevant		Only in hot summer months.		√	√

Observations: *[1] Grass carp can be an exception. [2] In experimental phase.*

A basic difference between the three presented culture techniques is how the diet required for the maintenance and growth of fish is ensured. In CBF only natural food is the food source, in pond culture, a combination of natural food and supplementary feeds, while in intensive culture systems, the entire diet of fish must be built on nutritionally complete industrial feeds.

TABLE A1-5: APPROXIMATE TABLE FISH PRODUCTION POTENTIALS OF THE DIFFERENT FISH CULTURE SYSTEMS

Commercially valued groups and species of fish	Culture-based fisheries (CBF)	Pond culture	Intensive culture systems[1]			
			Earth ponds[2]	Tank culture[3]	Cage culture	In-pond RAS
	kg/ha		kg/m^3			
Coldwater species						
Salmonidae	1-15	Not relevant	~ 20	~ 50	~ 35	Yes[4]
Coregonidae		~ 1000	~ 20	~ 50	~ 35	Yes[4]
Warmwater and tropical species						
Acipenseridae	1-10	~ 1000	~ 5	~ 30	~ 20	Yes[4]
Common carp	20-200	500-3000	~ 5	~ 40	~ 30	Yes[4]
Chines major carps			Yes[5]			
Medium size carps			~ 5	~ 30	~ 20	Yes[4]
Pike	2-15[6]	15-100[6]	Yes[5]			
European catfish			~ 5	~ 40	~ 30	Yes[4]
Perch, pikeperch				~ 30		Yes[4]
Paddlefish	As bighead carp					Yes[4]
Tilapia	Not relevant	500-2500[7]	~ 5	~ 40	~ 30	Yes[4]
African catfish			~ 10	~ 200	~ 120	Yes[4]
Pangasius	Not relevant		~ 10	~ 200	~ 120	Yes[4]

Observations: *[1] It is to note that in these columns extreme high production figures are excluded. [2] It is assumed that the water exchange in small earthen ponds (wintering and traditional Danish ponds) is extensive (0.1-4 times a day). [3] It is assumed that the water exchange in smaller or larger in- and outdoor fish rearing tanks is intensive, it is done several times a day. [4] The expectable production results highly depend on the applied RAS technology. [5] The intensive culture of this fish species is still in an experimental phase. [6] These figures are relevant within the overall results of CBF and carp pond polyculture. [7] Can be feasible only during hot summer months.*

The intention of the inventories in Tables A1-4 and A1-5 is to support farmers when feasible production options for intensification and/or diversification of fish production are considered.

ANNEX 2

INGESTION, DIGESTION AND EXCRETION OF FISH

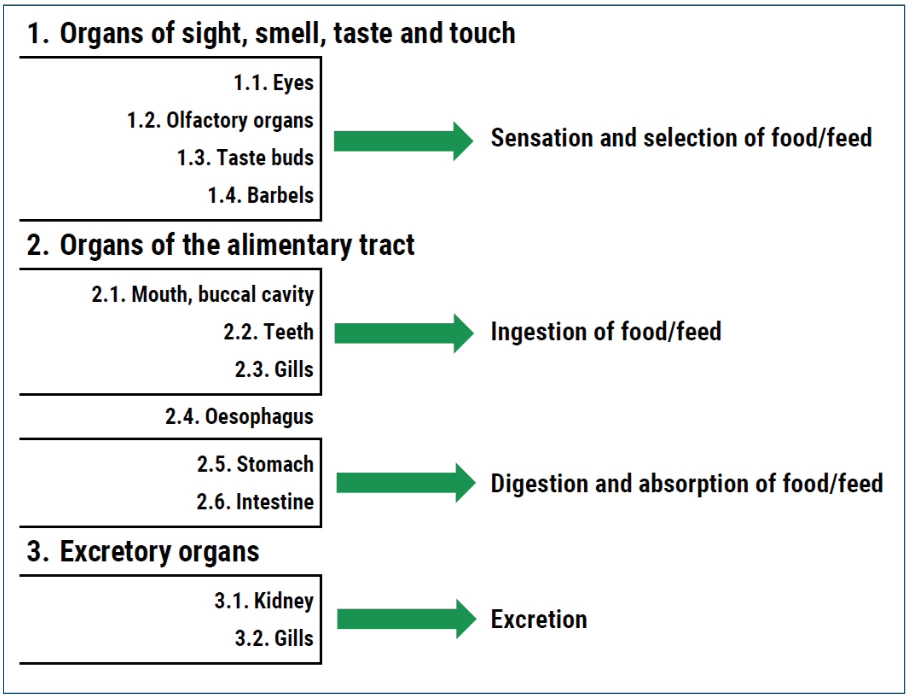
Familiarity with the overall and specific characteristics of ingestion, digestion and excretion processes of fish is important in practical fish farming. Knowing the organs which participate and are responsible for these processes helps to understand the behaviour and reactions of fish during culturing and feeding. Knowing the essential anatomical and physiological differences of such organs in economically important fish species allows the prediction and calculation of both results and consequences, including the impact of feeding on the aquatic environment.

CONTENT

1. ORGANS OF SIGHT, SMELL, TASTE AND TOUCH OF FISHES

Detection and selection of food and feed is complex, and species specific at fishes. The role of organs for sight, smell, taste and touch considerably varies for different families and species. It is the phylogenic consequence of their different biology, habitat, and diet which they specialized to.

FIGURE A2-1: ORGANS OF FISH RESPONSIBLE FOR FEEDING AND EXCRETION



Sight of fishes
Sight is an important sensory mechanism for most of the fishes. The position of the eyes is related to the feeding habit of fish hence may vary from species to species. Fish species feeding from the water column have their eyes on both sides of the head. For species like salmonids in general and trout in particular, the clear sight is a prime precondition for the accurate approach and capture of the food. In case of many pond fishes such as common carp and catfishes, sight has a secondary role in locating food. These fishes have other well developed sensory organs to compensate for the limited visual abilities to detect food.
Fish have no moveable eyelids; hence their eyes are exposed to increased vulnerability when handled.

Smelling of fish
The olfactory organs located in the nasal cavity are responsible for the smelling of fish. These paired organs do not only support detecting food, but also play a role in the location of familiar sites (e.g., hatching site of salmonids) and communication with other fish by means of *pheromones**. The water current moving through the nasal cavity carries the information to the lamellae of the olfactory organs equipped with chemical *receptors**. Sharpness of smell depends on the size of the nostrils as it limits the quantity of water passing around the olfactory organs. Usually there are separate inlets and outlets for water, but in case of tilapia (and cichlids) there is only one single opening on each side of the head ([95], [49] and [90]).

Tasting of fish
Chemoreception has an outstanding role in the detection, location and selection of food, especially in opaque and turbid waters. Flavours are perceived by taste buds found everywhere on the body surface of fish. Though the actual number of taste buds varies in different species, the highest concentrations of them can be found on organs and body parts which are directly involved in the food uptake. These are the barbels, lips, buccal cavity, gill arches, throat and areas around the pharyngeal teeth ([95] and [49]). From the above-mentioned body parts and organs barbels are characteristic to cyprinids and catfishes and are often mobile and used for touching and tasting of food.

There are two different tasting systems for fish and taste buds are distinguished accordingly. The first type of buds is found on the outer body surface, the barbels, lips and the front section of the buccal cavity. This exterior group of buds sense and convey stimuli to the brain through *facial nerves**. The second type of buds is found in the rear of the buccal cavity and the gill arches and transfers the received stimuli through the *vagus** and *glossopharyngeal** nerves. The first type of buds is responsible for finding and picking the food, while the second one coordinates the swallowing of food [49].

2. THE ALIMENTARY TRACT OF FISH

Like organs of detection and selection of food, organs of the alimentary tract are highly specialized based on the feeding habit and food spectrum of fishes. The organs of the alimentary tract listed in Figure A2-1 can be separated into two groups: the organs of ingestion and digestion.

2.1 ORGANS OF FOOD INTAKE

The organs of food intake are the mouth, buccal cavity, teeth and gill rakers found on the arches of gills.

Mouth of fish

The position and size of the mouth well reflects the feeding habit and food spectrum of different fish species. Herbivorous and omnivorous fish species have a relatively smaller mouth while plankton feeders and predator species have a relatively larger mouth which can be widely opened.

The mouth can be located above (superior), at the end (terminal) or below (inferior) the tip of the snout. The position of the mouth indicates both the mode and direction of feeding. Fishes which grab the food (prey) have a terminal mouth located in the middle of the head, pointing forward (common carp, pike, pikeperch, etc.). Those feeding from the water column or the surface (razbora [stone moroko], silver and bighead carps and their hybrids) have a superior location of mouth, while the ones feeding from the bottom (sturgeons) have an inferior mouth. Some of the species like common carp can actively extend and protrude its lips. This characteristic allows common carp to dig in the bottom for food.

Unlike in terrestrial animals, there is no digestion in the buccal cavity of fish. However, there is mucus production which supports the binding of small food particles and the smooth passing of food towards the digestive tract.

The strong muscles of the buccal cavity, together with the pharyngeal bone and gill cover can create a vacuum or a pressure as needed, which is outstandingly important both for the respiration and feeding of fish. While feeding, fish can easily suck food up when vacuum is created and filter the plankton when pressure is generated in the buccal cavity. Asp is a predator species of the cyprinid family. It has no teeth on its jaws to grab the prey, instead, it is supported with a widely opened mouth together with the vacuum to capture, i.e., suck the prey.

The pharyngeal bones help to press out water from consumed natural food of high moisture content before it is swallowed.

Teeth of fish

There are three different types of teeth in fish: mandibular, buccal, and pharyngeal ones. Most active predators like salmonids, pike and pikeperch have strong jaws and relatively large mandibular teeth. Catfishes have brush like small teeth, while other species have scrapper-like lips. Certain species have buccal teeth which, similarly to teeth on jaws, do not chew or prepare the food mechanically for digestion, but only hold back the prey before it is swallowed whole. Cyprinids have no teeth at all. Their pharyngeal teeth overtake the task to prepare the food mechanically for digestion, unlike the above described two types of teeth. In common carp these strong, molar-like teeth crash and grind the food against a horny pad. In grass carp the pharyngeal teeth are sharp which easily cut up the fibrous plants (leaves and stems) into small pieces before they are swallowed. In case of the predator asp, the pharyngeal teeth grind the sucked prey into pieces.

Filtering organs of fish

Some fish species such as silver and bighead carps and their hybrids feed on plankton and any floating particles, which are in the range of the filtering capacity of the fish. Water filtration within the mouth is done by the help of modified gill rakers. These dense, comb-like apparatuses (silver and bighead carps have sponge-like filters) retain the filtrate that mixed with mucus can be swallowed [49]. The form and density of the filtering apparatus determines the size range of filtered phyto- and zooplankton (and floating particles), which is preserved and consumed by the fish.

Though common carp is not considered as a filtering fish, it is still able to retain a mass of zooplankton throughout its entire life. As common carp grows the size of zooplankton which the fish can filter also grows. Finally, it mainly consumes specimens of zooplankton *taxa** which size is larger than 0.25 mm ([66], [3] and [42]).

The oesophagus is the last organ involved in the ingestion of fish. It is a short, elastic muscular tube opening from the pharynx, with a ring of strong muscles (sphincter), which prevents water entering to the digestive tract.

2.2 THE ORGANS OF DIGESTION

The primary function of the digestive tract is to convert the consumed food/feed into an absorbable form for fish. The secondary function is to eliminate wastes developed during digestion.
By means of digestive *enzymes** proteins, lipids and carbohydrates of ingested food/feed are converted into absorbable nutrients. Nutrients produced during digestion are used:

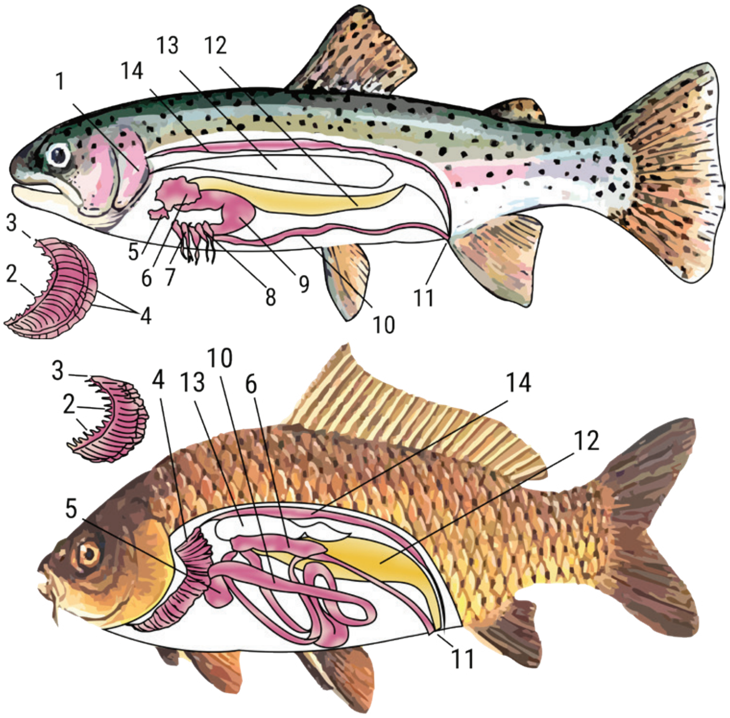
For maintenance

- To cover energy requirements of life processes;
- To maintain the body, i.e., cells and tissues.

For growth

To support the growth of fish (bones and muscles) and the development of gonads (eggs and sperm) in sexually matured, adult fish.
Nutrients for later use are temporarily or permanently stored in specialized organs and in specific body parts, such as glycogen (a soluble carbohydrate) in the liver and skeletal muscles. A part of nutrients is stored in lipids (triglycerides) in the form of body fats, which are mobilized when needed. Nutrients, particularly carbohydrates, absorbed in excess quantities are deposited as fat in the abdominal cavity, around the digestive organs and in the tissues of certain body parts. This is also species specific, together with the extent, quality, and quantity of deposited nutrients, which basically determines the quality of fish flesh discussed in Annex 4.

FIGURE A2-2: SCHEMATIC ILLUSTRATION OF THE DIFFERENCES BETWEEN THE DIGESTIVE TRACTS OF WIDELY CULTURED FISH WITH OR WITHOUT STOMACH



1. Opercula (gill cover), 2. Gill raker, 3. Gill arch, 4. Gill filaments 5. Heart, 6. Liver, 7. Pyloric caecae and pancreas, 8. Spleen, 9. Stomach, 10. Intestine, 11. Anus and urogenital papilla, 12. Gonad, 13. Swim bladder , 14. Kidney

The organs of digestion are the stomach and the intestine in some fish species or only the intestine in others. This diversity of fish is an evolutionary consequence, the result of accommodation to different types and ranges of natural food during the phylogeny of species [91].
Species of fish specialized in preying on other fish have a glandular stomach where the digestion of the prey consumed in one piece starts. The shape and size of the stomach depends on the species and shows a wide diversity. In pikeperch the stomach is rather tube-like while in rainbow trout or European catfish it is more sack-like, that allows the intake of excessive quantities of food/feed. The stomach to intestine length ratio in different species is: European catfish – 1:1.6, eel – 1:2, rainbow trout – 1:2.5, pike – 1:3, pikeperch – 1:4 and perch – 1:7.

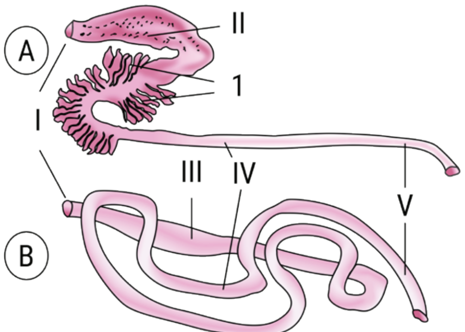
Common carp and other cyprinids have no stomach, only a small, dilated intestine, which is compensated by a continuous feeding. The intestine of such species is a “simple” tube in the abdomen (i.e., in the belly). The intestine of common carp is considerably broader at the inlet and forms several bands which comprise seven horizontal sections and six bands.

It was observed that while the ratio of intestine length to body length increases, the ratio to body weight decreases by age [92].

When fish feeding is discussed the relative length of the digestive tract, i.e., the gut (RGL) is used. This shows how much longer the gut is than the body of fish. It is an important parameter which is species specific, even if the actual length of the gut may vary according to the individual life history of the fish. Based on the summary of Hepher [49] this figure varies between 0.46 and 0.68 for carnivores, and 2.16 for the herbivorous grass carp. For microphages, like silver carp and Mozambique tilapia, it is about 5.28-6.29 and for omnivores, such as common carp and goldfish, it is 2.2 and 5.2, respectively.

Digestion process in fishes with stomach considerably differs from that of stomachless fishes, where commercially important cyprinids belong to. Apparent differences between the two main types of digestive tracts are presented in Figure A2-2 and Figure A2-3.

FIGURE A2-3: SCHEMATIC ILLUSTRATION OF THE DIFFERENCES BETWEEN THE DIGESTIVE TRACTS OF FISHES WITH OR WITHOUT A STOMACH



(After: [91] and [92])

I. *Oesophagus,* ***II.*** *Stomach,* ***III.*** *Foregut,* ***IV.*** *Midgut,* ***V.*** *Hindgut,* ***A. Rainbow trout*** *(****1.*** *pyloric caeca),*
B. Common carp

The stomach of a fish ends in *pyloric caeca**. Their number depends on and is characteristic to the species. Caeca support both the digestion and storage of nutrients. When a fish starves for a longer period, e.g., about 3-4 weeks, the pyloric caeca degenerate. Even if the food uptake of fish returns to the required level, nutrient utilization will remain considerably reduced, even by 50% [49].

The hydrochloric acid in the gastric juice decreases the pH for the optimal activity of the digestive enzyme (pepsin), which splits up the proteins. Bile juice is formed in the liver and stored in the gall bladder, and empties into the midgut. Bile juice is responsible for supporting the lipase enzyme breaking down the fat into fatty acids and glycerol. Digestion of carbohydrates also starts in the midgut by means of an enzyme (amylase) excreted by the pancreas.
In fish with stomach, the absorption of nutrients already starts in the stomach and is completed in the midgut. In stomachless fish there are no considerable morphological differences between sections of the intestine, but there are functional ones. Fat digestion and absorption takes place in the foregut, carbohydrate digestion and absorption in the midgut, while according to Dabrowski [19] and Steffens [92] protein digestion and absorption already start in the foregut, but culminates and is completed in the hindgut.

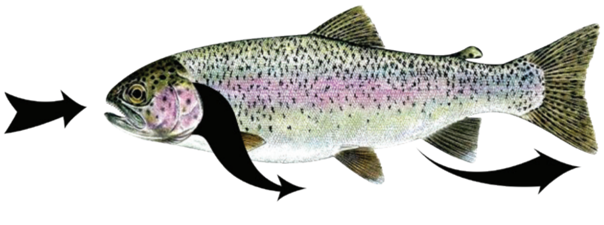
3. EXCRETORY ORGANS

The primary role of excretion is to remove the metabolic wastes and maintain the optimal chemical composition of blood. Kidneys and gills are the main excretory organs of fish.
As Széky [95] summarized absorbable nutrients, which are produced during digestion, are either incorporated during the course of *anabolic** or are used within the *catabolic** processes. By-products of this process (i.e., of *metabolism**) include carbon dioxide (CO_2) and different substances dissolved in water (Na, Cl, sulphate, phosphates, and ammonia and urea from protein metabolism). These are transported by the blood to the excretory organs: kidneys and gills.
Kidneys of fish run along the full length of the abdominal cavity. They are located above the swim bladder, below the spine and adhere tightly to it. Kidneys are responsible for filtering out unnecessary or even toxic substances listed above. These substances are dissolved in water and excreted by the kidney in the form of urine in freshwater fish species, which is released through the urinary pores, and some of them through the gills.
The bloodstream transports carbon dioxide in the form of bicarbonate (HCO_3) directly to the gill, where most of it decomposes into carbon dioxide and water ($CO_2 + H_2O$) and then exits the body during external respiration. Not only do gills release carbon dioxide from the body, but 90% of the ammonia (NH_3) and 70% of the urea produced during protein metabolism are removed from the fish body through them.

Faeces are released from the fish through the anus. Their consistency and chemical composition, i.e., environmental impact depends on the quality and quantity of the food/feed ingested, as well as on several different factors that determine and influence ingestion and digestion of food/feed. These influencing factors are discussed in Chapter 4 of the main text.

The estimated amount of released metabolic wastes and their environmental impact are further discussed in Annex 7 and Annex 8 and are summarized in Chapters 5 and 6 of the main text.

FIGURE A2-4: EXCRETION IN FISH



The metabolic wastes are released back into the water where the food/feed was taken from. Faeces are released through the anus, while carbon dioxide, ammonia and urea through the gills.

ANNEX 3

FOOD SPECTRUM, FEEDING HABIT, FEEDS AND EXPECTABLE GROWTH OF COMMERCIALLY IMPORTANT FISH SPECIES IN CENTRAL AND EASTERN EUROPE, THE CAUCASUS AND CENTRAL ASIA

This annex, focusing on the feeding and growth of fish, is an inventory and a concise presentation of commercially important fish species found and cultured in the region. Similar to a widely accepted and followed practice, fish species in this annex are also grouped according to their thermal requirements. It is one of the most important determining factors of fish production.

The first chapter presents a short statistical review of all freshwater species in the region, i.e., Central and Eastern Europe, the Caucasus, and Central Asia.

In the second chapter, widely cultured fishes are listed and presented shortly, as the third chapter provides a concise introduction and a summary of both peaceful and predator fish species, which are either less useful or even harmful in fish ponds or are potential future species for pond culture or intensive culture systems.

Information on key characteristics of fish species presented in this annex were checked against two basic sources of information. These were the work of Pintér [81] and FishBase edited by Froese and Pauly [46].

CONTENT

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[1] *Fish species listed under "tropical freshwater species" are different from the Aller Aqua arrangement. It indicates here that these species cannot survive winter temperatures; thus, their rearing is limited in the region.*

1. OVERVIEW OF FRESHWATER FISH SPECIES FOUND IN THE REGION

In order to support orientation within the scientific classification of fishes, Table A3-1 lists the name of 46 freshwater fish families present in the region. In this table, both the total number of fish species belonging to these families and the number of species in the region are indicated. Naturally, from the high number of fish species found in the region, only a relatively few are currently cultured or are useful, harmful, or potential species for the future.

TABLE A3-1: NAME OF FAMILIES AND NUMBER OF FISH SPECIES FOUND IN THE WORLD AND THE REGION

Order	Family	Number of species	
		World	Region
Petromyzontiformes	Petromyzontidae	64	12
Acipenseriformes	**Acipenseridae**	**25**	**12**
	Polyodontidae	**2**	**1**
Anguilliformes	**Anguillidae**	**20**	**1**
Clupeiformes	Clupeidae	188	8
Cypriniformes	Acheilognathidae	74	5
	Catostomidae	79	3
	Cyprinidae	**1 682**	**52**
	Cobitidae	216	32
	Catostomidae	79	3
	Gobionidae	215	13
	Leuciscidae	667	132
	Nemacheilidae	704	31
	Xenocyprididae	160	8
Characiformes	Serrasalmidae	101	1
Siluriformes	**Pangasiidae**	**29**	**1**
	Siluridae	**107**	**2**
	Clariidae	**117**	**1**
	Sisoridae	267	1
	Ictaluridae	**51**	**3**
Esociformes	**Esocidae**	**7**	**1**
	Umbridae	7	2
Salmoniformes	**Salmonidae**	**226**	**52**
Gonorynchiformes	Chanidae	1	1
Osmeriformes	Osmeridae	15	1
Gadiformes	Lotidae	5	1
	Gadidae	22	46
Syngnathiformes	Syngnathidae	307	3
Gobiiformes	Odontobutidae	23	3
	Gobiidae	1 952	46
Anabantiformes	**Channidae**	**43**	**1**
Pleuronectiformes	Citharidae	6	1
	Pleuronectidae	67	1
Cichliformes	**Cichlidae**	**1 743**	**2**
Atheriniformes	Atherinidae	69	1
Cyprinodontiformes	Poeciliidae	273	5
	Aphaniidae	34	1
	Valenciidae	3	1
Beloniformes	Adrianichthyidae	37	2
Mugiliformes	Mugilidae	78	6
Blenniiformes	Blenniidae	403	1
Centrarchiformes	**Centrarchidae**	**38**	**3**
Eupercaria/misc	Moronidae	6	3
Perciformes – Per.	**Percidae**	**239**	**15**
Perciformes – Gas.	Gasterosteidae	19	3
Perciformes – Cott.	Cottidae	292	10
Total		**10 762**	**534**

(After [46])

***Observation**: Some of the species of families highlighted with bold are commercially important, hence produced in the different culture systems in the region.*

2. COMMERCIAL FISH SPECIES CULTURED IN THE REGION

2.1 COLD FRESHWATER FISH SPECIES (SALMONIDS)

Species belonging to the family of Salmonidae and the subfamily of Coregonidae have been cultured for centuries. In addition, there are native trouts in the region - among others, brown trout *(Salmo trutta)*, Ohrid trout *(Salmo letnica)*, Sevan trout *(Salmo ischchan)*, Amu Darya trout *(Salmo trutta oxianus)*, etc. - which are intensively produced for restocking purposes, especially their advanced fry and juveniles. Of the different coldwater species, rainbow trout *(Oncorhynchus mykiss)* and Arctic charr *(Salvelinus alpinus)* are the most widely produced in intensive culture systems throughout the entire region. There is also a wide range of species of the Coregonidae subfamily, which are very important in natural and man-made cold waters in the whole region. For this reason, some of them, like European whitefish *(Coregonus lavaretus)*, northern whitefish *(Coregonus peled)*, and Baikal whitefish *(Coregonus migratorius)* were introduced across the region. The subsequent sections summarize feeding and growth-related information on Arctic charr, Atlantic salmon (freshwater), brown trout, rainbow trout, and white fish.

Arctic charr *(Salvelinus alpinus)*
Thermal class of fish: Coldwater fish, within preference to the range of about 16 ºC when fed, despite spawning and development of eggs requiring much colder water.
Food spectrum, feeding habit: Carnivores and predators, grows well on nutritionally complete industrial feeds.
Size and age of sexual maturation: 50-60 cm, 4-10 yrs.
Body weight of largest specimen: 14.8 kg


Image by courtesy of Aller Aqua

Brown trout *(Salmo trutta)*
Thermal class of fish: Coldwater fish, with a preference of about 16ºC when fed, though spawning and egg development requires colder water.
Food spectrum, feeding habit: Carnivores and predator. Grows well on nutritionally complete industrial feeds.
Age of sexual maturation: 3-4 yrs.
Body weight of largest specimen: 20.1 kg


Image by courtesy of Aller Aqua

TABLE A3-2: SIZE OF BROWN TROUT IN THE NATURE AND UNDER FARM CONDITIONS

Time required			In natural waters	In intensive culture systems [1]
Year	Approximate length of the growing season (month)			
	Per year	Cumulative	Size (g/fish)	
1st	7-8	7-8	2-10	~ 80
2nd	12	19-20	10-80	~ 1200
3rd	12	31-32	20-300	

Observation: *[1] Water temperature as in natural cold waters exposed to daily and seasonal changes of weather.*

Rainbow trout *(Oncorhynchus mykiss)*
Thermal class of fish: Coldwater fish, with a preference of about 16 ºC when fed, though spawning and egg development requires colder water (8-12 ºC).
Food spectrum, feeding habit: Carnivores and predator. Grows well on nutritionally complete industrial feeds.
Size and age of sexual maturation: 5-6 kg, 2-3 yrs.
Body weight of largest specimen: 21.8 kg


Image by courtesy of Aller Aqua

TABLE A3-3: SIZE OF RAINBOW TROUT IN THE NATURE AND UNDER FARM CONDITIONS

Time required			In natural waters	In intensive culture systems [1]
Year	Approximate length of the growing season (month)			
	Per year	Cumulative	Size (g/fish)	
1st	7-8	7-8	≤ 100	~ 100
2nd	12	19-20	≤ 350	~ 1500
3rd	12	31-32	≤ 1000	

Observation: *[1] Water temperature as in natural cold waters exposed to daily and seasonal changes of weather.*

Atlantic salmon – freshwater *(Salmo salar)*
Thermal class of fish: Coldwater fish.
Food spectrum, feeding habit: Carnivores and predators grows well on nutritionally complete industrial feeds.
Age of sexual maturation: 3-5 yrs.
Size and body weight of largest specimen: 149 cm, 33 kg

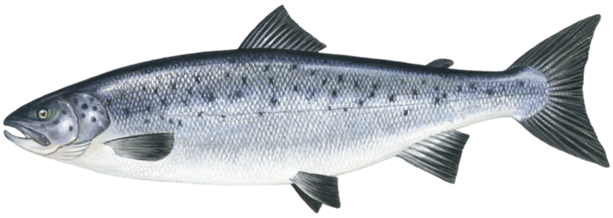


Image by courtesy of Aller Aqua

Whitefish (*Coregonus lavaretus*)
Thermal class of fish: Coldwater fish, with a preference of about 16 ºC when fed, though spawning and egg development requires extremely cold water (4-5 ºC).
Food spectrum, feeding habit: Carnivores and predator. Its diet also includes all planktonic and large crustaceans. Grows well on nutritionally complete industrial feeds.
Age of sexual maturation: 2-3 yrs.
Size and body weight of largest specimen: 73 cm, 10 kg


Image by courtesy of Aller Aqua

2.2 WARM FRESHWATER FISH SPECIES (STURGEONS, PIKES, CARPS, CATFISHES, EELS, SUNFISHES, AND PERCHES)

Sturgeons belong to the family of Acipenseridae. They are considered to be primitive species with bony plates on the body. They are anadromous fishes as they spend most of their life in seas and only return to freshwater to spawn. There are 25 species in this family. In nature, they grow slowly but large and reach sexual maturity even within decades. Most sturgeon species are endangered as they are overfished for their high-quality roe *(caviar)* and meat. Sturgeons are reared in farms for two distinct reasons; production of advanced fry and fingerling for stocking natural waters and grow females for their roe to produce caviar. Five species are especially in the focus of attention of fish producers: Russian sturgeon *(Acipenser gueldenstaedtii)*, Siberian sturgeon *(Acipenser baerii)*, stellate sturgeon *(Acipenser stellatus)*, beluga or giant sturgeon *(Huso huso)*, ship sturgeon *(Acipenser nudiventris)*, sterlet *(Acipenser ruthenus)* and American paddlefish *(Polyodon spathula)*.

Russian or Danube sturgeon *(Acipenser gueldenstaedtii)*
Thermal class of fish: Warmwater, with a preference for a cooler range (around 18 ºC).
Food spectrum, feeding habit: Benthic feeder: worms, crustaceans, insects, and insect larvae, mainly from the benthos. Grows well on nutritionally complete industrial feeds.
Age of sexual maturation:
♀ 12-16 yrs. (22-24 kg), ♂ 11-13 yrs. (15-18 kg).
Size, body weight and age of largest specimen: 236 cm TL maximum weight: 115 kg; maximum reported age: 46 yrs.

Sterlet *(Acipenser ruthenus)*
Thermal class of fish: Warmwater, with a preference for a cooler range (around 18 ºC).
Food spectrum, feeding habit: Benthic feeder. Grows well on nutritionally complete industrial feeds.
Age of sexual maturation: ♀ 4-9 yrs., ♂ 3-6 yrs.
Size, body weight and age of largest specimen: 70-90 cm, 2-4 kg (maximum 6-7 kg), > 20 yrs.

TABLE A3-4: AGE AND WEIGHT AT MATURATION AND DURATION OF SUCCESSIVE CYCLES OF GAMETOGENESIS IN WILD AND FARMED STURGEON BREEDERS

Species	Age and size at puberty						Generation intervals of females (years)	
	Males		Females					
	Wild (y)	Farmed (y)	Wild		Farmed		Wild	Farmed
			Time (y)	Weight (g)	Time (y)	Weight (g)		
Russian sturgeon	8-10 (7-10)	3-4 [1.5-1.6]	10-14 (8-15)	9.9-18	**6-8 [2.6-4.1]**	**7.4-14**	3-5	1-3 [0.8-1.2]
Stellate sturgeon	5-6 (3-8)	3-4 [1.5-1.6]	8-10 (6-13)	4.4-13.7	**5-7 [2.6-3.5]**	**5.4-9**	3-4	1-2 [0.8-1]
Beluga	12-14 (9-14)	5-8 [2.6-3.8]	6-18 (11-19)	71-150	**9-12 [4.3-5.5]**	**32-65**	≥ 4-10	2-3 [0.9-1.9]
Sterlet	3-8	2-3 [0.9-1.4]	3-12	0.3-2.5	**3-5 [1.9-2]**	**0.3-2.5**	2-3	1-2 [0.4-0.6]

Observation: *Data in round parentheses pertains to Azov populations. Data in square parentheses indicates the year of maturation expectable in tempered water fish farms (water temperature at about 18 ºC).*

(Source: [11])

Pikes – Five species belong to the family of Esocidae. Only one of them is found in waters of the region: northern pike or simple pike is an excellent sport fish. However, there are many muscle bones (fishbones) in its flesh, which reduces its popularity as food fish.

Northern pike *(Esox lucius)*
Thermal class of fish: Warmwater fish
Food spectrum, feeding habit: Carnivorous, predator. Experiments are ongoing with nutritionally complete industrial feeds in intensive culture systems for rearing them.
Age of sexual maturation: ♂ 2-3 yr. ♀ 3-4 yr. in production zone V-VI (see explanation in Annex 9).
Size and body weight of largest specimen: 150 cm, 35 kg

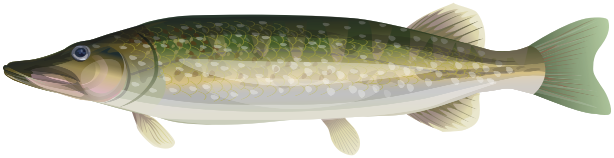


Image by courtesy of Aller Aqua

TABLE A3-5: SIZE OF NORTHERN PIKE IN NATURE AND UNDER FARM CONDITIONS (PRODUCTION ZONE: V-VI)

Time required			In natural waters	In pond culture	In intensive culture systems
Year	Approximate length of the growing season (month)				
	Per year	Cumulative	Size of fish (g)		
1st	~ 7	~ 7	≤ 180	≤ 250	This is in experimental phase.
2nd	~ 8	~ 15	≤ 540	≤ 800	
3rd	~ 8	~ 23	≤ 1000	≥ 1000	

Carps – Species of the Cyprinidae family dominate warming-up waters of the region. They represent the largest number of indigenous and introduced species of lower sections of rivers and inland water bodies of the plains. They are often called carps. Among them there are carps with small, medium, and large body sizes. In this section commercially important large carps are presented: the common carp, silver carp, bighead carp and their hybrids and grass carp.

Common carp *(Cyprinus carpio)*
Thermal class of fish: Warmwater fish with a broad spectrum when intensively and efficiently fed (18-28 °C).
Food spectrum, feeding habit: Omnivore feeds on tender water plants, zooplankton, worms, insects, insect larvae, etc. Grows well on nutritionally complete industrial feeds.
Age of sexual maturation: ♂ 2-3 yr. ♀ 3-4 yr. in production zone V-VI (see explanation in Annex 9).
Size and body weight of largest specimen: 120 cm TL, 46 kg

Image by courtesy of Aller Aqua

TABLE A3-6: SIZE OF COMMON CARP IN NATURE AND UNDER FARM CONDITIONS (PRODUCTION ZONE: V-VI)

Time required			In natural waters [1]	In pond culture		In intensive culture systems [2]
Year	Approximate length of the growing season (month)			In 3 year long cycle	In 2 year long cycle	
	Per year	Cumulative	Size of fish (g)			
1st	~ 4	~ 4	55-60	20-30	200-250	~ 250
2nd	~ 6	~ 10	320-325	200-300	1500-2000	~ 3000
3rd	~ 6	~ 16	740-745	1500-2000	-	
4th	~ 6	~ 22	1150-1160	2500-3000	-	

Observation: *[1] In midsection of river Danube. The attainable large size of fish during the first years in the nature demonstrates the growth potential of the species, which is not fully exploited in pond culture because of the much higher stocking density. [2] Water temperature as in natural warming up waters exposed to daily and seasonal changes of weather.*

Silver carp *(Hypophthalmichthys molitrix)* **and silver and bighead carp hybrid**
Thermal class of fish: Warmwater fish with a preference for water temperature higher than 20 °C.
Food spectrum, feeding habit: Filter feeder. Silver carp: Able to filter any floating organisms and particles with a size between 30 and 40 microns. Fry feed on dry feed until switching to the food spectrum characteristic of the species. This happens around 2.5-3 cm TL. Silver and bighead carp hybrid: Filter feeder. Depending on the proportion of the two parent species can filter any floating organisms and particles with a size between 40 and 300 microns. Fry feed on dry feed.
Age of sexual maturation: ♂ 4-6 yr. ♀ 5-6 yr. in production zone V-VI (see explanation in Annex 9).
Size and body weight of largest specimen: 130 cm, 48.5 kg

Image by courtesy of Aller Aqua

Bighead carp *(Aristichthys nobilis)*
Thermal class of fish: Warmwater fish with a preference for water temperature higher than 20 °C.
Food spectrum, feeding habit: Filter feeder. Able to filter any floating organisms and particles with a size between 60 and 300 microns. Fry feed on dry feeds.
Age of sexual maturation: ♂ 6-7 yr. ♀ 7-8 yr. in production zone V-VI (see explanation in Annex 9).
Body weight of largest specimen: 56.8 kg

Image by courtesy of Aller Aqua

TABLE A3-7: SIZE OF SILVER AND BIGHEAD CARPS IN NATURE AND UNDER FARM CONDITIONS (PRODUCTION ZONE: V-VI)

Time required			In natural waters	In pond culture		In intensive culture systems
Year	Approximate length of the growing season (month)			In 3 year long cycle	In 2 year long cycle	
	Per year	Cumulative	Size of fish (g)			
1st	~ 4	~ 4	≥ 20	20-30	200-250	n/a
2nd	~ 6	~ 10	≥ 300	200-300	1000-3000	
3rd	~ 6	~ 16	≥ 1000	1000-3000	-	

Grass carp *(Ctenopharyngodon idella)*
Thermal class of fish: Warmwater fish with a preference for water temperature higher than 20 °C.
Food spectrum, feeding habit: Herbivore, fresh green terrestrial and aquatic plants.
Age of sexual maturation: ♂ 5-6 yr. ♀ 6-8 yr. in production zone V-VI (see explanation in Annex 9).
Body weight of largest specimen: 39.8 kg

Image by courtesy of Aller Aqua

TABLE A3-8: SIZE OF GRASS CARP IN NATURE AND UNDER FARM CONDITIONS (PRODUCTION ZONE: V-VI)

Time required			In natural waters	In pond culture		In intensive culture systems
Year	Approximate length of the growing season (month)			In 3 year long cycle	In 2 year long cycle	
	Per year	Cumulative	Size of fish (g)			
1st	~ 4	~ 4	≥ 20	20-30	200-250	This is in experimental phase.
2nd	~ 6	~ 10	≥ 300	200-300	1000-3000	
3rd	~ 6	~ 16	≥ 1000	1000-3000	-	

Medium-size cyprinids related to fish culture are the tench, bream, crucian carp, and gibel carp (or goldfish). These are good sport fishes, and some of them are a delicacy such as tench, but most of them are considered secondary food fish.

Breams, crucian, and gibel carps were often used in the past to be stocked as substitutions when the stocking material of common carp was not enough.

These species, especially gibel carp, may become dominant in insufficiently managed natural waters. This indicates the need for planned CBF management within other commercially important fish species take over the dominance.

FIGURE A3-1: CRUCIAN AND OTHER MEDIUM-SIZE CARP SOLD AS FOOD FISH IN THE REGION

Tench *(Tinca tinca)*
Thermal class of fish: Warmwater fish
Food spectrum, feeding habit: Omnivore, benthic feeder. Grows well on nutritionally complete industrial feeds.
Age of sexual maturation: ♂ 2-3 yr. ♀ 3-4 yr. in production zone V-VI (see explanation in Annex 9).
Size and body weight of largest specimen: 70 cm SL, 6.9 kg

Image by courtesy of Aller Aqua

TABLE A3-9: SIZE OF TENCH IN NATURE AND UNDER FARM CONDITIONS (PRODUCTION ZONE: V-VI)

Time required			In natural waters	In pond culture	In intensive culture systems[1]
Year	Approximate length of the growing season (month)				
	Per year	Cumulative	Size of fish (g)		
1st	~ 4	~ 4	5-10	10-20	~ 100
2nd	~ 6	~ 10	20-40	50-100	~ 500
3rd	~ 6	~ 16	150-300	~ 500	

Observation: [1] *Water temperature as in natural warming up waters exposed to daily and seasonal changes of weather.*

Bream *(Abramis brama)*
Thermal class of fish: Warmwater fish
Food spectrum, feeding habit: Omnivore, benthic feeder.
Age of sexual maturation: 3-4 yr. in production zone V-VI (see explanation in Annex 9).
Size and body weight of largest specimen: 82 cm, 6 kg

Image by courtesy of Aller Aqua

Crucian carp *(Carassius carassius)*
Thermal class of fish: Warmwater fish
Food spectrum, feeding habit: Omnivore.
Age of sexual maturation: 2-3 yr. in production zone V-VI (see explanation in Annex 9).
Size and body weight of largest specimen: 55 cm, 4.3 kg

Image by courtesy of Aller Aqua

Gibel carp *(Carassius auratus)*
Thermal class of fish: Warmwater fish
Food spectrum, feeding habit: Omnivore, food and feed competitor of common carp.
Size/age of largest specimen: 48 cm

Image by courtesy of Aller Aqua

Catfishes – From the three commercially important catfishes cultured in the region, the European catfish, which belongs to the Siluridae family, is a warm-water species native to the entire region. The two other catfishes presented in the next chapter are air-breathing tropical fishes. Therefore, neither their culture conditions nor the expected results can and should be compared with this one. European catfish is produced both in pond culture and different intensive culture systems.

European catfish *(Silurus glanis)*
Thermal class of fish: Warmwater fish
Food spectrum, feeding habit: Carnivore, predator. Grows well on nutritionally complete industrial feeds.
Age of sexual maturation: ♂ 2-3 yr. ♀ 4-5 yr. in production zone V-VI (see explanation in Annex 9).
Size and body weight of largest specimen: 277 cm, 143.9 kg

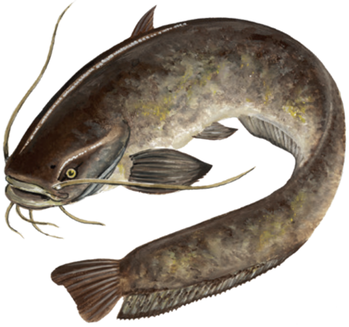


Image by courtesy of Aller Aqua

TABLE A3-10: SIZE OF EUROPEAN CATFISH IN NATURE AND UNDER FARM CONDITIONS (PRODUCTION ZONE: V-VI)

Time required			In natural waters[1]	In pond culture	In intensive culture systems[2]
Year	Approximate length of the growing season (month)				
	Per year	Cumulative	Size of fish (g)		
1st	~ 4	~ 4	~ 30	20-40	~ 200
2nd	~ 6	~ 10	~ 150	200-300	~ 1000
3rd	~ 6	~ 16	~ 500	~ 1000	~ 2500
4th	~ 6	~ 22	~ 1200	1600-1700	

Observation: *[1] In river Tisza. [2] Water temperature as in natural warming up waters exposed to daily and seasonal changes of weather.*

Eels – Two species of the Anguillidae family are produced in intensive culture systems: the European eel and the Japanese eel.

Thermal class of fish: Warmwater fish, but tolerate a wide range of temperature.
Food spectrum, feeding habit: Carnivore, depending on the food available, their food spectrum is rather broad. Grows well on nutritionally complete industrial feeds.
Age of sexual maturation: ♂ 6-12 yrs., ♀ 9-20 yrs.
Size and body weight of largest specimen: 135 cm, 7 kg

Image by courtesy of Aller Aqua

Sunfishes – Fish species in the region belonging to the Centrarhidae family were introduced from North America. Among them, largemouth bass is a popular sportfish and food fish, especially in Western Europe (France), but some of the fish farms in Central and Eastern Europe also propagate and rear these species.

Largemouth bass *(Micropterus salmoides)*
Thermal class of fish: Warmwater fish, with a preference for warming still waters.
Food spectrum, feeding habit: Carnivore, fish predator.
Age of sexual maturation: Mating starts between 5 and 12 years. Length of maturation depends on environmental and feeding conditions. Grows well on nutritionally complete industrial feeds.
Body weight of largest specimen: 10.1 kg

Image by courtesy of Aller Aqua

Perches – There are three commercially important species of the Percidae family produced in fish farms. These are the perch, pikeperch, and Volga pikeperch. In the 1950s a well-established production technology of pikeperch was developed for pond culture. In recent decade the nutritionally complete industrial feeds allow their production also in intensive culture systems.

European perch *(Perca fluviatilis)*
Thermal class of fish: Warmwater fish
Food spectrum, feeding habit: Carnivore, fish predator. Grows well on nutritionally complete industrial feeds.
Size and age of sexual maturation: 11-23 cm, ♂ 1-2 yrs., ♀ 2-4 yrs.
Size and body weight of largest specimen: 58 cm, 3.8 kg

Image by courtesy of Aller Aqua

TABLE A3-11: SIZE OF EUROPEAN PERCH IN NATURE AND UNDER FARM CONDITIONS (PRODUCTION ZONE: V-VI)

Time required			In natural waters [1]	In pond culture	In intensive culture systems
Year	Approximate length of the growing season (month)				
	Per year	Cumulative	Size of fish (g)		
1st	~ 5	~ 5	5 (10)	3-5	These are usually practiced in tempered water systems.
2nd	~ 6	~ 11	10 (35)	15-30	
3rd	~ 6	~ 17	35 (100)	No information	

Observation: *[1] The lower and higher values in brackets represent the growth of slow- and fast-growing populations of the species.*

Pikeperch *(Sander lucioperca)*
Thermal class of fish: Warmwater fish
Food spectrum, feeding habit: Carnivore, fish predator. Grows well on nutritionally complete industrial feeds.
Size and age of sexual maturation: 28-46 cm, 3-10 yrs. (usually 4).
Size and body weight of largest specimen: 116 cm, 18.7 kg

Image by courtesy of Aller Aqua

TABLE A3-12: SIZE OF PIKEPERCH IN NATURE AND UNDER FARM CONDITIONS (PRODUCTION ZONE: V-VI)

Time required			In natural waters [1]	In pond culture	In intensive culture systems
Year	Approximate length of the growing season (month)				
	Per year	Cumulative	Size of fish (g)		
1st	~ 5	~ 5	50-60	30-70	These are usually practiced in tempered water systems.
2nd	~ 6	~ 11	190-200	200-400	
3rd	~ 6	~ 17	390-400	~ 1000	

Observation: *[1] In river Tisza and lake Balaton.*

Volga pikeperch *(Sander volgensis)*
Thermal class of fish: warmwater species
Food spectrum, feeding habit: Carnivore, fish predator. Most probably would grow well on nutritionally complete industrial feeds.
Size and age of sexual maturation: 20-30 cm, 3-4 yrs.
Size and body weight of largest specimen: 60 cm, 2.2 kg

Image by courtesy of Aller Aqua

2.3 TROPICAL FISH SPECIES (CICHLIDS AND CATFISHES)

Of the three tropical fish species presented in this chapter, tilapia and African catfish are widely cultured in the region.

Tilapia – From the wide range of cultured tilapia species with different improved strains, all-male stocks of Nile tilapia are usually produced in RAS. Still, where summer is long and hot, tilapia is also produced intensively in outdoor condition.

Nile tilapia *(Oreochromis niloticus)*
Thermal class of fish: Tropical waters.
Food spectrum, feeding habit: Omnivorous, feeds on phytoplankton and benthic algae. Insect larvae are also consumed, as well as detritus. Young fish is more omnivorous than adults. Grows well on nutritionally complete industrial feeds.
Age of sexual maturation: ♂ 3-4 months, ♀ 4-5 months (in pond culture in its native range).
Size and body weight of largest specimen: 60 cm SL, 4.3 kg

Image by courtesy of Aller Aqua

Tropical catfishes – African catfish belong to the Clariidae and pangasius to the Pangasiidae family. Normally none of them can survive winters in a temperate climate.
They require high water temperature constantly. African catfish is more widely produced in the region of the two species.

African catfish *(Clarias gariepinus)*
Thermal class of fish: Tropical and subtropical waters.
Food spectrum, feeding habit: Omnivorous, bottom feeder, opportunist predator. Grows well on nutritionally complete industrial feeds.
Size of sexual maturation: ♂ 35-40 cm, ♀ 40-45 cm
Size and body weight of largest specimen: 190 cm, 42.5 kg

Image by courtesy of Aller Aqua

Pangasius *(Pangasius pangasius)*
Thermal class of fish: Tropical and subtropical waters.
Food spectrum, feeding habit: Carnivores; feed on snails, molluscs, plants, and smaller fishes. Grows well on nutritionally complete industrial feeds.
Size of sexual maturation: ♂ 45-50 cm, ♀ 45-50 cm (13-14 months)
Size and body weight of largest specimen: 80 cm, 7 kg

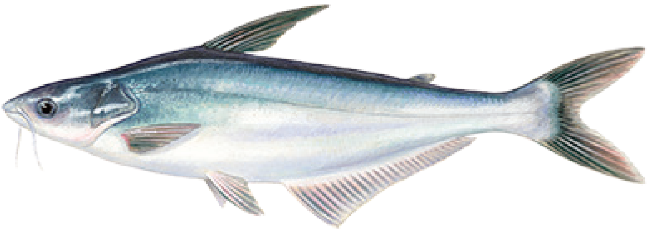


Image by courtesy of Aller Aqua

TABLE A3-13: SIZE OF NILE TILAPIA, AFRICAN CATFISH AND PANGASIUS IN INTENSIVE CULTURE SYSTEMS

Production of tilapia in 28 °C water			**Production of African catfish in 26 °C water**			**Production of pangasius in 30 °C water**		
Approximate length of production (months)		Attainable size (g/fish)	Approximate length of production (months)		Attainable size (g/fish)	Approximate length of production (months)		Attainable size (g/fish)
Per growth stage	Cumulative		Per growth stage	Cumulative		Per growth stage	Cumulative	
3.5-4	3.5-4	70	4-4.5	4-4.5	150	5-5.5	5-5.5	150
1.5-2	5-6	200	3.5	7.5-8	1000	2-2.5	7-8	500
4.5-5	9.5-11	1000	1-1.5	8.5-9.5	1500	3.5	10.5-11.5	1500

2. PROBLEMATIC AND POTENTIALLY IMPORTANT FISH SPECIES OF THE REGION

It is rather relative which fish is considered problematic or potentially important, as any of the fish species and their age groups can be harmful if they enter and are found in natural water or a fish farm (pond, tank, etc.) where they should not be present.

Small, peaceful fishes such as small-size cyprinids found in the region, are especially harmful if they enter a fry rearing pond or outdoor tank. Still, the same fish (for example, rasbora) can also be useful when they appear as food fish for predators reared in pond culture.

The same applies to different predator species: they are very valuable in polycultures, but it should be ensured that they cannot predate on the rest of the reared stocks of peaceful fishes.

