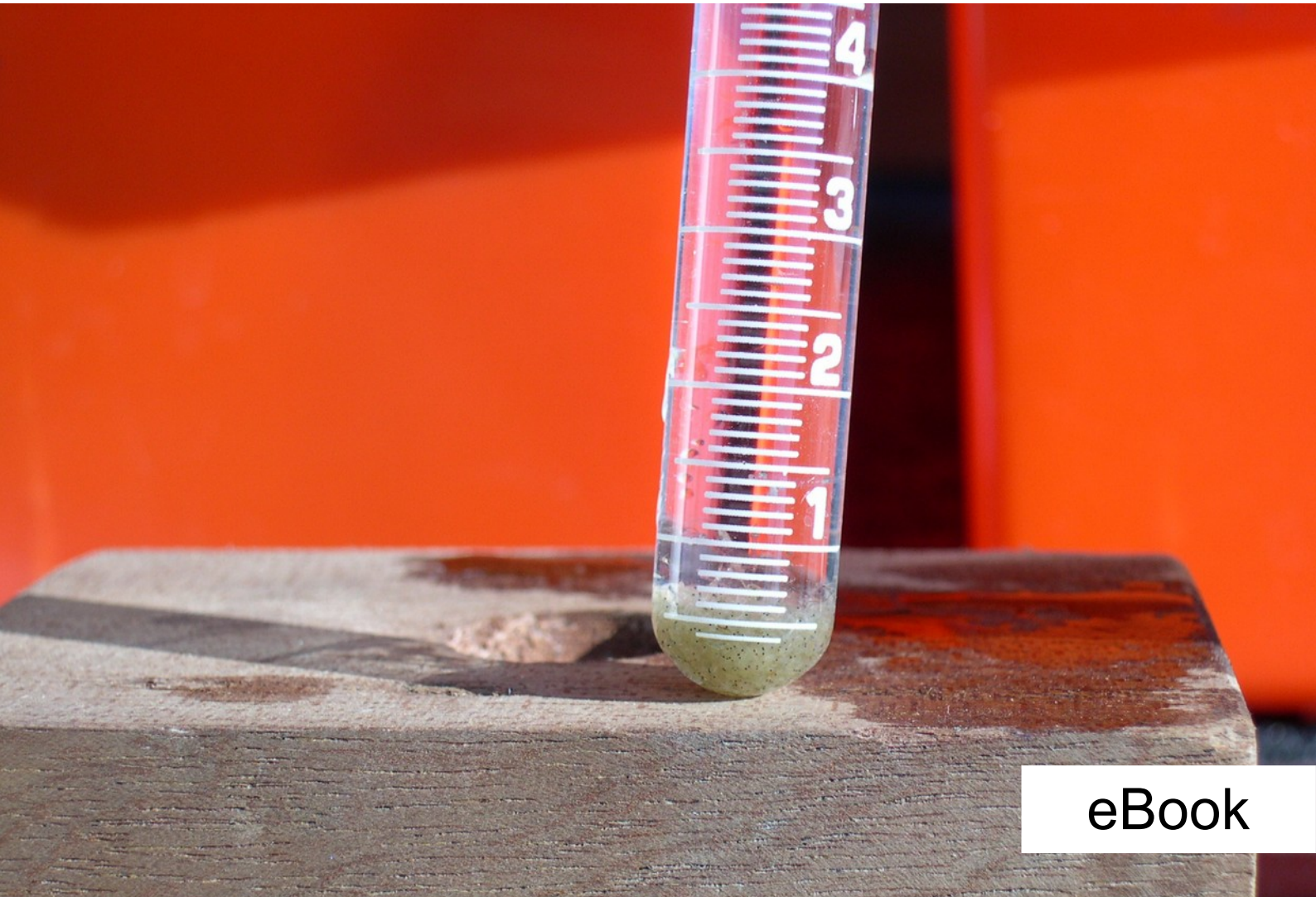
Federal Agency
for Water Management

Demand-oriented Feeding in Carp Pond Farming

The Settling Volume of Zooplankton



eBook

The Settling Volume of Zooplankton

Demand-oriented Feeding in Carp Pond Farming

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Contents

1 Introduction

Ponds are man-made artificial water systems, mostly used for fish farming. Ponds are an important element of the cultural landscape, leaving their mark on an entire region.