There are invasive species such as brown bullhead *(Ictalurus nebulosus)* of the Ictaluridae family or pumpkinseed *(Lepomis gibbosus)* Centrarhidae family, which can also create problems both in natural waters and in fish ponds.

The list could be continued, as each sub-region has some accidental or failed introductions as it was with the mentioned two fishes.

Regarding potentially important species, all native and indigenous coldwater fishes, including Danube salmon *(Hucho hucho)* and many Coregonids, belong to this category. In addition, the native burbot *(Lota lota)* and Northern snakehead *(Channa argus)* and species that could easily be domesticated and produced in fish farms of the region can be good candidates for future aquaculture.

FIGURE A3-2: SEVAN TROUT

Sevan trout (Salmo ischchan) one of the trout species which was introduced into some of the large lakes of Central Asia. For CBF its advanced fry and juvenile have been produced since decades. Today it is increasingly produced in intensive fish farms as food and sport fish.

ANNEX 4

EXPECTATIONS TOWARDS AND CRITERIA OF FISH AND FISH FEED QUALITIES

This annex covers quality criteria of produced fish and factors which determine these. Besides sensory qualities (texture, taste, appearance, etc.) and chemical composition of fish meat, the odour and off-flavour of cultured fish together with contaminants and residues that might be found in the meat of produced fish are also discussed.

Key food safety aspects of feeding fish, and common quality criterions of fish feeds and their accessible ingredients are also discussed and summarized.

Finally, an inventory of the most apparent feeds and feeding related problems are presented, which may result in nutrition related diseases.

CONTENTS

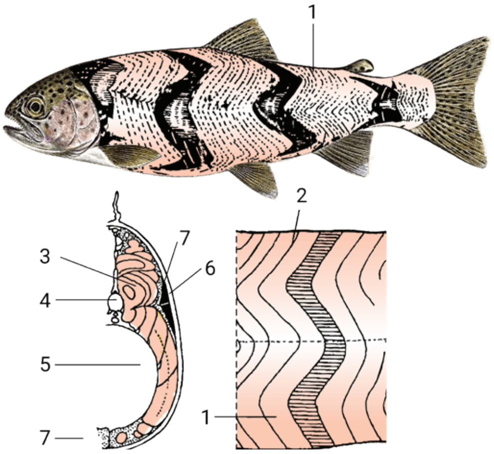
1. QUALITY CRITERIA OF FISH AND FISH MEAT

Muscles are found all over the fish body, but skeletal ones on the trunk and tail are the most important for consumers.

Fish flesh is a combination of muscle layers (also called muscle bundles), tissues connecting such layers, and the *adipose** tissue embedded between the muscle sheets. Though the shape and structure of the muscle vary by class and species, they show a similar pattern in all economically important species of the region. In salmonids and perches musculature shows a more segmental structure than in cichlids or carps. Characteristic patterns of the muscle structure of fish are presented in Figure A4-1.

Muscles of most fish contain pin-like “fishbones” located between the myomeres. These are ossified pin and/or Y-shaped connective tissues. These “fishbones” support the muscle layers that are exposed to higher loads. Their number is species specific (Table A4-1). There are more of them along the back and around the tail and fins, while fewer between the muscle layers that compose the trunk. In large fish muscle “fishbones” are large and thick, so they are less disturbing at consumption than those of younger/smaller specimens.

FIGURE A4-1: SCHEMATIC ILLUSTRATION OF THE MUSCULATURE OF FISH



(After [48] and [95])

1) Myomeres are layers of muscle fibres which are segmented with horizontal septa marked with black, 2) Sheet of connecting tissue, 3) Cross-section of muscle layers, 4) Backbone, 5) Abdomen, 6) Dark or red muscle, 7) Areas in carps where fat most frequently deposits.

TABLE A4-1: THE APPROXIMATE NUMBER OF PIN AND Y-SHAPED MUSCLE BONES IN SELECTED FISH SPECIES CULTURED IN THE REGION

Species	**Common carp**	**Silver carp**	**Bighead carp**	**Grass carp**	**Tench**	**Bream**
Number of Y-shaped bones	95-100	116	150	144	95-100	120-130
Species	**Crucian carp**	**Pike**	**Perches, pikeperch**	**Nile tilapia**	**Catfishes**	**Trouts**
Number of Y-shaped bones	80	115	25	a few	-	a few

(Source: [95] and [20])

1.1 SENSORY QUALITIES AND CHEMICAL COMPOSITION OF FISH MEAT

The taste which determines consumer preferences is highly subjective. There is a set of aspects which should be considered when the quality of fish meat is discussed. The amount of muscle “fishbones” and the structure, consistency, fattiness, colour, smell and taste of fish flesh jointly determine acceptance and preferences of consumers. These qualities are species and strain specific. Sensory qualities of wild fish and cultured pond fish meat depend on the season, water quality, and the type of natural food and supplementary feed consumed. In the case of intensive culture systems factors principally influencing the fish flesh quality are the water quality and the quality and quantity of ingested feed.

Most consumers consider the meat of predatory fish tastier than that of herbivores, and the meat of common carp and grass carp more preferred, than that of filtrating herbivore species, such as silver carp.

In addition to species, age is also an important factor to determine the sensory qualities of fish. The flesh of younger specimen might be more delicious, but the tiny muscle bones can be rather disturbing, while in elder specimens the muscle “fishbones” are larger hence less disturbing, but they may be fatter. In the nature the flesh of several years old specimens is dryer, stringy, with less flavour.

Accepting the above, it can be concluded that the sensory qualities of fish meat are not constant.

TABLE A4-2: APPROXIMATE CHEMICAL COMPOSITION OF FISH CULTURED IN THE REGION

Fish species	Water (%)	Protein (%)	Fat (%)	Minerals (%)
Rainbow trout	67-78	17.7-21.9	2.7-10.6	
Broun trout	70-79	18.8-19.1	1.2-10.8	
Common carp	73.5-80	15.5-18.9	1.2-12.7	~ 1
Silver carp	74.5-77	~ 18	4-6	~ 1
Bighead carp	72-75	17.5-18	6-9.5	~ 1
Grass carp	74.5-77	17-18.5	4.5-6.5	~ 1
Tench	77-78	14.5-15.5	5.7-5.9	~ 1
Pike	79-80	18-19	0.5-1	1-1.5
European catfish	76.5-80.5	17.5-18.5	1.5-4	~ 1
Perch	79-80	17.6-19	0.8	
Pikeperch	78-79.5	19-20	0.5-1	~ 1
Tilapia	80	12	5.6	2.6
Eel	60-71	14.2	8-31	
African catfish	71.3	19.3	8.1	1.5
Pangasius	74-80	12-22	0.4-5.7	0.8-2

(Source: [8], [10], [13], [20], [21], [44], [56], [58], [65], [89], [99], [101] and [102])

In most cases, chemical composition in Table A4-2 published by different authors is considered when fish meat quality is characterized. Though data presented in this table provides important information. Murray and Burt [75] recommended a more nuanced description and characterization of fish meat qualities. According to their opinion the structure of the fish meat and the nutrients it contains (i.e. water, proteins, fats, carbohydrates, vitamins, minerals and extractives) are the ones that predominantly determine physical and organoleptic qualities (odour, taste, palatability, etc.) and the suitability of fish meat for processing. Murray and Burt distinguished and used the terms "white" and "fatty" fish meat.

Water content of fish flesh

The water in the muscle (flesh) of fish is found in highly protein bound forms. Water content of "white" fish meat is approximately 80%. In "fatty" fish this value is around 70%. This is because while the protein content of fish meat is species specific and its value remains constant within a narrower range, there is a negative correlation between fat and water content of fish flesh. To a certain extent this means that fish gain fat at the expense of the water content of their flesh.

Protein content of fish flesh

Depending on species and individuals, the amount of protein in fish muscle is usually between 15% and 20%, but in extreme cases it can be even below 15% and up to 28% [75].

BOX A4-1: A SIMPLE METHOD TO CHECK THE APPARENT FAT CONTENTS OF FISH MEAT

Fatty fish is not equally popular throughout the region. Purchase of a modern tester that can determine the fat content of fish straight is expensive, while analyses need special laboratories. It is still possible to assess the fat content of freshly cut fish on farms for self-monitoring. Janurik suggests a simple method for this: the meat of freshly cut fish should be chopped into small, approximately one cubic centimetre pieces then placed in a bowl.

If fat already accumulates in the bowl within a short period of time due to the weight of the cubes, the fish can be considered fatty. This is especially true if the amount of accumulated fat is so much that it can be poured out of the bowl.

Fat content of fish flesh

Fat content of fish flesh can greatly vary depending on the species, strain, age, season and feeding. This is due to the quantity, quality, and utilization of ingested food. Fat is not evenly distributed in fish. Usually, fewer fat deposits in the muscles which are actively used (e.g., for swimming) than the ones less with physical exertion. Fat not only accumulates in the flesh, but also under the skin behind the head and around the abdomen, and even in the abdominal cavity around the internal organs.

Substances found in smaller amounts in fish flesh
Carbohydrates, vitamins, minerals, and extractives belong to these substances. Though they are found in small quantities, they still essentially and decisively determine organoleptic qualities of fish meat. Among these substances the amount of **carbohydrates** in “white” fish meat is less than 1%, but in the dark muscles of “fatty” fish this value can even reach 2%. The amount of **minerals** in the muscles and meat of fish is around 1%.

Extractives in fish flesh impart **flavours**. The name derives from the fact that they can be easily extracted by water or water-based solutions. Extractives include sugars, free amino acids (which are not bound to protein molecules) and nitrogenous bases, which are chemically ammonia related substances. Though extractives are present in small amounts in fish, still they fundamentally determine the quality, mainly the organoleptic properties of fish meat, such as odour, taste and palatability, which are species specific. While many of these substances are able to enrich the taste of a specific fish, some of them, the **volatile** compounds, directly contribute to the development of strong taste and odour, characteristic to species [75].

1.2 ODOUR AND OFF-FLAVOUR OF CULTURED FISH

Even today it is widely preconceived that fish, especially carps grown in ponds have an unpleasant, muddy taste. This taste, perceived differently by humans, is caused by *GSM (Geosmin)** and *MIB (2-methylisoborneol)**. These compounds are found in very small quantities in nature, but they are also widespread. They are produced in water by microscopic organisms floating or adhered to a surface, belonging to the Oscillatoria species of cyanobacteria [103]. According to Darázs and Aczél [20], the muddy odour and taste can easily be eliminated when live fish is stored in fresh flow-through water for a few days.
Jüttner and Watson [61] investigated the possibility of eliminating negative impacts of GSM and MIB on drinking water bases, to improve the quality of drinking water. It has been concluded that the growth of cyanobacteria (blue-green algae) producing these hostile substances can be inhibited, reduced, or even stopped in oxygen rich, ecologically balanced waters.
There are also effective ways to prevent or inhibit the growth of these types of cyanobacteria in pond fish farms. The most obvious of these options are:
- Drying and keeping the pond bottom dry as long time as possible;
- Hindering the development of a sludge layer by a rational manuring/fertilization.

In the case of algae blooms a reduction or even a temporary interruption of manuring/fertilization, together with adding chlorinated lime and depositing straw in pond water can be beneficial. Measures to maintain a high level of dissolved oxygen through the whole water body and the ventilation of sludge should also be part of the production technology of carps in ponds. FAO publications of Molnár, Székely and Láng [73], and Woynarovich, Kovács and Nagy [105] introduce how to combat such problems and are recommended when more detailed information is needed. According to Darázs and Aczél [20], common carp fed exclusively on maize may also have an unpleasant taste. This can be eliminated by switching to other components in the supplementary feed.

1.3 CONTAMINANTS AND RESIDUES IN FISH MEAT

There are national and international authorities and organizations which deal with food safety. In the European Union (EU) the legislative framework on the safety of food and nutrition is set under a relevant European Commission Regulation; *(EC) No. 178/2002* [26], where general principles and requirements of the food law and procedures regarding food and feed safety are set. Understanding these regulations helps to cope with both legislative and technical aspects of food safety measures. It is especially important for fish farmers planning to export fish to EU markets.

Contaminants in fish meat
From the nine groups of contaminants which are mycotoxins, metals/metal impurities, *3-MCPD*, PCBs*, POPs**, *PAHs**, *melamine**, *erucic acid** and *nitrates** the following ones can be found in fish flesh:
- Metals and metal impurities (lead, cadmium, mercury, *methylmercury**, inorganic tin)
- Polychlorinated biphenyls (*dioxins** and dioxin-like PCBs)
- POPs (persistent organic pollutants)
- PAHs (polycyclic aromatic hydrocarbons)

Presence of the above listed contaminants is more likely in wild stocks of marine and in those freshwater fishes which are from polluted waters. This is especially true for wild predator fish species of the seas. They are more likely to accumulate contaminants excessively. That is one of the reasons for the increasing popularity of fish from aquaculture today. Maximum allowed levels for contaminants in foodstuffs are specified both at national and international levels, which must be confirmed when fish is marketed. In the EU a relevant Regulation *(EC) No 1881/2006/EU* [29] specifies the maximum allowable levels for selected contaminants in foodstuffs including fish (Box A4-2).

BOX A4-2: MAXIMUM LEVELS FOR CERTAIN CONTAMINANTS IN FOODSTUFFS

The European Union (EU) has set maximum levels for certain contaminants in food (1881/2006/EC) [29]. Foods containing contaminants in excess of the legal limits specified in the annexes of this legislation prohibit to be sold on European markets.

Pesticide residues, muscle building and growth promoting hormones in fish meat

Fish and fish meat appearing on markets must not contain pesticide residues or muscle building and growth promoting hormones and hormone-like substances and products. The list of such substances and related restrictions are introduced in the following European Directives: *96/22/EC* [25] (entitled: “Prohibition on the use of certain substances with a hormonal or *thyrostatic action** and of *beta-agonists** in stock farming”) and its amendments issued in 2003 *(2003/74/EC)* [27].

Pharmacologically active substances and their residues in fish meat

Fish and fish meat must not contain pharmacologically active substances above the maximum residue limits permitted by EU *Regulation (EC) No 37/2010* [31] entitled: “Pharmacologically active substances and their classification regarding maximum residue limits in foodstuffs of animal origin”). This regulation also includes the text with European Economic Area (EEA) relevance that is useful for those trading with the EU.

2. QUALITY CRITERIA OF FISH FEEDS AND THEIR INGREDIENTS

Depending on the intensity of production and the species of fish produced, different types of feeds are used. Though these feeds have different nutritional qualities, there are still some universal, systematically applicable aspects which should be observed when feeds are selected and used.

Perceptions and awareness on the quality of feed provided to fish have fundamentally changed, i.e., developed throughout the last decades. Earlier concepts of fish feeding agreed on and allowed a limited use of poor quality, defective, even spoiled, and contaminated feed. At present it is agreed and extensively advocated that only proper quality feed, feed ingredients and additives should be utilized. National and international standards on animal feed quality criterions may slightly vary at national levels, still in principle EU Regulation *(EC) No 183/2005* [28] (entitled: “Requirements for feed hygiene, text with EEA relevance”) sufficiently covers necessary information, especially when fish production is connected or planned to be connected to EU markets.

According to Jávor and Szigeti [59] fish feeds can be classified by physical, chemical, and biological factors, some of which can reduce or even damage the quality of feed. These can be physical, chemical, biological, and microbiological hazards detailed below.

Physical hazards

- Presence of seeds and weeds as contaminants in the diet that may cause indigestion, inflammation of the alimentary tract or poisoning of fish (Figure A4-2).
- Presence of plastic or metal shards, soil or stone pieces among the grains and/or feed particles. This is more likely when cheap, poor-quality grains are purchased, as demonstrated in Figure A4-2.

Chemical hazards

- Presence of pharmacological residuals and prohibited substances in fish feeds such as antibiotics (discounting medicated feeds) and substances having a hormonal, e.g., thyrostatic action.

FIGURE A4-2: FREQUENTLY USED WHEAT WASTE AS SUPPLEMENTARY FEED OF COMMON CARP

Such tailings used as supplementary feed carry the chance that nutritional requirements of fish remain unsatisfied and even intestinal inflammation can develop.

- Presence of contaminants in the feed in higher concentrations than permitted. Such contaminants include the ones listed in the previous chapter and described in the glossary; metals and metal impurities, 3-MCPD, PCBs, POPs, PAHs, melamine, erucic acid and nitrates.
- The residue levels of herbicides, insecticides and pesticides in grains and feed ingredients of plant and animal origin is higher than permitted by the law.
- Rodenticides mixed with feed due to an improper use and/or disposal in the granary.
- Presence of toxic chemicals that may seep on the farm while being stored, especially when feeds and such chemicals are kept in the same store.
- Harmful constituents that may be present in some feeds, e.g., *protease inhibitors** found in certain legumes, such as soybean or *gossypol** in cotton seed.

BOX A4-3: UTILIZATION OF BROKEN GRAINS AND MILL SWEEPINGS AS FISH FEED

Physically damaged, broken grain and mill sweepings are suitable for feeding fish with the condition that they are not spoiled, damped and/or contaminated.

Mill screenings may contain metal or plastic particles or shards, which are hazardous when ground together with the grain. Fish are ingesting them with the chance of having wounds and/or inflammations in the digestive tract.

Biological hazards
- Insects, rodents, birds, and other animals can spread pathogens of various diseases.
- Inadequate insect and rodent control resulting in their proliferation.
- Toxin production (mycotoxins) of field and storage moulds.

Microbiological hazards
- Bacterial and/or fungal infection of stored feed.
- Presence, survival, and multiplication of field and/or storage moulds in wet grain.
- Presence, survival, and multiplication of Salmonella in fishmeal.
- Presence of viruses, *prions**, bacteria, unicellular and other parasites and fungi in the feed while stored.

The above-mentioned hazards are a smaller, but very important section of the potential dangers which are directly exposed on fish feeds and indirectly on the health of fish fed. Due to the diversity and specific characteristics of the hazards, they need to be monitored and addressed in a complex manner.

3. FEED AND FEEDING RELATED DISEASES

Feed and feeding related diseases are extensively discussed in many widely available publications on fish health. Nutritional pathology and morphological signs of nutrient deficiency and toxicity in farmed fish described by Tacon in 1992 [96], and Molnár and colleagues in 2019 [73] are among the publications which cover a wide range of species and culture systems and are recommended when detailed information is needed.
Consequently, the objective of this chapter is to provide a concise introduction to the problem and present an inventory on the subject.

3.1 NUTRITIONAL DEFICIENCIES AND DISORDERS

The most radical nutritional deficiency is when fish are starving. It may happen in any type of a culture system with any fish kept in a confined culture space. This is a serious management problem which does not need further explanation.
If some ingredients of the fish diet such as proteins, lipids or carbohydrates are deficient, that will result in slow growth and high feed conversion ratio (FCR). When relative and absolute quantities of diet components remain below a certain level, nutritional deficiency related diseases will develop. These are usually grouped according to the substances which are in short supply in the diet. Consequently, there are amino-acid, fatty acid, vitamin, and mineral deficiencies.
Reasons and manifested symptoms may vary by species and culture systems. Hence, nutritional deficiencies may develop and appear differently in pond culture and intensive culture systems.

Nutritional deficiencies and disorders in pond polyculture
It is difficult to detect and diagnose nutritional deficiencies in fish which feed entirely on natural food.
The only apparent sign of a possible deficiency is that the growth of the fish stock remains behind the expected production. If, in addition to the slow growth fish are even starting to lose weight, either the natural food production of the pond should significantly be increased, or the suffering fish stock should partly be removed from the pond.

Grass carp is a special member of the polyculture in ponds. This fish is not fed if stocked in low densities, especially when the pond is well covered with aquatic vegetation. Still, as soon as all water weeds are consumed, grass carp needs to be fed with fresh terrestrial plants. Chronically starving or even underfed grass carp is not only growing slower but is also losing weight and develop diseases that are well noticeable.

Another widely experienced problem is when grass carp consume the supplementary feed of common carp. Consequently, fat deposits in the liver in an unhealthy manner.
An evident sign of the problem is the enlarged, yellow liver. When grass is fed in the morning in adequate quantities well before feeding common carp, such problems will not occur.
The diet of common carp in ponds consists of both natural food and supplementary feeds. As explained in Annex 6 the nutritional value of supplementary feed should be seasonally adjusted. When the adjustment fails, fish will not receive the required nutritional balance, resulting in the development of excessive, sometimes even unhealthy fat deposits, which may risk an unsuccessful wintering (Box A4-4).

Vitamin and mineral deficiencies are hardly experienced in pond polycultures. Such deficiencies may start to develop and appear at about 2.4 t/ha fish biomass and above [50].

Nutritional deficiencies and disorders in intensive culture systems
The success of intensive culture systems basically depends on how good, nutritionally complete feed is provided for fish. This feed is the only source to cover all dietary requirements of fish, including vitamins and minerals, which make any kind of deficiencies apparent (Box A4-5).

Slow growth and high FCR are evident signs of qualitative and/or quantitative deficiencies of used feed. Development of vitamin and/or mineral deficiency related diseases is a sign of feeding and feed related problems (Figure A4-3).

It is to note that the consistency of applied feed is also very important. Dusty pellets with inadequate water stability not only influence FCR considerably but may also cause mortality as shown in Figure A4-4.

Overfeeding in the form of obesity is a rather frequent problem in common carp and rainbow trout ponds used for fee fishing. Both species are rapacious and inclined to overfeed. Therefore, the fish deposits fat in unhealthy quantities. Relative overfeeding is when the actual, usually very low water temperature is not properly observed and fish intake more feed than they can digest. This may also cause mortality when the ingested feed remains in the alimentary tract, undigested, due to low water temperature when the peristaltic movement of alimentary tract is slow, and the digestion is improper.

BOX A4-4: RELATIONSHIP BETWEEN UNSATURATED FATTY ACIDS AND CARP FEEDING

In pond fish cultures unsaturated fatty acids (UFAs) are largely absorbed into fish meat from natural food organisms or from carefully prepared feeds.

UFAs are physiologically important for fish as they do not solidify when water is cooling, followed by the temperature of the fish body. Thus, fish can maintain the fluidity of cell membranes; consequently, they can overwinter better [17].

Saturated fatty acids (SAFAs) are built into the fish body primarily due to an excessive grain (e.g., wheat) feeding. There is a close correlation between the dry matter content and the fat content of the fish body. Protein content of fatter fish is always lower than that of the ones with less fat. Older and overfed fish stocks, which could consume less natural food, are always fatter than the younger ones consuming a lot of natural food. The lack of natural food can be compensated by improving the composition of supplementary feed and/or using nutritionally balanced and complete industrial feed as outlined in Chapter 5 of the main text and in Annex 6.

FIGURE A4-3: CRACKED SCALP OF AFRICAN CATFISH

(Photo by courtesy of György Csaba and Mária Láng)

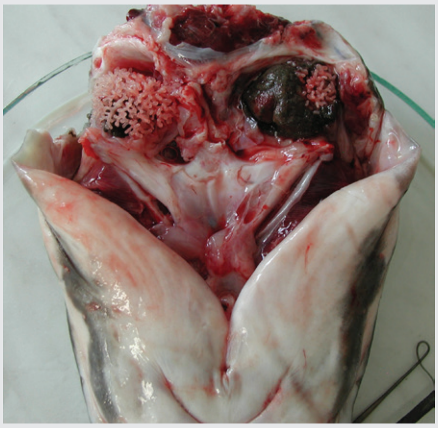
A sign of severe vitamin C deficiency.

3.2 NUTRITIONAL TOXICITY

Nutritional toxicity may happen when contaminated feed or feed ingredients are used. The cause of contamination can be external, may happen when potentially toxin-containing feed ingredients (e.g., soya bean, linseed, cottonseed) are not properly processed before use, but may also derive from an improper storage of feed. Consequently, mycotoxins produced by moulds may be the cause of nutritional toxicity, when on incorrectly stored damp toxicogenic mould is developed.

The impact of consumed feed on the aquatic environment where fish are enclosed in intensive systems is also a primary aspect to consider when fish health is discussed. Such nutrition related environmental problems can be linked to the high FCR. High FCR causes an increased load on the culture system, while increased concentration of ammonia and accumulated faeces generate biological (BOD) and chemical (COD) oxygen demands. These later, especially when accumulate, may cause a constant and/or acute oxygen shortage and even the death of fish.

FIGURE A4-4: DAMAGED ACCESSORY RESPIRATORY ORGAN OF AFRICAN CATFISH



(Photo by courtesy of György Csaba and Mária Láng)

Dusty feed particles deposit on and clog the respiratory organ that inflames (on the right) and eventually kill the fish

BOX A4-5: NUTRITIONALLY COMPLETE INDUSTRIAL FEEDS FOR INTENSIVE FISH CULTURE SYSTEMS

As fish feeds produced for intensive culture systems must be nutritionally complete, the compilation and production of such feeds are beyond the capacities of fish farms. Thus, these feeds with constant, reliable qualities are produced by specialised, professional companies. Fish reared on the feeds of such reliable companies do not suffer in nutritional deficiencies and disorders, if the products are used exactly as recommended.

BOX A4-6: TOXICITY AND POISONING BECAUSE OF MANURING

It may happen that the organic fertilizers used for increasing the natural fish food production of pond water is contaminated with detergents, chemicals, drug residuals or poisons used on the farm, where the organic fertilizers are purchased from. Such contaminated organic fertilizers can cause serious health problems and even mass mortality. For this reason, it is recommended to check and confirm that the organic fertilizers do not contain any substances potentially harmful for fish.

ANNEX 5

CHEMICAL COMPOSITION AND ENERGY OF NATURAL FISH FOODS, AND FEEDS USED IN POND CULTURE AND INTENSIVE CULTURE SYSTEMS

This annex provides a concise overview of the characteristics of natural fish foods and feeds. Without such insight neither proper supplementary feeding, nor the correct use of nutritionally complete industrial feeds is possible.

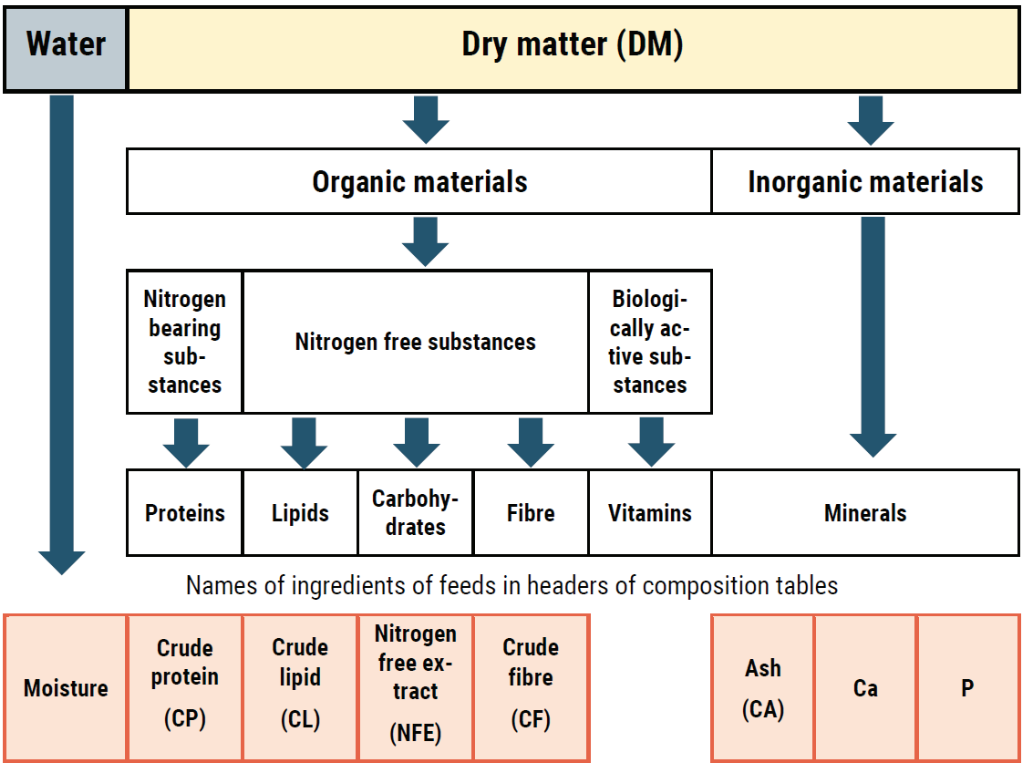
CONTENT

1 CHEMICAL COMPOSITION OF FISH FEEDS

Nutritional properties of feeds are determined by their composition shown in Figure A5-1. In this figure the arrangement helps to link and identify different groups of components which build up foods and feeds.

Components of foods and feeds are approximately the same, only their proportions and qualities are specific to each individual food or feed. Names used in Figure A5-1 follow the same nomenclature as that of technical books. This helps the search, comparison and selection of feeds, ingredients, and feed additives.

FIGURE A5-1: A SCHEMATIC PRESENTATION OF THE COMPOSITION OF FISH FOODS AND FEEDS



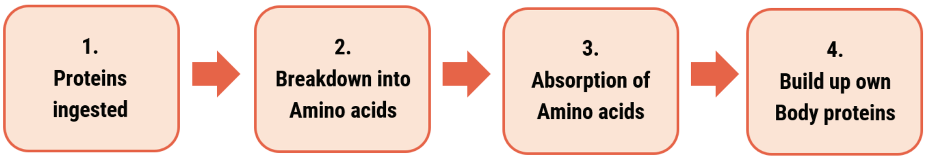
1.1 MOISTURE AND DRY MATTER

The consistency and quality of feeds is basically influenced by their water content. There is a practical distinction between air-dry feed (8-14% water content), green feed (35-85% water content) and root-based feed (78-95% water content). Feeds containing more water than air-dry ones are also called juicy feeds [86].
All ingredients in the feed other than water are part of the dry matter. The sum of water content and dry matter content must be 100% in all cases. Dry matter content determines, among others, the gross and digestible energy content, as well as preservability and storability of feeds [86].

1.2 PROTEINS

Nitrogen-containing materials in feeds are collectively referred to as proteins or crude protein (CP). Each feed has its specific quality and quantity of proteins. Normally crude protein content is measured and indicated as one of the most important macronutrients

FIGURE A5-2: SCHEMATIC STEPS OF BUILDING IN INGESTED PROTEINS IN THE COURSE OF DIGESTION IN FISH



for animal husbandry, including fish culture. Previously digestible crude protein (DCP) was considered as the most important food/feed quality determining indicator, which is a part of the crude protein that an animal of a given species and age is able to digest. Consequently, the informative value of DCP is species and age specific, thus cannot be used as a universal, widely, and equally applicable parameter of feeds.

Among the organic materials in feeds, proteins are the carriers of life. Without them no life would be possible. All cells in animals contain proteins. The protein content of feeds is especially important for animals including fish, because in contrast to plants, animals cannot build their own body proteins only from proteins.
Proteins are giant, long-chain, complex, organic molecules consisting of 18-23 different *amino acids**. The actual number and range of amino acids is a protein-specific characteristic. Generally speaking, animals, thus fish are unable to synthesize nearly half of the amino acids, which are thus called essential amino acids. According to New [78], essential amino acids for fish are: (1) arginine, (2) histidine, (3) isoleucine, (4) leucine, (5) lysine, (6) methionine, (7) phenylalanine, (8) threonine, (9) tryptophan and (10) valine.

Usually, the essential amino acid content of feed is provided in proportion to crude protein content. It is necessary to note that not only the right quality (type) and quantity, but also the appropriate proportion of essential amino acids in the diet of fish is important. If this is not recognised, fish cannot properly utilize protein:

- When some of the amino acids are in excess to the requirement of fish, these are broken down and excreted;
- Shortage of some of the essential amino acids hinder the protein synthesis.

In other words, essential amino acids that are present in the smallest quantities (also called limiting amino acids) determine the efficiency of protein utilization.

In extensive and semi-intensive pond culture production the role of essential and limiting amino acids in the feeds is not that important because fish are able to cover most of these components from natural food. Therefore, detailed information on amino acids for composing simple feed mixtures and compound feeds on farms are not so essential. In case of interest, information can be found in different fish nutrition textbooks.

1.3 LIPIDS

The first group of nitrogen free substances is lipids. Fats, oils, waxes, and any other compounds that are soluble in organic solvents but not in water are called lipids. In tables presenting the chemical composition of feeds, such as tables of the Appendix, lipids are indicated as crude fat (CF) or crude lipid (CL).

Fats are the most important among lipids. They are not only a source of energy in feeds, but are also essential for the survival, growth, and reproduction of fish. The ones melting at low temperature and having a liquid consistency at room temperature are oils, while others with a higher melting point, which are solid at room temperature are called fats.
Fats and oils are made up of *fatty acids** and glycerol. Fatty acids can be saturated or unsaturated. Saturated fatty acids play a major role in the structure of the body and are satisfying energy needs. Unsaturated fatty acids are involved in *intermediate metabolism**.

Linoleic (C18:2 n-6) and α-linolenic (C18:3 n-3) acids are essential fatty acids. As essential fatty acids, they must be supplied to animals through the feed [86].
Erucic acid (C22:1 n-9) is a fatty acid considered to be a contaminant in food. It is found in higher concentrations in oils pressed from conventional varieties of rape and of mustard seed. To overcome this problem new rapeseed varieties (00 and 000) are developed that contain a minimal amount (less than 1%) of erucic acid [86].

The fatty acid composition of feeds also determines that of fed fish, and ultimately the nutritional value of fish meat and fat. Therefore, now it is consciously influenced through feeding to meet human needs over the production of functional foods [7]. Description of functional foods see in Box A5-1.

BOX A5-1: FUNCTIONAL FOOD

In the traditional sense all food is considered to be functional, as they provide the required nutrients i.e. proteins, fats, carbohydrates, etc. for the body. Nowadays functional foods are engineered with adding plus components that the original raw material otherwise does not contain.
These can be proteins, lipids, carbohydrates, fibre, vitamins and/or minerals. The final objective of such foods is to provide additional health benefits beyond the original basic nutritional ones [34].

1.4 NITROGEN-FREE EXTRACT

The second group of nitrogen free substances is nitrogen free extracts (NFE). Chemically this is not a uniform group, it is a fraction of feeds that contains carbohydrates, mainly sugars, and starch. According to Mézes [68] they have at least three functions in feeding:

- Provide energy;
- Serve as raw materials for fat production.
- Add flavour to feed.

As it is among the cheapest nutrients in many countries of the region, feeds with high carbohydrate content provide a most economic source of energy to supplementary feeds of common carp produced in traditional pond polyculture. The ratio of carbohydrates in animal tissues is 0.5-1%, while in plants, mainly in cereal grains 50-80%. In plants carbohydrates serve as reserve nutrients [86]. Carbohydrates are built up of carbon (C), hydrogen (H) and oxygen (O). There are different types of carbohydrates:

- **Monosaccharides:** simple carbohydrates, including pentoses (five C atoms in a molecule) and hexoses (six C atoms in a molecule). They dissolve well in water and have a sweet taste. They play a key role in cellular metabolism and mainly occur in fruits, young plant shoots and some tubers.
- **Disaccharides:** sugars with a most simple compound made up of two monosaccharide units. Major disaccharides are sucrose, lactose and maltose and are mostly present in germinating plants.
- **Trisaccharides:** consist of three monosaccharide units and are found mainly in vegetables.
- **Polysaccharides:**
  Starch – plays an important role in the nutrition of animals, including omnivorous fish. It occurs in cereal grains and potatoes.
  Glycogen – reserve nutrient of animal origin, its role in feeding is not significant. It is found in animals, fungi, and algae.
  Inulin – easily digestible sweet compound found in Jerusalem artichokes, onions, and chicory.
  Mixed polysaccharides – vegetable mucus and gums. They are neither digestible nor degradable, therefore have no significance in practical feeding.
- **Organic acids:** include among others malic acid, citric acid, tartaric acid, oxalic acid, etc. These may have physiological importance. Lactic acid and volatile fatty acids (e.g., acetic acid present in silage) are useful, the role of butyric acid is indifferent, while oxalic acid can even be harmful, because it binds calcium in the bloodstream.

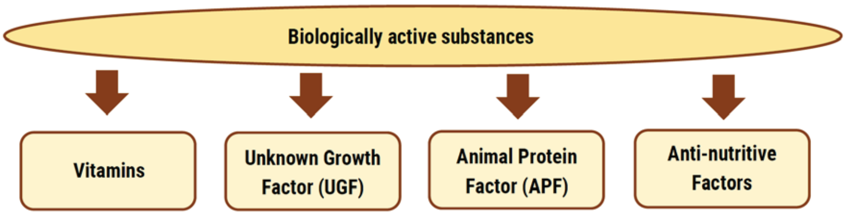
1.5 FIBRE

The third group of nitrogen free substances is fibre, indicated in feed as crude fibre (CF). It makes up the cell wall and the supporting tissue of plants. The chemical structure of fibres are different. After Mézes [68], most important compounds that make up crude fibre are:

- **Cellulose** content in crude fibre is around 50%. Among farm animals only ruminants are able to break down and digest cellulose directly in rumen, while in other terrestrial farmed animals, cellulose is broken down in the caecum and colon (large intestine) by enzymes of bacterial origin. Cellulase activity in the intestinal tract of herbivorous and omnivorous fishes is also the result of bacterial activities.
- **Hemicellulose** content in crude fibre may vary between 10% and 30%. It is mainly found in cell walls of young plants. It easily decomposes under the influence of bacterial enzymes and chemicals.
- **Vegetable adhesives, mucilage** and gum swell and gelatinize in the presence of water. These are the binders in cell walls, their digestibility is medium or poor. Pectin is indigestible but may have a role in the treatment of digestive problems due to its gel formation, as it has a good dietary effect.
- **Encrusting materials** build up in the cell wall during the aging of plants, e.g., lignin. They reduce the digestibility of the plant materials as they are resistant to both chemical and enzymatic breakdown. In addition, encrusting materials impair the digestibility of other nutrients.

In general, digestibility of crude fibre is determined by the content of easily digestible carbohydrates in the feed, the bacterial flora of the digestive tract, and the species, variety and maturity of plants fed or included in the feed. The role of crude fibre in fish feed is species specific.

FIGURE A5-3: SCHEMATIC DIVISION OF BIOLOGICALLY ACTIVE SUBSTANCES



1.6 VITAMINS

Vitamins are biologically active substances together with other groups, presented in Figure A5-3. Vitamins occur in very small amounts in the body of animals, but they are essential for physiological processes. Vitamins are present, participate in and regulate all metabolic functions of the body.

Vitamins are divided into two groups: fat-soluble and water-soluble vitamins. Fat-soluble vitamins are found in natural fats, oils and in feeds containing them (Table A5-1). Water-soluble vitamins are present in non-fatty feeds, usually in plants. As Mézes [68] summarised, the exact vitamin content of raw plants used as feed and feed ingredients is not constant. It is determined by species, variety, *phenophases**, plant segment, climate, soil, harvest technique, storage, preparation, processing technology (of industrial feeds) and supplemental vitamin preparations (vitamin premixes).

Water-soluble vitamins are excreted in the urine, therefore must constantly be replenished. Fat-soluble vitamins can be stored in the adipose tissues and liver for a longer period of time, until they are depleted.

Physiological effects of vitamins are summarised in Table A5-2. Positive effects of vitamins are indispensable for the support and proper function of the sensory, digestive, and reproductive organs of fish.

TABLE A5-1: LIST OF VITAMINS

Fat-soluble vitamins
1. Vitamin A (retinol)
2. Vitamin D_2 and D_3
3. Vitamin E
4. Vitamin K_1, K_2, K_3
Water-soluble vitamins
1. Vitamin B_1 (thiamine, aneurin)
2. Vitamin B_2 (riboflavin)
3. Vitamin B_5 (pantothenic acid)
4. Vitamin B_6 (pyridoxine)
5. Vitamin B_{12} (formerly APF [Animal Protein Factor])
6. Niacin (nicotinic acid, B_3)
7. Biotin (formerly known as vitamin H or B_7)
8. Folic acid (vitamin B_c)
9. Vitamin C (ascorbic acid)
Vitamin-like substances
1. Choline (vitamin B_4)
2. Carnitine

In addition to solubility, vitamins are divided into inductive and zymogen groups:

- **Inductive vitamins** are demonstrably essential for living organisms, but their physiological role is not fully understood yet.
- **Zymogen vitamins** bind to and act on proteins either as a coenzyme component, or as an enzyme-like molecule.

TABLE A5-2: PHYSIOLOGICAL EFFECTS OF VITAMINS AND VITAMIN-LIKE SUBSTANCES

Physiological effects of vitamins	Fat-soluble vitamins	Water soluble vitamins	Vitamin-like substances
Acetylcholine* **formation**			Choline
Antioxidant* **effect**	Vitamin A and Vitamin E	Vitamin B2, Folic acid and Vitamin C	Carnitine
Blood clotting	Vitamins K1, K2, K3		
Bone formation	Vitamins D2 and D3	Folic acid and Vitamin C	
Ca and P metabolism	Vitamins D2 and D3		
Carbohydrate metabolism		Vitamin B1, Vitamin B5, Niacin and Biotin	
Carbon dioxide transfer		Biotin	
Cartilage formation		Folic acid and Vitamin C	
Collagen* **synthesis**		Vitamin B12, Folic acid and Vitamin C	
Differentiation, growth	Vitamin A		

Physiological effects of vitamins	Fat-soluble vitamins	Water soluble vitamins	Vitamin-like substances
Endothelial* protection		Folic acid and Vitamin C	
Enzyme builder		Vitamin B5, Vitamin B6, Niacin and Biotin	
Epithelial* protection		Niacin	
Fat metabolism, fatty acid synthesis		Vitamin B2, Vitamin B5, Vitamin B6, Niacin, Biotin and Folic acid	Carnitine
Haemoglobin* synthesis		Vitamin B12 and Folic acid	
Hydrogen transfer		Vitamin B2, Niacin, Folic acid and Vitamin C	
Immune protection, response	Vitamin A, Vitamins D2, D3 and Vitamin E	Folic acid	
Immunoglobulin* formation		Vitamin B6	
Insulin release	Vitamins D2 and D3		
Lipoprotein turnover			Choline
Liver protection	Vitamin E		
Membrane protection	Vitamin E		
Methyl donor			Choline
Mucosal protection	Vitamin A		
Nucleic acid* synthesis		Vitamin B12, Folic acid	
Prohormone	Vitamins D2 and D3		
Protection of the nervous system		Vitamin B1	
Protein metabolism		Vitamin B1, Vitamin B5, Vitamin B6, Niacin and Biotin	
Reproduction	Vitamin A and Vitamin E	Vitamin B2	
Skin protection		Vitamin B5, Vitamin B6 and Biotin	
Steroid* hormone synthesis	Vitamin A	Folic acid and Vitamin C	
Vision	Vitamin A		

(After [86])

Anti-nutritive substances are found in some feeds and feed ingredients. These are classified under the group name “other bioactive substances”. When present in the feed or water of animals, they reduce, delay, or even block the utilization of one or more nutrients listed in Box A5-2. The following inventory compiled by Mézes [69] provides a summary on anti-nutritive substances that may be present in the supplementary feeds of fish:

BOX A5-2: ANTI-NUTRITIVE SUBSTANCES

According to Dublecz [24], anti-nutritive substances can be grouped based on their physiological effects:

- Factors that reduce digestibility and utilization of proteins (protein inhibitors).
- Factors that reduce digestibility of carbohydrates (carbohydrate inhibitors).
- Factors that reduce digestion and utilization of minerals.
- Factors inactivating vitamins: antivitamins, vitamin-degrading enzymes.
- Factors that stimulate the immune system: allergenic proteins.

- **Protease inhibitors** are substances that inhibit enzymatic protein breakdown. Typical examples are legumes, mainly raw soybeans and extracted soybean meal without heat treatment. Trypsin inhibitors can be inactivated by a heat-sensitive wet treatment (toasting, extrusion) at 110 °C for 10-20 minutes.
- **Lectins** or **hemagglutinins** are found in beans and can cause problems or death in fish when fed raw. They also occur in other legumes, but in smaller, almost harmless quantities.
- **Saponins** may cause rupture or destruction of red-blood cells. They can be found in raw beet slices, leafy beet tops, molasses, and traditional varieties of lucerne.
- **Polyphenol-type compounds**, e.g., tannins. They precipitate proteins and can cause protein digestion disorders. They occur in sorghum, rapeseed, and fava bean *(Vicia faba)*. This group also includes gossypol, which is found in cotton seed.
- **Glycosides** are found in kernels of almonds and peaches, and in the grains of cruciferous oilseeds, canola, oil radish, mustard, and cabbage. When cyanogenic glycosides are hydrolysed, cyanide is formed, that can cause poisonings. The concentration of gluco-

sinolates, also called mustard oil glycosides in rapeseed should not exceed 25 µmol/g according to EU standards.
- **Alkaloids** is a group where most herbal medicines and poisons belong to. These are found among others in the green parts and sprouts of potatoes (solanine), in the seeds of white-, yellow- and blue-flowered lupine (lupanin), in grass pea *(Lathyrus sativus)* (beta-amino propionitril) and in certain weeds of pastures.
- **Antivitamins** can be divided into three groups based on their mechanisms of action:
  1. Competitive (competitor) inhibitors. These antivitamins competitive antagonist of vitamins and participate in physiological processes, but without the effect of the original ones (e.g., coumarin and vitamin K).
  2. Vitamin-degrading antivitamins: as indicated by their name, they neutralize the effect of original vitamins. They occur in the flesh of some marine fish, in certain cruciferous plants, in sorghum, flaxseed, and in part in corn, and are responsible for the breakdown of some vitamins (e.g., thiaminase).
  3. Avidin binds to biotin (vitamin H or B7) in feed and is present in crude egg white.
- **Nitrate** and **nitrite** content of feed can also cause poisoning. Nitrite is ten times more toxic than nitrate. Presence of sodium nitrite (E250), and the bactericidal potassium nitrite (E249) above a certain level in animal feeds can cause toxicity, and a sudden feeding of cruciferous, papilionaceous plants and oats can also result in poisonings in terrestrial animals. However, such effects have not been recognized in fish.

1.7 MINERALS

Mineral content of feed is expressed by the amount of crude ash, especially if no contamination (e.g., soil) is present in the sample. Minerals play a role in the growth, development, reproduction, and production of animals, including fish. According to Perason [80] fish are able to absorb some of the minerals needed. Still, the more intensively animals are kept (far from natural conditions), the more important mineral supplements in their diets are. This is due to the fact that minerals contribute to the development of the body structure (e.g., bones), some of them are amino acid constituents, and involved in *membrane transport**, and also in enzymatic and some *electrochemical** processes [68]. The most important factors influencing the utilization of minerals are their water solubility and the absolute and relative mineral content of feeds. Other relevant aspects influenced by individual animals are production levels (i.e., growth in the case of fish), the physiological state of the digestive tract, intestinal pH, and age, which are aggregated. Minerals are divided into groups described by Mézes [68] as follows:

Macro-elements
- **Calcium** (Ca) and **phosphorus** (P) should be discussed together as their absorption, utilization and excretion directly effects bone development. At least 99% of calcium are present in bones and 1% in cells/tissues, while the proportion of phosphorus in these is 80-85% and 15-20%, respectively.
- **Magnesium** (Mg): 70% in bones and 30% in liver.
- **Sodium** (Na) and **chlorine** (Cl) are part of the body's *buffer system**. They are not stored but are excreted quickly. If absent, appetite and protein utilization declines/deteriorates.
- **Potassium** (K) is found in the intracellular space of the body and plays a role in the growth of young organisms. Normally a small amount is present in the body and is excreted slowly.

Meso-elements
- **Sulphur** (S), among others, plays an important role in the synthesis and function of sulphur-containing amino acids and collagen.
- **Iron** (Fe) is primarily involved in the structure and function of haemoglobin.
- **Copper** (Cu) is involved in the catalysis of iron incorporation. Lack of it can cause growth failure, anaemia (secondary iron deficiency), indigestion and heart muscle degeneration.
- **Zinc** (Zn) occurs in all tissues. It has a biochemical role as it is a component of certain enzymes and required for vitamin A transport and protein synthesis.
- **Manganese** (Mn) is an essential element, an enzyme component found in the liver, bones, and kidneys. Lack of it can cause reproductive problems.

Trace and other elements[1]
- **Selenium** (Se) is a member of the biological antioxidant defence system as component of an antioxidant enzyme, glutathione peroxidase, and can take on the role of vitamin E. It is also involved in the development of an immune response and has a membrane stabilizing function as well.

[1] ***Iodine*** *(I),* ***molybdenum*** *(Mo),* ***cobalt*** *(Co),* ***fluorine*** *(F),* ***aluminium*** *(Al) and* ***silicon*** *(Si) are either not relevant or have significance in fish.*

Toxic substances

- **Nickel** (Ni) can very poorly be absorbed (1-1.5%). It damages the gills.
- **Cadmium** (Cd) causes irreversible kidney and testicular damages.
- **Lead** (Pb) accumulates in adipose tissues. It causes liver and genital damage when released.
- **Arsenic** (As) is highly poisonous but can have a partially positive effect on digestion when used in micro quantities.
- **Mercury** (Hg) accumulates in adipose tissues and is clearly toxic.
- **Nitrate** and **nitrite** are responsible for the reduction and destruction of the oxygen carrying capacity of blood, because irreversibly bound to haemoglobin; thus they are toxic. Nitrate is less toxic than nitrite.

2. ENERGY OF FEEDS

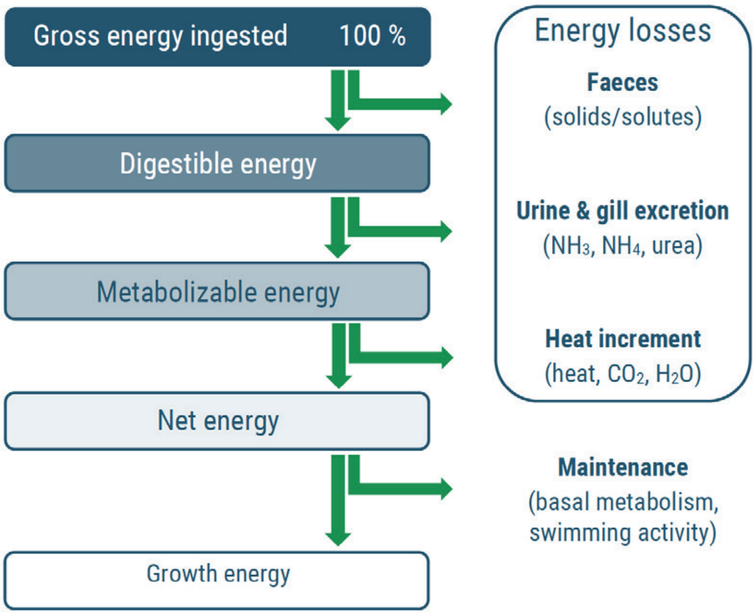


FIGURE A5-4: SCHEMATIC PRESENTATION OF THE UTILIZATION OF ENERGY IN FISH INGESTED WITH FOOD AND FEED

Every living organism needs energy to sustain life. In contrast to animals, plants are able to synthesize organic materials from inorganic ones. To complete this process, plants receive the energy straight from the sun. This process supports building their body tissues where the energy is stored.

Animals are unable to utilize the energy of solar (UV) radiation, so their energy need is covered from consumed feed. Energy mobilization in fish happens in the same way as in terrestrial animals, with the difference that fish do not use energy to maintain body temperature, as that is regulated by the temperature of water. However, there are some exceptions because there is heat production as a consequence of metabolic processes.

Similarly, to other animals, fish cover their energy needs from lipids, carbohydrates, and proteins. The utilization of lipids and carbohydrates are both physiologically and economically the most efficient to cover energy needs. Using proteins, more precisely amino acids to cover energy is neither economical nor healthy. It is initiated if no other source is available for mobilising life-sustaining energy.
Gross energy (GE) is a food/feed specific value. The caloric value of gross energy (expressed in MJ/kg) varies according to the chemical composition and is determined by laboratory tests.
As demonstrated in Figure A5-4 not all gross energy is utilised from the feed in fishes. The first loss is due to energy content of non-digestible nutrients. The remaining value is the digestible energy (DE) that depends on the nutritional qualities of feed, but its utilization is also influenced by the fish fed with it (e.g., species, strain, age, health, environmental conditions, etc.). This latter is manifested as FCR, and the nutritional energy of feed considerably contributes to it. Total estimated digestible energy of feeds is the sum of the digestible energy of each individual macronutrient found in them.

3. SUPPLEMENTARY FEEDS, FEED INGREDIENTS AND FEED SUPPLEMENTS USED IN POND CULTURE

The list of feed materials and mandatory information that needs to be shared is presented in the European Commission Regulation (EU) No. 68/2013 [32]. This provides a catalogue on all existing and potential feed materials from all over the world, so it is a useful guide for everyone interested. Not only the definition of the different feeds is in it, but also a declaration (list of qualities) compulsory for suppliers to provide.

In this catalogue both raw and processed feeds and feed materials are grouped according to a system that can also be used in the field:

1. Cereal grains and products derived thereof
2. Oil seeds, oil fruits, and products derived thereof
3. Legume seeds and products derived thereof
4. Tubers, roots, and products derived thereof
5. Other seeds and fruits, and products derived thereof
6. Forages and roughage, and products derived thereof
7. Other plants, algae and products derived thereof
8. Milk products and products derived thereof
9. Land animal products and products derived thereof
10. Fish, other aquatic animals, and products derived thereof
11. Minerals and products derived thereof
12. Fermentation (by-)products from micro-organisms
13. Miscellaneous feeds

3.1 GROUPING OF FISH FOOD AND FEED BY THEIR CHEMICAL COMPOSITION

Farmers producing fish in pond polyculture of carps must select and prepare the most suitable supplementary feeds possible. To support this, Table A-1 (of the Appendix) was prepared, presenting an approximate composition of both natural foods and feeds, feed ingredients and supplements used in the supplementary feeding of fish in pond culture practiced in the region.
Categorization of food and feed items used in Table A-1 meets field requirements of functional use in all aspects. The following inventory of the main classes of fish foods and feeds compiled by COFAD [15] supports an easy overview and use of table A-1:

1. **Natural fish food** is a large group of different aquatic organisms. It is characteristic of this group to have high water and protein contents.
    - 1.1. Bacteria colonies/flocks are food both for the zooplankton and just feeding fish larvae.
    - 1.2. Phytoplankton is the collective name of floating microscopic plants filtered by some fishes.
    - 1.3. Water weeds are food for grass carp, but tender shoots, roots and seeds are also consumed by larger common carp. Floating plants, such as duck weed are also readily consumed by common carp.
    - 1.4. Zooplankton is the collective name of tiny floating microscopic animals. Though they are able to swim actively, but this is usually not significant when compared to the movement that water currents cause.
    - 1.5. Insects and their larvae living and moving in the water column, pond bottom or among the aquatic vegetation are also consumed by common carp, but many of them are predators of fish larvae and fry.
    - 1.6. Worms and molluscs living on and in the pond bottom are ideal food for common carp, if they have the right size.
    - 1.7. Fish – though usually predator fish species are considered to be “fish eaters”, still, larger individuals of omnivorous (common carp) and even herbivorous fish (grass carp) sometimes grab and swallow early fry and fry.

2. **Green plants, forage** is rich in fibre.
    - 2.1 Fresh terrestrial grass and forage are good feeds for grass carp. Lucerne can be supplied to young grass carp.
    - 2.2 Dry forms, including lucerne hay or meal, are used as ingredients of compound fish feeds.

3. **Roots, tubers, fruits**
    - 3.1 Roots such as carrot can be valuable in the diet of brood fish because of its high carotene content. It is fed cooked and minced.
    - 3.2 Tubers like potato used to be an important feed for common carp. It was used as mixed with cereals. It needs to be washed and cooked before fed.
    - 3.3 Fruits mashed/minced and mixed with cereals can be provided as seasonal feeds, when they ripe in the production season.

4. **By-products**
    - 4.1 Mill by-products such as wheat, rice, barley etc. bran, polished, broken grains, etc. are widely used in themselves or as an ingredient in fish feeding, mainly as fibre source.
    - 4.2 Brewery by-products can well serve as fish feed due to their dietary effects, but they can also serve as protein, sugar, and water-soluble vitamin sources for fish due to their yeast content.
    - 4.3 Miscellaneous by-products from, among others, milk, fruit, and vegetable processing industries can also be a source of supplementary feed ingredients when mixed with energy feeds. Common carp can consume huge quantities of fresh pea even though it can result in health problems, thus needs special attention.

5. **Energy feeds**
    - 5.1 Grains, especially cereals, such as wheat, maize, sorghum, millet, barley, rye etc. are not rich in proteins but are traditional supplementary feeds for common carp due to their high starch content.

6. **Protein feeds**
    - 6.1 Plant based protein feeds are legumes, their extracted meals are one of the main sources of protein (e.g., soybean meal).
    - 6.2 Animal based protein feeds are fish, meat, and feather meals, and more recently insect larvae meal. They are widely used by all sectors of animal husbandry.

7. **Lipid feeds**
    - 7.1 Plant based lipid feeds include different vegetable oils.
    - 7.2 Animal based lipid feeds cover different oils, fats, and greases.

8. **Supplements**
    - 8.1 Mineral supplements
        - 8.1.1. Food lime, bone meal, etc.
        - 8.1.2. Mineral premixes
    - 8.2 Vitamin supplements
        - 8.2.1. Natural substances involve fresh fruits, but their availability is rather limited.
        - 8.2.2. Vitamin premixes
    - 8.3 Binders are materials (e.g., clays) which ensure consistency and water stability of fish feeds.
    - 8.4 Additives are flavours, drugs, antibiotics, as well as antioxidants.

9. **Concentrates** are manufactured products containing all important ingredients except bulky, energy rich grains which are added on the farms. These products are mainly for farmed animals. Exact details on the content and utilization must be provided by the producer, including the dilution rate (usually 20:80 percent) with wheat, maize, or any other cereals.

3.2 CHARACTERISTICS OF SUPPLEMENTARY FEEDS USED IN POND FISH FARMS

There is a more than hundred year-long tradition of using supplementary feeds in pond culture of common carp in the region. It has already been for decades when practical information on supplementary feeds were made widely available for field use. Many authors, including Tasnádi [98] compiled a concise inventory on the characteristics of feeds used in pond culture. This inventory, including advantages, disadvantages and limitations of feeds is shortly reviewed here. Though the use of some of the feeds mentioned here might be less relevant today, they can still support an overall understanding of supplementary feeds and feeding in the region.

Plants: include different grasses and lucerne. In fresh, chopped form they are fed with young grass carp, while the rougher ones in one piece are excellent for larger individuals of grass carp. Dried flours of lucerne may be important ingredients of farm made compound feeds.

Roots and tubers: traditionally used as fish food, especially potato, but nowadays it has low importance, unless hygienically and economically suitable items can be purchased. It is important to note that potato must well be cooked to eliminate the solanine found in the peel.

By-products and wastes of food industry: include green peas, tomato pomace, molasses, and yeast. They can be relevant if available in the right quality and quantity, for a reasonable price. Fresh green pea well complements the diet of common carp, but should be fed with attention as fish prefer to eat it and may quickly overfeed.

Energy-rich feeds: the most common supplementary feeds. As their carbohydrate content is high, they can and do increase the fat content of fish meat when fish are overfed:

- Maize and wheat – Wheat consumption results in firm fish fat due to its high saturated fatty acid content which is difficult to mobilize during winter. Maize, on the other hand, softens fat due to its high unsaturated fatty acid (linoleic acid) content and has a good effect on fat synthesis and mobilization processes [6]. Maize can often be infected with *Fusarium** moulds or become mouldy if stored improperly.
- Triticale is a hybrid of wheat and rye. Its nutritional value is similar to barley. Due to an easy contamination of rye-smut *(Claviceps purpurea)*, it is recommended to feed without grinding. It has the best biological value for fish.
- Sorghum and millet are worth feeding after grinding, as common carp cannot crack it, therefore can go through the digestive tract in practically undigested form.
- Rye feeding is rare in ponds nowadays, mainly because its nutritional value is lower than that of other cereals. Only the ones that went through post-ripening should be fed with common carp. Sprouted rye is a good source of vitamin E for brood fish. It can easily be infected with rye-smut, consequently, it should carefully be fed, without grinding.
- Autumn barley – Only this type of barley is used as feed, but not common in pond culture. It is richer in proteins than wheat, though hardens fat. It is well utilized/digested, but due to its high fibre content can cause intestinal inflammation.
- By-products of cereal processing – The quality of different brans depends on the species and variety of the grain. Due to their high fibre content, they cannot be exclusively fed. As observed in Hungary, adding 5-10% into the daily feed improves the dietary effect by improving the consistency of faeces. The relatively high content of vitamins (e.g., vitamin B1) and minerals (mainly phosphorus) is another reason for feeding them. The quality of flours (versatile flour [flour 8], low grade flour [animal feed flour] and tail flour) depends on the degree of contamination. It is recommended to use them wet, except for early fry rearing in ponds when they are mixed with other feeds/feed ingredients.

  Wheat flour in farm made compound feeds also serves as binder in pellets due to its starch content which is gelatinised during processing. This ensures an acceptable water stability that the pellet stays in one piece before being consumed (see details in Chapter 8 of the main text).

  It is not recommended to feed tailings, refuse/offal of grains remained after processing. If this happens, it should be used without grinding so that fish can pick proper, harmless parts.

Protein feeds of plant origin: including leguminous seeds.

- Lupine – Two varieties are known, the sweet and bitter lupine. Sweet and bitter lupine contain 0.1% and 2-3% of *lupinin-lupanin** alkaloids, respectively. Toxic symptoms called lupinosis do not visibly appear in common carp, still, proper preparation is a very important requirement if this feed is used. As a result of employing lupine-based feeds, polyunsaturated fatty acid content and fatty acid composition (high unsaturated fatty acid proportion) of fish meat becomes better than that of fish fed only with wheat [6].
- Soybean is important raw materials for carp feeding but can only be used after a heat treatment (toasting, roasting, and infrared irradiation) due to their trypsin inhibitor content.
- Peas are good common carp feeds in all respect.
- Beans were widely fed until the 1950s. Today, only the ones that are unfit for human consumption but still good to be fed with fish. Due to its antinutrient (trypsin inhibitors and lectins) content, it should never be fed raw, only after toasting or cooking.

Oilseeds include sunflower, flaxseed, rapeseed, groundnuts, cottonseed, oilcake and extracted oilseeds.

- Sunflower seeds as ingredients may only be fed in the form of extracted seeds. It has high fibre content which requires accurate grinding before use.
- Flaxseed is an occasional component in farm made compound feeds, and can only be used after a heat treatment (cooking).
- Groundnuts are hardly used as feed or feed ingredients in the region. Imported cargo unfit for human consumption is very likely unfit for fish consumption as well due to its mycotoxin (aflatoxins) contamination. If a batch is available and suitable for feeding, its proportion in the daily ratio should not be more than 10%.

- Oilcakes and extracted oilseed meals have a high protein content. Likely only lower quality, less suitable batches can be obtained for direct feeding of fish, but these are not recommended to be used. If the quality is good, the feed mixture should contain only about 10-20% of the daily feed portion.

Protein feeds of animal origin: include meat-and-bone meal, blood meal, fishmeal, insect larvae meal and by-products of milk processing like milk powder, whey powder and casein. They may be considered as components of farm made compound feed, as feeds usually contain these ingredients.

Simple feed mixtures: farm made feeds that typically contain two or three ground components, which are well mixed or even pressed into pellets if it is economically feasible. Otherwise, they are fed as dough. Such feeds are prepared when the CP content of the supplementary feed should be higher (about 15% CP) than that of energy rich grains.

Farm made compound feeds: prepared when an even higher (about 20-25%) CP is required in the supplementary diet of fish. In such cases several ingredients are mixed and pelleted on the farm. These feeds are good enough to properly serve the purpose of and support semi-intensive and intensive pond culture of common carp. These types of pelleted farm feeds are usually less water stable (water resistant), still, they can satisfy the purpose of feeding common carp with compound feed which has a nutritional value proportional to the intensity of production.

4. NUTRITIONALLY COMPLETE INDUSTRIAL FEEDS USED IN INTENSIVE CULTURE SYSTEMS

The need for a proper feeding of fish in general and salmonids which are produced in intensive culture systems in particular, triggered the development of fish feeds. The development of fish feeding from the middle of the last century until today has been tremendous. From feeding trout and salmon with minced raw fish, through diets prepared from a mixture of dry ingredients and ground offal from meat and fish processing plants, the use of nutritionally complete industrial feeds has been achieved by now.

Due to the efforts summarized in Box A5-3, the proportion of DE of nutritionally complete industrial feeds increased from about 75% to 85-93% and FCR in case for most fish species is already around or below 1. Feed development first started for salmonids, then later high quality industrial feeds have been developed for different other species as well in parallel, like catfishes, sturgeons, perches, tilapia, and common carp. From listed groups and species of fish, common carp and rainbow trout are the most widely cultured ones in the region, but an intensive production of arctic charr, whitefish, catfish, perches, and sturgeons also offer options for diversification. If thermal water resources are available, culturing of exotic tropical species, such as tilapia and African catfish can also be a feasible option, as proven in many countries of the region. The composition of nutritionally complete industrial fish feeds produced by Aller Aqua is described as those listed in Table A-2 in the Appendix.

BOX A5-3: KEY EFFORTS CONTRIBUTING TO THE DEVELOPMENT OF NUTRITIONALLY COMPLETE INDUSTRIAL FISH FEEDS

In the course of fish feed development scientists studied and researched:

- The chemical composition and nutritional value of fish foods which are consumed in nature.
- Nutrient content of existing and potential raw feeds and feed ingredients.
- Nutritional and environmental feeding requirements of fish.

These three main research areas, in close cooperation with and feedback from the field, resulted in a wide range of high-quality fish feeds used in intensive fish farms.

However, there are additional characteristics and attributes of nutritionally complete industrial feeds which make them particularly suitable for growing fish in intensive culture systems. These including low FCR and reduced environmental impact are presented in Table A-2. There is also a complete range of Aller Aqua feeds in this table for practically all cold, warm and tropical freshwater fish species cultured in the region (Table A5-3).

For the easier selection and use Table A-2 presents the following qualities of feeds:

- Name of feeds and the fish species to be fed with them.
- Type and size range of feeds.
- Size range of the fish to be fed.
- Composition of fish feeds.
- Environmental impact of feed when used.

All the above listed information is essential for a successful selection of feed specific for the age and size of fish species.

Under “Type” the physical consistency of feeds are presented. **Granulates** indicate feeds with different sizes developed and used for feeding early fry and fry. **Pellets** have a uniform size and are prepared for fry and growing fish.

“Size of feeds” provides basic information on a physical characteristic, as it is linked to nutritional qualities of feeds. This means that the composition of feeds is adjusted to the changing nutritional requirements of growing fish. As nutritional qualities of feed are adjusted as the size grows, not only the size of pellets is adjusted to the size of fish but also their nutritional qualities.

The last main column in Table A-2 is “Environmental impact” and contains all the information indispensable to calculate the impact of feeding on the aquatic environment. As environmental impact of feeds is in close relation with FCR, the expectable range of this very essential parameter of feeds is also indicated here.

TABLE A5-3: LIST OF MAIN FRESHWATER FISH SPECIES PRODUCED IN INTENSIVE CULTURE SYSTEMS IN THE REGION

Cold freshwater species
1. Arctic charr
2. Atlantic salmon (freshwater)
3. Brown trout
4. Rainbow trout
5. Whitefish
Warm freshwater species
1. Sturgeon
2. Common carp
3. Trench
4. Eel
5. European catfish
6. Perch
7. Pikeperch
Tropical freshwater species
1. Tilapia
2. African catfish
3. Pangasius

ANNEX 6

SELECTION AND ADJUSTMENT OF SUPPLEMENTARY FEEDS FOR COMMON CARP IN POND CULTURE AND THE NEED TO USE NUTRITIONALLY BALANCED AND COMPLETE INDUSTRIAL FEEDS IN PONDS

The overall physical and financial efficiency of pond culture basically depends on a successful selection and use of supplementary feeds. Therefore this annex provides a concise review both on the selection of feeds and the preparation of simple feed mixtures and farm made compound feeds, but the use of nutritionally balanced industrial feeds are also discussed, which are also within the feasible options to complement the natural food of common carp. Views and practical solutions presented in this annex aim to support farmers with simple but effective solutions applicable among typical farm conditions, where extensive, semi-intensive or intensive pond polyculture of common carp is practiced.
This annex also describes the conditions and presents the programming of the use of nutritionally complete industrial feeds in pond culture.

CONTENT

1. SELECTION OF SUPPLEMENTARY FEEDS AND FEED INGREDIENTS

In pond culture, the diet of common carp consists of natural food grown (produced) in the pond and artificial feed to supplemented natural food.
Therefore, such feeds are called supplementary feeds. A typical characteristic of such feeds is that they are only effective when consumed together with natural food.
Four groups of supplementary feeds can be distinguished:

- Plain feeds;
- Simple feed mixtures;
- Farm made compound feeds;
- Nutritionally balanced industrial feeds.

Feeds to be used as plain feed, as ingredients of simple mixtures or farm made compound feeds should be selected based on the review and description of the chemical composition and nutrient content of different feeds, detailed in Table A-1. Presentation of food and feed items in Table A-1 meets field requirements of practical use in all aspects. Consequently, it facilitates a simple qualitative and quantitative selection of feeds based on the degree of need to supplement natural fish food in a pond.

TABLE A6-1: TYPES OF FEEDS GIVEN AS SUPPLEMENTARY FEED TO THE DIFFERENT SIZE GROUPS OF COMMON CARP

Size group of common carp (g)	Type of feeds			
	Plain feeds	Simple feed mixtures	Farm made compound feeds	Nutritionally balanced industrial feeds
Larvae – 0.5	-	√	√	√
Three-summer-long culture period (1st, 2nd and 3rd year)				
0.5 – 25	-	√	√	√
25 – 250	-	√	√	√
250 – 2000	√	√	√	√
Two-summer-long culture period (1st and 2nd year)				
0.5 – 250	-	-	Growth may remain slow	√
250 – 2000				

Plain feeds
This group includes feeds that are directly used as single feedstuffs. They are classified as energy rich feeds. The role of such traditional feeds, which were earlier exclusively used as supplementary feeds, have changed for today. They are rarely used on their own when stocking material (advanced fry, one summer and two summer old fish) is reared. Though they are still fed plain in the third year of the production cycle, they are also important components of simple feed mixtures and farm made compound supplementary feeds used in extensive and semi-intensive pond culture of table fish.

Simple feed mixtures
This group of feeds is prepared on-farm and consist of two or a few different ingredients, with the aim to enrich protein, lipid and/or carbohydrate concentrations of the supplementary feed. These are used alike in the different intensity of pond culture.

Farm made compound feeds
This group of feeds are prepared on-farm and they serve as supplementary feeds for all age groups of common carp produced in pond culture.

Nutritionally balanced industrial feeds
These feeds are used for growing all age groups of common carp in semi-intensive, and especially in intensive pond culture.

This concise summary on the concept and logic of feeding fish in pond culture helps to decide and select the appropriate group and type of supplementary feeds:

- The role of natural fish food in the diet of fish is essential in pond culture and is a basic factor that determines the growth of fish biomass. The actual SC (standing crop) of natural food (i.e. zooplankton, aquatic worms, insect larvae, insects, etc.) depends on several factors, discussed in Annexes 7 and 8.
- Both the relative and absolute quantity of natural fish food changes seasonally. Additionally, it reduces as the SC of fish grows in the pond as the consequence of consumption by fish.
- For the above mentioned reasons, not only the quantity, but also the quality of supplementary feed offered for common carp should be enhanced.
- As the SC of fish grows, the relative quantity of natural food reduces, which slows down or even stops the growth of fish unless the quality and quantity of supplementary feed is adjusted, i.e. increased [50].

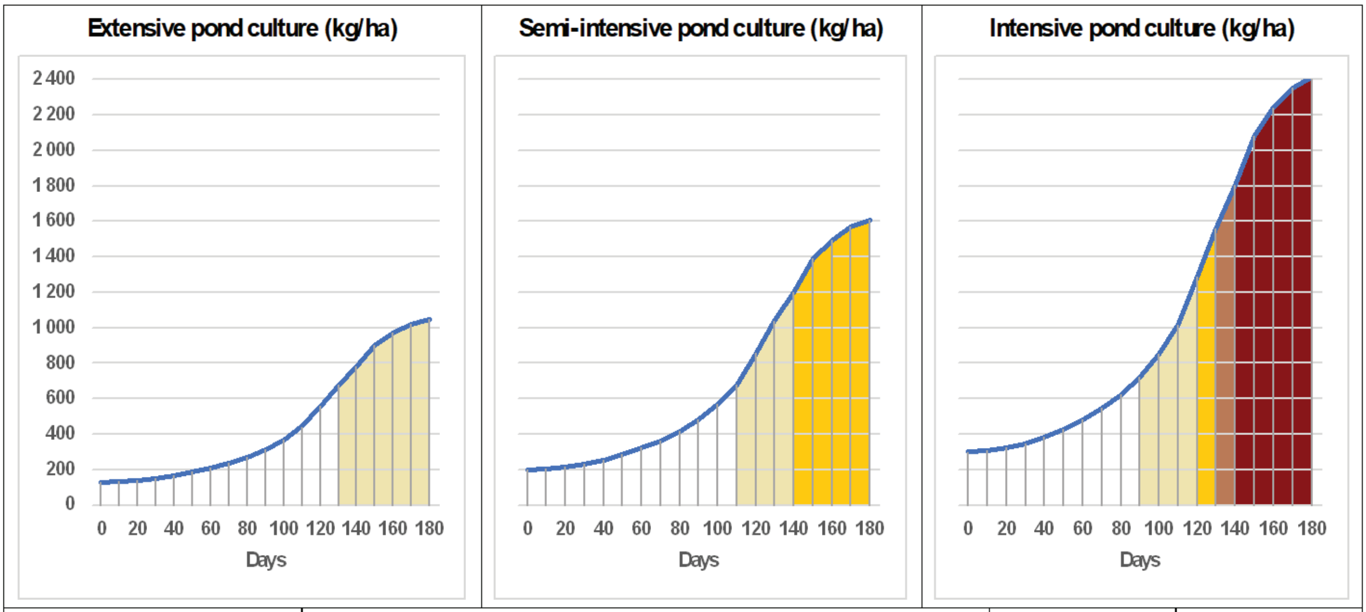
Figure A6-1 shows the correlation between SC, the need for CP adjustment of feeds and levels of SC when adjustment should be performed. For a successful delivery, Hepher and Pruginin [50] recommended a simple technique:
At the beginning of the production season only cereal grain should be fed with around 10% CP content, until SC in the pond hits 700 kg/ha. At this point the CP content of feed should be increased. As shown in Figure A6-1, the energy rich diet (based on cereal grains) should be gradually enriched with a farm made compound feed of about 25% CP content. After this, the diet of common carp will consist of all three components in a changing proportion, until the SC of fish exceeds 1800 kg/ha, following which only compound feed with 25% CP content should be provided. One of the possible recipes of such a compound feed is shown in Figure A6-4.

BOX A6-1: STANDING CROP (SC) AND CRITICAL STANDING CROP (CSC) IN POND CULTURE

Standing crop (SC) indicates the actual live weight of fish a given time in the fish pond (kg/ha). This term (SC) is also used to describe the estimated life weight of natural fish food organisms in a pond. Following the same logic, the actual live weight of fish grown in intensive culture systems is also expressed as SC (kg/m^3 or kg/m^2)

Due to the growing of fish (i.e. fish stock) not only the quantity, but also the quality of supplementary feed should be adjusted. The time of adjustment arrives when the diet comprising both natural food and supplementary feed cannot cover the requirement of maintenance and growth of fish. A sign of this is when growth is reduced, then even halted. This is the point which Hepher [49] characterised as “critical standing crop” (CSC).

FIGURE A6-1: CORRELATION BETWEEN THE STANDING CROP AND REQUIRED CRUDE PROTEIN CONTENT OF SUPPLEMENTARY FEED USED AT DIFFERENT INTENSITIES OF TABLE FISH PRODUCTION



Standing crop (SC) (kg/ha)		Supplementary feeds: Proportion of energy feed (grain) of about 10% CP content (%)	Supplementary feeds: Proportion of farm made compound feed of 25% CP content (%)	CP content of the mixture (%)	CP content with nautral food (%)
1	<700	100	0	~ 10.0	~ 35.0
2	700-1200	75	25	~ 15.0	~ 35.0
3	1200-1500	50	50	~ 18.0	~ 35.0
4	1500-1800	25	75	~ 22.0	~ 35.0
5	>1800	0	100	~ 25.0	~ 35.0

(After: [50])

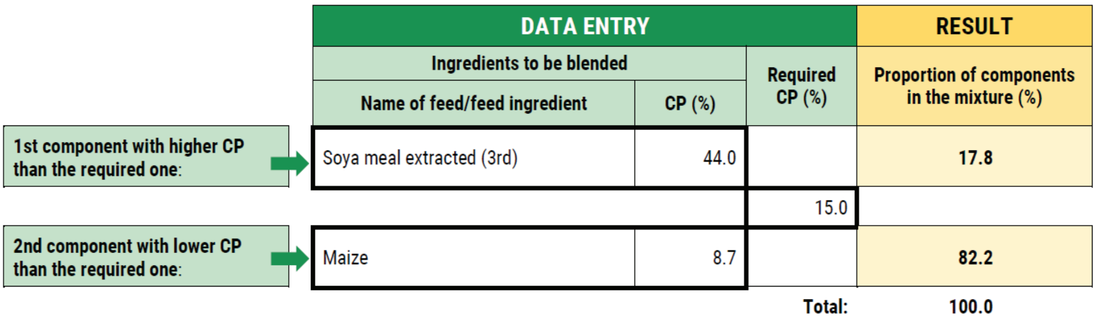
2. BALANCING INGREDIENTS IN FARM MADE FEEDS

Comparison, selection and balancing of farm made feeds is accomplished based on their chemical composition and nutritive value. Different types of feeds should be compared on either ‘as fed’ (‘as received’), or ‘DM’ basis. The first one (‘as fed’) shows concentrations of main components relative to a full content including water, while the second one (DM) expresses the concentration of components relative to the dry matter content, the quantity of a component as a percentage of dry matter (% of DM or DM%). Both ways of characterization of the composition of natural fish food, feeds and feed ingredients are correct with the condition that either the first or the second one should be used at a time. In Table A-1 of the Appendix the composition of feeds and feed ingredients are shown on both, i.e. ‘as fed’ and ‘DM’ basis.

2.1 COMPOSITION OF SIMPLE FEED MIXTURES

In practical fish farming, when mixing two types of feed in order to attain a suitable CP (or CL, NFE, etc.), Pearson square method is widely used. Today in the era of computers, paper based calculations are replaced by Excel spreadsheets. Figure A6-2 shows the computer version of a Pearson square, which helps to balance two ingredients in a feed mixture. An improved version of this is presented in Figure A6-3. This can be used when more than one component is planned to be included in a feed mixture of several ingredients.

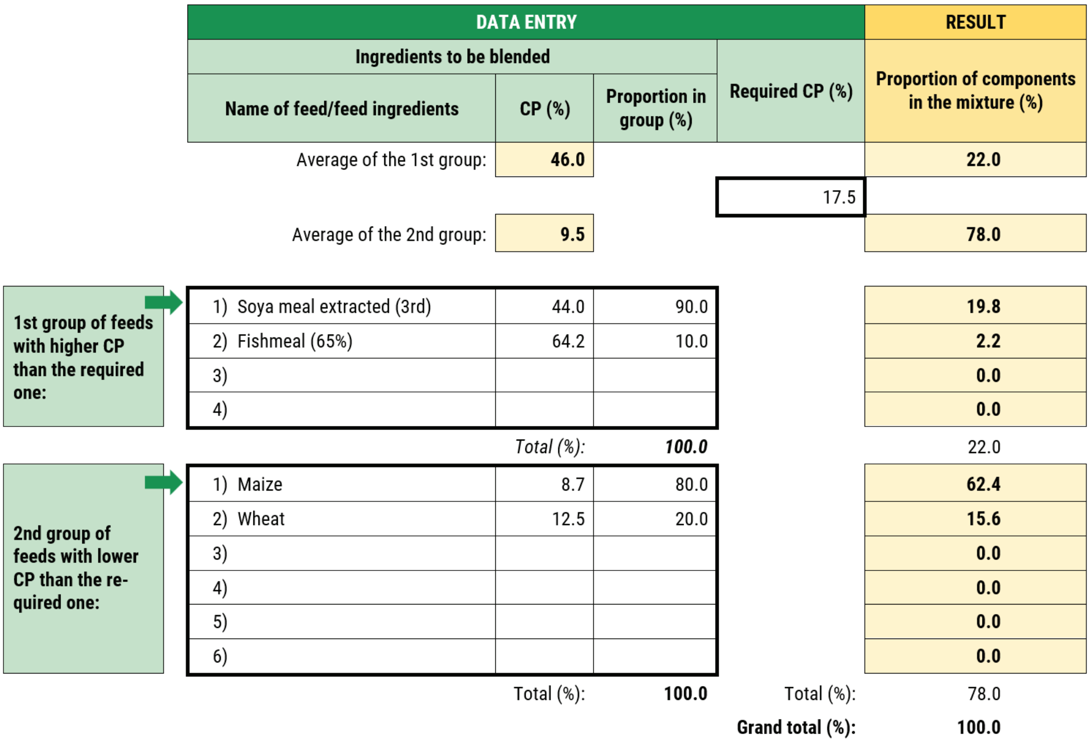
FIGURE A6-2: PEARSON SQUARE IN EXCEL SPREADSHEET TO CALCULATE PROPORTIONS OF TWO FEED COMPONENTS – AN EXAMPLE OF CALCULATIONS



	DATA ENTRY			RESULT
	Ingredients to be blended		Required CP (%)	Proportion of components in the mixture (%)
	Name of feed/feed ingredient	CP (%)		
1st component with higher CP than the required one:	Soya meal extracted (3rd)	44.0		**17.8**
			15.0	
2nd component with lower CP than the required one:	Maize	8.7		**82.2**
			Total:	**100.0**

(After: [15])

FIGURE A6-3: IMPROVED PEARSON SQUARE IN EXCEL SPREADSHEET TO CALCULATE THE PROPORTIONS OF COMPONENTS BOTH SEPARATELY AND IN GROUP – AN EXAMPLE OF CALCULATIONS



	DATA ENTRY				RESULT
	Ingredients to be blended			Required CP (%)	Proportion of components in the mixture (%)
	Name of feed/feed ingredients	CP (%)	Proportion in group (%)		
	Average of the 1st group:	**46.0**			**22.0**
				17.5	
	Average of the 2nd group:	**9.5**			**78.0**
1st group of feeds with higher CP than the required one:	1) Soya meal extracted (3rd)	44.0	90.0		**19.8**
	2) Fishmeal (65%)	64.2	10.0		**2.2**
	3)				**0.0**
	4)				**0.0**
		Total (%):	***100.0***		22.0
2nd group of feeds with lower CP than the required one:	1) Maize	8.7	80.0		**62.4**
	2) Wheat	12.5	20.0		**15.6**
	3)				**0.0**
	4)				**0.0**
	5)				**0.0**
	6)				**0.0**
		Total (%):	**100.0**	Total (%):	78.0
				Grand total (%):	**100.0**

(After: [15])

2.2 COMPOSITION OF FARM MADE COMPOUND FEEDS

Preparation of farm made compound feeds in fish farming has a long history in the region. Many pond fish farms still prepare supplementary feeds for themselves, just as it was done in the past. Fish farmers can use one of the numerous, extensively available receipts of common carp feeds. Still, in certain situations farm feeds need to be composed alone, e.g. when some of the ingredients recommended in a receipt are not readily available or when the aim is to use locally produced/available ingredients. For such instances it is advantageous to know how to compose farm feeds. The described method is expected to provide an introductory insight into feed formulation, and it also helps interested farmers to compile their feeds in a quality, that is proportional to the capacity of farm machinery and ingredients used.

On-farm feed formulation requires the consideration of the below aspects:

- **Dietary requirement of fish** – There is a huge literature on the subject of farmed fishes including common carp. Out of the available long lists of nutritional requirements of common carp, it is only the required approximate gross quantities of the key composition should be known in practical fish farming; macro nutrients (CP, CL, NFE and fibre), essential minerals (Ca and P) for bone formation and the energy requirements (Table A6-2).
- **Nutritional qualities of the feed** – Depending on the aimed quality of the feed to be prepared, it can be very complex. In case of farm made compound supplementary feeds aimed to complement the natural food with the missing nutrients. These are mainly the macro nutrients and essential bone/skeleton building minerals because the natural food in the overall diet of common carp covers the micro nutrients requirements up to about 2.4 t/ha fish biomass [50]. In the light of the previous chapter (Chapter 2.1) Table A6-2 together with the calculation tables presented in Figure A6-2, Figure A6-3 and Figure A6-4 supports the composition of supplementary compound feeds on the farm. One of such feed is presented in Figure A6-4.
- **Nutrient content of feed ingredients** – approximate composition of feeds are presented in Table A-1 of the Appendix. When accurate composition values of feed ingredients are needed, laboratory analyses of each batches of ingredients are indispensable.
- **Quantitative restrictions** – these in case of ingredients in farm made feed mixtures and compound feeds are based on traditional field observations and practices so should be checked in relevant national literatures and technical guidelines.
- **Cost of feed ingredients** – they can easily be obtained.

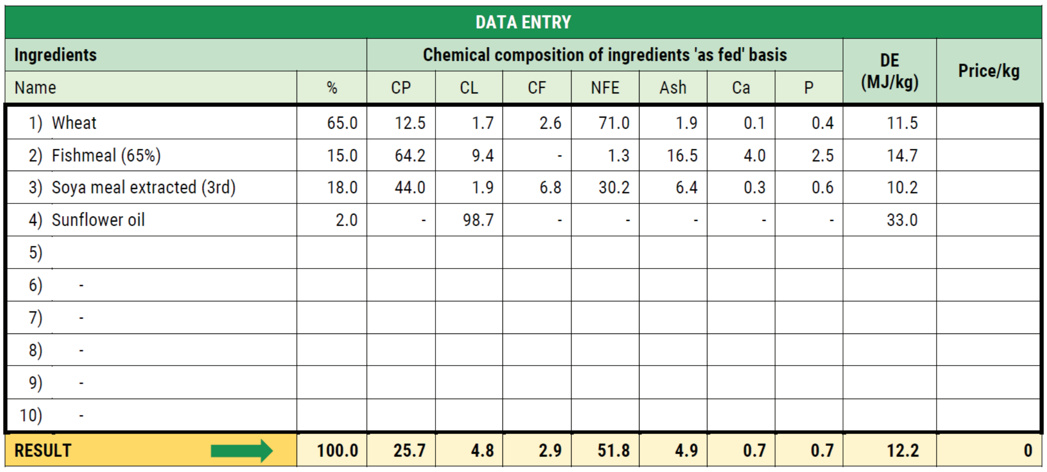
TABLE A6-2: APPROXIMATE DIETARY REQUIREMENT OF COMMON CARP AND THE COMPOSITION OF THE NATURAL FOOD ITS AGE GROUPS TYPICALLY CONSUME

Components	Early & advanced fry		Fingerling		Grower		Adult fish	
	Dietary requirement	Avg. of main natural food	**Dietary requirement**	Avg. of main natural food	**Dietary requirement**	Avg. of main natural food	**Dietary requirement**	Avg. of main natural food
Protein (%)	**45-40**	55-60	**40-38**	55-60	**38-32**	50-55	**32-30**	50-55
Lipid (%) min.	**12**	~ 22	**12-10**	~ 22	**10-6**	9-10	**6**	9-10
Fibre (%) max.	**5**	-	**5**	-	**6**	~ 0.5	**8**	~ 0.5
Carbohydrate (%)	**25**	-	**25**	-	**45**	~ 1.5	**48**	~ 1.5
Ca (%)	**0.5**	~ 7	**0.5**	~ 7	**0.5**	-	**0.5**	-
P (%)	**1.2**	-	**1.1**	-	**1**	-	**1**	-
GE (MJ/kg) min.	**20-18**	~ 2.7	**18-17.5**	~ 2.7	**18-17.5**	~ 2.5	**~ 17.5**	~ 2.5
DE (MJ/kg) min.	**13**	~ 2.7	**12**	~ 2.7	**11**	~ 2.5	**10**	~ 2.5
Negative factors	Stale, rotten, poisoned ingredients, rancid fats, fibre levels above 5-8%.							

(After: [18])

Feed formulation is usually done by specialized commercial computer programs by using a linear programming software. Nevertheless, such sophisticated programs are not required at farm level.

FIGURE A6-4: FEED FORMULATION SHEET ADAPTED TO EXCEL WORKSHEET – AN EXAMPLE OF CALCULATIONS



DATA ENTRY										
Ingredients		Chemical composition of ingredients 'as fed' basis							DE (MJ/kg)	Price/kg
Name	%	CP	CL	CF	NFE	Ash	Ca	P		
1) Wheat	65.0	12.5	1.7	2.6	71.0	1.9	0.1	0.4	11.5	
2) Fishmeal (65%)	15.0	64.2	9.4	-	1.3	16.5	4.0	2.5	14.7	
3) Soya meal extracted (3rd)	18.0	44.0	1.9	6.8	30.2	6.4	0.3	0.6	10.2	
4) Sunflower oil	2.0	-	98.7	-	-	-	-	-	33.0	
5)										
6) -										
7) -										
8) -										
9) -										
10) -										
RESULT ➡	**100.0**	**25.7**	**4.8**	**2.9**	**51.8**	**4.9**	**0.7**	**0.7**	**12.2**	**0**

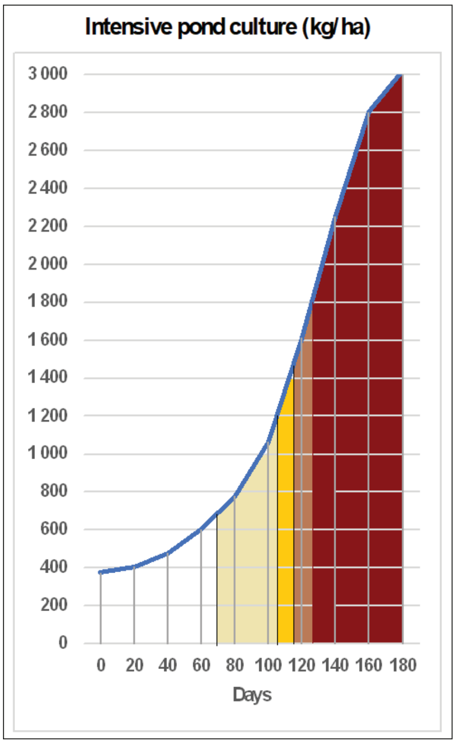
(After: [15])

In practical fish farming the step by step, ‘trial and error’ method serves well the purpose. In the past feed formulation was done in a paper based ‘Feed formulation’ table. At present this can be replaced by an Excel spreadsheet demonstrated in Figure A6-4. Steps of farm made compound feed formulation in this table are:

1. Selection of required and available ingredients.
2. Fill in the table with data, step by step.
    2.1 Fill in the composition, energy and price of protein rich components.
    2.2 Fill in the composition, energy and price of energy rich main components.

The two previous tables presented in Figure A6-2 and A6-3 are suitable to prepare a preliminary calculation and test possible matching options of ingredients.

FIGURE A6-5: CORRELATION BETWEEN THE GROWTH OF STANDING CROP AND THE NEED FOR USING HIGH QUALITY FEED IN INTENSIVE TABLE FISH PRODUCTION PONDS



3. USE OF NUTRITIONALLY BALANCED INDUSTRIAL FEEDS AS SUPPLEMENTARY FEEDS

Nutritionally balanced industrial feeds contain approximately 25% CP and are carefully balanced to the need of fish (see ALLER TOP in Table A-2). This is also widely used especially in intensive pond fish farms, where fast growth is especially important as the growing season is short. But such feeds are also used when reliable composition and quality of feed is needed which cannot be secured with farm made compound feeds.

The advantages of such feeds are those which a farm made feed cannot provide:
Steady, accurate composition and quality;
- Faster growth;
- More fish per pond unit area;
- Lower final P-FCR;
- Better water stability;

Use of nutritionally balanced industrial feeds at stocking material production
Proper feeding is important during the entire rearing procedure when common carp stocking material (0.5-1 g, 20-30 g and 200-300 g large fish) is produced. Stocking material is usually sold by number when the larger the fish the higher price is realised per fish. It is why the stocking materials are reared under semi-intensive or intensive pond culture conditions, when reliable quality supplementary feed is both technically and economically justifiable and feasible.
The expectable economic return is at least two folds:
- Higher price of a good quality stocking material;
- Lower mortality due to a better physical and health condition of stocked fish.

Use of nutritionally balanced industrial feeds at table fish production
There are different intensities of pond culture. On the contrary to rearing stocking material, table fish is produced on a wide scale of intensity from extensive through semi-intensive to intensive (Figure A6-1), including when production results approach to and close on the upper limits of pond culture (Figure A6-5).
Depending on both the intensity and the period of the season there is a range of choices regarding supplementary feeds to be used. The role of nutritionally balanced industrial feeds rises when increased higher results require the replacement of farm made compound feeds because the natural food drastically reduces in the pond, as well as when fish is prepared for wintering.
Technically and economically based shortening the production cycle of pond culture from three years to two years in the region became possible with the improvement of the quality of industrial feeds, which support fast growth.
There are different options for the shortening. One of these is an improved variation of the traditional techniques based on the use of nutritionally balanced and complete industrial feeds (Annex 10).

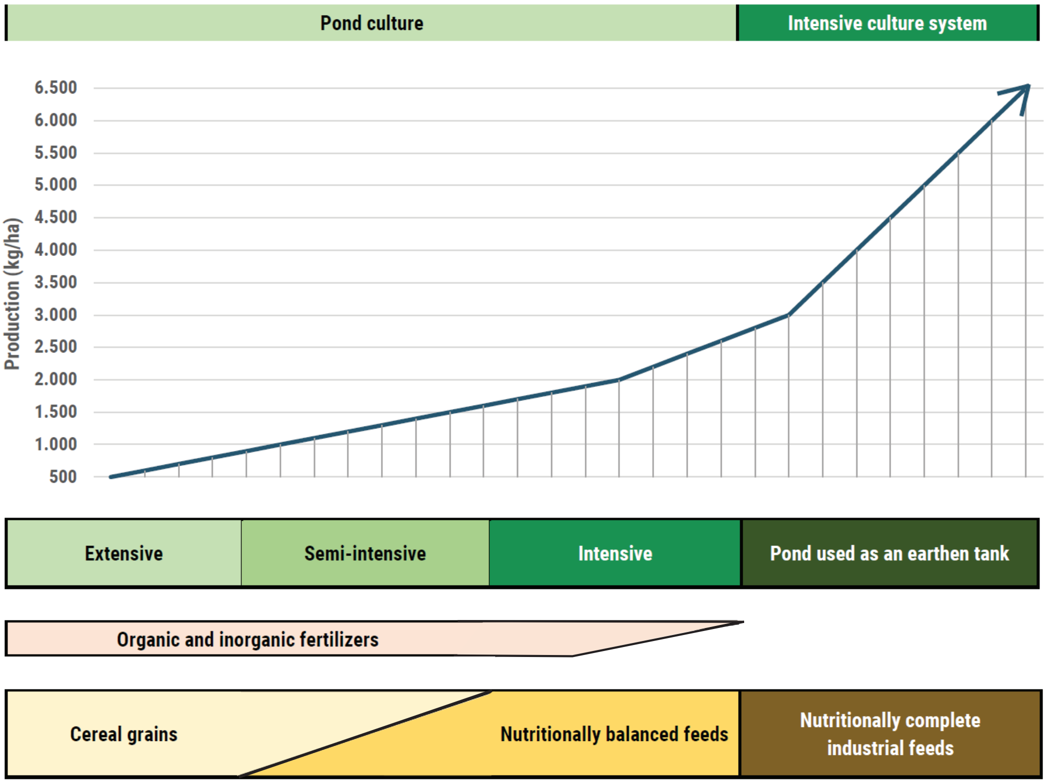
4. USE OF NUTRITIONALLY COMPLETE INDUSTRIAL FEEDS IN PONDS

Intensive pond carp polyculture adaptive research of Ruttkay [84] proved that there are limitations on increasing production results in pond culture. When the estimated SC reaches, then exceeds 3000 kg/ha, usually by the last months of the production season, (1) organic/inorganic fertilization should be stopped and (2) the use of nutritionally complete industrial feed should be started, as illustrated in Figure A6-6.

BOX A6-2: ROLE OF NATURAL FOOD IN FRESHLY INUNDATED EARTH TANKS AND PONDS PREPARED FOR INTENSIVE CULTURE

In well prepared freshly inundated earthen ponds the quantity of natural food is outstandingly high. This supports the quick start of fish growth especially when the natural food is supplemented with qualitatively and quantitatively adequate feeding.
Though not the same extent, but due to the plant nutrients found in the pond mud, the same happens when a pond is inundated without fertilization. Even if this natural food is finished up quickly when common carp is stocked at this first short period the nutritionally balanced industrial feeds can support well the growth of high-density fish. In this case (i.e. without preparatory organic/inorganic fertilization) the biomass of natural food decreases within a short time but the growth of fish can be maintained with nutritionally balanced industrial feed, until it is replaced with a nutritionally complete one (see Figure A6-6).

FIGURE A6-6: PROGRAMMING OF FERTILIZATION AND FEEDING IN INTENSIVE POND CULTURE – SWITCHING BETWEEN CULTURE SYSTEMS



(After [84])

The use of nutritionally complete industrial feeds is also justified in ponds when two summer long production cycle of common carp is practiced. It is a special tank culture method developed in Southern Europe. For this type of production good quality earthen tanks and wintering ponds (i.e. a few hundred or thousand square meters) or small fish ponds of a few hectares are used. In this case fertilization is often missing and at the beginning nutritionally balanced industrial feeds are used until the natural fish food lasts. When natural food exhausts farmers switch to nutritionally complete industrial feeds as summarised in Annex 10.

ANNEX 7

WATER QUALITY CRITERIA TO MAINTAIN DURING PRODUCTION IN THE DIFFERENT CULTURE SYSTEMS

Waters for aquatic organisms are not only a medium of their existence, where they take oxygen from, and release metabolic wastes into, but also are habitats, where fish live. Habitats ensure food for them, as well as this is the space where fish grow, propagate, die, and decay/decompose. Consequently, inland waters, including fish ponds, but also all intensive fish culture systems, are fragilely balanced aquatic ecosystems [23].

This annex aims to support fish farmers with practical information on water quality that influence the results of fish production. Consequently, this annex is an overview of the key physical, chemical, and biological properties of water, which basically determine both the quality and suitability of water for different types of fish culture systems. The same set of information helps to understand, monitor, and maintain required water quality both in pond fish culture and in intensive fish culture systems.

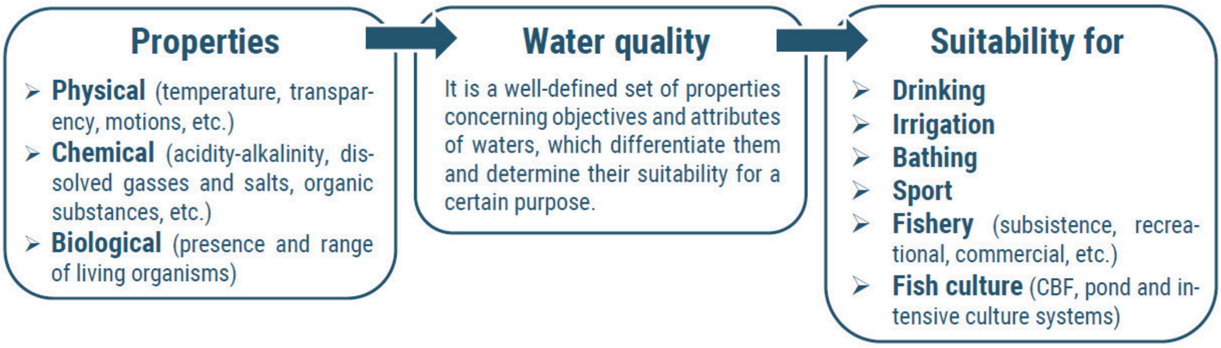
Considering the complexity and extent of the topic discussed, interested readers can find additional details, explanations, and recommendations for troubleshooting in an FAO publication on *"Survey and evaluation of water qualities – a field guide for managers of inland fisheries and fish farms"*. The same publication of Woynárovich, Kovács and Nagy [105] also serves as a guideline for structuring and presenting the subject of the current annex.

CONTENT

1. WATER QUALITY TO BE OBSERVED, MAINTAINED, AND MONITORED

Hungarian hydrobiologists found that it is important to distinguish between the properties, quality, and suitability of freshwater when they are monitored and selected for specific use ([22] and [77]). The concept is summarised and presented in Figure A7-1. Accordingly, water quality depends on the actual set of physical, chemical, and biological properties, which determine the suitability of water for a specific purpose.

FIGURE A7-1: CONNECTIONS BETWEEN PROPERTIES, QUALITY, AND SUITABILITY OF INLAND WATERS



Properties

- **Physical** (temperature, transparency, motions, etc.)
- **Chemical** (acidity-alkalinity, dissolved gasses and salts, organic substances, etc.)
- **Biological** (presence and range of living organisms)

Water quality

It is a well-defined set of properties concerning objectives and attributes of waters, which differentiate them and determine their suitability for a certain purpose.

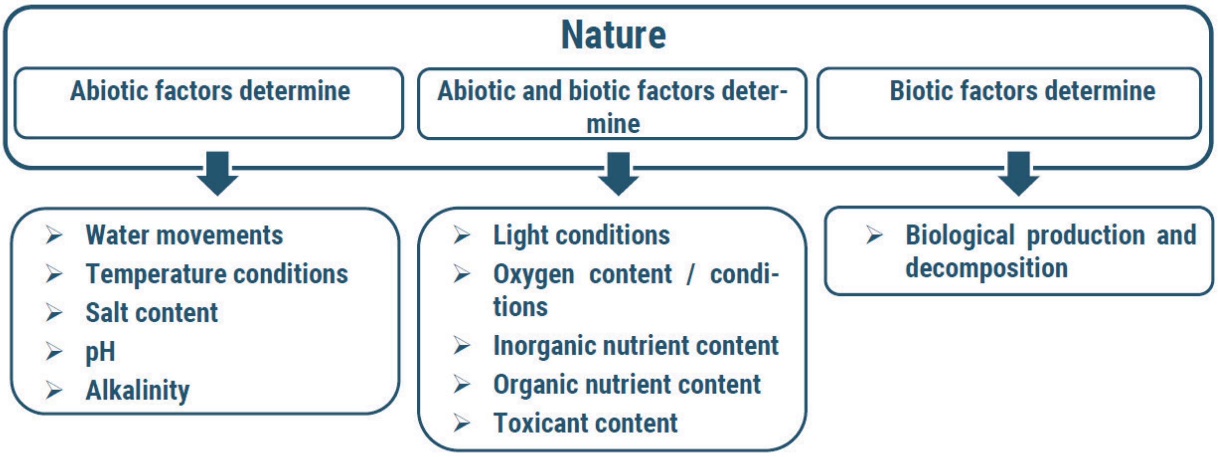
Suitability for

- **Drinking**
- **Irrigation**
- **Bathing**
- **Sport**
- **Fishery** (subsistence, recreational, commercial, etc.)
- **Fish culture** (CBF, pond and intensive culture systems)

(Source: [105])

Nagy and his colleagues [77] defined the factors which create and maintain distinct physical, chemical, and biological properties of waters. These are shown in Figure A7-2.