Pond farming has a long tradition in Austria, dating back at least to the 13th century. After a flourishing period in the 16th century, the number of ponds decreased. Today, the ponds and the product carp are again more in the focus of public interest. The largely extensive production methods and the consistently high quality of the fish produced are appealing to consumers.

Figure 1.1: Ponds are valuabel artificial wetland ecosystems, but more economic area thean wilderness. Figure: BAW

Moreover, the ponds and their littoral zones have not been discovered by conservationists in recent years. The modernization and mechanization of agriculture, as well as the water engineering measures of the 20th century, were accompanied by an impoverishment of the landscape in terms of wetlands and aquatic ecosystems. In this situation, ponds in the landscape formed and still form wetlands and an important refuge for wetland animals and plants. Their importance is underlined by the fact that parts of the wetlands are under nature protection and have been designated as NATURA 2000 areas. But ponds remain *farmland*. They are not a piece of wilderness and when ponds, for whatever reason, are no longer managed, they inevitably become degraded and disappear.

Management ensures the existence of ponds and so the aim of this small brochure is to provide the interested pond keeper with a practical tool to manage ponds according to natural food, i.e. zooplankton. Not feed tables and textbooks, but the natural food itself provides information on how the pond farmer should act. Thus, this method can be seen as a building block to a sustainable and extensive form of carp farming.

2 Sustainability in Pond Management

Karin Schlott

The term *GOOD PRACTICE* is often used by pond managers. There is a danger of equating traditional pond management with the concept of good practice.

Good professional practice is defined in Germany as follows (from: https://tinyurl.com/4tyf2mx2, 2023-07-27):

Good professional practice means, in pond and fish farming, the breeding and keeping of individual, several or all developmental and life stages of fish, crustaceans and shellfish and, in river and lake fisheries, the exploitation of these animals and life forms by catching and appropriation, as well as the management and care of fish stocks and fish waters with their biocoenoses. The guiding principle of good professional practice is the PRINCIPLE OF SUSTAINABILITY, which takes into account the protection of nature and the environment as well as social and economic interests. It complies with legal requirements and takes into account the latest scientific knowledge and practical experience. Good fishing practice contributes significantly to the conservation and protection of natural biodiversity, safeguards fish stocks in waters and promotes the production of high quality food in fish farming and aquaculture.

Sustainable pond management therefore means incorporating new knowledge from fisheries research and testing it in practice.

The scope of legislation relating to pond management is extensive and difficult for practitioners to understand. The most important regulations include the following:

In the context of sustainable management, the EU Water Framework Directive, which is implemented in Austria by the Austrian Water Act (BGBl 123/2006), is of primary importance. An essential principle is the prohibition of deterioration. This means, for example, that the use of the water must not lead to a deterioration of the water quality in the flowing waters. (Qualitätszielverordnung Ökologie, BGBl 99/2010). The Waste Water Emissions Ordinance (AEV Aquakultur; BGBl 397/2004) sets out the measures to be taken.

Animal welfare is regulated by the Animal Husbandry Ordinance (BGBl 485/2004). In appendix 10 of this ordinance it can be read under point 1.2. nutrition: *The diet must take into account the climatic conditions of the pond, i.e. in particular the type and quantity of natural food available and the nutritional and physiological requirements of the fish species concerned. If the natural food supply is insufficient, it must be supplemented in an appropriate form.*

The fact that common carp (*Cyprinus carpios*) feeds on small animals must be taken into account when feeding the carp. In case of a lack of natural food, feed should be used which is similar in composition to that of the food organisms, i.e. which also contains animal protein.

There is no automatic grafting in pond farming.

The assumption that more plant nutrients will automatically lead to an increase in fish production is not acceptable in carp pond management. Due to the very complex interactions in the pond ecosystem, the path from nutrients to the final product, fish, is never straight, but sometimes very tortuous, and can lead to situations that have extremely negative effects

on the fish stock and thus on production success. These include the disappearance of edible zooplankton organisms when the fish population is too high. This can lead to massive blooms of (blue) algae or, especially in the case of high nutrient levels, small zooplankton (e.g. bosmines, rotifers, ciliates) that are difficult to correct. These developments could be described as ecological dead ends.