FIGURE A7-2: WATER PROPERTIES DETERMINED BY ABIOTIC AND BIOTIC FACTORS OF NATURE



Nature

Abiotic factors determine

- **Water movements**
- **Temperature conditions**
- **Salt content**
- **pH**
- **Alkalinity**

Abiotic and biotic factors determine

- **Light conditions**
- **Oxygen content / conditions**
- **Inorganic nutrient content**
- **Organic nutrient content**
- **Toxicant content**

Biotic factors determine

- **Biological production and decomposition**

(Source: [77])

1.1 PHYSICAL PROPERTIES OF WATER IMPORTANT FOR FISH AND FISH CULTURISTS

From the different physical properties of water, the most important ones for the fish and fish cultures are the physical status, temperature, motion, stratification, and specific heat.

Physical state of water

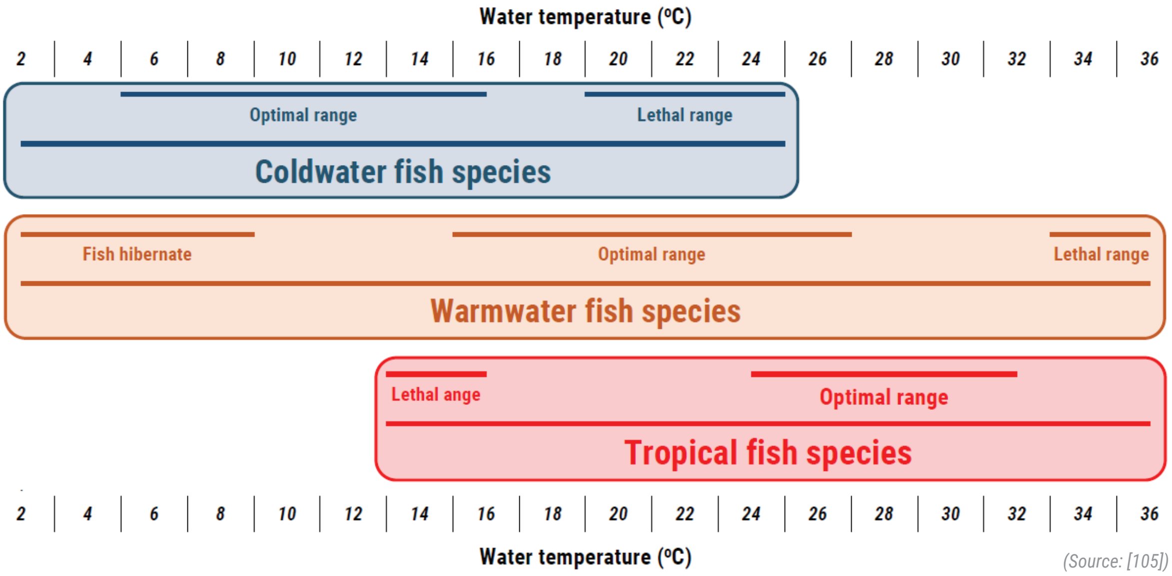
Water is the only substance that can widely be found in nature in three different physical states: ice, liquid, and gas. Water under 0 °C is ice (and its fine crystal form is the snow) that develops on surface water during winter. Ice on pond water, especially when covered with snow, closes the passage of light into the water and often causes oxygen shortage and generates *anaerobic**, toxic gas-producing conditions. For this reason, windows should be cut and maintained in ice. Developing ice expands and can crack up everything in its way. Therefore, it should be eliminated around concrete structures and machines used in pond water during winter.

Between 0 and 100 °C water is in a liquid state, while the gaseous form of water is vapour (its hot form is steam). Vapour is the result of evaporation, which is one of the factors that determine the water management of fish cultures. During summer, daily evaporation can even be 1-7 millimetres. However, it is to note that air temperature and wind can increase the intensity of evaporation, while air humidity reduces it.

Temperature of water

Most of the living aquatic organisms, including fish, are poikilotherm. This means that their motion, metabolism, growth, and propagation are temperature dependent. Their body temperature practically does not differ from that of the surrounding water. The consequence is that the intensity of their life functions slows down or speeds up as water temperature decreases or increases.

FIGURE A7-3: RANGES OF WATER TEMPERATURE: OPTIMAL, ACCEPTABLE AND LETHAL FOR COLDWATER, WARMWATER AND TROPICAL FISH SPECIES



(Source: [105])

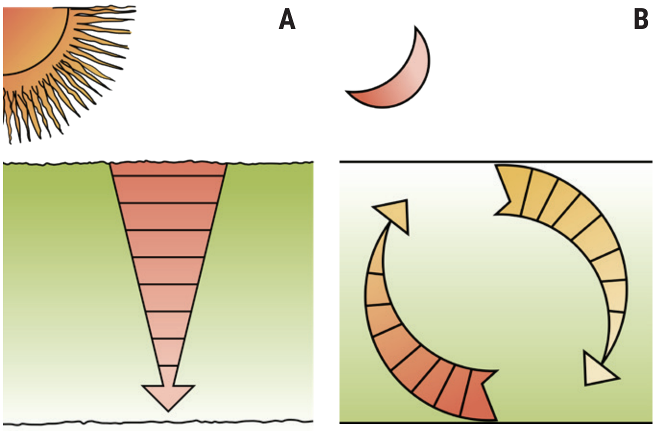
Depending on the dominant temperature of water in which a fish lives, grows and propagates, there are coldwater, warmwater, and tropical fish species. The extent of water temperature where fish grow the best is called optimal range, while the minimum and maximum ranges of water temperature where fish die, is called lethal range (Figure A7-3).

Water usually excessively warms up to the transparency level, below which water temperature may drop several degrees.

Motion and thermal stratification of the water

Unless being drastic, motion is a positive, desirable process in waters. The most frequent causes of motion derive from the differences in water levels, winds, and thermal circulation within a still water body. The consequences are horizontal and vertical currents that transport oxygen and nutrients between different points, including surface and bottom layers of water bodies. Even in relatively shallow fish ponds, thermal stratification and convectional currents explained in Figure A7-4 are a significant phenomenon, which cause daily vertical water circulation with all materials dissolved or floating in it.

FIGURE A7-4: THERMAL STRATIFICATION AND THE VERTICAL DAILY CIRCULATION OF WATER IN FISH PONDS



*A: Heat received during the daytime that causes **thermal stratification***. The water warms up from the surface. **B:** 1) Water starts to cool from the surface, as air is colder than water during the night. 2) Heat is lost during night-time through a **convectional current***.*

Specific heat

Water has a high *specific heat**; therefore, it warms and cools slower than the surrounding air. This guarantees that poikilotherm aquatic organisms are not exposed to radical thermal changes.

1.2 CHEMICAL PROPERTIES OF WATER IMPORTANT FOR FISH AND FISH CULTURISTS

The quality of water bodies, including fish ponds, depends on the range of materials found in them (Table A7-1). In this table, practical use of presented information is also indicated.

TABLE A7-1: AN OVERVIEW OF THE FORMS AS DIFFERENT MATERIALS ARE FOUND IN WATERS

Aspects	Emulsions and suspensions		Colloids	Solution
Size of particles	1000 μ[1] – 500 mμ		500 – 1 mμ	1 – 0.1 mμ
Settling of particles	Quick	Slow	No settling	
Paper filtering	Particles can be filtered		Particles cannot be filtered	
Brown motion*	Cannot be observed		Intense	Very intense
Examples	Oils	Different soils	Organic molecules	Dissolved gasses and salts

Observation: *[1] micron (μ) = 1000 millimicron (mμ) = 0.001 millimetre (mm)*

(Source: [23])

For the inventory of chemical properties of water, there is an increasing need of fish farmers to know, among others, about quantitative dissolved salt content (TDS), pH conditions, oxygen content (DO), inorganic and organic nutrient, and toxicant content of water.

Salt content of water

The chemical composition of water (i.e., the position of the two hydrogen atoms on the oxygen) makes it an excellent solvent. Therefore, the total quantity of dissolved salt (TDS) classifies different water bodies as indicated in Table A7-2.

TABLE A7-2: CLASSIFICATION OF WATER BODIES BY THEIR TOTAL SALT CONTENT (TDS)

Categories	Total dissolved salt (TDS) content			Approximate conductivity (μS/cm)
	mg/l or ppm	‰ or ppt	%	
Distilled water	0	0	0	0
Diluted fresh water	< 150	< 0.150	< 0.015	< 240
Fresh water	< 500	< 0.50	< 0.050	< 780
Concentrated fresh water	500-1 000	0.5-1.0	0.05-0.10	780-1 560
Diluted salt water	1 000-5 000	1.0-5.0	0.10-0.50	1 560-7 800
Moderately salt water	5 000-18 000	5.0-18.0	0.50-1.80	7 800-28 080
Concentrated salt water	18 000-30 000	18.0-30.0	1.80-3.00	28 080-46 800
Very concentrated salt water	30 000-40 000	30.0-40.0	3.00-4.00	48 800-62 400
Hypersaline brine water	> 40 000	> 40.0	> 4.00	> 62 400

(Source: [40])

Hardness

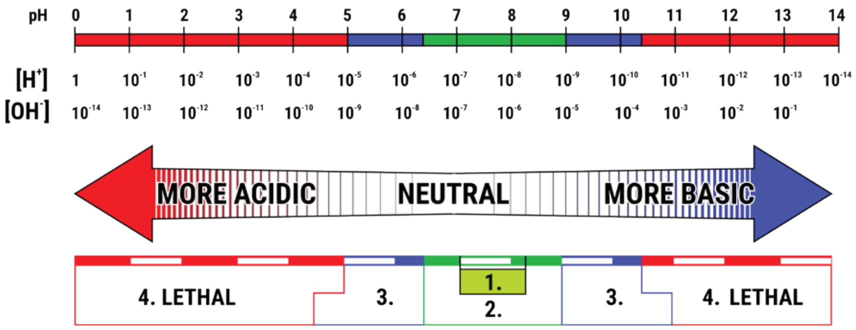
The presence of calcium (Ca^{++}) and magnesium (Mg^{++}) ions in water is responsible for the hardness. Their concentration may range on a wide scale from very soft (rain below 4 °dH [German hardness]) to very hard (fossil waters above 30 °dH) and determines how suitable a water is for fish culture.

pH conditions in waters

The soil, where water filtrates through, or which is around a water body determines if a water body is acidic, neutral or alkaline. The pH of water expresses the intensity of acidity or alkalinity, as demonstrated in Figure A7-5. Fishes are usually sensitive to pH changes, but the temporary daily fluctuations of pH values caused by intensive *assimilation** of phytoplankton are well tolerated by many of them, including cyprinids.

Alkalinity measures the *buffer capacity** of a water body, which indicates the resistance of water to pH changes.

FIGURE A7-5: pH SCALE AND SUITABILITY OF WATERS FOR FISH PRODUCTION



1) Optimal range of pH for fisheries and fish cultures: 7.0 – 8.3. ***2)*** *Acceptable pH ranges: 6.5 – 7.0 and 8.3 – 9.0.* ***3)*** *Harmful pH ranges for egg and larvae development of most fish species: pH 4-4.5 – 6.5 and 9.0 – 10-10.5.* ***4)*** *Toxic pH ranges for most freshwater fish species: below 4.0-4.5 and above 10.0-10.5 [50].*

The dissolved oxygen (DO) content of water

The existence of all aquatic *aerobic organisms** depends on the presence of oxygen dissolved in the water. Therefore, oxygen content/conditions in the water are primarily important both for fish and their natural food organisms. The main sources of oxygen in waters are:

- **Abiotic source:** oxygen penetrates into the water from the atmosphere through *diffusion**. It happens in the upper torrents and rapids of rivers, but strong winds and rains can also increase the oxygen content. In fish farms, oxygenation is done by aerators.
- **Biotic source:** *photosynthesis** of plants produces oxygen in daylight.

Due to an intensive diffusion or photosynthesis, as illustrated in Figure A7-7, water can temporarily be oversaturated, but excess oxygen will diffuse to the atmosphere as soon as DO source ceases.

FIGURE A7-6: MAXIMUM DO CONTENT OF FULLY SATURATED WATER AT DIFFERENT TEMPERATURES

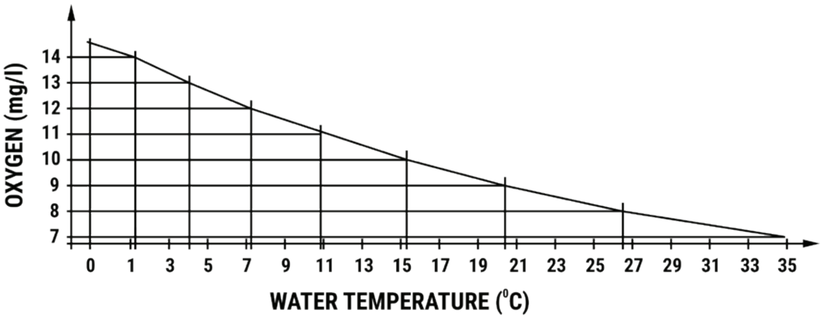
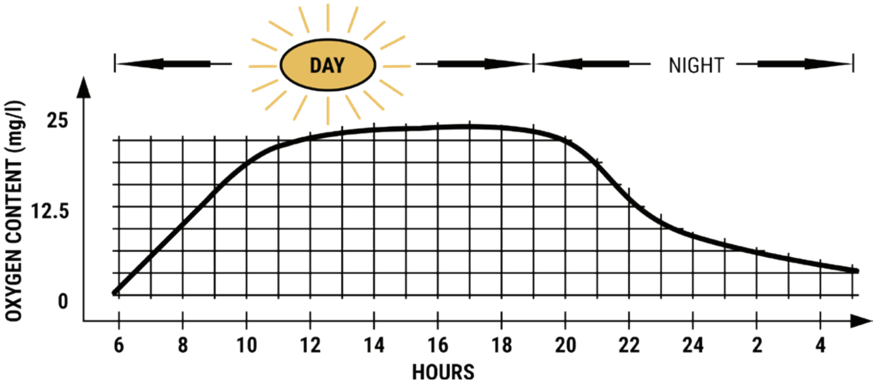


FIGURE A7-7: DAILY FLUCTUATION OF DO CONTENT IN EUTROPHIC LAKES AND FISH PONDS



During daytime, algae produce oxygen; as a result, water may become oversaturated by DO. When DO is too high in the afternoon, a radical fall can be expected during the night. This is due to the respiration of the biomass of algae, animals and microbiological oxygen consumption measured by ***BOD**** *and* ***COD**** *(Box A7-1).*

The actual maximum DO content of the water is temperature dependent. This means that maximum DO value (expressed in mg/l), which water can sustain is in equilibrium at a specific temperature. At the maximum values of DO contents presented in Figure A7-6, the saturation level is 100%. The main reasons for the reduction of oxygen in water are:

- **Abiotic:** Increased water temperature and chemical processes such as *mineralization** and *oxygen-consuming gases**.
- **Biotic:** *Biosynthesis** and respiration of aquatic plants and animals.
  Microbiological processes also consume a considerable amount of DO, especially when the organic nutrient content of water increases (Box A7-1). However, it must be remarked here that fish and fish populations are usually not the largest oxygen consumers, which is especially true in eutrophic waters and different fish culture systems.

Inorganic nutrient content of water – trophity

The qualitative and quantitative inorganic nutrient content of water regulates *trophity**. There are two groups, the nitrogen and *phosphorus** ones (Figure A7-8 and Figure A-9). The quantities of which determine whether a water body is oligotrophic, mesotrophic, eutrophic, or hypertrophic. These trophic levels indicate, among others, the productivity, and fish production potential of a water body (see Table A1-3).

The different forms of nitrogen in water are responsible for the *vegetative growth** of plants, including algae. Nitrogen is present in water as elemental, molecular nitrogen (N_2), nitrite (NO_2^-), nitrate (NO_3^-), and ammonium ion (NH_4^+), or organic compounds. These forms are converted to each other mainly with the help of different bacteria.

BOX A7-1: BIOCHEMICAL AND CHEMICAL OXYGEN DEMAND IN WATER

Biochemical oxygen demand (BOD) represents the amount of oxygen required by *aerobic** bacteria to remove organic matter from water. BOD is used as an index of the degree of organic pollution of water.
Chemical oxygen demand (COD) measures the organic nutrient content or saprobity of waters. It indicates how a water body is supplied with organic nutrients.

Phosphorus is essential for the *generative growth** of plants, which is a main cause of eutrophication in natural waters and often a limiting factor for natural food production in fish ponds.
Among inorganic phosphorus, the soluble orthophosphate forms ($H_2PO_4^{3-}$, HPO_4^{2-}, PO_4^{3-}, $FeHPO_4^+$, $CaH_2PO_4^+$) are accessible for plants. Phosphorus sources in natural waters can be communal (detergents), agricultural (fertilizers), or geological pollutants.
Laboratory analyses of nitrogen and phosphorous contents can be based on either elemental or molecular forms. Conversion ratios between the elemental and molecular forms are presented in Box A7-2.

BOX A7-2: READING AND INTERPRETING LABORATORY ANALYSES OF NITROGEN AND PHOSPHOROUS CONTENTS OF WATER

Elemental form – Molecular form
4.43 units NO_3 = 1 unit NO_3-N
1.22 units NH_3 = 1 unit NH_3-N
1.29 units NH_4 = 1 unit NH_4-N

2.29 units P_2O_5 = 1 unit P
3.07 units PO_4 = 1 unit P

Organic nutrient content of waters – saprobity

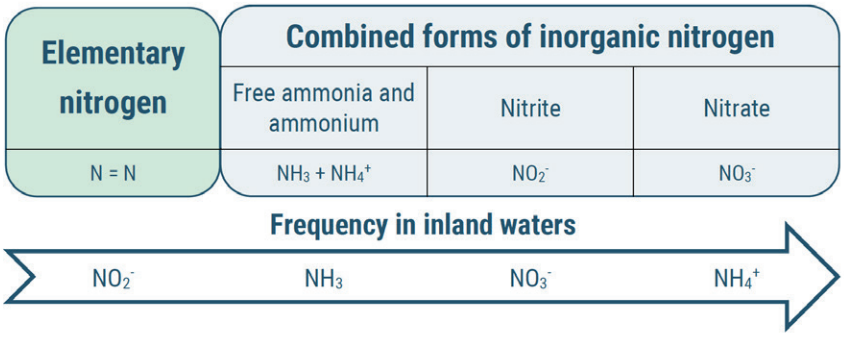
Saprobity indicates how water is supplied with organic nutrients. These particles have an outstanding role since they serve as nutrients for many different aquatic organisms, including zooplankton. Therefore, organic fertilizers are applied in pond culture. However, what may be advantageous in pond culture, can be disadvantageous in intensive culture systems, where the aim is to keep the organic nutrient content of water as low as possible. Saprobity is measured with BOD and COD, as described in Box A7-1.

Toxicants in waters – toxicity

The source of toxicants may be external (communal, agricultural, and industrial) or internal. There is a wide range of external toxicants; their possible number and potential source are practically unlimited. The most frequent internally developed toxicants in waters are:

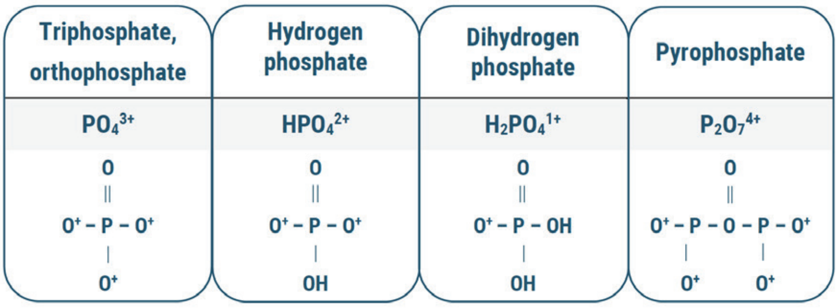
- **Ammonia (NH_3)** is produced by different groups of living organisms as an end-product of metabolism. One-third of consumed nitrogen is excreted by fish through the gills in the form of ammonia during respiration. Free ammonia (NH_3) and ammonium ion (NH_4^+) represent together the total ammonia

FIGURE A7-8: FORMS AND OCCURRENCE OF INORGANIC NITROGEN IN SURFACE WATER



Elementary nitrogen	Combined forms of inorganic nitrogen		
	Free ammonia and ammonium	Nitrite	Nitrate
N = N	$NH_3 + NH_4^+$	NO_2^-	NO_3^-

FIGURE A7-9: MOST FREQUENT PHOSPHATE IONS IN SURFACE WATER



Triphosphate, orthophosphate	Hydrogen phosphate	Dihydrogen phosphate	Pyrophosphate
PO_4^{3+}	HPO_4^{2+}	$H_2PO_4^{1+}$	$P_2O_7^{4+}$
O ‖ $O^+ – P – O^+$ | O^+	O ‖ $O^+ – P – O^+$ | OH	O ‖ $O^+ – P –$ OH | OH	O ‖ $O^+ – P – O – P – O^+$ | | O^+ O^+

(NH_3 + NH_4^+) content of pond water. The toxicity of ammonia is pH dependent. The amount of toxic ammonia increases with the increase of the pH value.
- **Hydrogen sulphide** (H_2S) is produced under anaerobic conditions by bacterial decomposition of proteins (sulphur-containing amino acids), degraded organic materials, and sulphates in the sludge. It dissolves very well in water and is strongly poisonous, especially when the pH of water is acidic.

TABLE A7-3: FREE AMMONIA CONTENT OF TOTAL AMMONIA AS PER pH VALUE

pH	10	9	8	7	6
Toxic concentration of total ammonia (mg/l) [1]	1.54	5.55	33.3	100	-
Proportional presence of free ammonia in total ammonia (%) [2]	85	36	5.4	0.6	0.1
Free ammonia contents in 5 mg/l total ammonia [2]	4.25	1.8	0.27	0.03	0.005

(Source: [1] [23] and [2] [100])

- **Algal toxicants:** algae do not specifically belong to dangerous organisms. Still, under certain conditions, they may cause massive fish mortalities, as some species can produce toxic materials (e.g. mycrocystin from blue-green algae), or they can dangerously reduce the oxygen content of water when blooming [73].
- **Methane** is the result of decomposition of organic materials under anaerobic conditions. It accumulates in the sludge, and when the atmospheric pressure changes, it leaves the sludge and removes oxygen from the water while oxidizing into CO_2.

1.3 BIOLOGICAL PROPERTIES OF WATER IMPORTANT FOR FISH AND FISH CULTURISTS

Knowledge of the biological properties of waters is especially important in culture-based fisheries (CBF) and pond fish culture due to a natural source of food for fish.
Both in CBF and pond culture aquatic life, the “food web” as the source of nutrients for fish is critically important. In the case of CBF, recognising natural fish food production capacity of waters for stocking is essential for ecologically, technically, and financially sustainable fishery management. In pond culture, the required quality of supplementary feeds throughout the production season is strongly influenced by the quality and quantity of natural food produced in the pond.

The principal biological activities within aquatic ecosystems build up and support biological productivity. This involves:
- Primary production, where living organisms, mainly plants, synthetize energy-rich organic materials from energy-poor inorganic materials through photosynthesis.
- Secondary production is the utilization of organic materials, i.e., transforming organic materials through consumption.

In fisheries and pond culture, fish is the final product of a complex biological cycle that takes place in water. This cycle includes primary and secondary production and the decomposition of living organic substances. For practical reasons and simplicity, the food web is often mentioned as a food chain or food pyramid. These expressions properly illustrate how the lives of different aquatic organisms are built on each other and how the survival of one depends on the existence of others (Figure A7-10).
The food pyramid is based on the primary production of *autotrophic organisms**. These are mainly green plants that can produce organic substances from inorganic ones such as carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, and other substances present in smaller quantities.
The second-largest group of aquatic organisms includes *heterotrophic organisms**. They have a decomposing type of metabolism. They are called secondary producers. A common characteristic is that they cannot produce organic substances from inorganic ones but convert and build organic substances into their bodies. These organisms, including fish, are found at different trophic levels, as illustrated in Figure A7-10.
In lakes, reservoirs, and ponds, the following four habitats are important for fish production:
- **Water surface**, called interfacial, provides space for plants and animals utilizing *surface tension**. They can permanently live here or for a certain period within their life cycle. Different species of flora and fauna live either on the air side[1] or on the water side[2] of the interface. Surface tension may block the excess of early fry of carps to the extremely fine feeds which remains on the air surface of water.
- **The water column** is an important biotope of standing water, especially fish ponds. It is inhabited by two main types of organisms: the *plankton** and the *nekton**. **Phytoplankton** comprises two different kinds of organisms: cyanobacteria (also referred to as blue-green algae) and unicellular green algae. From different phytoplankton organisms, unicellular green algae are required for fisheries and fish cultures. **Zooplankton** consists of heterotrophic planktonic organisms (i.e.,

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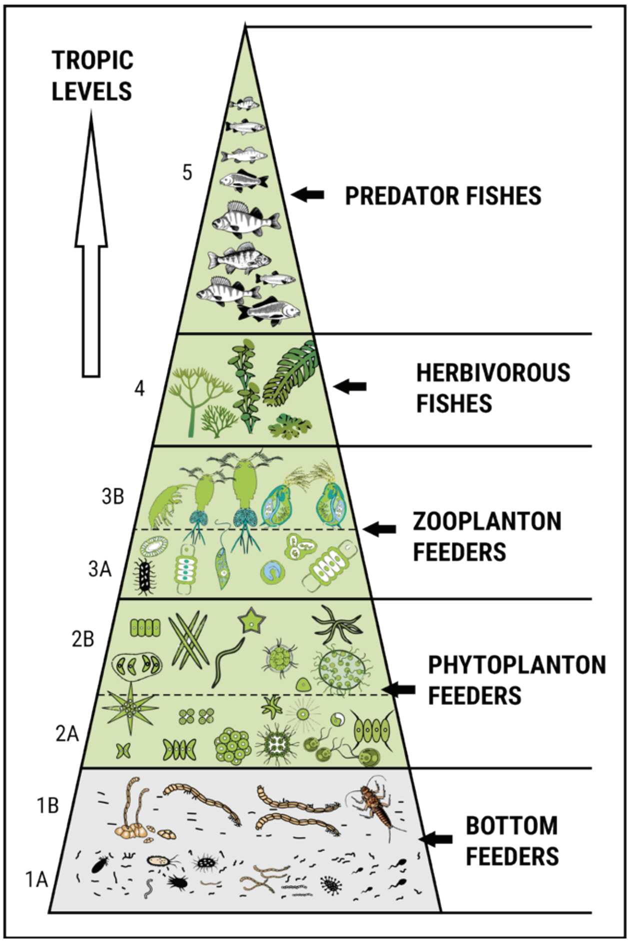
[1] Mosses, waterweeds with floating leaves and roots hanging free in the water column, "oil patch-like" iridescent films of bacteria and different insects.
[2] In addition to bacteria protozoans, hydroids, some rotifers, larvae of most mosquito species, flatworms and some snails live here.

animals). The most important zooplankton for fish production are protozoans, rotifers, cladocerans, and copepods.

- **Nekton** consists of all the organisms capable of intensive swimming or moving in the water column, independently from currents. These are, among others, ringed worms, large insects, their larvae, and different fish species.
- **The bottom** is rich in life. **Benthos,** which has flora and fauna of the bottom mud, contains different colonies of bacteria, algae, rotifers, larvae of mayflies, stoneflies, and dragonflies, larvae of chironomids, and worms like sludge worm (tubifex), snails, etc. Considering that many fish species - including the most widely cultured common carp and small cyprinids like breams and crucian carp - are bottom feeders. Therefore, benthos is the second most important natural fish food after plankton.
- **Firm surfaces** in waters such as stones, concrete, and earth structures (e.g., monks and dikes) or any other objects under the water are also occupied by living organisms (algae, sponges, worms, insects, larvae, etc.), which is called **biotekton.**
- **Spaces covered by macro vegetation** can be distinguished by the characteristic species. These can be floating plants rooted in the water, plants rooted in the bottom, and marsh plants rooted in the bottom and growing over the water surface.

FIGURE A7-10: FOOD PYRAMID IN WATERS – SOURCES OF NATURAL FISH FOOD AND THEIR CONSUMERS



*Different **trophic levels*** of fish feed are: **1A)** Detritus, **1B)** Zoobenthos, **2A** and **2B)** Phytoplankton, **3A, and 3B)** Zooplankton, **4)** Waterweeds, **5)** Fishes (see details in Annex 2 and 3)*

2. REQUIRED QUALITY PARAMETERS OF WATER IN DIFFERENT CULTURE SYSTEMS

The water quality requirements to be maintained in natural water bodies and the different culture systems are presented in this chapter. At recent decades there is an increasing demand for protection of and improvement in supporting fish life in freshwaters. Directive 2006/44/EC of the European Parliament and of the Council, issued in 2006 [30], sets the guiding and mandatory values of all key water quality parameters to be maintained in waters both for salmonids and cyprinids. These are listed in Table A7-4. The information presented in this table can also be considered as an introductory set of baseline data of required and acceptable aquatic environmental conditions to be maintained for fish in the surface waters.

Regarding fish culture, the tables in the subsequent chapters contain parameters which are essential for adequate monitoring and maintenance of the required water quality. Disregarding drastic signs of problems, like intense oxygen shortage when fish are gasping, becoming enervated, or even agonizing the values of water quality parameters may indicate when and in which form intervention is required. These help farmers to monitor and determine properly the time, nature, and extent of intervention to increase positive or reduce the negative effect of a specific quality parameters of water.

BOX A7-3: ORGANISMS OF THE PLANKTON

Plankton consists of:

1. Bakterioplankton
2. Phytoplankton
    - 2.1. Cyanobacteria (or blue algae)
    - 2.2. Unicellular green algae
    - 2.3. Filamentous algae
    - 2.4. Diatoms
    - 2.5. Euglenas
3. Zooplankton
    - 3.1. Protozoans
    - 3.2. Rotifers
    - 3.3. Cladocerans
    - 3.4. Copepods

TABLE A7-4: WATER QUALITY PARAMETERS SET BY THE EUROPEAN PARLIAMENT FOR PROTECTION AND IMPROVEMENT OF FISH LIFE IN FRESHWATERS

Water quality parameters	Salmonid waters		Cyprinid waters	
	Guide	Mandatory	Guide	Mandatory
Increase of temperature (°C)		≤ 1.5		≤ 3
Dissolved oxygen – O_2 (mg/l)	50% & ≥ 9	50% & ≥ 9	50% & ≥ 8	50% & ≥ 7
pH		6 to 9		6 to 9
Total suspended solids (mg/l)	≤ 25 (0)		≤ 25 (0)	
BOD_5 (mg/l O_2)	≤ 3		≤ 6	
Total phosphorus (mg/l P)				
Nitrite (mg/l NO_2)	≤ 0.01		≤ 0.03	
Non-ionized ammonia (mg/l NH_3)	≤ 0.005	≤ 0.025	≤ 0.005	≤ 0.025
Total ammonium (mg/l NH_4)	≤ 0.04	≤ 1	≤ 0.2	≤ 1
Total residual chlorine (mg/l HOCl)		≤ 0.005		≤ 0.005
Dissolved zinc (mg/l Zn)		≤ 0.3		≤ 1.0
Dissolved copper (mg/l Cu)	≤ 0.04		≤ 0.04	

(After: [30])

2.1 REQUIRED QUALITY OF WATER IN POND CULTURE

Both safe fish production and the increasing demand for intensification of pond culture call for regular monitoring and maintenance of water quality parameters in ponds. These are summarized in Table A7-5. Presented figures help determine the time and extent of organic and inorganic fertilization, use of lime, suspension of the load on the culture system, the start of aeration, or addition of fresh water.

TABLE A7-5: WATER QUALITY PARAMETERS REQUIRED FOR POND FISH CULTURE – WARMWATER SPECIES

Water quality parameters	Minimum	Required range	Maximum	Lethal
pH	6.5	6.5-8	8.5	<4-4.5 – >10-10.5
Dissolved oxygen – O_2 (mg/l)	4[1]	5-12[1]		Species dependent
Oxygen saturation (%)	50	above 70[1]		Species dependent
Conductivity (μS/cm)	250[1]	800 (1000-2700[1])	6000[1]	Species dependent
Salinity (‰)		0.5 – 1.5	5.0	Species dependent
Hardness (ppm)	100	120 – 180	300	
Alkalinity (mg $CaCO_3$/l)	20-30[2]	50-150[3]		
Ammonium ion – NH_4^+ (mg/l)		< 1.0	2.5	pH dependent (see Table A7-3)
Free ammonia – NH_3 (mg/l)			0.02	
Nitrite ion (mg/l)		< 0.1 (0.0[1])	0.3 (0.2[1])	
Nitrate ion (mg/l)		< 20 (1.0-10[1])	40 (15[1])	
Total nitrogen (mg/l)		2.5-10[1]	15[1]	
Chemical oxygen demand (mg/l)		8 (18-22[1])	12 (30[1])	
Orthophosphate ion (mg/l)		0.3 (0.6-1.8[1])	2.0	
Hydrogen sulphide – H_2S (mg/l)			0.002	pH dependent
Total iron (mg/l)		0.003	0.005	0.9
Arsenic (mg/l)		0.05	0.1	
Zinc (mg/l)		0.2	0.7	1.0
Mercury (mg/l)		0.0005	0.001	
Cadmium (mg/l)		0.003	0.004	0.005
Chlorine (mg/l)		0.01	0.02	0.1
Nickel (mg/l)		0.02	0.1	

(After: [79], [1] [53], [2] [109] and [3] [67])

Water quality parameters	Minimum	Required range	Maximum	Lethal
Lead (mg/l)		0.01	0.0	0.1
Copper (mg/l)		0.2	0.022	1.0
Cyanide (mg/l)		0.01	0.1	
Total suspended solids (TSS) (mg/l)		1 000	1 500	

(After: [79], [1] [53], [2] [109] and [3] [67])

2.2 REQUIRED QUALITY OF WATER IN INTENSIVE CULTURE SYSTEMS

Several fish species can be reared in different intensive culture systems. On the contrary to pond culture, the only guiding principle here is to follow the recommended feeding program and to maintain all water quality parameters within the required ranges presented in the tables of this chapter as follows:

- Required water quality parameters of intensive cultures of cold freshwater species – Table A7-6;
- Required water quality parameters of intensive sturgeon, perch, pikeperch and eel culture systems – Table A7-7;
- Required water quality parameters of intensive common carp, tench, European catfish, tilapia, African catfish and pangasius culture systems – Table A7-8.

TABLE A7-6: WATER QUALITY PARAMETERS REQUIRED FOR TROUT SPECIES

Water quality parameters	Optimal range	Acceptable ranges	Range of tolerance	Lethal
Temperature (°C)	10-16	5-10 and 17-20	20-25	above 25
pH	7.0-8.0		6.0-7.0 and 8.0-9.0	
Dissolved oxygen – O_2 (mg/l)	≥ 7		5-7	
Carbon dioxide – CO_2 (mg/l)		20-30		
Salinity (‰)			0-30	
Calcium hardness (mg/l)	50-300		300-400	
Ammonium ion – NH_4^+ (mg/l)	< 1			(see Table A7-3)
Free ammonia – NH_3 (mg/l)	< 0.0125	0.0125	< 0.18	
Nitrite-N (mg/l)	< 0.000012		< 0.1	
Nitrate-N (mg/l)	< 0.025		< 0.7	
Total suspended solids (TSS) (mg/l)	10-25	< 55	55-80	
Zinc (mg/l)	< 3.01	0.1-10		
Aluminium (mg/l)		0-71		
Cadmium (mg/l)		0-5		
Iron (nmol/l)	< 1			2500
Copper (µg/l)		55		

(After: [74] and [100])

TABLE A7-7: WATER QUALITY PARAMETERS REQUIRED FOR INTENSIVE CULTURE SYSTEMS OF STURGEON, PERCH, PIKEPERCH AND EEL

Water quality parameters	Sturgeon [1]		Perch and pikeperch [2]		Eel [3]	
	Optimal range	Tolerated range	Optimal range	Tolerated range	Optimal range	Tolerated range
Temperature (°C)	9-21		10-27	0.1-10 & 27-30	23-26	10-23
pH	6.5-7.5		≥ 6	3.9-6	7	6-6.5
Dissolved oxygen – O_2 (mg/l)	Saturated	≥ 4	7-9	≥ 3-4	3-6	≥ 3
Salinity (‰)	Fresh/brackish water		≤ 10	10-16	0-36	
Calcium hardness (mg $CaCO_3$/l)	50-400					
Ammonium ion – NH_4^+ (mg/l)	≤ 0.4	(see Table A7-3)	≤ 0.2	≤ 1	≤ 8	
Free ammonia – NH_3 (mg/l)	≤ 0.003		≤ 0.05	≤ 1	≤ 0.05	
Nitrite-N (mg/l)	≤ 0.08	0.08-0.15	≤ 3	≤ 15		
Nitrate-N (mg/l)	≤ 26		≤ 350	≤ 100		
Total suspended solids (TSS) (mg/l)	10		≤ 25			
Iron (mg/l)	≤ 0.01					
Hydrogen sulfide (µg/l)	≤ 0.002 pH dependent					

(After: [1] [11], [93], [2] [45] and [9], [3] [4])

TABLE A7-8: WATER QUALITY PARAMETERS REQUIRED FOR INTENSIVE CULTURE SYSTEMS OF COMMON CARP, TENCH, EUROPEAN CATFISH, TILAPIA, AFRICAN CATFISH AND PANGASIUS

Water quality parameters	Common carp, tench and European catfish [1]		Tilapia [2]		African catfish and pangasius [3]	
	Optimal range	Tolerated range	Optimal range	Tolerated range	Optimal range	Tolerated range
Temperature (°C)	20-28	0.5-20 & 28-30	25-30	10-25 & 30-35	25-30	10-25 & 30-40
pH	7-9	5.5-7 & 9-10.5		5-11	3-8	
Dissolved oxygen – O_2 (mg/l)	8	3.5-8 & > 8	4-6			≥ 0.5
Salinity (‰)	0.5-1.5	≤ 5	0-29			4-10
Calcium hardness (mg $CaCO_3$/l)	50-300					
Ammonium ion – NH_4+ (mg/l)	≤ 1.5	(see Table A7-3)	≤ 3	(see Table A7-3)	≤ 10	10-80
Free ammonia – NH_3 (mg/l)	0.04-0.2		≤ 0.1-0.17		≤ 0.34	
Nitrite-N (mg/l)	≤ 0.08	≤ 0.28	≤ 0.08		≤ 0.1	
Nitrate-N (mg/l)	≤ 70	< 250	40-60		≤ 140	
Total suspended solids (TSS) (mg/l)	≤ 100	≤ 370	≤ 100	100-200		
Zinc (mg/l)		≤ 2.0				
Hydrogen sulfide (µg/l)	≤ 0.002 (pH dependent)					

(After: [1] [47], [2] [35], [57], [63] [3] [100] and [87])

ANNEX 8

IMPACTS OF FISH FEEDING ON THE WATER QUALITY OF THE DIFFERENT CULTURE SYSTEMS

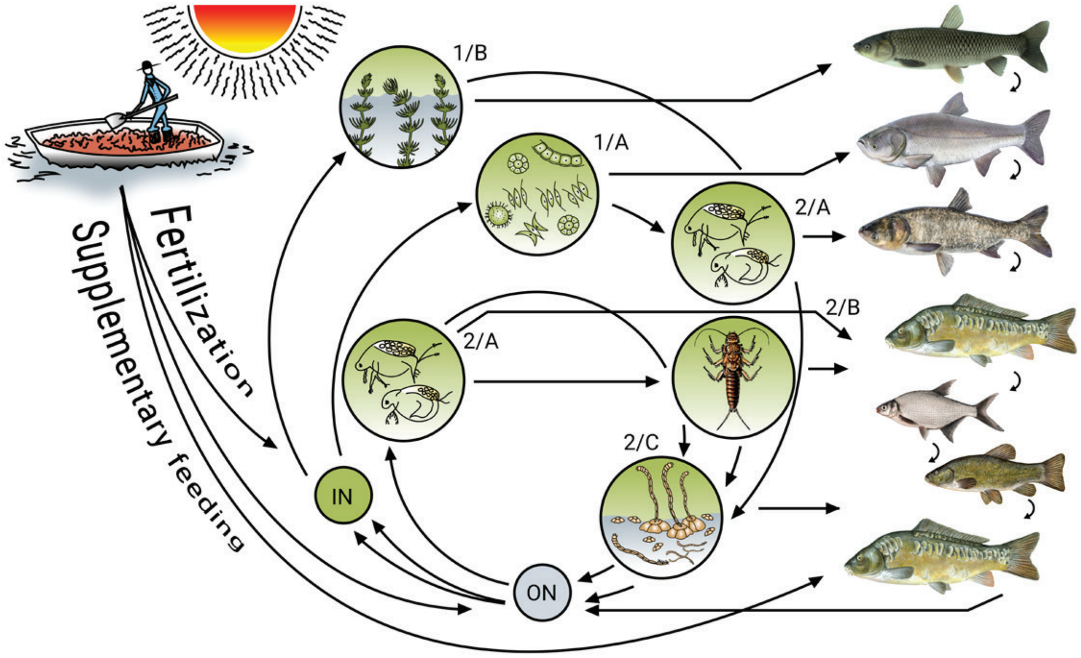
In the current annex, key aspects, and effects of feeding fish in the two main types of culture systems are discussed. Introduced technical information is specifically important when optimization and intensification of production are planned by a better utilization of all available resources like rearing space and water where there is a strong positive correlation between the quality of feed and the quantity of fish produced.

CONTENT

1. IMPACTS OF FEEDING ON WATER QUALITY IN POND CULTURE

In pond culture, the diet of fish (i.e., common carp) has two main components: natural food and supplementary feed (see figure A8-1). Both have considerable impacts on water quality.

FIGURE A8-1: A SCHEMATIC BIOLOGICAL CYCLE IN POND CULTURE-INDUCED AND MAINTAINED BY ORGANIC AND INORGANIC FERTILIZATION AND SUPPLEMENTARY FEEDING



Fish produced in pond culture results from a complex biological cycle generated by fertilization and supplementary feeding.
Fertilization: *Organic fertilizers supply the organic matter, i.e., organic plant nutrients (ON). These are directly used both by phyto- and zooplankton (1/A, 2/A) or are decomposed (mineralised) to inorganic plant nutrients (IN). Plant nutrients in inorganic fertilizers are directly used by phytoplankton and water weeds (1/A, 1/B). In addition, fish releases a part of ingested supplementary feeds as metabolic wastes. From these, ammonia and other nitrogenous compounds are used directly by plants, while faeces rich in organic nutrients and the different decaying dead organisms in the pond are decomposed and recycled into the biological cycle.*

1.1 FERTILIZATION AND ITS EFFECTS ON POND WATER QUALITY

Each fish pond has its natural fish food production capacity, which is increased and maintained by applying organic and inorganic fertilizers. Fish yields largely depend on how well and to what extent farmers can use fertilizers. In this sense, the purpose of fertilization is to accelerate the start of natural fish food production and keep it at the highest possible sustainable level.

Essential nutrients of fertilizers are organic nutrients, above all carbon [108], and inorganic plant nutrients like nitrogen, phosphorus, and additionally calcium, i.e., lime.

Typically, **organic fertilizers** or **manures** are used to increase the natural fish food production of pond water. On the contrary to arable crop production, when manure is matured before use, fresh manure can most efficiently generate the desired, best quality zooplankton production (Box A8-1). The strength and efficiency of organic fertilizers depend on the chemical composition, presented in Table A8-1. The current chemical composition of manures depends on the quality of feed fed and its management (dry or wet manure treatment). Consequently, there are "stronger" and "weaker" manures.

BOX A8-1: POND-SIDE EVALUATION OF THE PRODUCTIVITY OF FISH PONDS

There are many well-established methods for monitoring, controlling, and estimating the food production capacity of fish ponds, described in different kinds of literature. From these, the quantitative and qualitative check of zooplankton is the simplest and most efficient one, as these organisms are the best indicators of a healthy and fertile pond water environment, not to mention that zooplankton is also an important natural food for common carp ([76] and [52]).

TABLE A8-1: APPROXIMATE CHEMICAL COMPOSITION OF THE MANURE OF SELECTED FARM ANIMALS

Composition	Dairy cattle	Fattening beef cattle	Pig	Duck	Laying hen	Broiler chicken	Horse
Dry matter (DM) content of fresh manure (%)	12.7	11.6	9.2	43.0	25.2	25.2	20.9
As % of DM							
Organic matter (OM)	82.5	85.0	80.0	60.5	70.0	70.0	80.0
Total carbon (50% of OM)	41.3	42.5	40.0	30.3	35.0	35.0	40.0
Total nitrogen	3.9	4.9	7.5	4.5	5.4	6.8	2.9
Total phosphorus	0.7	1.6	2.5	1.8	2.1	1.5	0.5
Total potassium	2.6	3.6	4.9		2.3	2.1	1.8
BOD_5	16.5	23.0	33.0		27.0		
COD	88.0	95.0	95.0		90.0		
In 1 ton of fresh manure							
Dry matter (DM) (kg/t)	127.0	116.0	92.0	430.0	252.0	252.0	209.0
Organic matter (OM) (kg/t)	104.8	98.6	73.6	260.2	176.4	176.4	167.2
Total carbon (kg/t)	52.4	49.3	36.8	130.1	88.2	88.2	83.6
Total nitrogen (kg/t)	5.0	5.7	6.9	19.4	13.6	17.1	6.1
Total phosphorus (kg/t)	0.9	1.9	2.3	7.7	5.3	3.8	1.0
Total potassium (kg/t)	3.3	4.2	4.5		5.8	5.3	3.8
BOD_5 (kg/t)	21.0	26.7	30.4		68.0		
COD (kg/t)	111.8	110.2	87.4		226.8		

(After [70])

TABLE A8-2: NITROGENOUS AND PHOSPHORUS FERTILIZERS WIDELY USED IN THE REGION

Name of chemical fertilizer	Active ingredients			
	Chemical composition	N (%)	P_2O_5 (%)	CaO (%)
Ammonium nitrate (AN)	NH_4NH_3	33.5-34	-	-
Calcium ammonium nitrate (CAN)	$NH_4NO_3 + CaMg(CO_3)_2$	27	-	7
Ammonium sulphate (S: 14%) (AS)	$(NH_4)2SO_4$	21	-	-
Monoammonium phosphate (MAP)	$NH_4H_2PO_4$	11-12	52	-
Diammonium phosphate (DAP)	$(NH_4)2H_2PO_4$	18-22	46	-
Liquid ammonia	NH_3, NH_4OH, $NH_3 + H_2O$	4-12	-	-
Urea Ammonium Nitrate – liquid (UAN)	NH_3, NH_4OH	30	-	-
Urea	$CO(NH_2)_2$	44-46	-	-
Superphosphate (simple superphosphate)	$Ca(H_2PO_4)_2$	-	16-20	-
Double superphosphate (DSP)	$Ca(H_2PO_4)_2$	-	32-48	-
Triple superphosphate (TSP)	$Ca(H_2PO_4)_2$	-	44-53	-
Nitro-phosphate (NP)	$Ca(H_2PO_4)_2$	20	17-28	-
Ammoniated superphosphate	$Ca(H_2PO_4)_2$	3-5	14-28	-
Hyper phosphate		-	26	40

(Source: [85])

Inorganic or **chemical fertilizers** are also widely used in pond culture. The actual products available and used are country and region-specific. Table A8-2 presents most of the inorganic fertilizers found in the region.
According to Ribiánszky and Woynárovich [82], the effect of lime on pond culture is outstanding:

- Lime has a positive effect on the overall fertility of ponds. First of all it increases the buffer capacity (i.e., alkalinity) of pond water and bottom sludge.
- Lime also has a positive effect on the nitrogen cycle.

Further, liming accelerates the decomposition and mineralization of organic matter making it chemically available without deoxygenation of the water [67].

A necessary condition to efficiently apply phosphorus fertilizer is a weak alkaline sludge that keeps phosphorus in a loose bond. It is much more difficult to mobilize phosphorus from acidic sludge. This justifies a consecutive application of phosphorus and lime with the condition that about 10-14 days are left between the spreading of lime and phosphorus. However, it is important to note that automatic liming is not recommended and is not equally applicable in all types of ponds. If there is no previous farm experience with the application of lime, it should be consulted with a hydrobiologist.

TABLE A8-3: APPROXIMATE QUANTITIES OF ORGANIC AND INORGANIC FERTILIZERS FOR USE WHEN REARING ADVANCED FRY AND LARGER FISH IN POND CULTURE

Name	Total quantity (kg/ha)		% of total quantity	
	Active nutrient content	As traded	Preparatory dose	Later use in small portions
Advanced fry rearing (about 0.75-1.25 months)				
Lime (92-95%)	235-330	250-350	100	-
Manure (poultry) (OM)	45-55 (65-85)	400-500 (600-800)[1]	100	-
Urea	46-92	100-200	100	-
Superphosphate	14-23	75-125	100	-
Production of one-summer-old fish in the three-year production cycle				
Lime (92-95%)	280-375	300-400	25	75
Manure (poultry) (OM)	125-160	1200-1500	25	75
Urea	138-276	300-600	25	75
Superphosphate	41-68	225-375	25	75
Production of two-summer-old fish and table fish				
Lime (92-95%)	185-375	200-400	25	75
Manure (poultry) (OM)	315-525	3000-5000	25	75
Urea	184-230	400-500	25	75
Superphosphate	54-72	300-400	25	75

Observation: *[1] Quantity of manure when no chemical fertilizers are added/applied.* *(After: [53] and [55])*

TABLE A8-4: ANNUAL PROGRAMMING OF THE APPLICATION OF ORGANIC AND INORGANIC FERTILIZERS AND FEEDS IN THREE- AND TWO-YEAR-LONG PRODUCTION CYCLES OF CARP POND POLYCULTURE (PRODUCTION ZONE: V-VI)

Items	Months of fish feeding							
	Total	March	April	May	June	July	Aug[1]	Sept[1]
Production of fish in a three-year-long production cycle								
Rearing ~ 25 g large one-summer-old fish[2]								
Quantity of fertilizers (%)	**100%**			25%	25%	25%	20%	5%
Quantity of feed (%)	**100%**			2%	3%	15%	40%	40%
Rearing ~ 250 g large two-summer-old fish[2]								
Quantity of fertilizers (%)	**100%**	0%	25%	25%	25%	10%	10%	5%
Quantity of feed (%)	**100%**	2%	5%	12%	20%	25%	25%	13%
Rearing of table fish[2]								
Quantity of fertilizers (%)	**100%**	0%	25%	25%	25%	10%	10%	5%
Quantity of feed (%)	**100%**	2%	5%	12%	20%	25%	28%	10%
Production of fish in the two-year-long production cycle								
Rearing ~ 200-250 g large one-summer-old fish								
Quantity of fertilizers (%)	**100%**	-	-	25%	25%	25%	20%	5%
Quantity of feed (%)	**100%**	-	-	-	15%	30%	40%	15%
Rearing of table fish								
Quantity of fertilizers (%)	**100%**	0%	25%	25%	25%	10%	10%	5%
Quantity of feed (%)	**100%**	2%	5%	12%	20%	25%	28%	10%

Observation: *[1] In the last months of production season when feeding level is increased the use of organic/inorganic fertilizers is conditional.* *(After: [2] [53])*

Limestone ($CaCO_3$), quicklime (CaO), slaked lime ($Ca(OH)_2$) and chlorinated lime ($Ca(OCl)_2$) are used in fish farms to disinfect pond bottom, buffer pond water and support the biological cycle. Out of the listed limes, chlorinated lime is primarily used as a disinfectant, which does not raise the pH value of water [73].

Organic and inorganic fertilizers are used in the preparation of fish ponds. Later, in smaller doses, they can maintain the productivity of pond water. However, corresponding guiding figures presented in Table A8-3 should be applied with care and attention. As indicated in this table, 25% of the total quantity of lime and organic and inorganic fertilizers should be applied during pond preparation.
The remaining 75% should be distributed in several equal portions throughout the season, especially during peak months, from May to August. From August, fertilizers should conditionally and very carefully be used; together with an increased amount of feed, they may overload the pond ecosystem and cause problems, including oxygen shortage, in the mornings. Table A8-4 presents some guiding figures on the distribution of fertilizers over the production season, where red cells warn about critical periods, when it must be carried out cautiously if fertilization found necessary.
During maintenance fertilization, it is unnecessary to apply a higher dose in the pond than 12-14 kg/ha nitrogen and 4-5 kg/ha phosphorus active substance per time. However, it is recommended to add once every two weeks when the water temperature is above 18-20 °C.
Phosphorus in compound forms, found in the pond bottom sludge can be returned into the biological cycle by stirring or ventilating the mud.
Fish farmers often distribute or even heap manure on the bottom before the pond is inundated. As the aim is to fertilize the water and not the pond bottom, the effect of fertilizers can be ensured and increased if they are evenly distributed over the water surface.

BOX A8-2: RULE OF THUMB FIGURES TO THE DETERMINATION OF A DAILY APPROXIMATE MAXIMUM LOADABILITY OF A FISH POND

The loadability of a fish pond is important because this shows how intensive the management of fish production in a pond can be. Loadability depends on many factors such as the length and intensity of solar radiation, water temperature, trophity, and saprobity. Out of these, trophity and saprobity are the primary determining factors. According to Schroeder [88], there is a maximum amount of organic matter within a period of time, which a pond can digest. The maximum amount is 100-200 kg/ha/day dry-weight manure or 70-140 kg/ha/day organic matter of manure. It correlates with the report of Coche [14]: "A top input, in the order of 50 kg C/ha/day will result in high fish production without concomitant water quality problems, although this input rate varies according to temperature".

In the same FAO EIFAC report [14], Coche concluded that fish ponds could digest 450 kg, 116 kg, and 65 kg BOD/ha/day under tropical, subtropical, and temperate climates, respectively. This information is particularly important when an in-pond RAS is planned.

Though it is more laborious, the result will compensate for the efforts. Furthermore, this practice will also reduce excessive deposition of nutrients and prevent the increase of organic mud at the bottom where most of the nutrients are bound and may enable the formation of toxic gasses under anaerobic conditions. In addition the fertilization completed earlier than the inundation, it supports the mass production of aquatic macro-vegetation that is practically a loss of plant nutrients.

1.2 SUPPLEMENTARY FEEDING AND ITS EFFECTS ON POND WATER QUALITY

Excreted metabolic wastes (ammonia, urea, faeces, etc.) of fish have a similar effect on the bio-chemical cycle of ponds as the manure of farmed animals [67].
The actual load can be properly defined as it depends on the quantity and quality (FCR) of used supplementary feeds.

The approximate quantities of different excreted substances are determined based on ingested feed as presented in Table A8-5. The extent of this load can be rather significant, especially by the second half of the production cycle, as most of the supplementary feeds for common carp are delivered at this period (see Table A8-4).

TABLE A8-5: RANGE AND APPROXIMATE QUANTITIES OF SELECTED METABOLIC WASTES OF FISH FED WITH TRADITIONAL SUPPLEMENTARY FEEDS

Ingested feed-related metabolic wastes released into the water	Multiplier[1]
Ingested supplementary feed	1.0
Faeces – TSS (0.3 kg/kg supplementary feed)	0.3
BOD – C content of faeces (~50%) x 1.2	0.18
COD – BOD x 2.5	0.45
TAN – about 3% of ingested feed	0.03
Total phosphorus (Total P)	0.005

Observation: *[1] Based on the recommendation of Dr. Endre Janurik.*

FIGURE A8-2: A SIMPLE PRECOMPUTED EXCEL TABLE TO CALCULATE SEPARATE OR JOINT IMPACT OF THE DIFFERENT FERTILIZERS AND SUPPLEMENTARY FEEDS IN POND CULTURE – AN EXAMPLE OF CALCULATIONS

Organic and inorganic nutrients	Impact of fertilizers (kg)				Impact of feeds (kg)			Grand total (kg)
	Organic fertilizer	Inorganic fertilizers (N)	Inorganic fertilizers (P)	Subtotal (kg)	Grains and farm-made feeds	Industrial feeds FCR 0.0	Subtotal (kg)	
Quantity applied ➡	450	150	100		350	0		
Faeces (TSS)					105.0		**105.0**	**105.0**
Faeces (N in faeces figures are per 100 fish production)						0.0		
Faeces (P in faeces figures are per 100 fish production)						0.0		
N in water (figures are per 100 fish production)						0.0		
P in water (figures are per 100 fish production)						0.0		
Total dry matter (TDM)	113.4			**113.4**			**0.0**	**113.4**
Total organic matter (TOM)	79.4			**184.4**	105.0		**105.0**	**184.4**
Total carbon	39.7			**92.2**	52.5		**52.5**	**92.2**
BOD	30.6			**93.6**	63.0		**63.0**	**93.6**
COD	102.1			**259.6**	157.5		**157.5**	**259.6**
TAN				**10.5**	10.5		**10.5**	**10.5**
Total Nitrite				**0.0**			**0.0**	**0.0**
Total Nitrate				**0.0**			**0.0**	**0.0**
Total Nitrogen (TN)	2.4	67.5		**69.9**		0.0	**0.0**	**69.9**
Total phosphorus (TP)	2.6		18.0	**22.4**	1.8	0.0	**1.8**	**22.4**

1.3 JOINT EFFECTS OF FERTILIZATION AND SUPPLEMENTARY FEEDING ON POND WATER QUALITY

It is useful to know the maximum (Box A8-2) and approximate inorganic and organic nutrient load on a culture system. In the case of pond culture, it is the combined effect of organic and inorganic fertilizers and metabolic wastes excreted by fish. Figure A8-2 presents a simple precomputed xls table where the load of all types of supplementary feeds and fertilizers can be both separately and jointly calculated.

The separate columns for the two main types of supplementary feeds and for the organic and inorganic fertilizers allow to fill in any of those which are actually used and their joint effects should be known. The distinction at supplementary feeds is that producers have already estimated the impact values in the case of industrial feeds as discussed in the next chapter.

2. IMPACT OF FEEDING ON THE WATER QUALITY OF INTENSIVE CULTURE SYSTEMS

In intensive culture systems, it is practically only the ingested feed and the oxygen consumption of fish that influence water quality.
Therefore, in addition to the fast growth of fish via efficient feed conversion, reduced environmental impact of feeds is the component that positively influences results. Hence familiarity with the environmental impact of feeds used in intensive culture systems is especially important. Knowing these coherencies is vital in practical fish farming for the following reasons:

- There are strict environmental restrictions in many countries on the nutrient content of the effluent water of fish farms.
- The use of cages are conditional to strict environmental permissions and the environmental load of cage fish culture is strictly monitored.

For these reasons, fish feeds used in intensive culture systems should have the least possible impact on the aquatic environment. The same objective applies for in-pond RAS or cages/enclosures operated in fish ponds, as the environmental load of feeds and the achievable maximum biomass of fish in such combined culture systems have a close negative correlation. The more fish a farm wish to produce in a specific culture space, the used feeds should have the smallest possible amount of environmental impact.

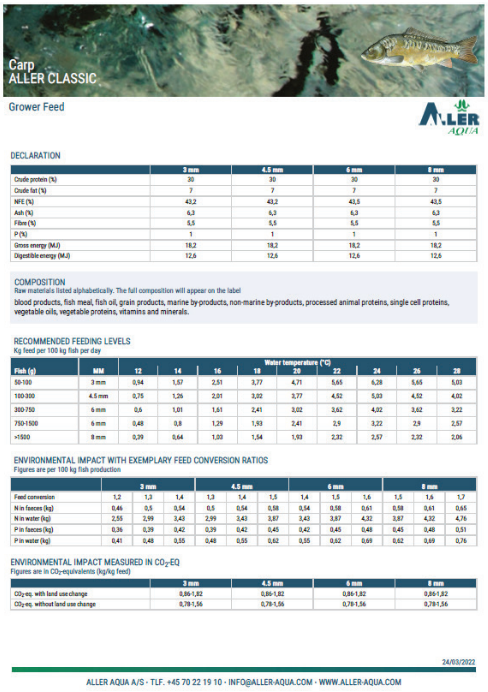
In the case of Aller Aqua, the environmental impact with exemplary feed conversion ratios is presented on the datasheet of each feed produced for different fish species (Figure A8-3). These datasheets can be found on the Aller Aqua website (www.aller-aqua.com/).

On the fish species datasheets of Aller Aqua, nitrogen (N) and phosphorus (P) contents are indicated in faeces and water separately as per 100 kg fish production. These figures depend on FCR that are summarised in Table A-2 of the Appendix. Majority of N and P contents of faeces can be settled and screened as they are in solid forms, but the dissolved N and P in water can only be removed from the culture space by a water exchange.

In the case of pond culture and combined culture systems such as in-pond RAS or cages/enclosures operated in ponds, there is no technical justification for an intensive exchange of water, as the pond ecosystem should be able to digest the nutrient load of feeding.

For practical reasons, environmental impact figures are indicated as per 100 kg of produced fish on the datasheets. The original figures are also useful to calculate the impact of ingested feed as per the actual weight of feed fed. This can be calculated if the figures of N and P in faeces and water, indicated on Aller Aqua datasheets, are divided by (FCR x 100) and multiplied by 1000. Obtained results will display the quantity of N and P in faeces and water in gram, excreted after 1 kg of ingested feed. Following the above logic, the approximate impacts of 1 kg of ingested Aller Aqua feeds can easily be calculated to which the minimum and maximum figures are presented in Table A-2 and the exact ones in Aller Aqua datasheets.

FIGURE A8-3: ALLER AQUA DATASHEET – AN EXAMPLE



Carp
ALLER CLASSIC

Grower Feed

ALLER AQUA

DECLARATION

	3 mm	4.5 mm	6 mm	8 mm
Crude protein (%)	30	30	30	30
Crude fat (%)	7	7	7	7
NFE (%)	43,2	43,2	43,5	43,5
Ash (%)	6,3	6,3	6,3	6,3
Fibre (%)	5,5	5,5	5,5	5,5
P (%)	1	1	1	1
Gross energy (MJ)	18,2	18,2	18,2	18,2
Digestible energy (MJ)	12,6	12,6	12,6	12,6

COMPOSITION
Raw materials listed alphabetically. The full composition will appear on the label
blood products, fish meal, fish oil, grain products, marine by-products, non-marine by-products, processed animal proteins, single cell proteins, vegetable oils, vegetable proteins, vitamins and minerals.

RECOMMENDED FEEDING LEVELS
Kg feed per 100 kg fish per day

		Water temperature (°C)								
Fish (g)	MM	12	14	16	18	20	22	24	26	28
50-100	3 mm	0,94	1,57	2,51	3,77	4,71	5,65	6,28	5,65	5,03
100-300	4.5 mm	0,75	1,26	2,01	3,02	3,77	4,52	5,03	4,52	4,02
300-750	6 mm	0,6	1,01	1,61	2,41	3,02	3,62	4,02	3,62	3,22
750-1500	6 mm	0,48	0,8	1,29	1,93	2,41	2,9	3,22	2,9	2,57
>1500	8 mm	0,39	0,64	1,03	1,54	1,93	2,32	2,57	2,32	2,06

ENVIRONMENTAL IMPACT WITH EXEMPLARY FEED CONVERSION RATIOS
Figures are per 100 kg fish production

	3 mm			4.5 mm			6 mm			8 mm		
Feed conversion	1,2	1,3	1,4	1,3	1,4	1,5	1,4	1,5	1,6	1,5	1,6	1,7
N in faeces (kg)	0,46	0,5	0,54	0,5	0,54	0,58	0,54	0,58	0,61	0,58	0,61	0,65
N in water (kg)	2,55	2,99	3,43	2,99	3,43	3,87	3,43	3,87	4,32	3,87	4,32	4,76
P in faeces (kg)	0,36	0,39	0,42	0,39	0,42	0,45	0,42	0,45	0,48	0,45	0,48	0,51
P in water (kg)	0,41	0,48	0,55	0,48	0,55	0,62	0,55	0,62	0,69	0,62	0,69	0,76

ENVIRONMENTAL IMPACT MEASURED IN CO_2-EQ
Figures are in CO_2-equivalents (kg/kg feed)

	3 mm	4.5 mm	6 mm	8 mm
CO_2-eq. with land use change	0,86-1,82	0,86-1,82	0,86-1,82	0,86-1,82
CO_2-eq. without land use change	0,78-1,56	0,78-1,56	0,78-1,56	0,78-1,56

24/03/2022

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3. ON-FARM MONITORING OF KEY WATER QUALITY PARAMETERS

It is impossible to overemphasise the importance of a regular inspection of fish stocks, both visually and by sampling. It must be an integral part of the daily routine, regardless if the culture system is pond or intensive. Supervision in early mornings and during feeding is even mandatory, as, on these occasions, the behaviour of fish can be well observed.

Suffocating, unbalanced fish gathering at the water inlet, or fish struggling with too strong currents are obvious signs of problems. However, less drastic signs such as loosing appetite and becoming enervated can also indicate problems. Therefore, in addition to observing fish, monitoring the physical, chemical, and biological status of the water and, if necessary, measuring different water parameters will definitely contribute to the safety and success of fish production.

Tables at the end of Annex 7 describe required key water quality parameters to maintain per culture system and fish species. Figures presented in these tables together with expectable (calculated and/or measured) impacts on water quality facilitate efficient on-farm monitoring and evaluation of most important water quality parameters:

- Water temperature;
- pH;
- Dissolved oxygen (DO);
- Total ammonia nitrogen (TAN);
- Nitrite nitrogen (Nitrite-N);
- Nitrate nitrogen (Nitrate-N);
- Phosphorus (Total-P).

FIGURE A8-4: TEST KITS DEVELOPED FOR AQUARISTS

Easily applicable high-tech test kits devoted to fish farms are the best choices. Recognised test kits developed for aquarists are less expensive but can still be reliable enough to use. Before such kits are applied, it is recommended to test their accuracy.

There are different options for purchasing and using equipment to monitor water quality. However, before making a decision on the type of tools to buy and use, certain practical aspects should be considered, as summarized below [105].

First, the reasons and objectives of using such tools should be considered, as well as who will use and maintain them. For example, thermometers and test kits for aquarists are cheaper but less accurate than even the analytical instruments developed explicitly for field work.

Instruments are usually very accurate and easy to use. However, they are not only more expensive but also require specialized regular maintenance that is not always straightforward in farm conditions.
For the above reasons, a systematic and thorough inventory of key aspects should be considered:

- Reasons and objectives;
- Financial and human resources;
- Selection, reliability, and price of available tools.

It should also be recognized that a basic set of water analytical tools is only required to check pH and DO, while an advanced set should additionally include kits to check nitrate, nitrite, and phosphate.
Suppose this set is further complemented with a tool to measure ammonium/ammonia in waters that are likely to develop in large quantities (e.g., in intensive culture systems). In that case, this supply will completely support the on-farm monitoring of important water parameters.
For further information, check the FAO publication on "Survey and evaluation of water quality – A field guide for managers of inland fisheries and fish farms", where more detailed information is available.
In case of regularly returning problems related to water quality, it is recommended to consult with a specialised laboratory.

BOX A8-3: NEED FOR ACCURATE WATER QUALITY MONITORING UNITS

In intensive, first of all industrial type culture systems such as RAS, the regular monitoring of the water quality by sophisticated tools is important for collection of data on system status for determining the necessary interactions. Only here is reasonable to invest for purchasing equipment working with high accuracy. However, permanent or occasionally rented specialists must be employed here for running and maintaining these units.

ANNEX 9

SUMMARY OF PRIMARILY DETERMINING FACTORS OF FISH PRODUCTION

Knowing circumstances and factors influencing the efficiency and results of fish production are of key importance for successful selection of the most effective culture system and technique. Accordingly, this annex summarises those factors which primarily determine the result of fish production.

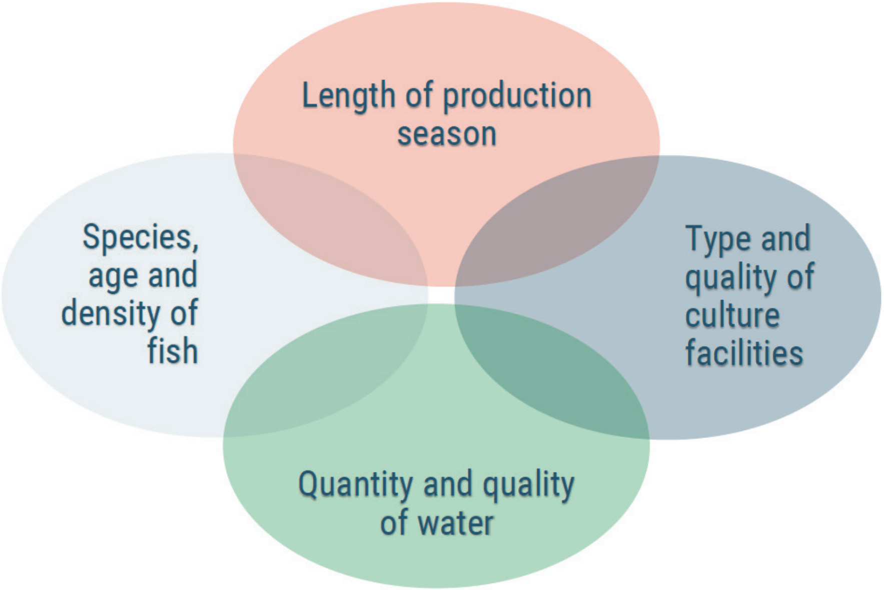
CONTENT

Out of the many different objectives and management-dependent factors, there are four that basically determine fish production: first is the length of the production season, second is the quality of culture facilities, third is the quantity and quality of water, and the fourth is the species, age and density of cultured fish. These topics will be discussed in this annex, including techniques to improve and maintain essential water quality parameters both in fish ponds and in other culture devices.

1. LENGTH OF THE PRODUCTION SEASON

It is widely known and experienced that there are two main types of fish farms that differ from each other. The first group of fish farms is where the water temperature is exposed to climate and weather, while the second group is not exposed to them.

FIGURE A9-1: MOST IMPORTANT INFLUENCING FACTORS WHICH DETERMINE THE SELECTION OF CULTURE SYSTEMS AND ATTAINABLE RESULTS



1.1 LENGTH OF PRODUCTION SEASON IN FISH FARMS EXPOSED TO CLIMATE AND WEATHER

Climate determines both meteorology (i.e., processes and phenomena of the atmosphere) and weather (i.e., the state of the atmosphere at a specific place and time; temperature, wind, rain, etc.). Consequently, climate and effects of climate change described in Box A9-1 are among the most important factors affecting the length and results of fish production, especially in fish farms where the water temperature is influenced by seasons.

In pond culture, solar radiation and air temperature are directly responsible for the quality and intensity of aquatic life. In addition, heat exchange between air and water, seasonal and daily heat stratification of water layers, and icing affect fish production.

Precipitation, evaporation, and runoffs may change the halobity, trophity, and saprobity of waters, while winds and fronts (sudden changes of air pressure) may alter water layers and oxygen concentration and can also be responsible for the release of toxic gasses from the mud.

BOX A9-1: EFFECTS OF CLIMATE CHANGE ON CULTURE BASED FISHERIES AND FISH CULTURE

From the five key indicators of climate change, NASA names the accelerated process of Arctic sea ice and land ice (glaciers) melting as having a direct effect on inland fisheries and fish cultures in the region. Indicators of the Environmental Protection Agency (EPA) are more specific and relevant to fisheries and fish culture:

- Weather and climate changes manifest in extreme temperatures, heavy precipitations, and droughts.
- Due to changing snow and ice conditions, altering water resources manifest in shrinking glaciers, unusually thick ice on lakes, extreme snowfalls, and snow covers and snow-packs.
- Indicators directly related to agriculture include:
  - Changing stream flows.
  - Changing the length of the growing season.
  - Changing leafing and blooming data in agriculture and *phenological response** of fish and their natural food organisms.

According to the World Meteorological Organization [104], extreme weather events such as floods, droughts, hurricanes, and unseasonable temperatures can adversely influence water quality and fisheries and fish culture.

TABLE A9-1: PRODUCTION ZONES AND EXPECTABLE RESULTS OF CARP POLYCULTURE – ONLY NATURAL FISH PRODUCTIVITY (THERE IS NO FERTILIZATION AND SUPPLEMENTARY FEEDING)

Zones	**Average air temperature above 15 °C**			**Expectable results of table fish production (kg/ha)**				
	Days per year	Weeks per year	Month per year	Common carp	Silver carp	Bighead carp	Grass carp	Total
I	60 – 75	9 – 11	2 – 2.5					
II	76 – 90	11 – 13	2.5 – 3	100	-	50	50	**200**
III	91 – 105	13 – 15	3 – 3.5	100	-	50	50	**200**
IV	106 – 120	15 – 17	3.5 – 4	120	200	100	50	**470**
V	121 – 135	17 – 19	4 – 4.5	120	250	100	50	**520**
VI	136 – 150	19 – 21	4.5 – 5	130	300	100	50	**580**
VII	151 – 175	21 – 25	5 – 6	130	350	150	50	**680**

(Source: [39])

Before the 1990s, at the time of central planning of state economy practiced in some of the sub-regions, aquaculture zones were also identified similarly to agro-climatic zones. This supported the development of production standards (norms) for carp polyculture in fertilized ponds, where common carp was fed with traditional supplementary feeds. Zones were established based on the annual number of days when the average daily air temperatures were above 15 °C. This concept was investigated and further developed by Fedorov (2014) for determining expectable table fish production results in unfertilized, fertilized and fertilized and supplementary fed carp pond polyculture. These are presented in Tables A9-1, A9-2 and A9-3. The original fish productivity indexes and those adapted by Fedorov (2014) for Kazakhstan are presented in Table A9-3.

TABLE A9-2: PRODUCTION ZONES AND EXPECTABLE RESULTS OF CARP POLYCULTURE –ONLY ORGANIC AND INORGANIC FERTILIZATION (THERE IS NO SUPPLEMENTARY FEEDING)

Zones	**Average air temperature above 15 °C**			**Expectable results of table fish production (kg/ha)**				
	Days per year	Weeks per year	Month per year	Common carp	Silver carp	Bighead carp	Grass carp	Total
I	60 – 75	9 – 11	2 – 2.5					
II	76 – 90	11 – 13	2.5 – 3	500	-	100	50	**650**
III	91 – 105	13 – 15	3 – 3.5	600	-	150	50	**800**
IV	106 – 120	15 – 17	3.5 – 4	700	600	150	50	**1500**
V	121 – 135	17 – 19	4 – 4.5	700	600	200	50	**1550**
VI	136 – 150	19 – 21	4.5 – 5	800	600	200	50	**1650**
VII	151 – 175	21 – 25	5 – 6	800	600	250	50	**1700**

(Source: [39])

TABLE A9-3: PRODUCTION ZONES AND PLANNING NORMS – FERTILIZATION AND SUPPLEMENTARY FEEDING OF COMMON CARP

Zones	**Average air temperature above 15 °C**			**Expectable results of table fish production (kg/ha)**					
	Days per year	Weeks per year	Month per year	**Former norms**	Common carp	Silver carp	Bighead carp	Grass carp	Total
I	60 – 75	9 – 11	2 – 2.5	**800**					
II	76 – 90	11 – 13	2.5 – 3	**1 400**	1 500	-	150	50	**1 700**
III	91 – 105	13 – 15	3 – 3.5	**1 600**	1 800	-	200	50	**2 050**
IV	106 – 120	15 – 17	3.5 – 4	**1 900**	2 000	600	200	50	**2 850**
V	121 – 135	17 – 19	4 – 4.5	**2 200**	2 000	600	300	50	**2 850**
VI	136 – 150	19 – 21	4.5 – 5	**2 400**	2 400	600	300	50	**3 350**
VII	151 – 175	21 – 25	5 – 6	**2 600**	2 400	600	400	50	**3 450**

(Source: [71] and [39])

Production zones presented in Table A9-1 are also suitable to indicate potential locations for rearing coldwater fish species outdoor, especially whitefish.

Surface waters are used for rearing trout and Arctic charr in mountainous regions. Though such farms are widespread throughout the region, winter months may slow down fish growth considerably.

1.2 LENGTH OF PRODUCTION PERIOD IN FISH FARMS THAT ARE NOT EXPOSED TO CLIMATE

Intensive fish farms supplied with underground water are not exposed to considerable seasonal changes. In such farms, the water temperature remains practically constant, ensuring a fast growth of fish if fed properly. Furthermore, there is no interruption or slowdown of growth here, as the production cycle is all year round.
Depending on the temperature, underground waters can support the intensive production of coldwater (Arctic charr, trout, etc.), warmwater (sturgeon, European catfish, perch, pikeperch, common carp), or tropical fish species (tilapia, African catfish).

FIGURE A9-2: TROUT FARM SUPPLIED WITH SURFACE WATER

There is a seasonal fluctuation of water temperature when surface waters may considerably cool down.

2. QUALITY OF CULTURE FACILITIES

Quality and usability of culture facilities (i.e., fish ponds, tanks, cages, and enclosures) basically determine achievable results.

TABLE A9-4: CHARACTERIZATION OF FISH PONDS BY PRODUCTIVITY DETERMINED BY SOIL FERTILITY

Productivity	Attainable results without fertilization and supplementary feeding[1] (kg/ha)	
	Monoculture of common carp	Polyculture of carps
Very good	180-200	450-500
Good	120–180	300-450
Medium	80–120	200-300
Weak	< 80	< 200

Observation: *[1] In production zones IV-V.*

Fish ponds
At the evaluation of quality and usability of fish ponds, the followings should be considered:

- **Water supply** is a critical quality of fish ponds that basically determines the usability of a fish pond as it is detailed in the subsequent chapter.
- **The soil where the pond is built:** similarly to arable lands, the productivity of fish ponds may vary between very good and weak, as demonstrated with figures in Table A9-4.
- **Location:** defines how the pond is exposed to sun radiation, main winds, runoffs of rains, and the approachability with vehicles, especially when the area is large.
- **Depth:** older fish ponds have an average depth of about 1-1.5 m. Today, when new fish ponds are built, they are recommended to hold about 1.5 m of average water depth. Furthermore, due to climate change and intensification of production, the Serbian model of a two-year-long production cycle of common carp in intensive pond monoculture is recommended for ponds with an average depth of 2 meters.
- **Bottom and bottom mud:** the bottom should facilitate complete drainage, and an inner harvesting pit at the drainage may help the collection of fish located. Thick mud on the pond bottom where anaerobic environment may develop, creates suitable conditions for producing toxic anaerobic gasses.
- **Physical status:** dikes of fish ponds should be in good shape, and at least some of them should be accessible with a vehicle to supply manure, feed, etc. Concrete structures (water supply furrow/pipe, monk, etc.) should also be in good working condition.
- **Size:** it is rather relative to which sizes of fish ponds are considered small, medium, or large. In regions with a long tradition of pond culture, even several-ten-hectare large ponds are not considered too large, and there are also fish farms where ponds are well above 100 hectares. From the production point of view, the larger a fish pond is, the less intensive management is possible.

Small earth ponds

In former times small earth ponds with proper water supply, exchange and drainage were built for two reasons; to rear trout or to winter (store) the fish produced in production ponds.

Even today, in the north, where nutritionally complete industrial feed based trout farming is dominant, it is practiced in small, relatively narrow but long, several hundred square meters large earthen ponds, called Danish ponds.

Wintering ponds are also small (500-1000 m^2) and deep (2 m) earth structures. In the past, such wintering ponds were left dry during summers to disinfect their soils for the next wintering. However, as these ponds are suitable for intensive rearing of fish, they are often used for that during the summers but also during the winters for trout.

Outdoor tanks

Nowadays, small ponds described above are lined with geomembrane or paved with concrete, but lately are also fully built from concrete. This is especially true for trout farms of the region.

FIGURE A9-3: A TYPICAL TROUT FARM

Indoor troughs and tanks

These devices are made from fiberglass, polyethylene, polypropylene or PVC tarpaulin. Smaller troughs and tanks (100-500 l) are used to rearing advanced fry and fingerlings, while larger, up to a few tenths of cubic meters rearing devices are used to raise growers and table fish.

Cages and enclosures

Both floating cages and enclosures are invented and used for intensive fish rearing in a water body or a fish pond. Depending on the water body where cages are placed and the size of fish reared in them, their shape and size in inland aquaculture may significantly vary. Therefore, it is important to consider how they can be accessed, fish fed, and handled when setting cages. Discounting relatively small size hapas, which are used for rearing advanced fry and small fingerlings and are installed in shallow waters, cages should be deposited into deep waters. When cages are set in fish ponds, they should be established in the deepest part of the pond to have at least a 0.6 meter gap between the bottom of the pond and of the cage. To reduce the excessive deposit of waste under the cage, from time to time, it should be moved to another suitable location of the pond.

Enclosures made from netting materials are used for intensive fish culturing within ponds, where the depth of water does not allow the use of cages. These enclosures look like rectangular fish cages, but their bottoms lay on the ground of the pond. The enclosures made from heavy-duty netting materials facilitate an intensive production of fish within fish ponds. They actually serve as a simple variation of in-pond RAS fish culture systems [16].

3. QUANTITY AND QUALITY OF WATER

Improvement and maintenance of water quality have basic differences in pond culture and intensive culture systems:

- In **pond culture**, the aim is to maintain a healthy, productive ecosystem, where fish and natural fish food are produced in the same water body. To ensure this, pond water is enriched with organic and inorganic nutrients. This, together with the metabolic wastes of fish, should not generate a more intensive biological cycle than the pond water can hold, process (digest) and keep in balance. The first sign of an unbalanced fish pond life is when oxygen shortage appears in early mornings, cloudy days, occasionally at fronts and sharp weather changes, later regularly, regardless if the weather is nice or not.
- In **intensive culture systems** fish must receive a nutritionally complete industrial feed, as natural food is not present. This allows an expansion of the number of reared fish in a unit volume of water, but as a result, both the quantity of metabolic wastes and the demand for oxygen increase.

It can be concluded that from a water quality point of view, the presence of sufficient dissolved oxygen is a primary objective for both culture systems, while the removal of metabolic waste is differently considered. In pond cultures, these should be utilized by pond life, but in intensive culture systems, these should be removed before their concentration increases beyond problematic/lethal.

Consequently, the two most obvious ways to supply oxygen and remove harmful metabolic waste are aeration and due water exchange.

3.1 REPLACEMENT AND EXCHANGE OF WATER

Replacement of evaporated and seeped water with fresh, clean one is a primary water management task in fish ponds. Occasional, partial water exchange in fish ponds may be justified, especially at the second half of the production season. Still, a regular water exchange in a traditional pond culture should not be part of the production technology. Such action indicates that fertilization and supplementary feeding need to be carefully examined and adjusted, mostly reduced. Continuous water exchange is part of the production technology in intensive culture systems, such as in small earth ponds and tanks. The rate should be proportional to DO consumption and the need to remove metabolic waste produced in rearing devices.

For intensive culture systems, there are practical numbers for water exchange rates. However, these may vary on a broad scale, as the replacement (exchange) rate of water depends on water temperature, fish species, age groups, density, feed, cleaning, and self-cleaning of the rearing structure or device.

As a start, water exchange rates recommended by literature should be followed with a close day-round inspection and observation of fish. Together with this, a more exact water exchange rate can be determined if DO, ammonia, nitrite, and nitrate content of effluent water is regularly measured, as described in the last chapter of Annex 8.

The first sign of oxygen shortage and/or accumulation of toxic materials in the rearing device is when fish gather at the inflow, become enervated, and lose appetite. However, not only an insufficient rate of water exchange in the rearing device can be harmful, but a too fast water flow should also be avoided. To determine the speed of water flow in a device, the length of fish should be measured. Water should not flow faster within 1 second than the average total length of cultured fish; however, maximum velocity should not exceed 20 cm/sec (12 m/min), even if the body length of fish is longer than 20 cm [51].

In cages and enclosures, water exchange within the culture space is performed by currents and aerators operated at critical periods of the day/night.

BOX A9-1: OXYGENATION

In modern, high-tech, intensive aquaculture systems, it is impossible to satisfy the oxygen demand of an outstandingly increased number of fish by a water exchange or aeration. This is the case when oxygenation should be considered. As it is an expensive technology, careful research of assets and gaps should be reviewed, and a feasibility study must be carried out before the machinery is purchased, installed and operated.

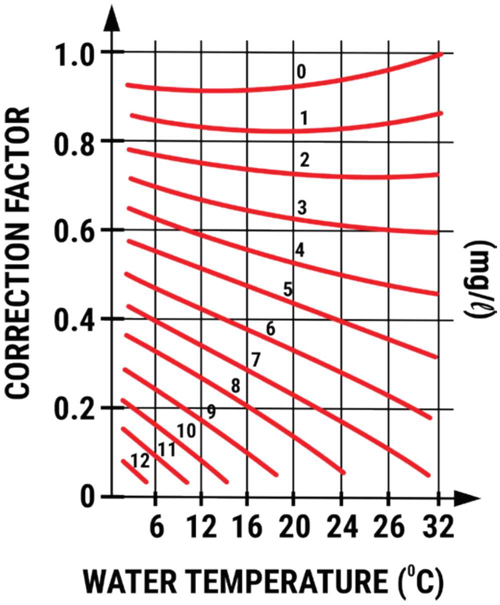
3.2 AERATION

As demonstrated in Figure A7-7, the oxygen level in ponds has a diurnal fluctuation: the minimum level is reached before sunrise and the maximum one in the early afternoon. Amplitude is the consequence of the balance between the photosynthetic production and the respiration of living organisms together with the oxygen consumption of chemical/biochemical processes. This amplitude can be very large in fish ponds, where oxygen may drop far below 1 mg/l in the dark period, while the saturation level at daylight may be above 100 %. Moreover, during days with low wind, thermal stratification may develop in ponds (Figure A7-4), which hampers the penetration of oxygen from upper water layers, where oxygen is oversaturated, to lower ones.

Aeration in fish ponds has two aims: (1) to increase (and maintain) oxygen levels, and (2) to cease (end) stratification by mixing water layers and evenly distribute DO content in the water body.

The efficiency of aerators (regardless of being used in ponds or intensive culture systems) can be described by STOR and SAE values. STOR is the Standard Oxygen Transfer Rate, which shows the quantity of oxygen transferred into the water in a unit of kg O_2/h (hour). SAE is the Standard Aeration Efficiency, which indicates the energy efficiency of an aerator in kg O_2/kWh (kilowatt-hour). These values describe the efficiency of aeration in standard environment, where the original

FIGURE A9-4: CORRECTION FACTORS IN DETERMINING OXYGEN DISSOLUTION OF AERATORS UNDER OPERATING CONDITIONS



(Source: [62])

The actual DO values (in mg/l) when the aeration starts are indicated on the curves in the diagram.

(starting) oxygen level is zero. However, the actual efficiency of aeration in waters where DO content is above zero, is always lower. Here correction factors should be used for determining the actual efficiency of aeration. The correction factors depend on actual DO concentration and temperature (Figure A9-4). Therefore, when different aeration devices are operated, SAE values must be multiplied by this correction factor to get the real oxygen transfer.

FIGURE A9-5: AERATORS USED MAINLY IN FISH PONDS

Air tubes with 0.1-2.2 m^3 air/meter/hour, efficiency is diameter and depth dependent

Vertical pump aerator with an efficiency of: SAE: 0.73-1.52 kg O_2/kWh

Surface, paddlewheel aerator with an efficiency of: SAE: 1.2-2.9 kg O_2/kWh

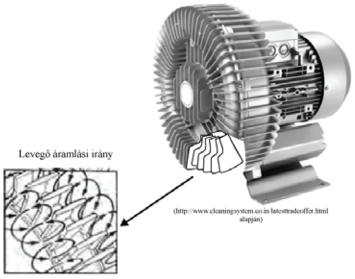
Spray aerator with an efficiency of: SAE: 0.06-0.17 kg O_2/kWh

Jet aerator in the water with an efficiency of: SAE: 2.4 kg O_2/kWh

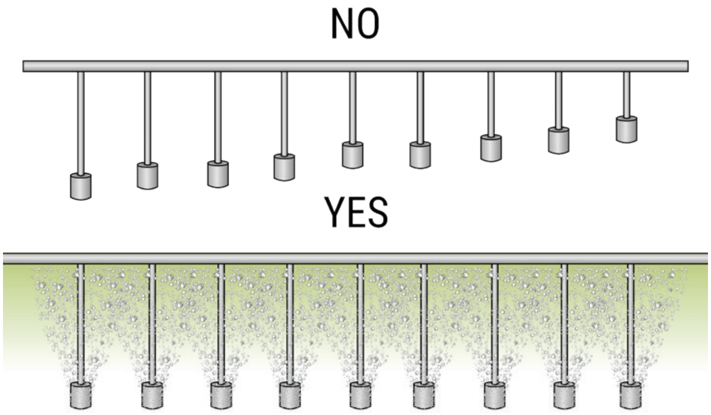
Water jet exhauster with an efficiency of: 2.0-2.3 kg O_2/kWh

Air-stone with 1,2 m^3/hour air supply transferring about 0.25 kg O_2/day

Regenerative blower to supply underwater aerator devices



(http://www.cleaningsystem.co.in/latesttradeoffer.html alapján)



Pipeline for air supply to cease stratification. At setting air-stones should be fixed into the same depth otherwise those placed into deeper water will not work properly.

FIGURE A9-6: AERATORS USED MAINLY IN INTENSIVE CULTURE SYSTEMS

Left: In−pond RAS – an intensive unit aerated with airlift. Center: An aerator set at the side of a cage. Left: The schematic operation of an air lift (1. Blower. 2. Continuous suction of water and 3. Continuous flow of water.

4. FISH SPECIES, AGE GROUPS, AND DENSITY

Fish species produced in the region are not equally suitable for all types of culture systems; thus, achievable results cannot be the same. Moreover, rearing of different age/size groups of the same species usually requires different technical solutions. These distinctions largely derive from, whether:

- The fish is coldwater, warmwater, or tropical species.
- The oxygen demand of fish is high, medium, or low.
- The fish can additionally support its breathing from the air, as African catfish or pangasius (and snakehead, etc.) do.
- The younger and older age groups of fish species can properly be fed in the different culture systems.
- The younger or older age groups of the given fish species are fed in the same or in a different culture system.

Though correlation between the actual number and attainable individual size of fish is negative in all types of culture systems, still the actual reasons may be different (Figure A9-7 and A9-8).

In pond culture the primary limiting factor of increasing the number of fish per unit area is the actual productivity of pond manifested in the availability of natural fish food. As intensity increases water quality becomes the secondary limiting factor in pond culture, which is often improved with occasional, regular (even continuous) aeration and/or with partial or total exchange of water.

In intensive culture systems feed cannot be the limiting factor if nutritionally complete industrial feeds are used. Therefore in these culture systems water quality is the primary limiting factor, which are improved with due exchange of water, aeration (oxygenation) and/or degassing of water. Here the secondary limiting factor is the actual physical space in which fish grow (Figure A9-8).

When water supply and oxygen conditions of a culture system cannot support fish production in densities planned or expected, then the number of fish should be reduced. However, in the case of steady, good quality water supply and reliable machinery for aeration, the stocking density may increase, provided that it is supported with:

- Continuous and close inspection and observation of fish behaviour.
- Accurate monitoring of essential water qualities.
- Systematic sampling of fish in due intervals in order to check their physical and health conditions.

BOX A9-2: WIDESPREAD MISTAKES IN RELATION TO COMPARISON OF ACHIEVABLE FISH PRODUCTION RESULTS

There are two often met mistakes when fish production results are compared.

The first is when results achieved in the two basically different fish culture systems (i.e., pond culture and intensive culture systems) are compared. The second one is when the production of air breathing catfishes in intensive culture systems are compared to the production results of other fish species, which have only gills to breath.

Both of these types of comparisons are incorrect and unprofessional.

FIGURE A9-7: CORRELATION BETWEEN THE STOCKING DENSITY AND THE EXPECTABLE FINAL SIZE OF FISH IN THE DIFFERENT REARING SYSTEMS

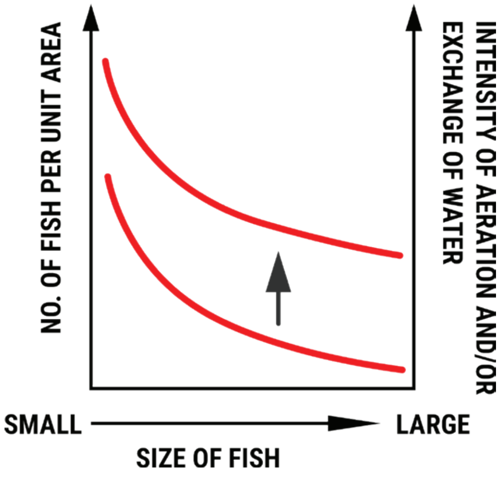


FIGURE A9-8: AT-A-GLANCE COMPARISON OF THE PRIMARY AND SECONDARY LIMITING FACTORS OF THE DIFFERENT FISH CULTURE SYSTEMS

	Pond culture	Intensive culture systems
Primary limiting factor ➡	Natural fish food	Water quality
Secondary limiting factor ➡	Water quality	Physical space for fish

It is here to mention that in intensive pond culture and in-pond RAS it is the pond water itself which digests (eliminates) the metabolic wastes excreted by fish. Therefore, it is important to adjust and maintain the balance of the released wastes products and pond life which consume and eliminate these wastes. In such culture systems careful planning of sustainable balance is essential (see Chapter 3 in the main text). Figure A9-10 presents the two options of planning:

Repeated summer fishing – in this case there is a higher initial load of fish biomass which is maintained on a balanced level with regular partial harvesting i.e., fishing of market size table fish during the summer.

One single autumn harvest – at this option there is a lower initial load of fish biomass which gradually increases as fish grow, that is harvested in one shift at the end of the production season.

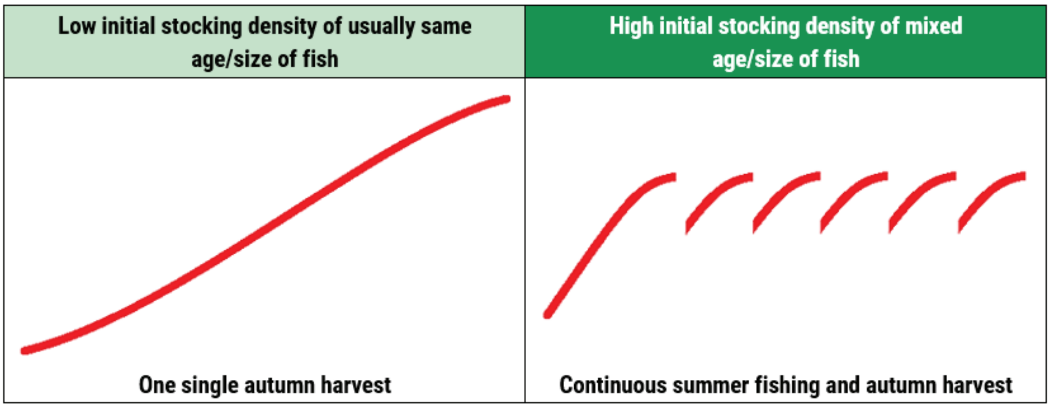
At these cases not only the initial number, but also the size range of stocked fish is different.

In intensive culture systems applying different technical solutions for removal of faeces from tanks may considerably reduce the need for exchange of water and the necessity of intensive aeration or will allow to stock and rear more fish in a given unit area or water volume.

FIGURE A9-9: ALGAE BLOOM IN AN IN-POND RAS

Such view of water in a fish pond or in an in-pond RAS indicates acute water quality problems.

FIGURE A9-10: SCHEMATIC PRESENTATION OF THE DIFFERENCE BETWEEN TOTAL AND PARTIAL HARVEST BASED PRODUCTION OF TABLE FISH IN INTENSIVE POND CULTURE AND IN-POND RAS



ANNEX 10

ATTAINABLE PRODUCTION RESULTS

It is important to know what results can be realistically planned if both production conditions and technical management are adequately harmonized. Therefore this annex presents a detailed, fact based, concise summary of required main inputs and expectable results in different fish culture systems.
In the first chapter stocking figures of culture based fisheries (CBF) are presented in order to assist owners and leaseholders to select the range, age/size and number of fish feasible for stocking.
In the second chapter key production figures of pond fish culture are displayed. This shows a wide range of options from extensive to intensive pond mono-, bi- and polycultures of carps[1] and other commercially important fish species of pond fish culture. Consequently, rearing of advance fry, stocking materials for table fish production and rearing of table fish are presented in separate tables.
In the third chapter the key production figures of intensive culture systems are shown in three subsequent groups: cold freshwater, warm freshwater and tropical[2] freshwater fish species.

CONTENT

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[1] *In this annex carps include common carp and the Chinese major carps; silver carp, bighead carp, their hybrids and grass carps.*

[2] *Fish species listed under "tropical freshwater species" is different from AA arrangement. It is meant to indicate that these species are not able to survive winter temperatures, thus their rearing is limited in the region.*

1. RESULTS IN CULTURE BASED FISHERIES

The success of culture based fisheries (CBF) depends on a careful planning and execution of the stocking of different fish species. Guiding technical principles and steps include:

- Literature research and study of both previous stocking and fishing data.
- Verification of the physical, chemical and biological properties of the water body in focus. It is especially important to check the range of available natural fish food and estimate the number of both aquatic and terrestrial predators (birds) of fish.
- The selection of suitable fish species together with their age/size groups for stocking should be proportional to the fish growing capacity of the water body.
- In natural waters stocking must be combined with regular fishing. This also provides an adequate follow up on the growth of stocked fish.

Though each natural water body is a unique ecosystem, figures presented in Table A10-1, A10-2 and A10-3 can be useful when CBF is planned.

TABLE A10-1: AGE GROUP AND NUMBER OF DIFFERENT FISH SPECIES FOR STOCKING INTO NATURAL WATERS, WHERE CULTURE BASED FISHERIES IS PRACTICED

Species	Eggs	Feeding larvae	Advanced fry	Fingerling/grower		Large fish	Brood fish
				(25-50 g)	(100-300 g)		
	(fish/ha)						
Cyprinids							
Common carp		1000-20000	100-400	200-600	200-400		1-2/20 ha
Grass carp	N/A			1000 [1]	100 [1]		
Silver/bighead carps	N/A				100-400		
Predator fish species							
Pikeperch	1000-5000		10-200	Max. 60	max 10		
European catfish	200-2000		100-200	Max. 50	30-35		
Expected survival rates							
Survival rate (%)	1-3	1-5	10-30	About 50	60-80	above 80	

Observation: *[1] The number also depends on the quantity of water weeds.*

(After [2])

TABLE A10-2: NUMBER AND SIZE OF YEARLY STOCKED CARPS WITH AN EXPECTED YIELD OF ABOUT 50-200 KG/HA IN WARMING UP NATURAL WATERS

Age group of fish	Stocking			Growing		Capture	
	Weight (fish/g)	Fish/ha	kg/ha	Years until harvest	Survival rate [1] (%)	Catchability (%)	Weight (kg)
Feeding larvae		15000	-	~ 3	0.5-1	~ 50	~ 1.5
Small advanced fry	0.2	1500	~ 0.3	2-3	1-5	~ 50	~ 1.5
Large advanced fry	0.5 – 1.0	320	0.2-0.3	2-3	10-30	~ 50	~ 1.5
Fingerling	20 – 30	230	4.5-7	~ 2	~ 35	~ 50	~ 1.5
	50 – 100	85	4-8.5	~ 2	~ 50	~ 50	~ 2
Grower	200 – 300	65	13-20	~ 1	60-80	~ 50	~ 2

Observation: *[1] The survival rate largely depends on the range of predator species present in the stocked water.*

TABLE A10-3: STOCKING OF DIFFERENT AGE/SIZE GROUPS OF TROUT FOR ANGLING TOURISM

Quantity	Age/size of stocked fish			
	Fry (0.2-0.5 g/fish)	Advanced fry (2 g/fish)	Juvenile (30-100 g/fish)	Grower (200 g/fish)
In streams (water flow: > 10-15 l/sec)	4-6 fish/10 m	1-3 fish/10 m	1-2 fish/15-20 m	1-2 fish/20-50 m [1]
In coldwater reservoirs or lakes	-	-	100 kg/ha	100-150 fish/ha
Expectable survival rate (%)	~ 30%	50-60%	90%	practically 100%

Observation: *[1] 1-3 fish/rapids*

(After [51])

2. RESULTS IN POND FISH CULTURE

2.1 REARING ADVANCED FRY

Rearing advanced fry of carps and selected predators which are also part of pond polyculture has a long experience in the region. The key characteristics and criteria of the advanced fry of commercially important carps and predator fish species are as follows:

- Fish ponds should be in good physical condition and should not be larger than a few hectares, as there is a negative correlation between chance for intensification, attainable results and the physical condition and size of pond.
- The usual way of rearing advanced fry in a pond is monoculture, but bi- or polycultures of peaceful species can also be feasible. However, it is important that the total number of stocked larvae should be the same as planned in a monoculture.
- In case of peaceful carps feeding is based on natural food, which is supplemented with good quality farm made compound or nutritionally balanced industrial feeds.
- Predator species are not fed, in their case natural food is the only source of nutrients.

Most widely followed stocking densities and related expectable results are presented in Table A10-4.

TABLE A10-4: PRODUCTION FIGURES OF REARING 3-6 WEEK OLD ADVANCED FRY IN POND CULTURE

Fish species	**Stocked (ha)**			**SVR %**	**Harvested (ha)**		
	Feeding larvae (1000 pcs.)	Size (g/fish)	Total weigh (kg)		Advanced fry (1000 pcs.)	Size (g/fish)	Total weigh (kg)
Cyprinids							
Carps	500-2000	-	-	30-40	150-800	0.2-2	300-400
Bream	eggs on nests	-	-	5-20	150-400	0.2-1	150-200
	500-1000	-	-	30-40			
Tench	500-1000	-	-	30-40	150-400	0.2-0.5	75-100
Predator fish species							
Pike	100-500	-	-	10-40	10-200	0.25-1.5	15-50
Pikeperch	Eggs on nests	-	-	5-20	50-400	0.25-1	50-100
	250-1000	-	-	20-40			
E. catfish	50-250	-	-	20-40	10-100	0.5-2	20-50
Sturgeons[1]							
Russian s.	75-80	0.08-0.1	7.5-8	30-50	23-40	1.5-2	45-60
Siberian s.	67-75	0.07-0.09	5.2-6	30-50	22-34	1.5-2	45-50
Stellate s.	60-80	0.06-0.08	~ 5	30-50	21-35	1.5-2	40-50
Beluga s.	90	0.1-0.12	~ 9	30-50	27-45	1.5-2	55-70
Sterlet	50-60	0.04-0.06	2.5-3	30-50	17-28	1.5-2	35-40
Paddlefish	60-65	0.04-0.06	3-3.5	30-50	20-30	1.5-2	40-45

(Source: [107], [1][11])

2.2 REARING TABLE FISH IN THREE-YEAR-LONG PRODUCTION CYCLES

Three-year-long production cycle of carps and selected predator fish species in pond polyculture is the traditional way of culturing fish in the region. Characteristics of this technique are:

- The number, individual size and total weight of fish produced in different intensities of pond polyculture are optimized. Accordingly, production cycle of table fish lasts for three years.
- There are many variations of the applied proportion of different carp species. Accordingly, either common carp or the two filter-feeding Chinese major carps (silver and bighead carps) are the main species. In ponds which are excessively covered with water weeds, grass carp may also be the main species.

- When any of the Chinese major carps are the main species, common carp is hardly or not even fed. When common carp is the main species, supplementary feeds discussed in Annex 6 should be used. Table A10-5 and A10-6 presents production figures of a three-year-long cycle of table fish production in pond polyculture, where common carp is the main species.
- When predator fishes are also stocked, it is important that they should be much smaller than peaceful carps.
  The quantity of predator fish species depends on the amount of trash fish entered and present in the pond.

FIGURE A10-1: SCREEN USED FOR PREVENTING THE ENTRY OF WILD FISH INTO THE POND WHILE IT IS FILLED UP

Such screening is especially important for advanced fry and fingerling rearing ponds.

TABLE A10-5: SIMPLIFIED SEMI-INTENSIVE PRODUCTION FIGURES OF REARING ONE- AND TWO-SUMMER-OLD STOCKING MATERIALS IN POND CULTURE – THE 1ST AND 2ND YEARS OF A THREE-YEAR PRODUCTION CYCLE

Fish species	Stocked (ha)			SVR %	Harvested (ha)		
	No. of fish	Size (g/fish)	Total weigh (kg)		No. of fish	Size (g/fish)	Total weigh (kg)
Semi-intensive production of one-summer-old fish							
C. carp	45000-60000	0.5	20-30	60	27000-36000	25	680-900
S. carp	15000-20000	0.5	10-10	60	9000-12000	25	230-300
Bh. Carp	5000-10000	0.5	5-5	60	3000-6000	25	80-150
G. carp	5000-10000	0.5	5-5	60	3000-6000	25	80-150
Predators	About 5-10% of the total number of fish stocked.						
Total	**70000-100000**	-	**40-50**	-	**42000-60000**	-	**1100-1500**
Semi-intensive production of two-summer-old fish							
C. carp	6000-8000	25	150-200	70	4200-5600	250	1050-1400
S. carp	1500-2500	25	40-60	70	1050-1750	250	260-440
Bh. Carp	500-1000	25	10-30	70	350-700	250	90-180
G. carp	500-1000	25	10-30	70	350-700	250	90-180
Predators	About 5-10% of the total number of fish stocked						
Total	**8500-12500**	-	**210-320**	-	**5950-8750**	-	**1500-2200**

(After: [52])

TABLE A10-6: SIMPLIFIED EXTENSIVE, SEMI-INTENSIVE AND INTENSIVE PRODUCTION FIGURES OF REARING TABLE FISH IN POND POLYCULTURE WHEN THE MAIN FISH IS COMMON CARP

Fish species	Stocked (ha)							SVR %	Harvested (ha)						
	No. of fish			Size (g/fish)	Total weigh (kg)				No. of fish			Size (g/fish)	Total weigh (kg)		
	Ext.	S.-Int.	Int.		Ext.	S-Int.	Int.		Ext.	S.-Int.	Int.		Ext.	S.-Int.	Int.
Extensive, semi-intensive and intensive production of table fish															
C. carp	500	700	1000	250	130	180	250	80	400	560	800	2000	800	1120	1600
S. carp	100	200	400	250	30	50	100	80	80	160	320	2000	160	320	640
Bh. Carp	10	50	50	250	0	10	10	80	8	40	40	2000	20	80	80
G. carp	40	50	50	250	10	10	10	80	32	40	40	2000	60	80	80
Predators	About 5-10% of the total number of fish stocked. They should be much smaller than the rest of the fish.														
Total	**650**	**1000**	**1500**		**170**	**250**	**370**		**520**	**800**	**1200**		**1040**	**1600**	**2400**

2.3 REARING OF TABLE FISH IN TWO-YEAR-LONG PRODUCTION CYCLES

From a three-year-long production cycle, the first two years should be reduced into one year. The basic criterions of shortening the production cycle are:

- Nutritionally balanced and complete industrial feeds should be used that ensure fast growth of common carp. For common carp, these are ALLER TOP and ALLER CLASSIC, which should be used as advised in Aller Aqua datasheets: https://www.aller-aqua.com/species/warm-freshwater-species/carp.
- Abundant space should be ensured for the proper growth of Chinese major carps.

In the two-year-long production cycle the first year is vital as this is the period which differs from the three-year-long production cycle. The differences are summarised in Table A10-7.

TABLE A10-7: EXPECTABLE RESULTS OF THE PRODUCTION OF 200-250 G LARGE STOCKING MATERIALS WITHIN THE FIRST YEAR OF A TWO-YEAR-LONG PRODUCTION CYCLE

Species	Stocked (ha)			SVR (%)	Harvested (ha)		
	No. of fish	Size (g/fish)	Total weight (kg)		No.	Avg. weight (g/fish)	Total weight (kg)
Two-year-long production cycle - 1st year in one step (~4 months)							
Common carp	11 000	0.5	6	70	7700	200-250	1540-1930
Silver and BH carps	3 000	0.5	2	70	2100	200-250	420-530
Grass carp	1 000	0.5	0.5	70	700	200-250	140-180
Total	**15000**		**8-9**	**70**	**10500**		**2100-2640**
Two-year-long production cycle - 1st year in two steps							
1st step (~1.5 months)							
Common carp	36000	0.5	20	60	21600	10-20	220-430
Silver and BH carps	11500	0.5	10	60	6900	10-20	70-140
Grass carp	2500	0.5		60	1500	10-20	20-30
Total	**50000**		**30**	**60**	**30000**		**300-600**
2nd step (~2.5 months)							
Common carp	11000	10-20	170	70	7700	200-250	1540-1930
Silver and BH carps	3000	10-20	50	70	2100	200-250	420-530
Grass carp	1000	10-20	20	70	700	200-250	140-180
Predator fish	About 5-10% of the total number of fish stocked. They should be much smaller than the rest of the fish.						
Total	**15000**		**240**		**10500**		**2100-2640**

The production of table fish in the second year should be done in the same way as in the three-year-long production cycle presented in Table A10-6.

3. RESULTS IN INTENSIVE CULTURE SYSTEMS

In case of intensive culture systems it is essential to use nutritionally complete industrial feeds. Without reliable feeds the healthy growth of fish cannot be ensured.

The range of expectable production results presented in the three subsequent subchapters are based on and linked to Aller Aqua feeds. In practical fish culture the following figures of intensive culture systems have prime importance:

- **Attainable individual growth and size of fish:** The initial and final weight of each size groups of reared fish allow to calculate both the growth and the quantity of feed that should be used to attain this growth.
- **Initial stocking density of fish:** The stocking figures presented in this chapter intends to provide for reliable orientation how stocking density changes by species and size groups of fish. These figures are also specific to the different structures/devices used in intensive culture systems.
- **Time (months) required to attain the expected growth:** In the subsequent figures growth of all fish groups was uniformly calculated at optimal water temperature characteristics to the species. This is the case when growth of fish is the shortest provided that other water properties including DO remain also in favourable ranges.
- **Quantity and quality of feed:** Together with many practical information of the book on the feeds to be used both their quality and quantity are shown in Table A-2 and A-3 of the Appendix.

For the sake of easy finding and orientation figures which show the growth curves in the below chapters are:

- Figures with growth curves of cold freshwater species; Figure A10-2, A10-3 and A10-4.
- Figures with growth curves of warm freshwater species; Figure A10-6, A10-7, A10-8, A10-10, A10-11, A10-12 and A10-13.
- Figures with growth curves of tropical freshwater species; Figure A10-15, A10-16 and A10-17.

Stocking density is also an important information. Though there is a wide range of stocking densities applied in practical fish culture, they are rather similar within the different groups and sizes of fish (coldwater, warmwater, tropical, air breathing, etc.) reared in intensive culture systems. Most probably it is only sturgeon species, especially their larger specimens which are the exceptions.

The initial number of stocked fish depends on the quality and quantity of water supply and aeration (even oxygenation). For this reason, there are no uniform equally applicable stocking numbers. Still stocking figures presented in Table A10-8 and A10-9 (salmonids), Table A10-10 (sturgeons) Table A10-11 (common carp and tench), Table A10-12 and A10-13 (eel and European catfish), Table A10-14 and A10-15 (pike and pikeperch), Table A10-16 (tilapia) and Table A10-17 (African catfish and pangasius) can be useful at planning.

At the calculation of stocking numbers, the water exchange in **small earthen ponds** (wintering and traditional Danish ponds) is assumed extensive; it is done only a few times (about 0.1-4 times) a day, if it is done at all especially at the beginning of the rearing period. In smaller or larger in- and outdoor **tanks** it is assumed that water exchange is intensive. It is done several times a day even hourly, while in fish seed rearing troughs/tanks the exchange of water can be much more intensive. It is to note that in the subsequent stocking tables extreme high stocking numbers are excluded.

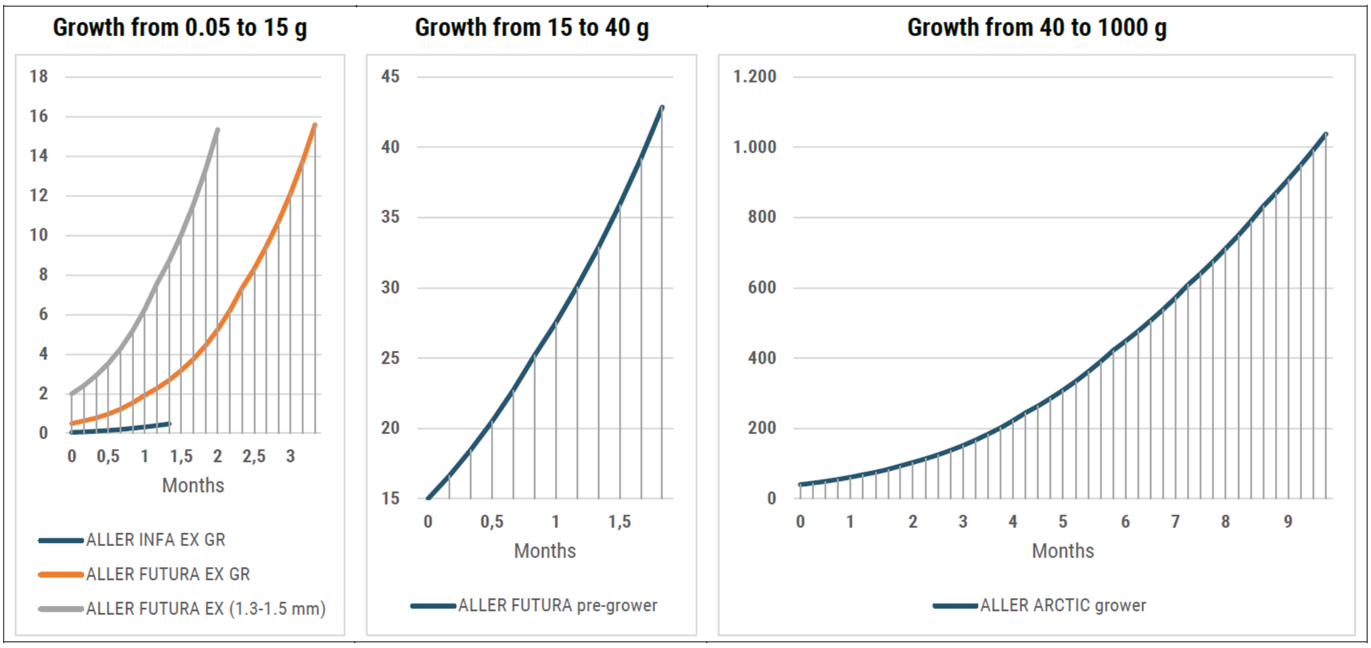
3.1 COLD FRESHWATER SPECIES

In this chapter tables and curves of the key production data of Arctic charr, brown trout, white fish and rainbow trout are presented.

TABLE A10-8: APPROXIMATE INITIAL STOCKING DENSITIES OF ARCTIC CHARR AND WHITEFISH IN INTENSIVE CULTURE SYSTEMS

Type of culture device	**Initial mean stocking densities in subsequent size groups (initial and final weight in grams)**										
	0.05-0.1	0.1-0.2	0.2-0.3	0.3-0.5	0.5-2	2-7	7-15	15-40	40-100	100-400	400-1000
	Number of fish (No. fish/m³)										
Earthen pond								200	100	40	20
Trough, tank	15000	10000	8500	6000	4000	1500	1000	500	250	100	50
Hapa, cage					3000	1000	750	400	200	70	40

FIGURE A10-2: REARING ARCTIC CHARR AND WHITEFISH IN INTENSIVE CULTURE SYSTEMS (WATER TEMPERATURE: 16 ^{0}C)

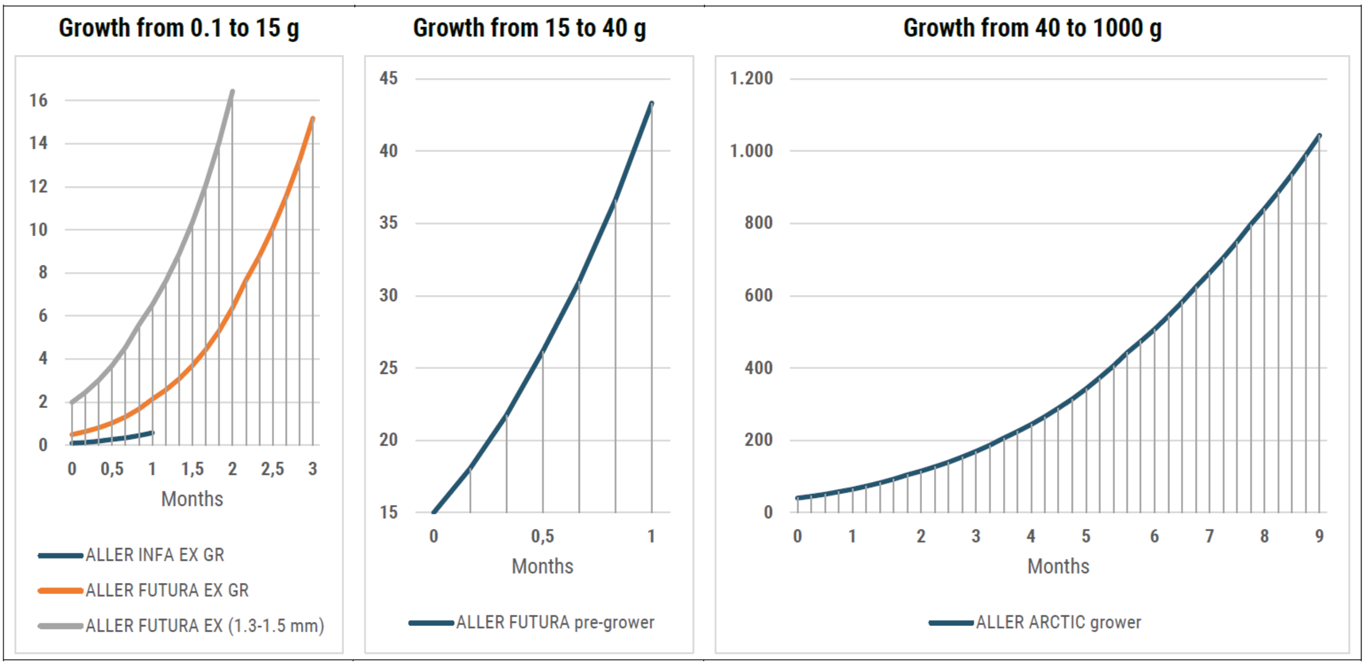


Observation: *See details in Table A-3 of the Appendix.*

TABLE A10-9: APPROXIMATE INITIAL STOCKING DENSITIES OF BROWN AND RAINBOW TROUT IN INTENSIVE CULTURE SYSTEMS

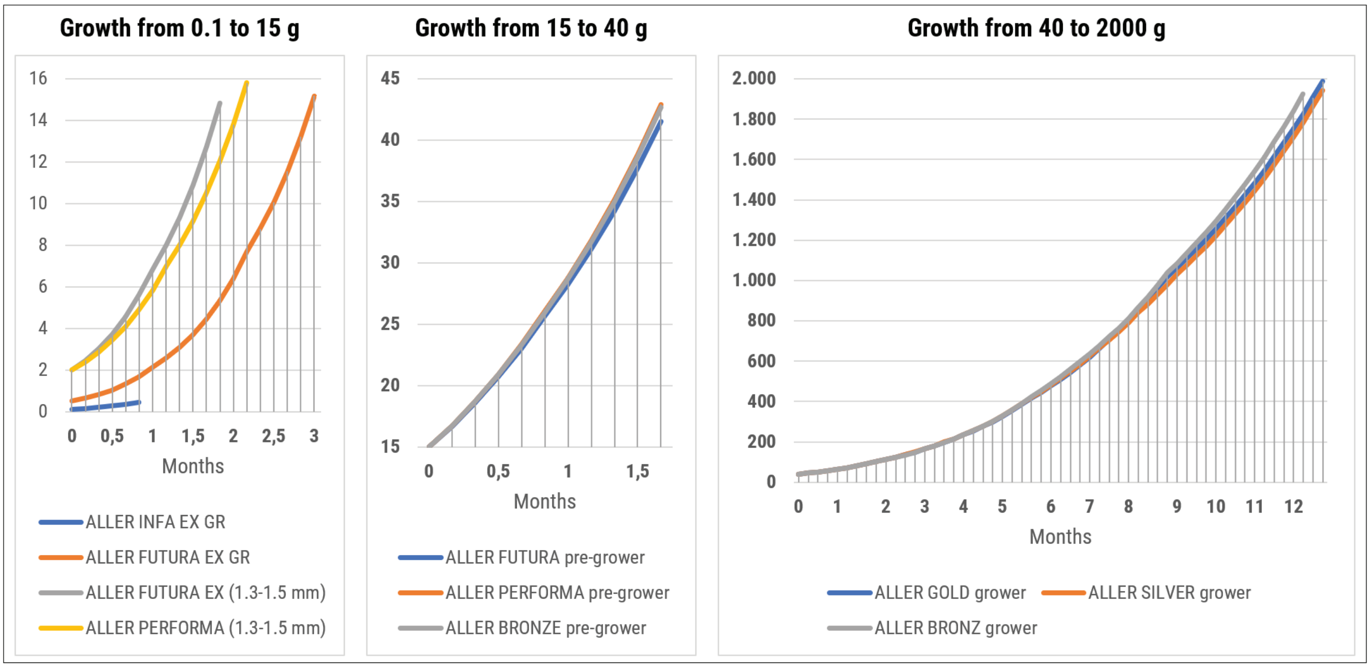
Type of culture device	Initial mean stocking densities in subsequent size groups (initial and final weight in grams)										
	0.1-0.2	0.2-0.3	0.3-0.5	0.5-2	2-7	7-15	15-40	40-100	100-400	400-1000	1000-2000
	Number of fish (No. fish/m^3)										
Earthen pond							200	100	40	20	10
Trough, tank	10000	8500	6000	4000	1500	1 000	500	250	100	50	25
Hapa, cage				3000	1000	750	400	200	70	40	20

FIGURE A10-3: REARING BROWN TROUT IN INTENSIVE CULTURE SYSTEMS (WATER TEMPERATURE: 16 ^{0}C)



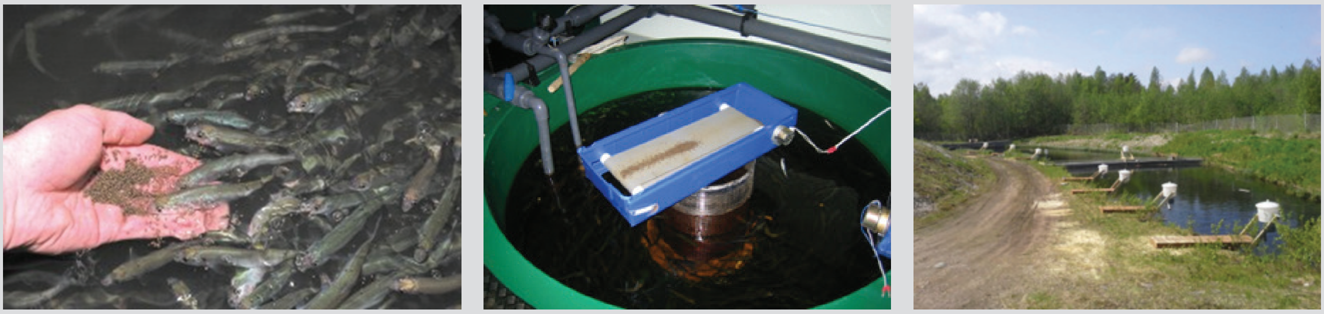
Observation: *See details in Table A-3 of the Appendix.*

FIGURE A10-4: REARING RAINBOW TROUT IN INTENSIVE CULTURE SYSTEMS (WATER TEMPERATURE: 16 ^{0}C)



Observation: *See details in Table A-3 of the Appendix.*

FIGURE A10-5: FEEDING COLD FRESHWATER FISH



(Source of photos: Presentation of Vesa Määttä on 'Rearing advanced Fry of Coregonids', FAO – CACFish Regional Workshop, Bishkek 27-30 October 2014)

A good example how well fish can be domesticated (Left). Automatic belt feeder for fry (Centre). Demand feeders used outdoor (Right).

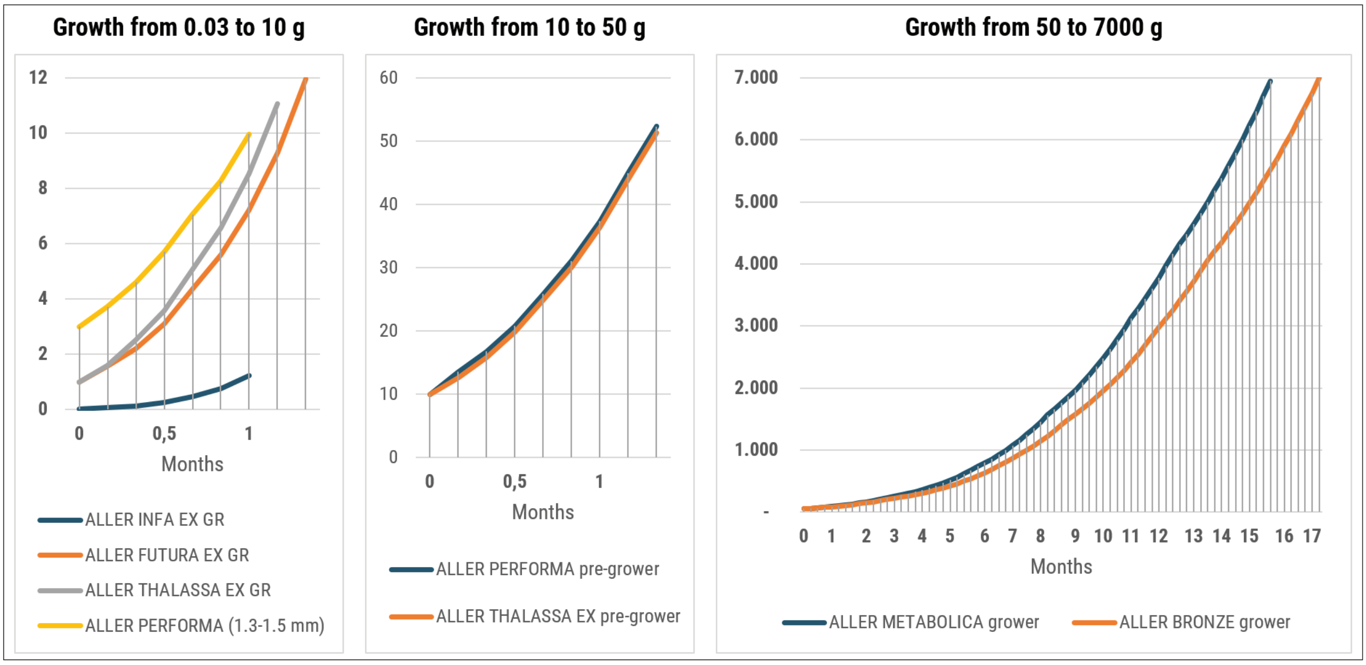
3.2 WARM FRESHWATER SPECIES

In this chapter tables and curves of the key production data of sturgeon, common carp, tench, eel, European catfish, perch and pikeperch are presented.

TABLE A10-10: APPROXIMATE INITIAL STOCKING DENSITIES OF STURGEONS IN INTENSIVE CULTURE SYSTEMS

Type of culture device	**Initial mean stocking densities in subsequent size groups (initial and final weight in grams)**													
	0.03-0.2	0.2-0.5	0.5-1	1-5	5-10	10-25	25-50	50-100	100-200	200-800	800-1500	1500-3000	3000-4000	4000-7000
	Number of fish (No. fish/m³)													
Earthen pond				150	100	40	40	25	18	5	3	2	1	1
Trough, tank	2500	1500	1000	500	300	200	150	100	75	25	20	10	8	4
Hapa, cage		1050	700	350	210	140	105	70	53	18	14	7	5	3
Enclosure				150	100	40	40	25	18	5	3	2	1	1

FIGURE A10-6: REARING STURGEON IN INTENSIVE CULTURE SYSTEMS (WATER TEMPERATURE: 18 °C)



Growth from 0.03 to 10 g

Growth from 10 to 50 g

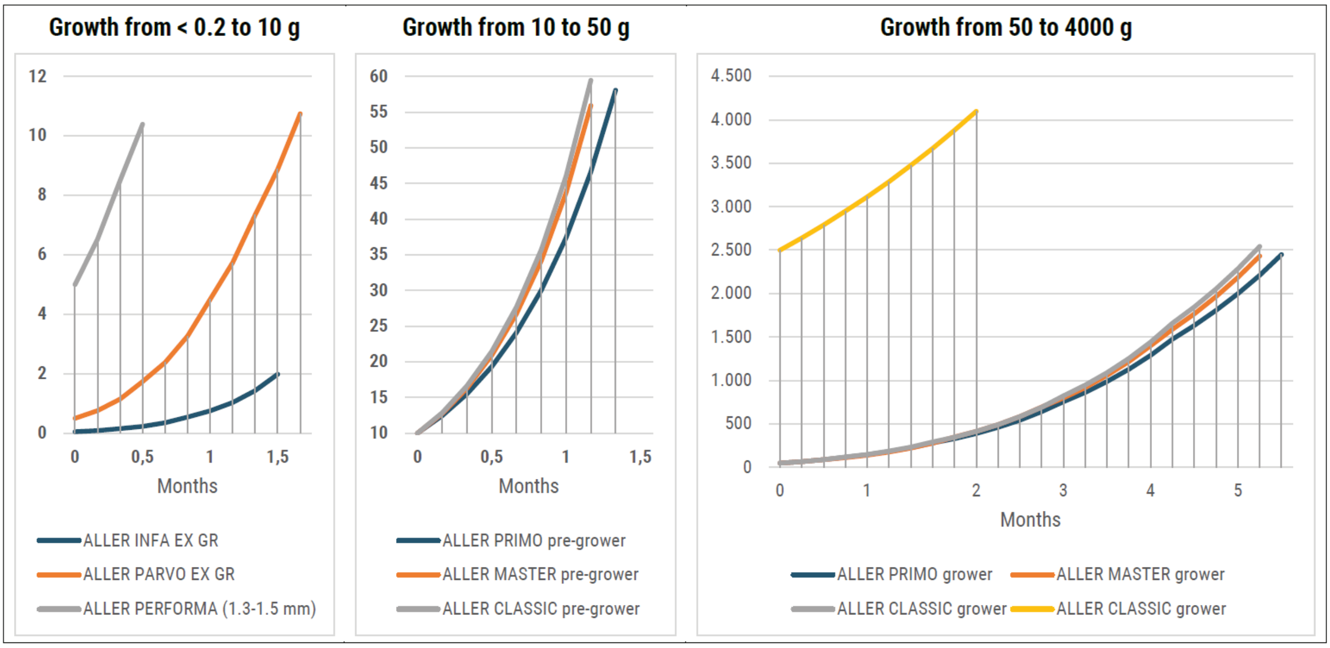
Growth from 50 to 7000 g

Observation: *See details in Table A-3 of the Appendix.*

TABLE A10-11: APPROXIMATE INITIAL STOCKING DENSITIES OF COMMON CARP AND TENCH IN INTENSIVE CULTURE SYSTEMS

Type of culture device	Initial mean stocking densities in subsequent size groups (initial and final weight in grams)											
	≤ 0.2	0.2-0.5	0.5-2	2-5	5-8	8-10	10-50	50-100	100-300	300-500	500-1500	1500-2500
	Number of fish (No. fish/m³)											
Earthen pond				150	130	100	40	25	12	8	3	2
Trough, tank	10000	6000	4000	2000	1560	1250	300	200	80	60	30	15
Hapa, cage	7000	4200	2800	1400	1100	880	210	140	60	40	20	10
Enclosure				150	125	100	40	25	12	8	3	2

FIGURE A10-7: REARING COMMON CARP IN INTENSIVE CULTURE SYSTEMS (WATER TEMPERATURE: 24 °C)



Observation: *See details in Box A10-1 and Table A-3 of the Appendix.*

Feeding common carp during winters

Though the metabolism of common carp slows down during winter months, still, a regularly offered, adequate quantity of high-quality feed can reduce, or even eliminate winter losses. The role of Aller Aqua products in feeding common carp during wintering has recently been summarised by Kozák [64]. He suggests the use of feeding trays, where Aller Primo common carp feed is given to fish, under a close monitoring. He estimates the necessary amount of feed as about 0.05-0.1% of the body weight, when the water temperature is around 4 °C.

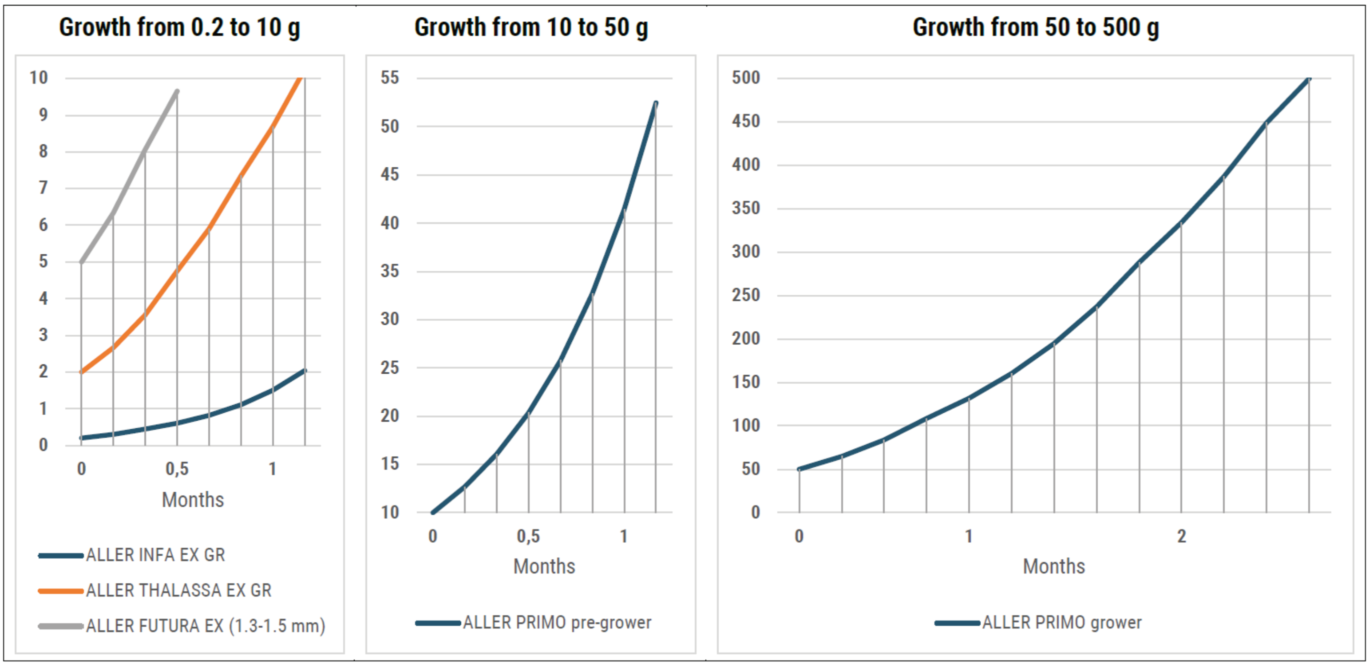
BOX A10-1: ALLER INFA EX GR FOR COMMON CARP AS FIRST FEED

Advanced fry rearing of 0.2-2 large common carp in fertilized ponds with supplementary feeds is widely practiced in the region. Still, there are cases when the use of a reliable first feed, such as ALLER INFA EX GR (0.1-0.4 mm) is technically inevitable, as well as financially justifiable.

One of the typical situations is when due to a persisting cold front common carp larvae produced in the hatchery cannot be stocked. Another situation is when there is no suitable pond, only tanks or hapas where feeding larvae can be reared to a larger size.

In such cases a combined first feeding of live food (Artemia or zooplankton) and the suitable size of ALLER INFA EX GR serve the purpose well.

FIGURE A10-8: REARING TENCH IN INTENSIVE CULTURE SYSTEMS (WATER TEMPERATURE: 24 °C)



Observation: *See details in Table A-3 of the Appendix.*

BOX A10-2: SIZE OF THE FIRST FEED OF FEEDING LARVAE OF SELECTED WARM FRESHWATER FISH SPECIE

It was described by Horvath and Tamás [97] already in the early 1970’s that one of the most important limiting factors of feeding fish larvae and early fry is to supply them with proper size of food/feed which can be consumed, preyed easily. It is because they observed that fish larvae starved even in waters rich in zooplankton, if their size was too large for the feeding larvae to grab and swallow.

Therefore, the size of the first food of larvae and early fry of many commercially important warm freshwater fishes were observed and published. Accordingly, in case of common carp it is 100-300 µm, while the size of the first feed of tench, European catfish and pikeperch is around 50-100 µm, 200-500 µm and 50-150 µm respectively [53]. These practical information helps and supports the selection of the right first feed of these fish species.

Traditionally CBF and pond culture were the only source to supply the market with eel and warm freshwater predators. The elaboration of their production technologies in intensive culture systems have been accomplished including the complete range of feeds for all size categories.

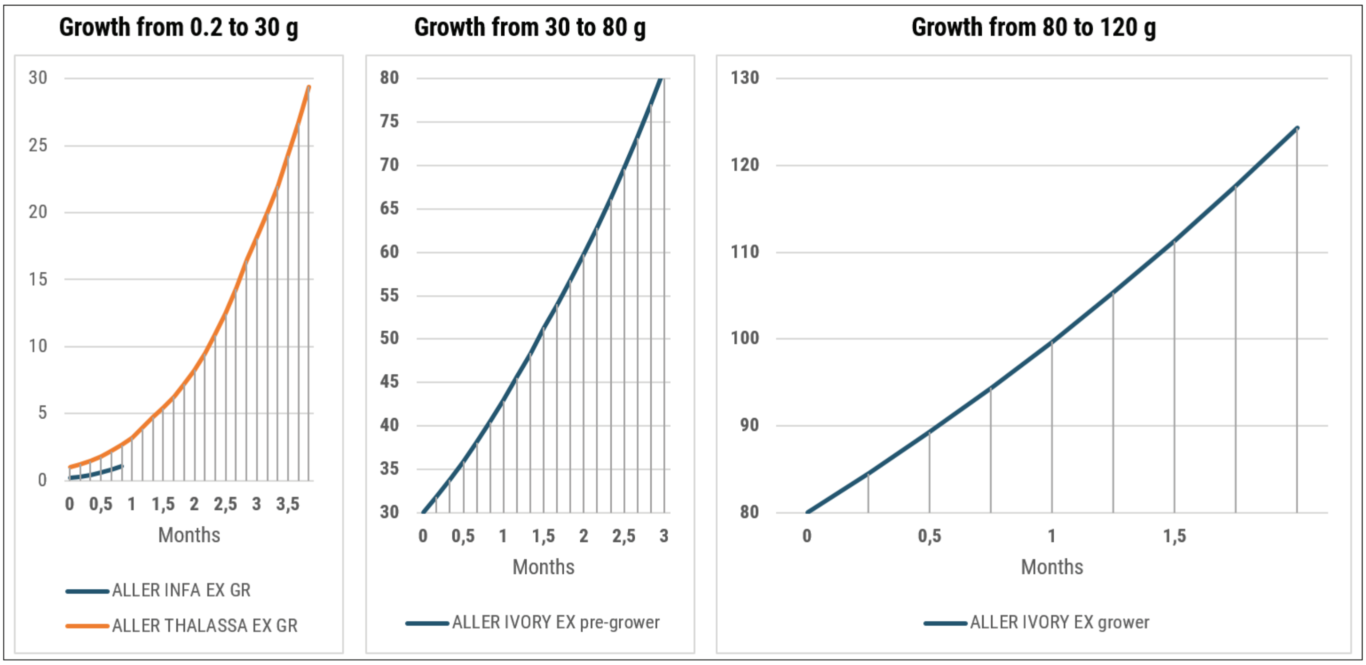
In the subsequent section of this chapter the key production figures of eel, European catfish, perch and pikeperch are presented.

FIGURE A10-9: EUROPEAN CATFISH - A SPECIES OF THE FUTURE

TABLE A10-12: APPROXIMATE INITIAL STOCKING DENSITIES OF EEL IN INTENSIVE CULTURE SYSTEMS

Type of culture device	**Initial mean stocking densities in subsequent size groups (initial and final weight in grams)**							
	0.2- 0.5	0.5-1	1-5	5-15	15-30	30-80	80-120	120-250
	Number of fish (No. fish/m^3)							
Trough, tank	6000	5000	4000	1500	1500	600	500	250

FIGURE A10-10: REARING EEL IN INTENSIVE CULTURE SYSTEMS (WATER TEMPERATURE: 24 °C)

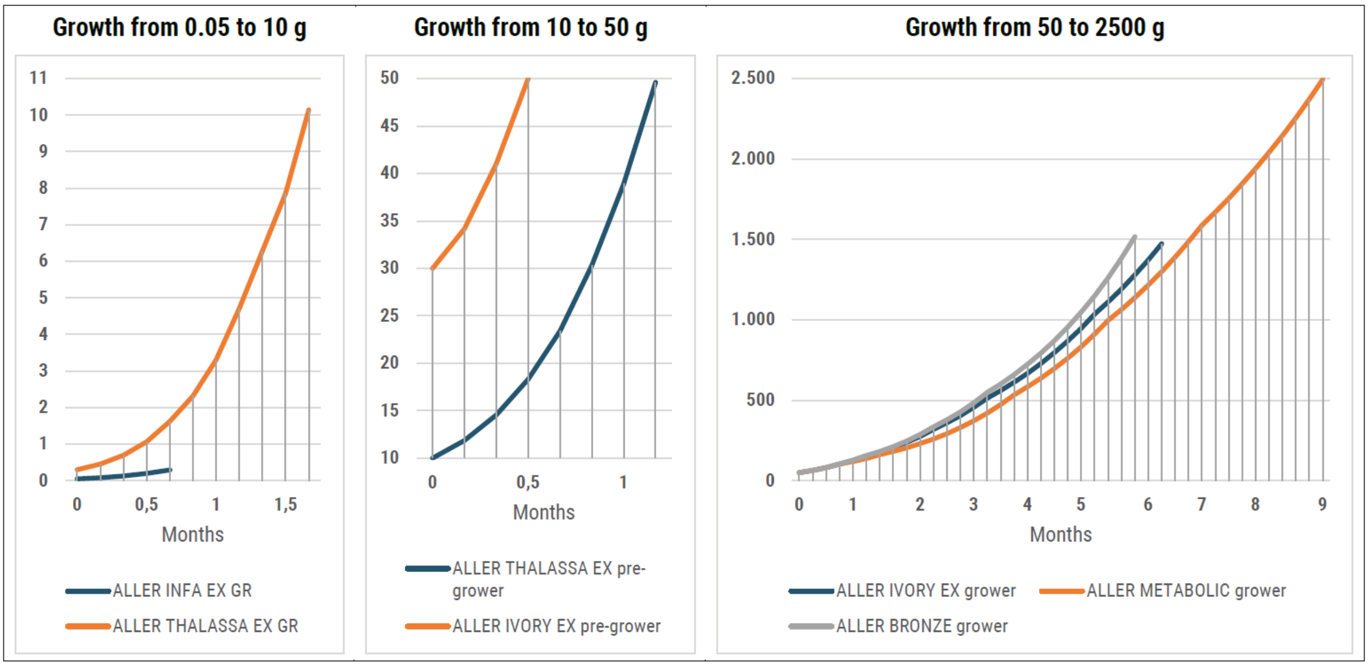


Observation: *See details in Table A-3 of the Appendix.*

TABLE A10-13: APPROXIMATE INITIAL STOCKING DENSITIES OF EUROPEAN CATFISH IN INTENSIVE CULTURE SYSTEMS

Type of culture device	Initial mean stocking densities in subsequent size groups (initial and final weight in grams)										
	0.05-0.1	0.1-0.3	0.3-1.5	1.5-4	4-10	10-50	50-150	150-500	500-1000	1000-1500	1500-2500
Number of fish (No. fish/m³)											
Earthen pond				125	100	40	20	8	4	3	2
Trough, tank	15000	8500	5000	2500	1250	300	150	60	40	30	15
Hapa, cage		6000	3500	2000	1000	200	130	40	30	20	10
Enclosure				125	100	40	20	8	4	3	2

FIGURE A10-11: REARING EUROPEAN CATFISH IN INTENSIVE CULTURE SYSTEMS (WATER TEMPERATURE: 26 °C)

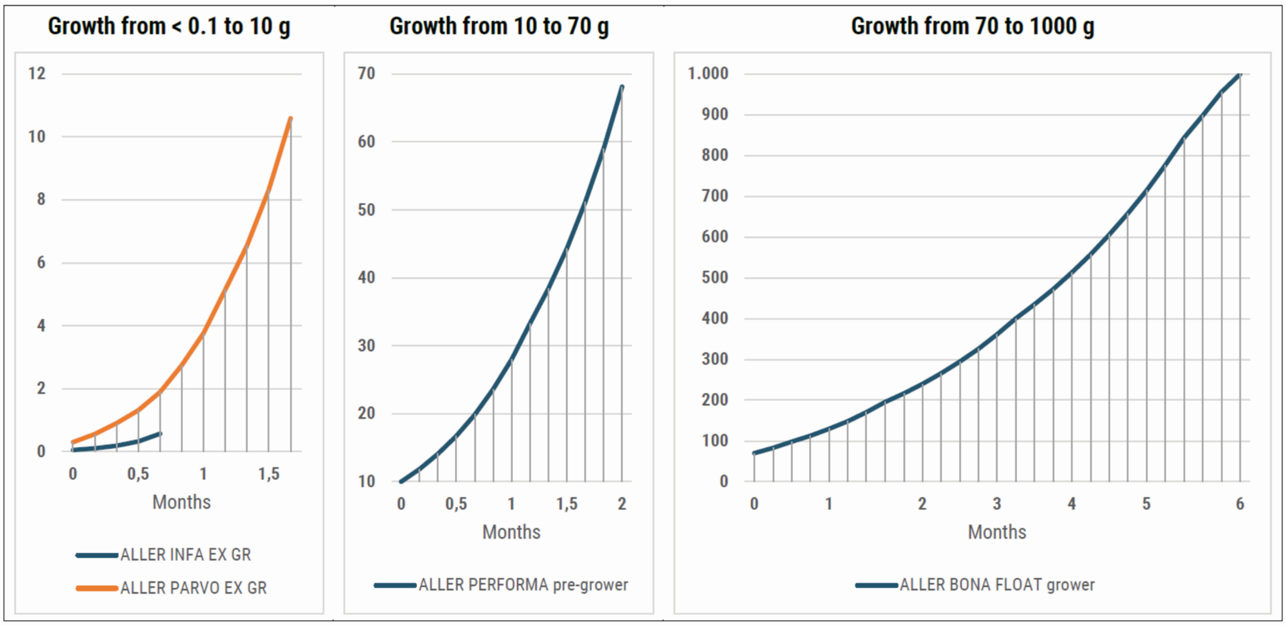


Observation: *See details in Table A-3 of the Appendix.*

TABLE A10-14: APPROXIMATE INITIAL STOCKING DENSITIES OF PERCH IN INTENSIVE CULTURE SYSTEMS

Type of culture device	**Initial mean stocking densities in subsequent size groups (initial and final weight in grams)**									
	0.05-0.2	0.2-0.5	0.5-1	1-4	4-7	7-10	10-20	20-50	50-150	150-500
	Number of fish (No. fish/m^3)									
Trough, tank	10000	6000	4000	2500	1500	1000	500	300	150	60

FIGURE A10-12: REARING PERCH IN INTENSIVE CULTURE SYSTEMS (WATER TEMPERATURE: 26 °C)

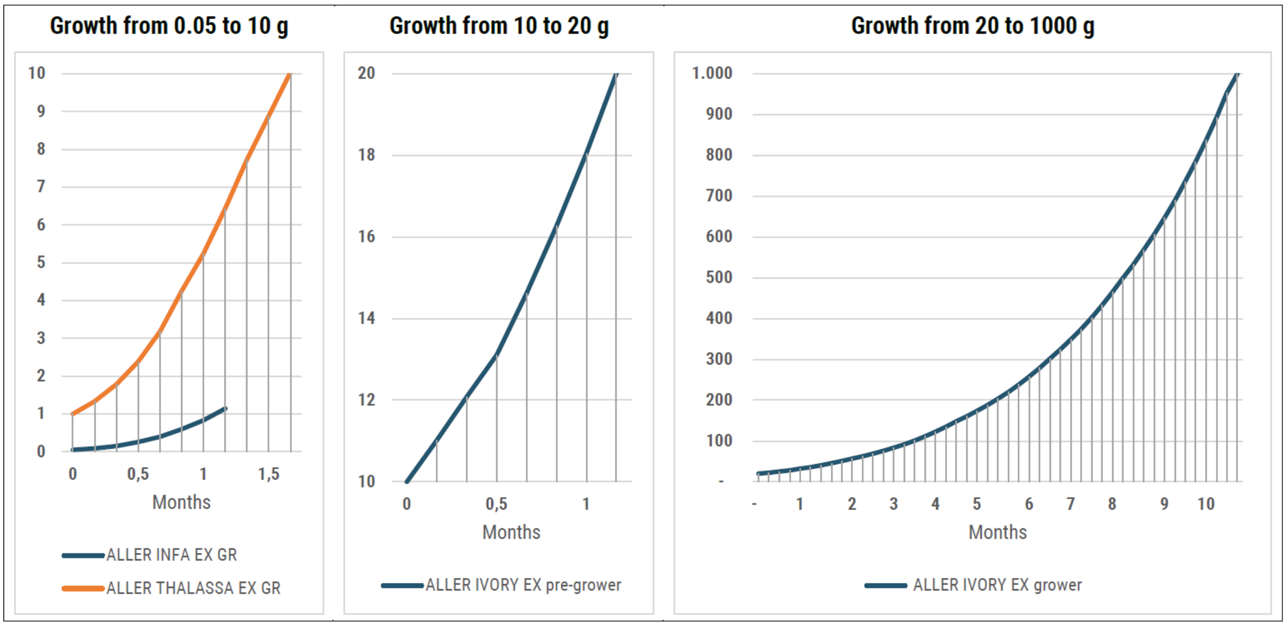


Observation: *See details in Table A-3 of the Appendix*

TABLE A10-15: APPROXIMATE INITIAL STOCKING DENSITIES OF PIKEPERCH IN INTENSIVE CULTURE SYSTEMS

Type of culture device	**Initial mean stocking densities in subsequent size groups (initial and final weight in grams)**										
	0.05-0.2	0.2-0.5	0.5-1	1-4	4-7	7-10	10-20	20-50	50-150	150-500	500-1000
	Number of fish (No. fish/m^3)										
Trough, tank	10000	6000	4000	2500	1500	1000	500	300	150	60	30

FIGURE A10-13: REARING PIKEPERCH IN INTENSIVE CULTURE SYSTEMS (WATER TEMPERATURE: 26 °C)



Observation: *See details in Table A-3 of the Appendix.*

3.3 TROPICAL FRESHWATER SPECIES

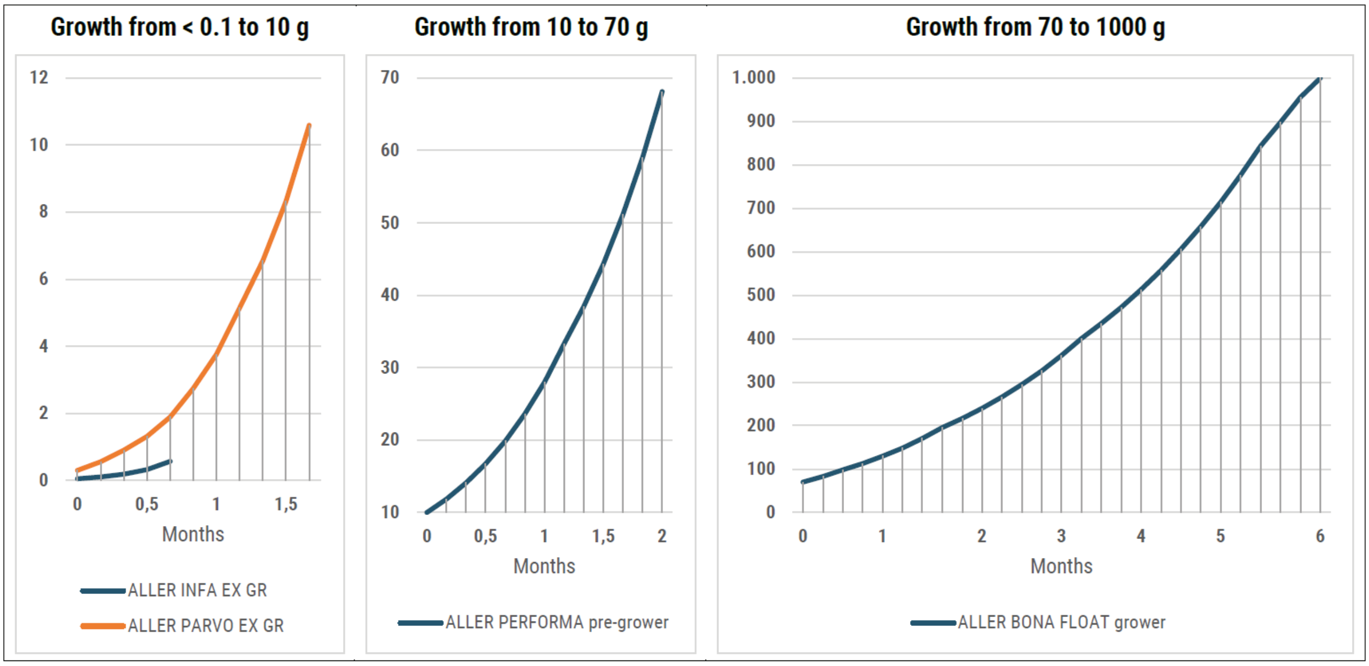
Production of tropical species especially tilapia and African catfish in intensive culture systems is increasingly practiced. In warmer countries of the region, they are reared in wintering ponds during summers, but typically they are reared in thermal-water-based fish farms, often in RAS.

FIGURE A10-14: AFRICAN CATFISH IN A HUNGARIAN FISH FARM

TABLE A10-16: APPROXIMATE INITIAL STOCKING DENSITIES OF TILAPIA IN INTENSIVE CULTURE SYSTEMS

Type of culture device	Initial stocking densities at different size groups (No./m³)										
	≤ 0.1	0.1-0.3	0.3-0.5	0.5-1	1-6	6-10	10-70	70-200	200-500	500-800	800-1000
	Number of fish (No. fish/m³)										
Earthen pond				500	125	100	15	10	8	6	5
Trough/tank	15000	8500	6000	4000	1500	1000	250	100	60	50	40
Hapa/cage		6000	4500	3000	1200	700	150	70	40	35	30
Enclosure				500	125	100	15	10	8	6	5

FIGURE A10-15: REARING TILAPIA IN INTENSIVE CULTURE SYSTEMS (WATER TEMPERATURE: 28 °C)

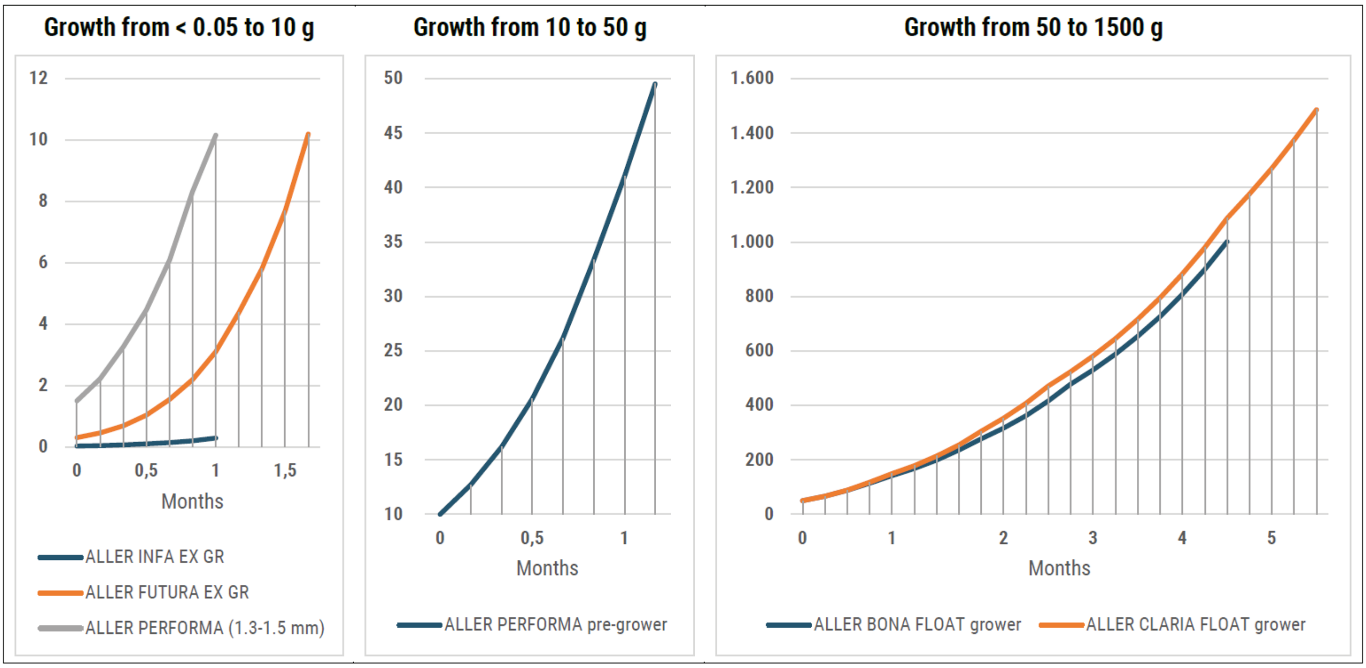


Observation: *See details in Table A-3 of the Appendix.*

TABLE A10-17: APPROXIMATE INITIAL STOCKING DENSITIES OF AFRICAN CATFISH AND PANGASIUS IN INTENSIVE CULTURE SYSTEMS

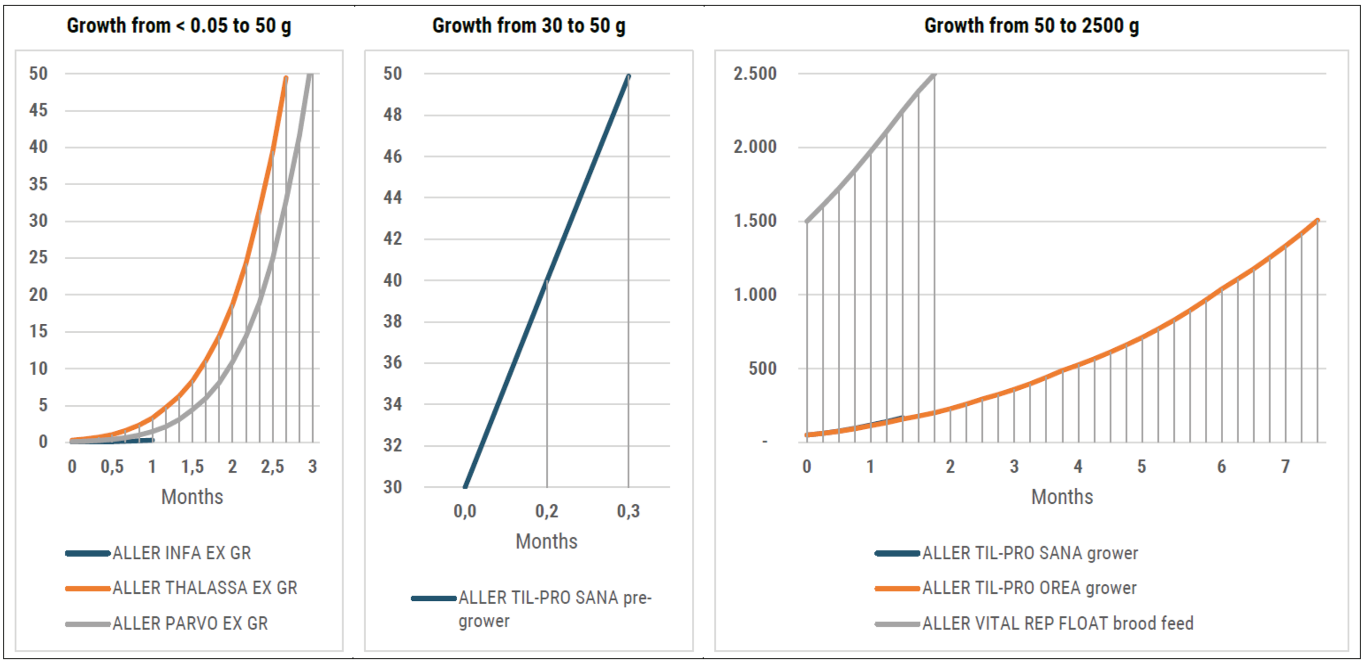
Type of culture device	Initial mean stocking densities in subsequent size groups (initial and final weight in grams)									
	< 0.05	0.05-0.1	0.1-0.3	0.3-1.5	1.5-4	4-10	10-50	50-150	150-500	500-1000	1000-1500
	Number of fish (No. fish/m³)										
Earthen pond				1000	500	300	80	35	15	10	7-8
Trough, tank	20000	15000	8500	5000	5000	5000	2000	1500	600	500	350
Hapa, cage	12000	9000	5000	3000	3000	3000	1200	800	360	300	200
Enclosure				1000	500	300	80	35	15	10	7-8

FIGURE A10-16: REARING AFRICAN CATFISH IN INTENSIVE CULTURE SYSTEMS (WATER TEMPERATURE: 26 °C)



Observation: *See details in Table A-3 of the Appendix.*

FIGURE A10-17: REARING PANGASIUS IN INTENSIVE CULTURE SYSTEMS (WATER TEMPERATURE: 26-30 °C)



Observation: *See details in Table A-3 of the Appendix*

APPENDIX

The presentation of the tables in this appendix aims to support farmers in selecting both supplementary feeds used in pond culture and nutritionally complete industrial feeds used in intensive culture systems.

The first table lists the composition and energy of natural fish foods, feed ingredients, and supplementary feeds. Because of reasons (each crop may differ) discussed in Annex 5, the composition of each item listed in Table A-1 is informative. It should be observed accordingly, even if several decades of field experiences proved worldwide that such accuracy in the presentation of composition of supplementary feeds is adequate to be used successfully in fish farms.

Out of the wide range of Aller Aqua feeds, the second table presents a selection produced for freshwater fish species most frequently used in the region. Therefore, contrary to Table A-1, this table contains declared compositions.

The third table contains some key details on those Aller Aqua feeds which are summarised in Annex 10. These details support the planning of both the quantity and the programming of selected feeds. Here, in addition to the type of feed, the size, the growth stage (initial and final weight) of fed fish, and the FCR of feed are listed, together with the estimated quantities of feeds required for the growth of thousand fish. In these tables, the expectable growth of fish at optimum temperature is also estimated. This latter one, of course, will be proportionally longer in colder and warmer water.

CONTENT

TABLE A-1: APPROXIMATE COMPOSITION OF NATURAL FISH FOODS, FEEDS AND FEED INGREDIENTS WIDELY USED IN POND CULTURE IN THE REGION [1]

Type of feeds	Approx. composition of fish foods and feeds calculated on "as-fed" basis (values in %)									Avg. Energy (MJ/kg)		Approx. composition of fish foods and feeds calculated on DM basis (values in %)						
	Moist	**DM**	**CP**	**CL**	**CF**	**NFE**	**CA**	**Ca**	**P**	**GE**	**DE**	**CP**	**CL**	**CF**	**NFE**	**CA**	**Ca**	**P**
1. Natural fish foods																		
1.1 Bacterium-plankton																		
Bacteria	80.0	20.0	13.2	1.3	0.3	2.7	2.5			4.7	2.9	66.0	6.5	1.5	13.5	12.5		
1.2 Phytoplankton																		
Algae (*Chlorella vulgaris*)	85.0	15.0	6.7	1.2	1.3	3.6	2.1			3.2	1.9	44.8	8.3	8.7	24.0	14.2		
Algae (*Spirulina maxima*)	85.0	15.0	10.4	1.0	0.1	2.3	1.2			3.7	2.3	69.3	6.7	0.5	15.3	8.1		
Algae (*Scenedesmus obliques*)	85.0	15.0	8.4	2.1	1.0	2.2	1.3			3.7	2.3	56.0	13.8	6.9	14.4	8.5		
Algae - sewage-grown	85.0	15.0	8.0	1.0	0.7	3.2	2.1			3.3	2.0	53.1	6.8	4.7	21.2	14.2		
Chara (C. vulgaris)	91.6	8.4	1.1	0.1	1.6	4.0	1.6			1.4	0.7	13.2	1.2	19.0	48.1	18.5		
1.3 Water weeds																		
Duckweed	95.8	4.2	1.0	0.2	0.6	1.4	0.9			0.7	0.4	22.8	5.1	13.5	33.6	21.2	2.8	1.0
Azolla	76.6	23.4	6.2	0.8	9.2	3.6	3.5			4.6	1.7	26.6	3.6	39.2	15.5	15.1		
Aquatic macro-vegetation (soft)	84.2	15.8	2.3	0.7	1.6	9.0	2.2			2.8	1.7	14.6	4.5	10.0	57.0	13.9		
Aquatic macro-vegetation (hard)	75.0	25.0	3.8	0.9	5.0	6.6	8.8			3.5	1.7	15.0	3.5	20.0	26.5	35.0		
1.4 Zooplankton																		
Crustacea – Cladocera	90.2	9.8	5.5	1.9		1.6	0.8			> 2.5	> 1.8	56.5	19.3		16.5	7.7		
Crustacea – Copepods	89.7	10.3	5.4	2.7		1.5	0.7			> 2.8	> 2.1	52.3	26.4		14.2	7.1		
Rotifers	88.8	11.2	7.2	2.3		1.0	0.7			> 3.1	> 2.2	64.3	20.3		9.2	6.2		
1.5 Insects																		
Artemia – Adult	65.0	35.0	19.7	4.1	1.0	4.2	6.1			8.0	5.4	56.4	11.8	2.9	12.1	17.4		
Artemia – nauplii	80.0	20.0	10.0	3.8	1.0	3.0	1.9			5.0	3.4	50.2	18.9	5.0	14.8	9.7		
Crustacea – Malacostraca	75.4	24.6	12.3	5.0			4.8			> 5.3	> 3.9	49.9	20.3			19.6		
Insects (miscellaneous)	76.8	23.2	13.0	4.3			1.1			> 5.3	> 3.8	55.9	18.6			4.9		
Insects - Chironomids (larvae)	80.9	19.1	11.3	0.9			1.1			> 3.5	> 2.3	59.0	4.9			5.8		
1.6 Worms and molluscs																		
Molluscs	67.8	32.2	12.7	2.5			10.6			> 4.5	> 3.1	39.5	7.8			32.9		
Oligochaetes	92.7	7.3	3.6	1.4			0.4			> 1.5	> 1.1	49.3	19.0			5.8		
1.7 Fish																		
Raw fish (fatty freshwater omnivore)	65.0	35.0	13.0	20.0	1.0	1.0	1.0			11.6	9.1	37.1	57.1	2.9	2.9	2.9		

[1] *After [50], [98], [78] and [86].*

Type of feeds	Approx. composition of fish foods and feeds calculated on "as-fed" basis (values in %)									Avg. Energy (MJ/kg)		Approx. composition of fish foods and feeds calculated on DM basis (values in %)						
	Moist	DM	CP	CL	CF	NFE	CA	Ca	P	GE	DE	CP	CL	CF	NFE	CA	Ca	P
Raw fish (not fatty freshwater)	75.0	25.0	17.0	9.0	0.1	0.1	1.0			8.2	6.0	68.0	36.0	0.4	0.4	4.0		
Raw fish (low oil, low protein)	83.0	17.0	13.3	1.3	0.0	0.0	1.9			4.2	2.8	78.2	7.6	0.0	0.0	11.0		
Raw fish (low oil, high protein)	81.5	18.5	16.3	0.6	0.0	0.0	1.6			4.8	3.1	88.2	3.2	0.0	0.0	8.6		
Raw fish (medium oil, high protein)	67.5	32.5	18.0	13.0	0.0	0.0	1.5			10.0	7.6	55.4	40.0	0.0	0.0	4.6		
Raw fish (high oil, low protein)	52.5	47.5	11.3	36.0	0.0	0.0	0.7			16.8	14.1	23.8	75.8	0.0	0.0	1.4		
2. Green plants, forage																		
2.1 Fresh																		
Clover (flowering)	80.3	19.7	3.7	0.7	4.4	9.0	1.9	0.32	0.06	3.7	1.6	18.8	3.6	22.3	45.7	9.6	1.6	0.3
Clover (young)	83.3	16.7	3.6	0.7	3.2	7.5	1.7	0.31	0.06	3.2	1.4	21.6	4.2	19.2	44.9	10.2	1.9	0.4
Lucerne (flowering)	75.5	24.5	4.9	0.6	6.9	9.4	2.7	0.41	0.08	4.6	1.8	20.0	2.4	28.2	38.4	11.0	1.7	0.3
Lucerne (young)	83.7	16.3	4.5	0.5	2.7	6.7	1.9	0.30	0.06	3.2	1.4	27.6	3.1	16.6	41.1	11.7	1.8	0.4
Pasture grass (fresh)	80.2	19.8	3.5	0.2	4.0	9.8	1.9	0.12	0.05	3.6	1.9	17.6	1.2	20.1	49.3	9.8	0.6	0.3
2.2 Dry																		
Lucerne flour (1st class)	8.9	91.2	21.6	2.7	20.0	36.6	10.3	1.66	0.26	17.5	7.4	23.7	2.9	21.9	40.2	11.3	1.8	0.3
Lucerne flour (2nd class)	8.6	91.5	19.1	2.5	23.8	36.8	9.3	1.56	0.25	17.5	7.0	20.9	2.7	26.0	40.2	10.2	1.7	0.3
Lucerne flour (3rd class)	6.5	93.5	17.8	2.4	28.4	36.1	8.8			17.9	6.7	19.0	2.6	30.4	38.6	9.4		
Lucerne hay (dry)	13.8	86.2	16.0	2.0	27.2	32.6	8.4			16.4	5.9	18.6	2.3	31.6	37.8	9.7		
Maize - whole plant flour	8.1	91.9	6.5	3.5	18.6	59.5	3.9			17.2	9.7	7.1	3.8	20.2	64.7	4.2		
Pasture hay (dry)	12.1	87.9	10.1	2.4	29.9	38.7	6.9			16.5	7.3	11.5	2.7	34.0	44.0	7.8		
3. Roots, tubers																		
Carrot	83.6	16.4	2.0	0.3	2.7	8.3	3.0			2.7	1.5	12.4	1.9	16.7	50.7	18.2		
Fodder beet	88.9	11.1	1.2	0.1	0.9	7.8	1.1	0.31	0.03	1.9	1.2	10.8	0.9	8.1	70.3	9.9	2.8	0.3
Potato	76.4	23.6	2.0	0.1	0.7	19.7	1.1	0.30	0.05	4.1	2.8	8.5	0.4	3.0	83.5	4.7	1.3	0.2
Potato pulp (dry)	10.0	90.0	4.5	0.5	12.2	69.6	3.2	0.26	0.06	15.9	9.6	5.0	0.6	13.6	77.3	3.6	0.3	0.1
Sugar-beet pulp (dry)	9.2	90.8	9.3	0.7	19.7	56.1	5.0	0.76	0.15	16.5	8.8	10.2	0.8	21.7	61.8	5.5	0.8	0.2
Sugar beet	76.7	23.3	1.2	0.1	1.2	19.7	1.1	0.41	0.03	4.0	2.7	5.2	0.4	5.2	84.5	4.7	1.8	0.1
4. By-products																		
4.1 Mill by-products																		
Barley – polished	10.8	89.2	12.4	2.0	1.2	71.8	1.8			16.8	11.7	13.9	2.2	1.3	80.5	2.0	0.0	0.0
Barley bran	12.1	87.9	11.6	3.1	11.4	56.7	5.1	0.14	0.37	16.5	10.0	13.2	3.5	13.0	64.5	5.8	0.2	0.4
Barley fodder flour	12.7	87.3	11.7	2.9	6.4	63.0	3.3	0.09	0.22	16.5	10.7	13.4	3.3	7.3	72.2	3.8	0.1	0.3
Lentil bran	12.4	87.6	23.1	1.0	7.4	53.7	2.5			17.6	10.7	26.4	1.1	8.4	61.3	2.8	0.0	0.0

Type of feeds	Approx. composition of fish foods and feeds <u>calculated on "as-fed" basis</u> (values in %)									Avg. Energy (MJ/kg)		Approx. composition of fish foods and feeds <u>calculated on DM basis</u> (values in %)						
	Moist	**DM**	**CP**	**CL**	**CF**	**NFE**	**CA**	**Ca**	**P**	**GE**	**DE**	**CP**	**CL**	**CF**	**NFE**	**CA**	**Ca**	**P**
Maize bran	10.0	90.0	9.0	4.1	23.4	49.5	5.1	0.47	0.29	17.4	9.0	10.0	4.6	26.0	55.0	5.7	0.5	0.3
Oat bran	11.0	89.0	8.1	3.1	21.1	51.4	5.3	0.09	0.43	16.6	8.8	9.1	3.5	23.7	57.8	6.0	0.1	0.5
Oat fodder flour	12.0	88.0	11.6	5.3	10.6	56.0	4.5	0.15	0.41	17.0	10.6	13.2	6.0	12.0	63.6	5.1	0.2	0.5
Pea fodder flour	11.3	88.7	22.3	2.0	7.1	53.9	3.4	0.12	0.25	17.7	8.7	25.1	2.3	8.0	60.8	3.8	0.1	0.3
Rice bran	11.4	88.6	11.5	12.8	9.6	44.9	9.7	0.67	1.68	17.8	11.7	13.0	14.5	10.8	50.7	11.0	0.8	1.9
Rice fodder flour	11.2	88.8	13.1	13.8	8.3	44.0	9.7	0.21	2.35	18.2	12.2	14.8	15.5	9.3	49.5	10.9	0.2	2.1
Rice pollard	9.1	90.8	13.8	17.3	6.5	45.2	0.0	0.00	0.00	19.5	13.7	15.2	19.1	7.2	49.8	00	0.0	0.0
Rye bran	11.3	88.7	14.4	3.0	10.9	55.4	5.0	0.10	1.16	16.9	10.2	16.2	3.4	12.3	62.5	5.6	0.1	1.3
Rye fodder flour	13.1	86.9	13.7	2.3	2.9	64.7	3.3	0.21	0.36	16.4	11.1	15.8	2.6	3.3	74.5	3.8	0.2	0.4
Wheat bran	11.7	88.3	14.9	4.1	10.0	54.4	5.4	0.12	1.05	17.1	10.6	16.8	4.6	11.4	61.6	6.1	0.1	1.2
Wheat fodder flour	12.2	87.8	15.5	3.9	5.3	59.4	3.7	0.11	0.63	17.1	11.2	17.7	4.4	6.0	67.7	4.2	0.1	0.7
Wheat germ	9.3	90.7	25.2	6.3	8.0	47.2	4.0	0.07	1.07	19.2	12.0	27.8	6.9	8.8	52.0	4.4	0.1	1.2
4.2 Brewery by-products																		
Apple marc dry	7.2	92.8	2.6	17.4	65.5	5.0	2.0	0.13	0.12	21.6	6.9	2.8	18.8	70.6	5.4	2.2	0.1	0.1
Beer marc (dry)	8.3	91.7	24.5	8.1	15.3	39.7	4.1	0.27	0.49	19.9	11.6	26.7	8.8	16.7	43.3	4.5	0.3	0.5
Beer marc (fresh)	76.1	23.9	6.5	2.1	4.0	10.2	1.1	0.07	0.13	5.2	3.0	27.2	8.8	16.7	42.7	4.6	0.3	0.5
Corn gluten feed (CGF)	8.4	91.6	65.4	1.4	1.5	21.4	1.9	0.05	0.59	22.8	13.6	71.4	1.5	1.6	23.4	2.1	0.1	0.6
DDGS – corn	11.5	88.5	24.3	11.5	5.6	42.8	4.3	0.20	0.80	19.7	13.1	27.5	13.0	6.3	48.4	4.9	0.2	0.9
Maize starch	8.4	91.6	0.6	0.1	0.2	90.5	0.2	0.00	0.03	15.8	11.5	0.7	0.1	0.2	98.8	0.2	0.0	0.0
Malt germ	6.6	93.4	26.6	1.0	14.1	45.3	6.4	0.21	0.74	18.5	10.2	28.5	1.1	15.1	48.5	6.9	0.2	0.8
Potato starch	12.0	88.0	0.4	0.1	0.0	87.1	0.4	0.04	0.01	15.1	11.0	0.5	0.1	0.0	99.0	0.5	0.0	0.0
Yeast	8.0	92.0	45.0	1.0	0.0	38.2	7.8	0.06	0.15	19.5	12.3	48.9	1.1	0.0	41.5	8.5	0.1	0.2
Yeast – beer	10.0	90.0	48.5	1.2	0.0	32.8	7.6	0.32	1.40	19.7	12.2	53.9	1.3	0.0	36.4	8.4	0.4	1.6
4.3 Miscellanea																		
Casein	10.5	89.5	80.3	1.1	0.0	4.4	3.8	0.61	0.98	23.7	15.2	89.7	1.2	0.0	4.9	4.2	0.7	1.1
Milk powder - f/full milk	5.5	94.5	25.3	26.8	0.0	36.3	6.0	0.96	0.76	23.5	18.0	26.8	28.4	0.0	38.4	6.3	1.0	0.8
Milk powder - f/skimmed milk	7.5	92.5	34.0	0.8	0.0	50.7	6.9	1.30	1.51	18.5	12.7	36.8	0.9	0.0	54.8	7.5	1.4	1.6
Molasses	22.0	78.0	8.4	0.0	0.0	62.1	7.5	0.23	0.02	13.0	9.1	10.8	0.0	0.0	79.6	9.6	0.3	0.0
Sugar	4.2	95.8	1.9	0.1	0.8	89.7	3.4	0.00	0.00	16.1	11.6	2.0	0.1	0.8	93.6	3.5	0.0	0.0
Tomato press cake	8.0	92.0	22.5	3.2	29.6	22.4	6.1	0.00	0.00	17.4	7.5	24.5	3.5	32.2	24.4	6.6	0.0	0.0
Torula yeast	7.0	93.0	46.5	6.0	0.5	32.0	0.0	0.00	0.00	20.9	13.4	50.0	6.5	0.5	34.4	0.0	0.0	0.0
Whey powder	5.8	94.2	12.2	0.8	0.0	72.3	8.9	0.92	0.66	16.1	11.5	13.0	0.8	0.0	76.8	9.4	1.0	0.7

Type of feeds	Approx. composition of fish foods and feeds calculated on "as-fed" basis (values in %)									Avg. Energy (MJ/kg)		Approx. composition of fish foods and feeds calculated on DM basis (values in %)						
	Moist	DM	CP	CL	CF	NFE	CA	Ca	P	GE	DE	CP	CL	CF	NFE	CA	Ca	P
5. Energy feeds																		
5.1 Grains																		
Barley	12.0	88.1	10.9	1.8	4.6	68.2	2.5	0.08	0.34	16.4	10.9	12.4	2.1	5.2	77.5	2.8	0.1	0.4
Maize	9.7	90.3	8.7	3.7	2.3	74.2	1.4	0.04	0.27	17.0	11.9	9.7	4.1	2.5	82.1	1.6	0.0	0.3
Millet	10.4	89.6	10.6	3.9	7.2	65.1	2.8	0.06	0.24	17.1	11.2	11.8	4.4	8.0	72.7	3.1	0.1	0.3
Oat	11.4	88.6	10.4	3.7	11.8	59.7	3.0	0.10	0.33	17.0	10.4	11.7	4.2	13.3	67.4	3.4	0.1	0.4
Rice (grain, meal)	11.0	89.0	9.1	2.5	8.5	63.9	5.1	0.21	2.35	16.2	10.3	10.2	2.8	9.5	71.8	5.7		
Rye	11.8	88.2	9.3	1.5	2.6	72.9	1.9	0.05	0.32	16.2	11.1	10.5	1.7	2.9	82.7	2.2	0.1	0.4
Sorghum	12.0	88.0	10.4	3.1	3.2	69.2	2.1	0.02	0.33	16.6	8.5	11.8	3.5	3.7	78.7	2.3	0.0	0.4
Triticale	11.9	88.1	10.3	1.1	2.6	72.2	1.9	0.05	0.33	16.2	11.1	11.7	1.2	3.0	82.0	2.2	0.1	0.4
Wheat grain	10.3	89.7	12.5	1.7	2.6	71.0	1.9	0.06	0.35	16.9	11.5	13.9	1.9	2.9	79.2	2.1	0.1	0.4
Wheat flour	10.3	89.7	12.5	1.7	2.6	71.0	1.9	0.03	0.18	16.9	11.5	13.9	1.9	2.9	79.2	2.1	0.0	0.2
6. Protein feeds																		
6.1 Plant origin																		
Cotton seed meal mechanically extracted	7.0	93.0	41.2	5.3	12.1	33.8	6.6	0.21	1.16	21.8	12.6	44.3	5.7	13.0	36.3	7.1	0.2	1.2
Cotton seed meal extracted	10.0	90.0	38.6	1.5	14.0	30.2	5.7	0.27	0.77	19.4	10.4	42.9	1.7	15.6	33.6	6.3	0.3	0.9
Horse bean	11.3	88.7	26.2	1.1	7.4	50.6	3.4	0.12	0.44	18.0	8.8	29.5	1.2	8.3	57.0	3.8	0.1	0.5
Lentil	9.5	90.5	24.0	0.9	2.6	60.3	2.7	0.00	0.00	17.9	9.2	26.5	1.0	2.9	66.6	3.0	0.0	0.0
Linseed (full fat)	9.6	90.4	22.0	34.0	6.1	24.0	4.1	0.25	0.40	24.4	17.9	24.3	37.6	6.7	26.5	4.5	0.3	0.4
Linseed meal extracted	9.5	90.5	34.2	2.8	8.9	38.3	6.4	0.35	0.95	19.0	11.2	37.8	3.0	9.8	42.3	7.0	0.4	1.0
Lupine (sweet)	12.0	88.0	38.3	4.6	14.5	26.3	4.3	0.13	0.43	20.0	9.8	43.5	5.2	16.5	29.9	4.9	0.1	0.5
Maize germ meal extracted	6.0	94.0	24.2	2.0	8.6	53.4	5.9	0.08	0.55	18.5	11.2	25.7	2.1	9.1	56.8	6.3	0.1	0.6
Pea	11.2	88.8	22.0	1.2	5.8	56.5	3.3	0.12	0.44	17.5	8.6	24.8	1.4	6.5	63.6	3.7	0.1	0.5
Rapeseed cake	9.2	90.8	30.4	12.3	10.4	31.5	6.2	0.87	1.01	20.7	11.6	33.5	13.5	11.5	34.7	6.8	1.0	1.1
Rapeseed meal extracted (00)	8.4	91.6	34.6	2.3	11.8	35.8	7.1	0.65	1.05	19.1	9.3	37.8	2.5	12.9	39.1	7.8	0.7	1.1
Rapeseed meal extracted	10.0	90.0	35.6	2.6	11.5	32.0	8.3	0.83	1.14	18.8	9.2	39.6	2.9	12.8	35.5	9.2	0.9	1.3
Soya (full fat)	10.2	89.8	33.7	18.6	6.9	25.4	5.2	0.22	0.60	22.3	13.7	37.5	20.7	7.7	28.3	5.8	0.2	0.7
Soya meal extracted (1st class)	10.6	89.4	48.2	1.6	5.7	27.1	6.8	0.30	0.59	19.9	10.5	53.9	1.8	6.4	30.3	7.6	0.3	0.7
Soya meal extracted (2nd class)	11.1	88.9	46.1	1.6	6.3	28.5	6.4	0.25	0.57	19.7	10.3	51.9	1.8	7.1	32.1	7.2	0.3	0.6
Soya meal extracted (3rd class)	10.7	89.3	44.0	1.9	6.8	30.2	6.4	0.30	0.56	19.6	10.2	49.3	2.1	7.6	33.8	7.2	0.3	0.6
Soya oilcake	9.0	91.0	45.5	7.0	7.4	29.8	6.8	0.20	0.73	22.0	12.1	50.0	7.7	8.1	32.7	7.5	0.2	0.8
Sunflower meal extracted	10.4	89.6	36.9	1.5	18.0	26.2	7.0	0.41	1.08	19.1	9.7	41.2	1.7	20.1	29.2	7.8	0.5	1.2
Sunflower meal extracted (1st class)	9.2	90.8	39.1	1.7	13.5	28.6	7.9	0.36	1.51	19.3	10.4	43.1	1.9	14.9	31.5	8.7	0.4	1.7

Type of feeds	Approx. composition of fish foods and feeds calculated on "as-fed" basis (values in %)									Avg. Energy (MJ/kg)		Approx. composition of fish foods and feeds calculated on DM basis (values in %)						
	Moist	DM	CP	CL	CF	NFE	CA	Ca	P	GE	DE	CP	CL	CF	NFE	CA	Ca	P
Sunflower meal extracted (2nd class)	8.2	91.8	36.6	1.8	17.2	28.6	7.6	0.30	1.23	19.4	10.0	39.9	2.0	18.7	31.2	8.3	0.3	1.3
Sunflower meal extracted (3rd class)	7.7	92.3	33.6	1.7	21.0	28.9	7.2	0.29	0.90	19.3	9.5	36.4	1.8	22.8	31.3	7.8	0.3	1.0
6.2 Animal origin																		
Blood meal	4.4	95.6	91.7	0.3	0.0	0.3	3.3	0.11	0.36	25.9	16.4	95.9	0.3	0.0	0.3	3.5	0.1	0.4
Carcass meal (mixed)	6.1	93.9	45.4	9.1	1.7	6.9	31.5	0.00	0.00	17.7	12.0	48.4	9.7	1.8	7.4	33.6	0.0	0.0
Egg – chicken	66.0	34.0	12.2	9.3		12.0	0.6	0.54	0.05	9.0	6.8	35.9	27.4	0.0	35.3	1.7	1.6	0.1
Feather meal	10.0	90.0	41.6	8.4	0.0	1.4	38.7			15.1	10.4	46.2	9.3	0.0	1.5	43.0		
Feather meal – hydrolysed	8.7	91.3	78.9	6.0	0.0	3.7	2.6	0.18	0.64	25.0	16.5	86.4	6.6	0.0	4.1	2.8	0.2	0.7
Fishmeal	7.7	92.3	66.5	7.4	0.0	1.5	17.0	5.50	3.20	21.7	14.5	72.0	8.0	0.0	1.6	18.4	6.0	3.5
Fishmeal (60%)	8.7	91.3	61.7	10.5	0.0	1.7	17.3	4.53	2.46	21.6	14.7	67.6	11.5	0.0	1.9	18.9	5.0	2.7
Fishmeal (65%)	8.6	91.4	64.2	9.4	0.0	1.3	16.5	3.95	2.51	21.8	14.7	70.2	10.3	0.0	1.4	18.1	4.3	2.7
Fishmeal (70%)	6.7	93.3	71.4	3.5	0.0	3.1	15.3	3.42	2.29	21.9	14.3	76.5	3.8	0.0	3.3	16.4	3.7	2.5
Mixed animal protein meal (54%)	6.4	93.6	54.9	17.5	0.0	2.5	18.7	5.34	2.51	22.5	15.9	58.7	18.7	0.0	2.7	20.0	5.7	2.7
Mixed animal protein meal (58%)	5.5	94.5	59.0	14.7	0.0	3.8	17.0	4.77	2.53	22.8	15.9	62.4	15.6	0.0	4.0	18.0	5.0	2.7
Mixed animal protein meal (62%)	6.7	93.3	62.4	11.8	0.0	3.2	15.9	4.40	2.77	22.5	15.4	66.9	12.6	0.0	3.4	17.0	4.7	3.0
Poultry offal meal	7.6	92.4	63.3	21.3	0.0	0.0	7.2	3.75	1.80	25.8	18.4	68.5	23.1	0.0	0.0	7.8	4.1	1.9
Shrimp meal	7.5	92.5	42.0	3.0	11.0	12.4	40.0	12.21	1.63	17.3	10.0	45.4	3.2	11.9	13.4	43.2	13.2	1.8
7. Lipid feeds																		
7.1 Plant origin																		
Coconut grease	0.5	99.5	0.0	98.3	0.0	0.0	0.0	0.00	0.00	37.4	32.9	0.0	98.8	0.0	0.0	0.0	0.0	0.0
Palm oil	0.8	99.2	0.0	98.0	0.0	0.0	0.0	0.00	0.00	37.2	32.8	0.0	98.8	0.0	0.0	0.0	0.0	0.0
Sunflower oil	1.1	98.9	0.0	98.7	0.0	0.0	0.0	0.00	0.00	37.5	33.0	0.0	99.8	0.0	0.0	0.0	0.0	0.0
Sunflower seed (kernel)	19.0	81.0	21.0	51.0	9.0		3.4	0.28	0.54	27.1	20.4	25.9	63.0	11.1		4.2	0.3	0.7
7.2 Animal origin																		
Fish oil	1.0	99.0	0.0	98.4	0.0	0.0	0.0	0.00	0.00	37.4	32.9	0.0	99.4	0.0	0.0	0.0	0.0	0.0
Pig fat	1.1	98.9	0.0	98.1	0.0	0.0	0.0	0.00	0.00	37.3	32.8	0.0	99.2	0.0	0.0	0.0	0.0	0.0
Poultry fat	0.8	99.2	0.0	98.5	0.0	0.0	0.0	0.00	0.00	37.4	33.0	0.0	99.3	0.0	0.0	0.0	0.0	0.0
Tallow	1.0	99.0	0.0	98.3	0.0	0.0	0.0	0.00	0.00	37.4	32.9	0.0	99.3	0.0	0.0	0.0	0.0	0.0
8. Mineral supplements																		
Bone meal – steamed	8.0	92.0	5.5	0.0	2.0	0.9	84.6	30.36	13.8	2.1	1.1	6.0	0.0	2.2	1.0	92.0	33.0	15.0

TABLE A-2: SELECTED ALLER AQUA FEEDS OF COLD, WARM AND TROPICAL FRESHWATER FISH SPECIES USED IN THE REGION [2]

FEED			SIZE OF FISH (g)	DECLARATION								ENVIRONMENTAL IMPACT [3]				
Name	**Type**	**Size** (mm)		**CP** (%)	**CF** (%)	**NFE** (%)	**Ash** (%)	**Fibre** (%)	**P** (%)	**GE** (MJ)	**DE** (MJ)	**FCR**	**N in faeces** (kg)	**N in water** (kg)	**P in faeces** (kg)	**P in water** (kg)
Arctic charr																
Recommended feed program																
ALLER INFA EX GR	Fry feed granulate	0.1-0.4	0.05-0.5	64	10	6.9	12.1	1.0	1.4	19.4	18.0	0.5-0.9	0.31-0.55	2.06-5.91	0.23-0.41	0.1-0.52
ALLER FUTURA EX GR	Fry feed granulate	0.5-1.6	0.5-7	60	15	5.7	12.6	0.7	1.4	21.2	19.7	0.5-0.8	0.29-0.46	1.76-4.47	0.21-0.34	0.06-0.35
		1.3-2	7-15	58	17	6.1	12.2	0.7	1.4	21.6	20.0	0.7-0.9	0.39-0.5	3.36-5.1	0.29-0.38	0.26-0.45
ALLER FUTURA EX	Fry feed pellet	1.3-1.5	2-15	58	17	6.0	10.1	0.9	1.2	21.6	20.1	0.5-0.8	0.28-0.45	1.61-4.23	0.18-0.28	0.01-0.23
ALLER FUTURA	Pre-grower pellet	2	15-40	47	25	13.5	7.1	1.4	1.0	23.5	21.2	0.7-0.9	0.43-0.55	2.2-3.61	0.21-0.27	0.06-0.2
ALLER ARCTIC	Grower pellet	3	40-250	47-49	23-25	13.5-16.5	5.5-7.5	0.8-2.3	0.8	23-26	20.6	0.8-1	0.49-0.61	2.9-4.32	0.22-0.27	0.12-0.25
		4.5	250-400	45-47	24-26	14.0-17.0	5.5-7.5	0.8-2.3	0.8	23.1-26.1	20.6	0.9-1.1	0.53-0.65	3.34-4.7	0.24-0.3	0.19-0.31
		6	400-1000	43-45	25-27	14.5-17.5	5.5-7.5	0.8-2.3	0.8	23.1-26.1	20.6	1-1.2	0.56-0.68	3.73-5.02	0.24-0.29	0.18-0.29
Atlantic salmon – freshwater																
Recommended feed program																
ALLER INFA EX GR	Fry feed granulate	0.2-0.4	0.2-0.5	64	10	6.9	12.1	1.0	1.4	19.4	18.0	0.5-0.8	0.31-0.49	2.06-4.96	0.23-0.36	0.1-0.41
ALLER FUTURA EX GR	Fry feed granulate	0.5-1.6	0.5-7	60	15	5.7	12.6	0.7	1.4	21.2	19.7	0.5-0.8	0.29-0.46	1.76-4.47	0.21-0.34	0.06-0.35
		1.3-2	7-15	58	17	6.1	12.2	0.7	1.4	21.6	20.0	0.7-0.9	0.39-0.5	3.36-5.1	0.29-0.38	0.26-0.45
ALLER FUTURA EX	Fry feed pellet	1.3-1.5	2-15	58	17	6.0	10.1	0.9	1.2	21.6	20.1	0.5-0.8	0.28-0.45	1.61-4.23	0.18-0.28	0.01-0.23
ALLER FUTURA	Pre-grower pellet	2	15-40	47	25	13.5	7.1	1.4	1.0	23.5	21.2	0.7-0.9	0.32-0.41	2.3-3.75	0.19-0.24	0.01-0.14
ALLER FLOW	Grower pellet	3	40-100	46	28	10.1	9.1	0.8	1.2	23.8	21.9	0.8-1	0.35-0.44	2.78-4.17	0.29-0.36	0.29-0.46
		4.5	100-400	44	30	10.3	8.8	0.9	1.2	24.1	22.1	0.9-1.1	0.38-0.46	3.21-4.53	0.32-0.4	0.38-0.54
Brown trout																
Recommended feed program																
ALLER INFA EX GR	Fry feed granulate	0.2-0.4	0.1-0.5	64	10	6.9	12.1	1.0	1.4	19.4	18.0	0.5-0.8	0.31-0.49	2.06-4.96	0.23-0.36	0.1-0.41
ALLER FUTURA EX GR	Fry feed granulate	0.5-1.6	0.5-7	60	15	5.7	12.6	0.7	1.4	21.2	19.7	0.5-0.8	0.29-0.46	1.76-4.47	0.21-0.34	0.06-0.35
		1.3-2	7-15	58	17	6.1	12.2	0.7	1.4	21.6	20.0	0.7-0.9	0.39-0.5	3.36-5.1	0.29-0.38	0.26-0.45

[2] *Updated on January 2022. See details at: https://www.aller-aqua.com/species* [3] *With exemplary feed conversion rations (Figures are per 100 kg fish production).*

FEED			SIZE OF FISH (g)	DECLARATION								ENVIRONMENTAL IMPACT [3]				
Name	Type	Size (mm)		CP (%)	CF (%)	NFE (%)	Ash (%)	Fibre (%)	P (%)	GE (MJ)	DE (MJ)	FCR	N in faeces (kg)	N in water (kg)	P in faeces (kg)	P in water (kg)
ALLER FUTURA EX	Fry feed pellet	1.3-1.5	2-15	58	17	6.0	10.1	0.9	1.2	21.6	20.1	0.5-0.8	0.28-0.45	1.61-4.23	0.18-0.28	0.02-0.23
ALLER FUTURA	Pre-grower pellet	2	15-40	47	25	13.5	7.1	1.4	1.0	23.5	21.2	0.7-0.9	0.32-0.41	2.3-3.75	0.21-0.27	0.06-0.2
ALLER ARCTIC	Grower pellet	3	40-100	47-49	23-25	13.5-16.5	5.5-7.5	0.8-2.3	0.8	23-26	20.6	0.8-1	0.49-0.61	2.9-4.32	0.22-0.27	0.12-0.25
		4.5	100-400	45-47	24-26	14.0-17.0	5.5-7.5	0.8-2.3	0.8	23.1-26.1	20.6	0.9-1.1	0.53-0.65	3.34-4.7	0.24-0.3	0.19-0.31
		6	400-1000	43-45	25-27	14.5-17.5	5.5-7.5	0.8-2.3	0.8	23.1-26.1	20.6	1-1.2	0.56-0.68	3.73-5.02	0.24-0.29	0.18-0.29
Rainbow trout																
Recommended feed program																
ALLER INFA EX GR	Fry feed granulate	0.2-0.4	0.1-0.5	64	10	6.9	12.1	1.0	1.4	19.4	18.0	0.5-0.8	0.31-0.49	2.06-4.96	0.23-0.36	0.1-0.41
ALLER FUTURA EX GR	Fry feed granulate	0.5-1.6	0.5-7	60	15	5.7	12.6	0.7	1.4	21.2	19.7	0.5-0.8	0.29-0.46	1.76-4.47	0.21-0.34	0.06-0.35
		1.3-2	7-15	58	17	6.1	12.2	0.7	1.4	21.6	20.0	0.7-0.9	0.39-0.5	3.36-5.1	0.29-0.38	0.26-0.45
ALLER FUTURA EX	Fry feed pellet	1.3-1.5	2-15	58	17	6.0	10.1	0.9	1.2	21.6	20.1	0.5-0.8	0.28-0.45	1.61-4.23	0.18-0.28	0.02-0.23
ALLER FUTURA	Pre-grower pellet	2	15-40	47	25	13.5	7.1	1.4	1.0	23.5	21.2	0.7-0.9	0.32-0.41	2.2-3.61	0.21-0.27	0.06-0.2
ALLER GOLD	Grower pellet	3	40-100	44-46	26-28	12.5-15.5	6.5-8.5	0.7-1.9	0.9	23.5-26.5	21.3	0.8-1	0.46-0.58	2.55-3.87	0.22-0.27	0.12-0.25
		4.5	100-400	42-44	28-30	12.5-15.5	6.0-8.0	0.7-1.9	0.9	23.9-26.9	21.6	0.9-1.1	0.5-0.61	2.95-4.21	0.24-0.3	0.19-0.31
		6 -8	400-1000 and above	40-42	30-32	12.5-15.5	6.0-8.0	0.7-1.9	0.9	24.1-27.1	22.0	1-1.3	0.52-0.68	3.29-5.1	0.27-0.35	0.25-0.39
ALLER PERFORMA	Fry feed pellet	1.3-1.5	2-15	48	21	13.2	8.7	1.1	1.2	22.1	20.0	0.6-0.9	0.28-0.41	1.58-3.75	0.2-0.3	0.1-0.37
	Pre-grower pellet	2	15-40	45	20	17.9	7.1	2.0	1.0	21.9	18.9	0.8-1	0.46-0.58	2.55-3.87	0.24-0.3	0.13-0.27
ALLER SILVER	Grower pellet	3	40-100	45	20	20	7	2	1	22.3	19.1	0.9-1.1	0.52-0.63	3.21-4.54	0.27-0.33	0.25-0.39
		4.5	100-400	43	22	20	7	2	1	22.6	19.5	1-1.2	0.55-0.66	3.58-4.85	0.3-0.36	0.32-0.46
		6-8	400-1000 and above	41	24	20	7	2	1	22.9	20.0	1.1-1.4	0.58-0,73	3.89-5.7	0.33-0.42	0.39-0.55

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[3] *With exemplary feed conversion rations (Figures are per 100 kg fish production).*

FEED			SIZE OF FISH (g)	DECLARATION								ENVIRONMENTAL IMPACT [3]				
Name	**Type**	**Size** (mm)		**CP** (%)	**CF** (%)	**NFE** (%)	**Ash** (%)	**Fibre** (%)	**P** (%)	**GE** (MJ)	**DE** (MJ)	**FCR**	**N in faeces** (kg)	**N in water** (kg)	**P in faeces** (kg)	**P in water** (kg)
ALLER SILVER FLOAT	Grower pellet	3	40-100	45	20	20	7	3	1	22.5	19.5	0.8-1	0.46-0.58	2.55-2.87	0.24-0.3	0.18-0.32
		4.5	100-400	43	22	20	7	3	1	22.8	20.1	0.9-1.1	0.5-0.61	2.95-4.21	0.27-0.33	0.25-0.39
		6-8	400-1000 and above	41	24	19.5	7.8	2.7	1	23	19.9	1-1.3	0.52-0.68	3.29-5.1	0.3-0.39	0.32-0.48
ALLER BRONZE	Pre-grower pellet	2	15-40	45	15	23.8	6.9	3.3	0.9	21.2	17.6	0.9-1.1	0.52-0.63	3.21-4.54	0.27-0.33	0.19-0.33
	Grower pellet	3-8	40-1000 and above	45	15	22.3	6.5	3.2	1.1	21.2	17.6	1-1.5	0.58-0.86	3.87-7.19	0.27-0.41	0.25-0.52
Additional feed program																
ALLER GOLD SUPPORT	Functional	3	40-100	44-46	26-28	12.5-15.5	6.5-8.5	0.7-1.9	0.9	23.5-26.5	21.3	0.8-1	0.46-0.58	2.55-3.87	1.22-1.27	1.12-0.25
		4.5	100-400	42-44	28-30	12.5-15.5	6.0-8.0	0.7-1.9	0.9	23.9-26.9	21.6	0.9-1.1	0.5-0.61	2.95-4.21	0.24-0.3	0.19-0.31
		6-8	400-1000 and above	40-42	30-32	12.5-15.5	6.0-8.0	0.7-1.9	0.9	24.1-27.1	22.0	1-1.3	0.52-0.68	3.29-5.1	0.27-0.35	0.25-0.39
ALLER REP EX	Broodstock feed	6-8	400-1000 and above	53	14	15.3	8.3	1.4	1.1	20.9	18.6	1-1.3	0.68-0.88	5.05-7.39	0.45-0.59	0.67-0.99
Whitefish																
Recommended feed program																
ALLER INFA EX GR	Fry feed granulate	0.1-0.4	0.05-0.5	64	10	6.9	12.1	1.0	1.4	19.4	18.0	0.5-0.9	0.31-0.55	2.06-5.91	0.23-0.41	0.1-0.52
ALLER FUTURA EX GR	Fry feed granulate	0.5-1.6	0.5-7	60	15	5.7	12.6	0.7	1.4	21.2	19.7	0.5-0.8	0.29-0.46	1.76-4.47	0.21-0.34	0.06-0.35
		1.3-2	7-15	58	17	6.1	12.2	0.7	1.4	21.6	20.0	0.7-0.9	0.39-0.5	3.36-5.1	0.29-0.38	0.26-0.45
ALLER FUTURA EX	Fry feed pellet	1.3-1.5	2-15	58	17	6.0	10.1	0.9	1.2	21.6	20.1	0.5-0.8	0.28-0.45	1.61-4.23	0.18-0.28	0.01-0.23
ALLER FUTURA	Pre-grower pellet	2	15-40	47	25	13.5	7.1	1.4	1.0	23.5	21.2	0.7-0.9	0.43-0.55	2.2-3.61	0.21-0.27	0.06-0.2
ALLER ARCTIC	Grower pellet	3	40-100	47-49	23-25	13.5-16.5	5.5-7.5	0.8-2.3	0.8	23-26	20.6	0.8-1	0.49-0.61	2.9-4.32	0.22-0.27	0.12-0.25
		4.5	100-400	45-47	24-26	14.0-17.0	5.5-7.5	0.8-2.3	0.8	23.1-26.1	20.6	0.9-1.1	0.53-0.65	3.34-4.7	0.24-0.3	0.19-0.31
		6	400-800 and above	43-45	25-27	14.5-17.5	5.5-7.5	0.8-2.3	0.8	23.1-26.1	20.6	1-1.2	0.56-0.68	3.73-5.02	0.24-0.29	0.18-0.29

[3] *With exemplary feed conversion rations (Figures are per 100 kg fish production).*

FEED			SIZE OF FISH (g)	DECLARATION								ENVIRONMENTAL IMPACT [3]				
Name	**Type**	**Size** (mm)		**CP** (%)	**CF** (%)	**NFE** (%)	**Ash** (%)	**Fibre** (%)	**P** (%)	**GE** (MJ)	**DE** (MJ)	**FCR**	**N in faeces** (kg)	**N in water** (kg)	**P in faeces** (kg)	**P in water** (kg)
Sturgeon																
Recommended feed program																
ALLER INFA EX GR	Fry feed granulate	0.2-0.4	0.03-1	64	10	6.9	12.1	1.0	1.4	19.4	18.0	0.5-0.8	0.31-0.49	2.06-4.95	0.23-0.36	0.1-0.41
ALLER FUTURA EX GR	Fry feed granulate	0.5-1.6	1-5	60	15	5.7	12.6	0.7	1.4	21.2	19.7	0.5-0.8	0.29-0.46	1.76-4.47	0.21-0.34	0.06-0.35
		1.3-2	5-10	58	17	6.1	12.2	0.7	1.4	21.6	20.0	0.7-0.9	0.39-0.5	3.36-5.1	0.29-0.38	0.26-0.45
ALLER THALASSA EX GR	Fry feed granulate	0.5-1.6	1-5	62	12	6.2	13.0	0.8	1.4	20.6	19.1	0.5-0.8	0.3-0.48	1.91-4.71	0.21-0.34	0.06-0.35
		1.3-2	5-10	60	14	6.6	12.6	0.8	1.4	21.0	19.3	0.7-0.9	0.4-0.52	3.57-5.37	0.29-0.38	0.26-0.45
ALLER IVORY EX	Pre-grower pellet	2	10-50	56	18	9.1	7.9	1.0	1.5	22.0	20.5	0.7-0.9	0.36-0,47	2.94-4.56	0.23-0.3	0.16-0.32
ALLER METABOLICA	Grower pellet	3-11	50-7000 and above	52	15	16	7	2	1.2	21.3	18.5	0.8-1.4	0.53-0.93	3.37-7.97	0.24-0.46	0.14-0.64
ALLER PERFORMA	Fry feed pellet	1.3-1.5	3-10	48	21	13.2	8.7	1.1	1.2	22.1	20.0	0.6-0.9	0.28-0.41	1.58-3.75	0.2-0.3	0.1-0.34
	Pre-grower pellet	2	10-50	45	20	17.9	7.1	2.0	1.0	21.9	18.9	0.8-1	0.35-0.43	2.66-4.02	0.24-0.3	0.17-0.31
ALLER THALASSA EX	Pre-grower pellet	2	10-50	48	15	19	7.4	2.6	1.1	20.9	18.2	0.8-1	0.49-0.61	2.9-4.32	0.26-0.33	0.24-0.39
ALLER PROGRESS EX	Grower pellet	3-6	50-4000	45	20	18.1	6.8	2.1	1	22	18.8	1-1.2	0.52-0.75	3.21-5.86	0.27-0.39	0.2-0.48
		8	4000-7000	48	18	15.5	8.2	2.3	1.1	21.5	18.5	1.2-1.4	0.74-0.86	5.73-7.14	0.38-0.45	0.46-0.61
ALLER TRIDENT EX	Grower pellet	3-8	50-7000	47	14	23.5	6.7	2.8	1.1	21.1	17.8	1-1.5	0.6-0.9	4.17-7.63	0.33-0.5	0.34-0.73
ALLER BRONZE	Pre-grower pellet	2	15-50	45	15	23.8	6.9	3.3	0.9	21.2	17.6	0.9-1.1	0.52-0.63	3.21-4.54	0.27-0.33	0.24-0.38
	Grower pellet	3-11	50-7000 and above	45	15	22.3	6.5	3.2	1.1	21.2	17.6	1-1.6	0.58-0.92	3.87-7.85	0.3-0.43	0.26-0.58
Additional feed program																
ALLER STURGEON REP EX	Broodstock feed	6-8 and 11	1500-7000 and above	52	12	17.9	8.5	1.6	1.4	20.3	17.8	1-1.4	0..67-0.93	4.9-7.97	0.36-0.59	0.41-0.94
Common carp																
Recommended feed program																
ALLER INFA EX GR	Fry feed granulate	0.2-0.4	below 0.2, 0.2-2	64	10	6.9	12.1	1.0	1.4	19.4	18.0	0.4-0.8	0.25--0.45	1.1-4.95	0.18-0.36	0.01-0.41
ALLER PARVO EX GR	Fry feed granulate	0.5-2	0.5-10	44	9	29.4	9.3	2.3	1.1	18.7	14.4	0.5-1	0.28-0.56	0.49-3.73	0.18-0.36	0.07-0.49

[3] *With exemplary feed conversion rations (Figures are per 100 kg fish production).*

FEED			SIZE OF FISH (g)	DECLARATION								ENVIRONMENTAL IMPACT [3]				
Name	**Type**	**Size** (mm)		**CP** (%)	**CF** (%)	**NFE** (%)	**Ash** (%)	**Fibre** (%)	**P** (%)	**GE** (MJ)	**DE** (MJ)	**FCR**	**N in faeces** (kg)	**N in water** (kg)	**P in faeces** (kg)	**P in water** (kg)
ALLER PERFORMA	Fry feed pellet	1.3-1.5	5-10	48	21	13.2	8.7	1.1	1.2	22.1	20.0	0.5-0.8	0.23-0.37	0.86-3.03	0.18-0.29	0.02-0.27
ALLER PRIMO	Pre-grower pellet	2	10-50	37	12	32.5	7	3.5	1	19.6	15.7	1-1.2	0.47-0.57	2.7-3.79	0.3-0.36	0.27-0.41
	Grower pellet	3-8	50-1500 and above	37	12	32.5	7	3.5	1	19.6	15.7	1-1.5	0.47-0.71	2.7-5.42	0.3-0.45	0.27-0.62
ALLER MASTER	Pre-grower pellet	2	10-50	35	9	36.3	7	4.7	1.1	18.8	14.9	1.1-1.3	0.49-0.58	2.92-3.95	0.36-0.43	0.42-0.57
	Grower pellet	3-8	50-1500 and above	35	9	37	6.9	4.5	1.2	18.9	14.9	1.1-1.6	0.49-0.72	2.92-5.49	0.37-0.54	0.43-0.82
ALLER CLASSIC	Pre-grower	2	10-50	30	7	43.5	6.5	5	1	18.2	12.6	1.2-1.4	0.46-0.54	2.55-3.43	0.36-0.42	0.41-0.55
	Grower pellet	3-8	50-4000	30	7	43.2	6.3	5.5	1	18.2	12.6	1.2-1.7	0.46-0.65	2.55-4.76	0.36-0.51	0.41-0.76
ALLER TOP	Grower pellet	3-8	50-1500 and above	25	7	48.6	5.4	5.0	0.9	17.8	12.5	1.4-1.9	0.45-0.61	2.4-4.24	0.37-0.5	0.43-0.74
Additional feed program																
ALLER CLASSIC VITAMAX	Functional	2	10-50	30	7	43.5	6.5	5	1	18.2	12.6	1-1.2	0.29-0.35	1.76-2.66	0.36-0.43	0.76-2.66
		3-8	50-1500 and above	30	7	43.5	6.5	5	1	18.2	12.6	1.4-1.9	0.54-0.73	3.43-5.65	0.42-0.57	0.55-0.9
Tench																
Recommended feed program																
ALLER INFA EX GR	Fry feed granulate	0.2-0.4	0.2-2	64	10	6.9	12.1	1.0	1.4	19.4	18.0	0.5-0.8	0.31-0.49	2.06-4.95	0.23-0.36	0.1-0.41
ALLER THALASSA EX GR	Fry feed granulate	0.5-1.6	2-8	62	12	6.2	13.0	0.8	1.4	20.6	19.1	0.5-0.8	0.3-0.48	1.91-4.71	0.21-0.34	0.06-0.35
		1.3-2	8-10	60	14	6.6	12.6	0.8	1.4	21.0	19.3	0.7-0.9	0.4-0.52	3.57-5.37	0.29-0.38	0.26-0.45
ALLER FUTURA EX	Fry feed pellet	1.3-1.5	5-10	58	17	6.0	10.1	0.9	1.2	21.6	20.1	0.5-0.8	0.28-0.45	1.61-4.23	0.18-0.28	0.01-0.23
ALLER PRIMO	Pre-grower pellet	2	10-50	37	12	32.5	7	3.5	1	19.6	15.7	0.8-1	0.38-0.47	1.61-2.7	0.24-0.3	0.13-0.27
	Grower pellet	3-6	50-1500 and above	37	12	32.5	7	3.5	1	19.6	15.7	1-1.4	0.47-0.66	2.7-4.87	0.3-0.42	0.27-0.55

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[3] *With exemplary feed conversion rations (Figures are per 100 kg fish production).*

FEED			SIZE OF FISH (g)	DECLARATION								ENVIRONMENTAL IMPACT [3]				
Name	**Type**	**Size** (mm)		**CP** (%)	**CF** (%)	**NFE** (%)	**Ash** (%)	**Fibre** (%)	**P** (%)	**GE** (MJ)	**DE** (MJ)	**FCR**	**N in faeces** (kg)	**N in water** (kg)	**P in faeces** (kg)	**P in water** (kg)
Eel																
Recommended feed program																
ALLER INFA EX GR	Fry feed granulate	0.2-0.4	0.2-0.1	64	10	6.9	12.1	1.0	1.4	19.4	18.0	0.5-0.8	0.31-0.49	2.06-4.95	0.23-0.36	0.1-0.41
ALLER THALASSA EX GR	Fry feed granulate	0.5-1.6	1-15	62	12	6.2	13.0	0.8	1.4	20.6	19.1	0.5-0.8	0.3-0.48	1.91-4.71	0.21-0.34	0.06-0.35
		1.3-2	15-30	60	14	6.6	12.6	0.8	1.4	21.0	19.3	0.7-0.9	0.4-0.52	3.57-5.37	0.29-0.38	0.26-0.45
ALLER IVORY EX	Pre-grower	2	30-80	56	18	9.1	7.9	1.0	1.5	22.0	20.5	0.9-1.1	0.47-0.57	4.56-6.18	0.3-0.37	0.27-0.42
	Grower pellet	3	80-120 and above	56	18	9.1	7.9	1.0	1.5	22.0	20.5	1-1.2	0.52-0.62	5.37-7	0.33-0.4	0.35-0.5
European catfish																
Recommended feed program																
ALLER INFA EX GR	Fry feed granulate	0.2-0.4	0.05-0.3	64	8	8.9	12.1	1.0	1.4	19.4	18.0	0.5-0.8	0.31-0.49	2.06-4.95	0.23-0.36	0.1-0.41
ALLER THALASSA EX GR	Fry feed granulate	0.5-1.6	0.3-4	62	12	6.2	13.0	0.8	1.4	20.6	19.1	0.5-0.8	0.3-0.48	1.91-4.71	0.21-0.34	0.06-0.35
		1.3-2	4-10	60	14	6.6	12.6	0.8	1.4	21.0	19.3	0.7-0.9	0.4-0.52	3.57-5.37	0.29-0.38	0.26-0.45
ALLER THALASSA EX	Pre-grower pellet	2	10-50	48	15	19	7.4	2.6	1.1	20.9	18.2	0.7-0.9	0.36-0.47	2.94-4.56	0.23-0.3	0.11-0.27
ALLER IVORY EX	Pre-grower pellet	2	30-50	56	18	9.1	7.9	1.0	1.5	22.0	20.5	0.7-0.9	0.36-0.47	2.94-4.56	0.23-0.3	0.11-0.27
	Grower pellet	3	50-150	56	18	9.1	7.9	1.0	1.5	22.0	20.5	0.8-1	0.41-0.52	3.75-5.37	0.27-0.33	0.19-0.35
		4.5-6	150-1500	54	20	8.2	8.9	0.9	1.1	22.2	20.6	0.9-1.2	0.47-0.62	4.56-7	0.3-0.4	0.27-0.5
ALLER AP EX	Grower pellet	9-11	1000-1500 and above	56	18	7.9	9.1	1.0	1.2	21.8	20.1	1.1-1.4	0.59-0.75	6.51-9.14	0.4-0.51	0.5-0.79
ALLER METABOLICA	Grower pellet	3-11	50-1500 and above	52	15	16	7	2	1.2	21.3	18.5	0.9-1.5	0.6-1	4.14-8.73	0.32-0.54	0.33-0.83
ALLER BRONZE	Grower pellet	3-8	50-1500 and above	45	15	22.3	6.5	3.2	1.1	21.2	17.6	1-1.5	0.58-0.86	3.87-7.19	0.27-0.45	0.25-0.61
Perch																
Recommended feed program																
ALLER INFA EX GR	Fry feed granulate	0.1-0.4	0.05-1	64	10	6.9	12.1	1.0	1.4	19.4	18.0	0.5-0.9	0.31-0.55	2.06-5.91	0.23-0.41	0.1-0.52
ALLER THALASSA EX GR	Fry feed granulate	0.5-1.6	1-7	62	12	6.2	13.0	0.8	1.4	20.6	19.1	0.5-0.8	0.3-0.48	1.91-4.71	0.21-0.34	0.06-0.35

[3] *With exemplary feed conversion rations (Figures are per 100 kg fish production).*

FEED			SIZE OF FISH (g)	DECLARATION								ENVIRONMENTAL IMPACT [3]				
Name	Type	Size (mm)		CP (%)	CF (%)	NFE (%)	Ash (%)	Fibre (%)	P (%)	GE (MJ)	DE (MJ)	FCR	N in faeces (kg)	N in water (kg)	P in faeces (kg)	P in water (kg)
ALLER IVORY EX	Pre-grower pellet	2	10-20	56	18	9.1	7.9	1.0	1.5	22.0	20.5	0.8-1	0.41-0.52	3.75-5.37	0.27-0.33	0.19-0.35
	Grower pellet	3	20-50	56	18	9.1	7.9	1.0	1.5	22.0	20.5	0.8-1	0.41-0.52	3.75-5.37	0.27-0.33	0.19-0.35
		4.5-6	50-1000	54	20	8.2	8.9	0.9	1.1	22.2	20.6	0.9-1.2	0.47-0.62	4.56-7	0.3-0.4	0.27-0.5
ALLER NOVA EX	Pre-grower pellet	2	10-20	53	11	19.0	9.5	1.3	1.3	20.3	17.5	0.8-1	0.39-0.49	3.39-4.92	0.31-0.39	0.29-0.48
ALLER METABOLICA	Grower pellet	3-6	20-1000	52	15	16	7	2	1.2	21.3	18.5	0.8-1.2	0.4-0.6	3.51-6.63	0.34-0.36	0.13-0.41
Pikeperch																
Recommended feed program																
ALLER INFA EX GR	Fry feed granulate	0.1-0.4	0.05-1	64	10	6.9	12.1	1.0	1.4	19.4	18.0	0.5-0.9	0.31-0.55	2.06-5.91	0.23-0.41	0.1-0.52
ALLER THALASSA EX GR	Fry feed granulate	0.5-1.6	1-7	62	12	6.2	13.0	0.8	1.4	20.6	19.1	0.5-0.8	0.3-0.48	1.91-4.71	0.21-0.34	0.06-0.35
		1.3-2	7-10	60	14	6.6	12.6	0.8	1.4	21.0	19.3	0.7-0.9	0.4-0.52	3.57-5.37	0.29-0.38	0.26-0.45
ALLER IVORY EX	Pre-grower pellet	2	10-20	56	18	9.1	7.9	1.0	1.5	22.0	20.5	0.8-1	0.41-0.52	3.75-5.37	0.27-0.33	0.19-0.35
	Grower pellet	3	20-50	56	18	9.1	7.9	1.0	1.5	22.0	20.5	0.8-1	0.41-0.52	3.75-5.37	0.27-0.33	0.19-0.35
		4.5-6	50-1000	54	20	8.2	8.9	0.9	1.1	22.2	20.6	0.9-1.2	0.47-0.62	4.56-7	0.3-0.4	0.27-0.5
ALLER AP EX	Grower pellet	9	above 1000	56	18	7.9	9.1	1.0	1.2	21.8	20.1	1.1-1.3	0.59-0.7	6.51-8.2	0.4-0.47	0.5-0.67
ALLER NOVA EX FLOAT	Grower pellet	3-6	20-1000	51	12	19.7	9.8	2.5	1.4	20.6	17.4	0.9-1.3	0.44-0.64	4.15-7.22	0.32-0.47	0.33-0.66
		8-11	above 1000	50	14	18.1	9.6	2.3	1.3	20.8	17.7	1.2-1.4	0.59-0.69	6.45-7.99	0.43-0.5	0.58-0.75
Tilapia – Europe																
Recommended feed program																
ALLER INFA EX GR	Fry feed granulate	0.1-0.4	Below 0.1, 0.1-0.5	64	10	6.9	12.1	1.0	1.4	19.4	18.0	0.5-0.9	0.31-0.55	2.06-5.91	0.23-0.41	0.1-0.52
ALLER PARVO EX GR	Fry feed granulate	0.5-2	0.3-10	44	9	29.4	9.3	2.3	1.1	18.7	14.4	0.6-1.1	0.34-0.62	1.14-4.37	0.25-0.46	0.15-0.64
ALLER PERFORMA	Pre-grower pellet	2	10-70	45	20	17.9	7.1	2.0	1.0	21.9	18.9	0.9-1.1	0.52-0.63	3.21-4.45	0.27-0.33	0.2-0.34
ALLER BONA FLOAT	Grower pellet	3-6	70-800 and above	42	12	28.2	6.8	3.0	1	20	15.7-15.8	1-1.4	0.54-0.75	3.43-5.91	0.27-0.38	0.2-0.45
ALLER PRIMO FLOAT	Grower pellet	3-6	70-800 and above	37	12	35.2	6.2	3.6	1.0	20.1	15.4	1-1.4	0.47-0.66	2.7-4.87	0.36-0.5	0.41-0.75

[3] With exemplary feed conversion rations (Figures are per 100 kg fish production).

FEED			SIZE OF FISH (g)	DECLARATION								ENVIRONMENTAL IMPACT [3]				
Name	**Type**	**Size** (mm)		**CP** (%)	**CF** (%)	**NFE** (%)	**Ash** (%)	**Fibre** (%)	**P** (%)	**GE** (MJ)	**DE** (MJ)	**FCR**	**N in faeces** (kg)	**N in water** (kg)	**P in faeces** (kg)	**P in water** (kg)
African catfish – Europe																
Recommended feed program																
ALLER INFA EX GR	Fry feed granulate	0.1-0.4	below 0.05, 0.0.5-0.3	64	10	6.9	12.1	1.0	1.4	19.4	18.0	0.5-0.9	0.31-0.55	2.06-5.91	0.23-0.41	0.1-0.52
ALLER FUTURA EX GR	Fry feed granulate	0.5-1.6	0.3-4	60	15	5.7	12.6	0.7	1.4	21.2	19.7	0.5-0.8	0.29-0.46	1.76-4.47	0.21-0.34	0.06-0.35
		1.3-2	4-10	58	17	6.1	12.2	0.7	1.4	21.6	20.0	0.7-0.9	0.39-0.5	3.36-5.1	0.29-0.38	0.26-0.45
ALLER FUTURA EX	Fry feed pellet	1.5	4-10	58	17	6.0	10.1	0.9	1.2	21.6	20.1	0.6-0.8	0.28-0.45	1.61-4.23	0.18-0.28	0.01-0.23
ALLER PERFORMA	Fry feed pellet	1.3-1.5	1.5-10	48	21	13.2	8.7	1.1	1.2	22.1	20.0	0.5-0.8	0.23-0.37	0.86-3.03	0.18-0.29	0.06-0.32
	Pre-grower pellet	2	10-50	45	20	17.9	7.1	2.0	1.0	21.9	18.9	0.8-1	0.46-0.58	2.55-3.87	0.24-0.3	0.12-0.26
ALLER CLARIA FLOAT	Pre-grower pellet	2	10-50	45	12	25.1	6.4	3.5	0.9	20.3	17.2	0.7-0.9	0.4-0.52	1.89-3.21	0.21-0.27	0.06-0.2
	Grower pellet	3	50-150	45	12	26.4	6	2.6	1	20.3	17	0.8-1	0.46-0.58	2,55-2.87	0.24-0.3	0.13-0.27
		4.5	150-500	42	12	29.5	5.6	2.9	1	20.2	16.6	0.9-1.1	0.48-0.59	2.81-4.05	0.27-0.33	0.2-0.34
		6	500-1000	40	12	32	5.1	2.9	0.9	20.2	17.1	1-1.2	0.51-0.61	3.14-4.32	0.27-0.32	0.2-0.33
		8	1000-1500 and above	38	10	36.2	4.7	3.1	0.9	19.6	16.3	1.1-1.3	0.54-0.63	3.4-4.52	0.3-0.35	0.26-0.39
ALLER BONA FLOAT	Grower pellet	3-6	50-1500	42	12	28.2	6.8	3.0	1	20	15.7-15.8	0.9-1.3	0.48-0.7	2.81-5.29	0.3-0.43	0.27-0.57
Pangasius																
Recommended feed program																
ALLER INFA EX GR	Fry feed granulate	0.1-0.4	below 0.05, 0.0.5-0.3	64	10	6.9	12.1	1.0	1.4	19.4	18.0	0.5-0.9	0.31-0.55	2.06-5.91	0.23-0.41	0.1-0.52
ALLER THALASSA EX GR	Fry feed granulate	0.5-1.6	0.3-4	62	12	6.2	13.0	0.8	1.4	20.6	19.1	0.5-0.8	0.3-0.48	1.91-4.71	0.21-0.34	0.06-0.35
		1.3-2	4-50	60	14	6.6	12.6	0.8	1.4	21.0	19.3	0.7-0.9	0.4-0.52	3.57-5.37	0.29-0.38	0.26-0.45
ALLER PARVO EX GR	Fry feed granulate	0.5-2	0.1-50	44	9	29.4	9.3	2.3	1.1	18.7	14.4	0.5-1	0.28-0.56	0.49-3.73	0.18-0.36	0.07-0.49
ALLER TIL-PRO SANA	Pre-grower pellet	2	30-50	37	10	36.0	5.5	2.5	1.0	19.5	15.3	0.8-1	0.28-0.36	1.7-2.81	0.23-0.29	0.1-0.24
	Grower pellet	3	50-150	37	10	36.0	5.5	2.5	1.0	19.5	15.3	1-1.2	0.47-0.57	2.7-3.79	0.29-0.34	0.24-0.37
ALLER TIL-PRO OREA		3-6	50-1500	33	6	47.9	5.2	2.9	1	18.9	15.0	1.1-1.5	0.46-0.63	2.59-4.54	0.33-0.45	0.34-0.62
Additional feed program																
ALLER VITAL REP FLOAT	Broodstock feed	15	above 1500	33	6	42.8	6.3	4.0	1.1	18.2	12.7	1.2-1.4	0.51-0.59	3.08-4.05	0.4-0.46	0.49-0.65

(Source: [1])

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[3] *With exemplary feed conversion rations (Figures are per 100 kg fish production).*

TABLE A-3: PLANNING FIGURES ON THE USE OF ALLER AQUA FEEDS LISTED IN ANNEX 10

FEED				Initial and final weight (g)	EXPECTABLE RESULTS			
Name	**Type**	**Size** (mm)	**CP** (%)		**Growth** (kg/1000 fish)	**FCR**	**Feed** (kg/1000 fish)	**Approx. period** (months)
Arctic charr fed at 16 °C								
ALLER INFA EX GR	Fry feed granulate	0.1	64	0.05-0.15	0.1	0.5-0.7	0.05	0.5
		0.2		0.15-0.25	0.1	0.6-0.8	0.05	0.25
		0.4		0.25-0.5	0.25	0.7-0.9	0.2	0.5
	Total				**0.45**	**0.5-0.9**	**0.3**	**1.25**
ALLER FUTURA EX GR	Fry feed granulate	0.5-1	60	0.5-2	1.5	0.5-0.7	0.9	1
		0.9-1.6		2-7	5	0.6-0.8	3.5	1.25
		1.3-2	58	7-15	8	0.7-0.9	6.4	1
	Total				**14.5**	**0.5-0.9**	**10.8**	**3.25**
ALLER FUTURA EX	Fry feed pellet	1.3	58	2-7	5	0.5-0.7	3	1.25
		1.5		7-15	8	0.6-0.8	5.6	0.75
	Total				**13**	**0.5-0.8**	**8.6**	**2**
ALLER FUTURA	Pre-grower pellet	2	47	15-40	**25**	**0.7-0.9**	**20**	**1.75**
ALLER ARCTIC	Grower pellet	3	47-49	40-250	210	0.8-1	189	4.5
		4.5	45-47	250-400	150	0.9-1.1	150	1.5
		6	43-45	400-1000	600	1-1.2	660	4
	Total				**960**	**0.7-1.2**	**999**	**10**
Brown trout fed at 16 °C								
ALLER INFA EX GR	Fry feed granulate	0.2	64	0.1-0.25	0.15	0.5-0.7	0.1	0.5
		0.4		0.25-0.5	0.25	0.6-0.8	0.2	0.5
	Total				**0.4**	**0.5-0.8**	**0.3**	**1.0**
ALLER FUTURA EX GR	Fry feed granulate	0.5-1	60	0.5-2	1.5	0.5-0.7	0.9	1
		0.9-1.6		2-7	5	0.6-0.8	3.5	1.25
		1.3-2	58	7-15	8	0.7-0.9	6.4	0.75
	Total				**14.5**	**0.5-0.9**	**10.8**	**3**
ALLER FUTURA EX	Fry feed pellet	1.3	58	2-7	5.0	0.5-0.7	3	1
		1.5		7.15	8	0.6-0.8	5.6	1
	Total				**13**	**0.5-0.8**	**8.6**	**2**
ALLER FUTURA	Pre-grower pellet	2	47	15-40	**25**	**0.7-0.9**	**20**	**1**
ALLER ARCTIC	Grower pellet	3	47-49	40-100	60	0.8-1	54	1.75
		4.5	45-47	100-400	300	0.9-1.1	300	3.5
		6	43-45	400-1000	600	1-1.2	660	3.5
	Total				**960**	**0.7-1.2**	**1 014**	**8.75**
Rainbow trout fed at 16 °C								
ALLER INFA EX GR	Fry feed granulate	0.2	64	0.1-0.25	0.15	0.5-0.7	0.1	0.5
		0.4		0.25-0.5	0.25	0.6-0.8	0.2	0.25
	Total				**0.4**	**0.5-0.8**	**0.3**	**0.75**
ALLER FUTURA EX GR	Fry feed granulate	0.5-1	60	0.5-2	1.5	0.5-0.7	0.9	1
		0.9-1.6		2-7	5	0.6-0.8	3.5	1.25
		1.3-2	58	7-15	8	0.7-0.9	6.4	0.75
	Total				**14.5**	**0.5-0.9**	**10.8**	**3**
ALLER FUTURA EX	Fry feed pellet	1.3	58	2-7	5	0.5-0.7	3	1
		1.5		7-15	8	0.6-0.8	5.6	1
	Total				**13**	**0.5-0.8**	**8.6**	**2**

FEED				Initial and final weight (g)	EXPECTABLE RESULTS			
Name	Type	Size (mm)	CP (%)		Growth (kg/1000 fish)	FCR	Feed (kg/1000 fish)	Approx. period (months)
ALLER PERFORMA	Fry feed pellet	1.3	48	2-7	5	0.6-0.8	3	1.25
		1.5		7-15	8	0.7-0.9	5.6	1
	Total				**13**	**0.6-0.9**	**8.6**	**2.25**
ALLER FUTURA	Pre-grower pellet	2	47	15-40	**25**	**0.7-0.9**	**20**	**1.75**
ALLER PERFORMA	Pre-grower pellet	2	45	15-40	**25**	**0.8-1**	**22.5**	**1.75**
ALLER BRONZE	Pre-grower pellet	2	45	15-40	**25**	**0.9-1.1**	**25**	**1.75**
	Grower pellet	3		40-100	60	1-1.2	66	1.75
		4.5		100-400	300	1.1-1.3	360	3.75
		6		400-1000	600	1.2-1.4	780	3.25
		8		1000-2000	1 000	1.3-1.5	1 400	3.75
	Total				**1 960**	**1-1.5**	**2 606**	**12.5**
ALLER GOLD	Grower pellet	3	44-46	40-100	60	0.8-1	54	1.75
		4.5	42-44	100-400	300	0.9-1.1	300	3.75
		6	40-42	400-1000	600	1-1.2	660	3.25
		8		1000-2000	1 000	1.1-1.3	1 200	4
	Total				**1 960**	**0.8-1.3**	**2 214**	**12.75**
ALLER SILVER	Grower pellet	3	45	40-100	60	0.9-1.1	60	1.75
		4.5	43	100-400	300	1-1.2	330	3.75
		6	41	400-1000	600	1.1-1.3	720	3.5
		8		1000-2000	1 000	1.2-1.4	1 300	4
	Total				**1 960**	**0.9-1.4**	**2 410**	**13**
Whitefish fed at 16 °C								
ALLER INFA EX GR	Fry feed granulate	0.1	64	0.05-0.15	0.1	0.5-0.7	0.05	0.5
		0.2		0.15-0.25	0.1	0.6-0.8	0.05	0.25
		0.4		0.25-0.5	0.25	0.7-0.9	0.2	0.5
	Total				**0.45**	**0.5-0.9**	**0.3**	**1.25**
ALLER FUTURA EX GR	Fry feed granulate	0.5-1	60	0.5-2	1.5	0.5-0.7	0.9	1.25
		0.9-1.6		2-7	5	0.6-0.8	3.5	1.25
		1.3-2	58	7-15	8	0.7-0.9	6.4	1
	Total				**14.5**	**0.5-0.9**	**10.8**	**3.5**
ALLER FUTURA EX	Fry feed pellet	1.3	58	2-7	5	0.5-0.7	3	1.25
		1.5		7-15	8	0.6-0.8	5.6	1
	Total				**13**	**0.5-0.8**	**8.6**	**2.25**
ALLER FUTURA	Pre-grower pellet	2	47	15-40	**25**	**0.7-0.9**	**20**	**1.75**
ALLER ARCTIC	Grower pellet	3	47-49	40-100	60	0.8-1	54	2
		4.5	45-47	100-400	300	0.9-1.1	300	3.75
		6	43-45	400-1000	600	1-1.2	660	4
	Total				**960**	**0.8-1.2**	**1 014**	**9.75**
Sturgeon fed at 18 °C								
ALLER INFA EX GR	Fry feed granulate	0.2	64	0.03-0.5	0.47	0.5-0.7	0.3	0.75
		0.4		0.5-1	0.5	0.6-0.8	0.4	0.25
	Total				**0.97**	**0.5-0.8**	**0.7**	**1**
ALLER THALASSA EX GR	Fry feed granulate	0.5-1	62	1-2	1	0.5-0.7	0.6	0.25
		0.9-1.6		2-5	3	0.6-0.8	2.1	0.25
		1.3-2	60	5-10	5	0.7-0.9	4	0.75
	Total				**9**	**0.5-0.9**	**6.7**	**1.25**

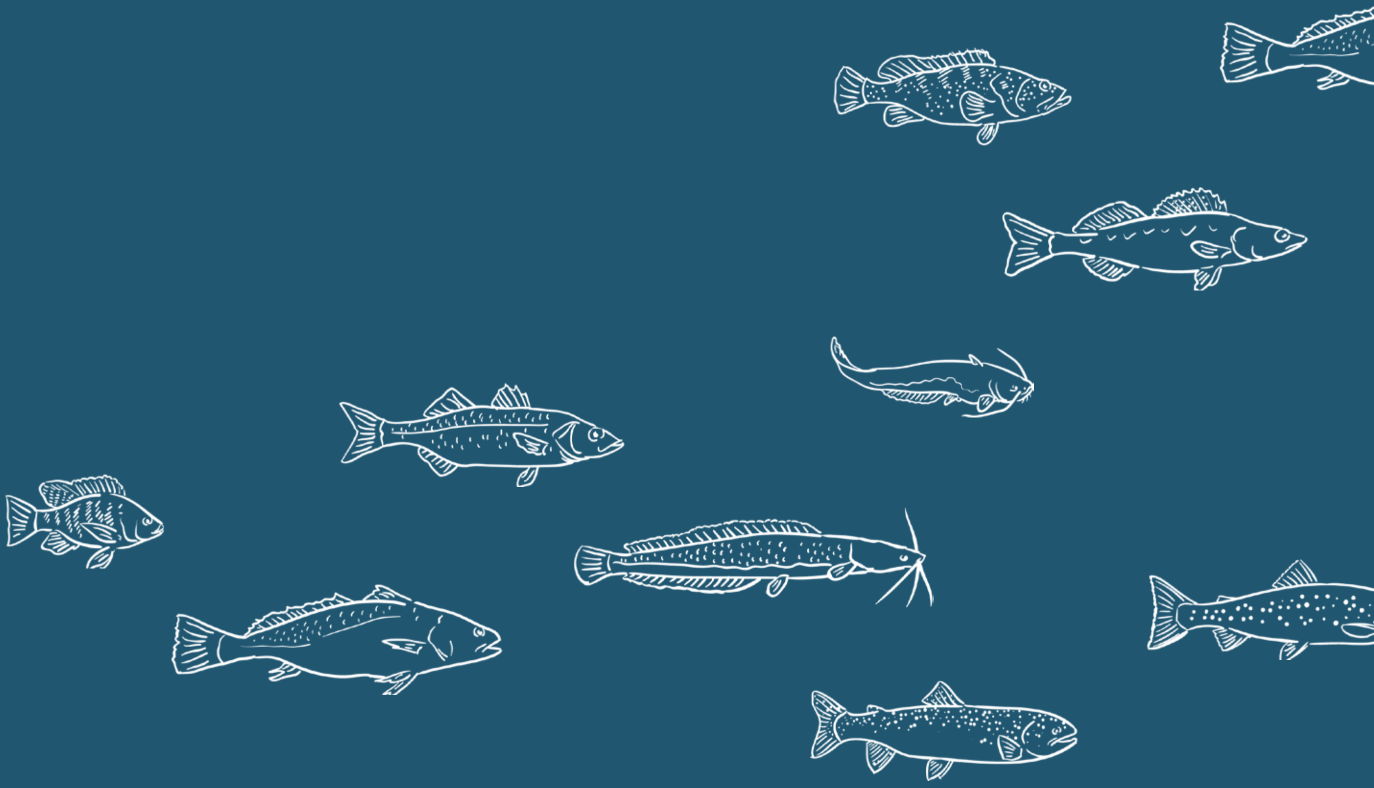
FEED				Initial and final weight (g)	EXPECTABLE RESULTS			
Name	Type	Size (mm)	CP (%)		Growth (kg/1000 fish)	FCR	Feed (kg/1000 fish)	Approx. period (months)
ALLER FUTURA EX GR	Fry feed granulate	0.5-1	60	1-2	1	0.5-0.7	0.6	0.25
		0.9-1.6		2-5	3	0.6-0.8	2.1	0.5
		1.3-2	58	5-10	5	0.7-0.9	4	0.75
	Total				**9**	**0.5-0.9**	**6.7**	**1.5**
ALLER PERFORMA	Fry feed pellet	1.3	48	3-6	3	0.6-0.8	2.1	0.5
		1.5		6-10	4	0.7-0.9	3.2	0.5
	Total				**7**	**0.6-0.9**	**5.3**	**1**
ALLER THALASSA EX	Pre-grower pellet	2	48	10-50	**40**	**0.8-1**	**36**	**1.25**
ALLER PERFORMA	Pre-grower pellet	2	45	10-50	**40**	**0.8-1**	**36**	**1.25**
ALLER BRONZE	Pre-grower pellet	2	45	10-50	**40**	**0.9-1.1**	**40**	**1.25**
	Grower pellet	3		50-200	150	1-1.2	165	2.75
		4.5		200-1500	1 300	1.1-1.3	1 560	6
		6		1500-4000	2 500	1.2-1.4	3 250	4.75
		8		4000-7000	3 000	1.3-1.5	4 200	3.75
		9-11		>7000		1.4-1.6	-	-
	Total				**6 950**	**1-1.6**	**9 175**	**17.25**
ALLER METABOLICA	Grower pellet	3	52	50-200	150	0.8-1	135	2.5
		4.5		200-1500	1 300	0.9-1.1	1 300	5.5
		6		1500-4000	2 500	1-1.2	2 750	4.25
		8		4000-7000	3 000	1.1-1.3	3 600	3.25
		9-11		>70000		1.2-1.4	-	-
	Total				**6 950**	**0.8-1.4**	**7 785**	**15.75**
Common carp fed at 24 °C								
ALLER INFA EX GR	Fry feed granulate	0.1	64	< 0.2	0.15	0.5-0.7	0.1	0.5
		0.2		0.2-0.5	0.30	0.6-0.8	0.2	0.25
		0.4		0.5-2	1.5	0.7-0.9	1.2	0.75
	Total				**1.95**	**0.5-0.9**	**1.5**	**1.5**
ALLER PARVO EX GR	Fry feed granulate	0.5	44	0.5-2	1.5	0.5-0.7	0.9	0.5
		0.5-1		2-5	3	0.6-0.8	2.1	0.5
		0.9-1.6		5-8	3	0.7-0.9	2.4	0.25
		1.3-2		8-10	2	0.8-1	1.8	0.25
	Total				**9.5**	**0.5-1**	**7.2**	**1.5**
ALLER PERFORMA	Fry feed pellet	1.3	48	5-8	3	0.5-0.7	1.8	0.25
		1.5		8-10	2	0.6-0.8	1.4	0.25
	Total				**5**	**0.5-0.8**	**3.2**	**0.5**
ALLER PRIMO	Pre-grower pellet	2	37	10-50	**40**	**1-1.2**	**44**	**1.3**
	Grower pellet	3		50-100	50	1-1.2	55	0.75
		4.5		100-300	200	1.1-1.3	240	1
		6		300-1500	1 200	1.2-1.4	1 560	2.25
		8		1500-2500	1 000	1.3-1.5	1 400	1.25
	Total				**2 450**	**1-1.5**	**3 255**	**5.25**
ALLER MASTER	Pre-grower pellet	2	35	10-50	**40**	**1.1-1.3**	**48**	**1.25**
	Grower pellet	3		50-100	50	1.1-1.3	60	0.75
		4.5		100-300	200	1.2-1.4	260	1.25
		6		300-1500	1 200	1.3-1.5	1 680	2.25
		8		1500-2500	1 000	1.4.1.6	1 500	1.25
	Total				**2 450**	**1.1-1.6**	**3 500**	**5.5**

FEED				**Initial and final weight** (g)	**EXPECTABLE RESULTS**			
Name	**Type**	**Size** (mm)	**CP** (%)		**Growth** (kg/1000 fish)	**FCR**	**Feed** (kg/1000 fish)	**Approx. period** (months)
ALLER CLASSIC	Pre-grower pellet	2	30	10-50	**40**	**1.2-1.4**	**52**	**1.25**
	Grower pellet	3		50-100	50	1.2-1.4	65	0.75
		4.5		100-300	200	1.3-1.5	280	1
		6		300-1500	1 200	1.4-1.6	1 800	2.5
		8		1500-2500	1 000	1.5-1.7	1 600	1.25
				2500-4000	1 500	1.5-1.7	2 400	2.00
	Total				**3 950**	**1.2-1.7**	**6 145**	**7.5**
Tench fed at 24 °C								
ALLER INFA EX GR	Fry feed granulate	0.2	64	0.2-0.5	0.3	0.5-0.7	0.2	0.5
		0.4		0.5-2	1.5	0.6-0.8	1.1	0.75
	Total				**1.8**	**0.5-0.8**	**1.3**	**1.25**
ALLER THALASSA EX GR	Fry feed granulate	0.5-1	62	2-5	3	0.5-0.7	1.8	0.5
		0.9-1.6		5-8	3	0.6-0.8	2.1	0.5
		1.3-2	60	8-10	2	0.7-0.9	1.6	0.25
	Total				**8**	**0.5-0.9**	**5.5**	**1.25**
ALLER FUTURA EX	Fry feed pellet	1.3	58	5-8	3	0.5-0.7	1.8	0.25
		1.5		8-10	2	0.6-0.8	1.4	0.25
	Total				**5**	**0.5-0.8**	**3.2**	**0.5**
ALLER PRIMO	Pre-grower pellet	2	37	10-50	**40**	**0.8-1**	**36**	**1.25**
	Grower pellet	3		50-100	50	1-1.2	55	0.75
		4.5		100-300	200	1.1-1.3	240	1.5
		6		300-500	200	1.2-1.4	260	0.75
	Total				**450**	**1-1.4**	**555**	**3**
Eel fed at 24 °C								
ALLER INFA EX GR	Fry feed granulate	0.2	64	0.2-0.5	0.3	0.5-0.7	0.2	0.5
		0.4		0.5-1	0.5	0.6-0.8	0.4	0.25
	Total				**0.8**	**0.5-0.8**	**0.6**	**0.75**
ALLER THALASSA EX GR	Fry feed granulate	0.5-1	62	1-5	4	0.5-0.7	2.4	1.5
		0.9-1.6		5-15	10	0.6-0.8	7	1.25
		1.3-2	60	15-30	15	0.7-0.9	12	1.25
	Total				**29**	**0.5-0.9**	**21.4**	**4**
ALLER IVORY EX	Pre-grower pellet	2	56	30-80	**50**	**0.9-1.1**	**50**	**3**
	Grower pellet	3	54	80-120	40	1-1.2	44	1.75
European catfish fed at 26 °C								
ALLER INFA EX GR	Fry feed granulate	0.2	64	0.05-0.1	0.05	0.5-0.7	0.1	0.5
		0.4		0.1-0.3	0.2	0.6-0.8	0.1	0.25
	Total				**0.25**	**0.5-0.8**	**0.2**	**0.75**
ALLER THALASSA EX GR	Fry feed granulate	0.5-1	62	0.3-1.5	1.2	0.5-0.7	0.7	0.75
		0.9-1.6		1.5-4	2.5	0.6-0.8	1.8	0.5
		1.3-2	60	4-10	6	0.7-0.9	4.8	0.5
	Total				**9.7**	**0.5-0.9**	**7.3**	**1.75**
ALLER THALASSA EX	Pre-grower pellet	2	48	10-50	**40**	**0.7-0.9**	**32**	**1.25**
ALLER IVORY EX	Pre-grower pellet	2	56	30-50	**20**	**0.7-0.9**	**16**	**0.5**
	Grower pellet	3		50-150	100	0.8-1	90	1.25
		4.5	54	150-500	350	0.9-1.1	350	2
		6		500-1500	1 000	1-1.2	1 100	3.25
	Total				**1 450**	**0.8-1.2**	**1 540**	**6.5**

FEED				Initial and final weight (g)	EXPECTABLE RESULTS			
Name	**Type**	**Size** (mm)	**CP** (%)		**Growth** (kg/1000 fish)	**FCR**	**Feed** (kg/1000 fish)	**Approx. period** (months)
ALLER METABOLICA	Grower pellet	3	52	50-150	100	0.9-1.1	100	1.5
		4.5		150-500	350	1-1.2	385	2.25
		6		500-1000	500	1.1-1.3	600	1.75
		8		1000-1500	500	1.2-1.4	650	1.75
		11		1500-2500	1 000	1.3-1.5	1 400	2.25
	Total				**2 450**	**0.9-1.5**	**3 135**	**9.5**
ALLER BRONZE	Grower pellet	3	45	50-150	100	1-1.2	110	1.25
		4.5		150-500	350	1.1-1.3	420	1.75
		6		500-1000	500	1.2-1.4	650	2
		8		1000-1500	500	1.3-1.5	700	0.75
	Total				**1 450**	**1-1.5**	**1 880**	**5.75**
Perch fed at 26 °C								
ALLER INFA EX GR	Fry feed granulate	0.1	64	0.05-0.2	0.15	0.5-0.7	0.1	0.5
		0.2		0.2-0.5	0.3	0.6-0.8	0.2	0.25
		0.4		0.5-1	0.5	0.7-0.9	0.4	0.5
	Total				**0.95**	**0.5-0.9**	**0.7**	**1.25**
ALLER THALASSA EX GR	Fry feed granulate	0.5-1	62	1-4	3	0.5-0.7	1.8	1
		0.9-1.6		4-7	3	0.6-0.8	2.1	0.5
		1.3-2	60	7-10	3	0.7-0.9	2.4	0.5
	Total				**9**	**0.5-0.9**	**6.3**	**2**
ALLER IVORY EX	Pre-grower pellet	2	56	10-20	**10**	**0.8-1**	**9**	**1.25**
	Grower pellet	3		20-50	30	0.8-1	27	2
		4.5	54	50-150	100	0.9-1.1	100	3
		6		150-500	350	1-1.2	385	4
	Total				**480**	**0.8-1.2**	**512**	**9**
Pikeperch fed at 26 °C								
ALLER INFA EX GR	Fry feed granulate	0.1	64	0.05-0.2	0.15	0.5-0.7	0.1	0.5
		0.2		0.2-0.5	0.3	0.6-0.8	0.2	0.5
		0.4		0.5-1	0.5	0.7-0.9	0.4	0.25
	Total				**0.95**	**0.5-0.9**	**0.7**	**1.25**
ALLER THALASSA EX GR	Fry feed granulate	0.5-1	62	1-4	3	0.5-0.7	1.8	0.75
		0.9-1.6		4-7	3	0.6-0.8	2.1	0.5
		1.3-2	60	7-10	3	0.7-0.9	2.4	0.25
	Total				**9**	**0.5-0.9**	**6.3**	**1.5**
ALLER IVORY EX	Pre-grower pellet	2	56	10-20	**10**	**0.8-1**	**9**	**1.25**
	Grower pellet	3		20-50	30	0.8-1	27	1.75
		4.5	54	50-150	100	0.9-1.2	100	2.5
		6		150-1000	850	1-1.2	935	6.25
	Total				**980**	**0.8-1.2**	**1 062**	**10.5**
Tilapia – Europe fed at 28 °C								
ALLER INFA EX GR	Fry feed granulate	0.1	64	< 0.1	0.05	0.5-0.7	0.05	0.25
		0.2		0.1-0.3	0.20	0.6-0.8	0.15	0.25
		0.4		0.3-0.5	0.20	0.7-0.9	0.2	0.25
	Total				**0.45**	**0.5-0.8**	**0.4**	**0.75**

FEED				**Initial and final weight** (g)	**EXPECTABLE RESULTS**			
Name	**Type**	**Size** (mm)	**CP** (%)		**Growth** (kg/1000 fish)	**FCR**	**Feed** (kg/1000 fish)	**Approx. period** (months)
ALLER PARVO EX GR	Fry feed granulate	0.5	44	0.3-0.5	0.2	0.6-0.8	0.1	0.25
		0.5-1		0.5-1	0.5	0.7-0.9	0.4	0.25
		0.9-1.6		1-6	5	0.8-1	4.5	0.75
		1.3-2		6-10	4	0.9-1.1	4	0.25
	Total				**9.7**	**0.6-1.1**	**9**	**1.5**
ALLER PERFORMA	Pre-grower pellet	2	45	10-70	**60**	**0.9-1.1**	**60**	**2**
ALLER BONA FLOAT	Grower pellet	3	42	70-200	130	1-1.2	143	1.75
		4.5		200-800	600	1.1-1.3	720	3.5
		6		800-1000	200	1.2-1.4	260	0.75
	Total				**930**	**0.9-1.4**	**1 123**	**6**
African catfish – Europe fed at 26 °C								
ALLER INFA EX GR	Fry feed granulate	0.1	64	< 0.05	0.03	0.5-0.7	0.05	0.25
		0.2		0.05-0.1	0.05	0.6-0.8	0.05	0.25
		0.3		0.1-0.3	0.2	0.7-0.9	0.15	0.5
	Total				**0.28**	**0.5-0.9**	**0.25**	**1**
ALLER FUTURA EX GR	Fry feed granulate	0.5-1	60	0.3-1.5	1.2	0.5-0.7	0.7	0.75
		0.9-1.6		1.5-4	2.5	0.6-0.8	1.8	0.5
		1.3-2	58	4-10	6	0.7-0.9	4.8	0.5
	Total				**9.7**	**0.5-0.9**	**7.3**	**1.75**
ALLER PERFORMA	Fry feed pellet	1.3	48	1.5-4	2.5	0.5-0.7	1.5	0.5
		1.5		4-10	6	0.6-0.8	4.2	0.5
	Total				**8.5**	**0.6-0.8**	**9.9**	**1**
ALLER PERFORMA	Pre-grower pellet	2	45	10-50	140	**0.8-1**	**126**	**1.25**
ALLER BONA FLOAT	Grower pellet	3	42	50-150	100	0.9-1.1	100	1
		4.5		150-500	350	1-1.2	385	1.75
		6		500-1000	500	1.1-1.3	600	1.75
	Total				**950**	**0.8-1.3**	**1 085**	**4.5**
ALLER CLARIA FLOAT	Grower feed	3	45	50-150	100	0.8-1	90	1
		4.5	42	150-500	350	0.9-1.1	350	1.75
		6	40	500-1000	500	1-1.2	550	1.75
		8	38	1000-1500	500	1.1-1.3	600	1
	Total				**1 450**	**0.8-1.3**	**1 590**	**5.5**
Pangasius fed at 26-30 °C								
ALLER INFA EX GR	Fry feed granulate	0.1	64	< 0.05	0.03	0.5-0.7	0.05	0.25
		0.2		0.05-0.1	0.05	0.6-0.8	0.05	0.25
		0.4		0.1-0.3	0.2	0.7-0.9	0.15	0.5
	Total				**0.28**	**0.5-0.9**	**0.25**	**1**
ALLER THALASSA EX GR	Fry feed granulate	0.5-1	62	0.3-1.5	1.2	0.5-0.7	0.7	0.5
		0.9-1.6		1.5-4	2.5	0.6-0.8	1.8	0.75
		1.3-2	60	4-50	46	0.7-0.9	36.8	1.5
	Total				**49.7**	**0.5-0.9**	**39.3**	**2.75**

FEED				Initial and final weight (g)	EXPECTABLE RESULTS			
Name	**Type**	**Size** (mm)	**CP** (%)		**Growth** (kg/1000 fish)	**FCR**	**Feed** (kg/1000 fish)	**Approx. period** (months)
ALLER PARVO EX GR	Fry feed granulate	0.5	44	0.1-0.3	0.2	0.5-0.7	0.1	0.25
		0.5-1		0.3-1.5	1.2	0.6-0.8	0.8	0.75
		0.9-1.6		1.5-4	2.5	0.7-0.9	2	0.5
		1.3-2		4-50	46	0.8-1	41.4	1.5
	Total				**49.9**	**0.5-1**	**44.3**	**3**
ALLER TIL-PRO SANA	Pre-grower pellet	2	37	30-50	**20**	**0.8-1**	**18**	**0.3**
	Grower pellet	3		50-150	100	1-1.2	110	1.5
ALLER TIL-PRO OREA	Grower pellet	3	33	50-150	100	1.1-1.3	120	1.5
		4.5		150-500	350	1.2-1.4	455	2.5
		6		500-1500	1 000	1.3-1.5	1 400	3.5
	Total				**1 450**	**1.1-1.5**	**1 975**	**7.5**



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