The role of predation by fish on prey species is often underestimated. Ancillary species such as coregonids, zander, pike or many other small fish species (e.g. roach) play a much more important role in the development of the pond ecosystem than is usually assumed by pond managers.

Comparison with terrestrial agriculture

Figure 2.1: Unlike other forms of livestock production in agriculture, the pond is both a stable and pasture. Figures: BAW (pond) and By wolvenraider - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=1117314 Wikipedia,2023-07-28

Pond farming is a special form of agriculture. However, it would be a serious misunderstanding with far-reaching consequences to equate terrestrial and aquatic land management. This is illustrated by a comparison between pasture management and pond management. In both cases management is related to the area (Table 2.1). However, the management of a carp pond is much riskier and more complicated than terrestrial livestock production.

The interactions between animal and environment are more intertwined in fish production than in terrestrial animal husbandry. While poor air quality in the cowshed has little effect on feeding behavior and animal health, poor water quality often has very negative consequences on production and fish health.

The interactions between animals and the environment are more complex in fish production than in terrestrial livestock production. While poor air quality in the barn has little effect on feeding behaviour and animal health, poor water quality often has a very negative impact on production and fish health.

THE POND IS STABLE AND PASTURE AT THE SAME TIME - this fact shapes the whole theory of pond production (Fig. 2.1).

In terms of responsible use of resources, every pond manager should have at least a basic understanding of the interaction between plant nutrients, natural food development and supplementary feeding.

For a better understanding of the interrelationships in the nutrient cycle or food chain, see the following figure (Fig. 2.2).

Table 2.1: Comparison of agricultural livestock production with pond production.

	Pasture	**Pond**
Number per unit area	The number of animals per unit area can be constantly monitored. Deviations in population density are easy to detect detect	The fixed number of fish can vary considerably during a production period (e.g. disease, lack of oxygen, fish-eating animals, uncontrolled reproduction, invasion of unwanted fish.
Fertilization	Determining nutrient status is methodologically simpler. The effects of fertilisation on forage develompment are clearly visible.	Determining nutrient status and the resulting fertiliser requirements is more complex. The consequences of fertilisation in terms of impact on natural food are not so easy to assess.
Natural food	The effect of the grazing activity of the animals can be seen immediately; if there is no suitable, forage base the animals can be moved to another grazing area.	The effects of fish preasure on natural food are not visible to the naked eye.

In principle, the aim of any pond management should be to convert the available plant nutrients into fish flesh by the shortest possible route through the plant primary production stage (phytoplankton = algae) and the animal secondary production stage (plankton and benthic animals). The shorter the food chain and the more efficient the energy transfer, the more likely this is to succeed (Fig. 2.2 above).

An easily understandable reason why this is not so easy to achieve in reality is that the path from primary production to secondary production is not always a straight line, due to differences in the size of individual phytoplankton species. In the course of a production season, nutrient ratios and feeding pressure on the phytoplankton can change in a way that results in the development of algae that are inedible for the daphnia (colony-forming or filamentous forms) (Fig. 2.2 below). **The development of fish food (daphnia) depends on the quantity and quality of phytoplankton as its own food base, in addition to fish feeding pressure. Water temperature obviously affects the rate of daphnia development, but not as much as is often assumed by practitioners.**

The far-reaching effects that the daphnia population can have on the state of the plankton in general are shown in Figure 2.3. There is a clear correlation between daphnia population density and the development of algal blooms [11]. The influence of pond management, in particular the increase in fish stocking density and nutrient input, on plankton composition is clearly shown in Figure 2.4. The development in Czech ponds since the end of the 19th century has been studied by a group of Czech scientists [12]. This compilation also shows that with higher fish stocking densities and high nutrient inputs, there is an increased tendency for the formation of inedible algae and zooplankton organisms, which are of no use to carp due to their small size. This means a break in the food chain and leads to an ecological dead end.

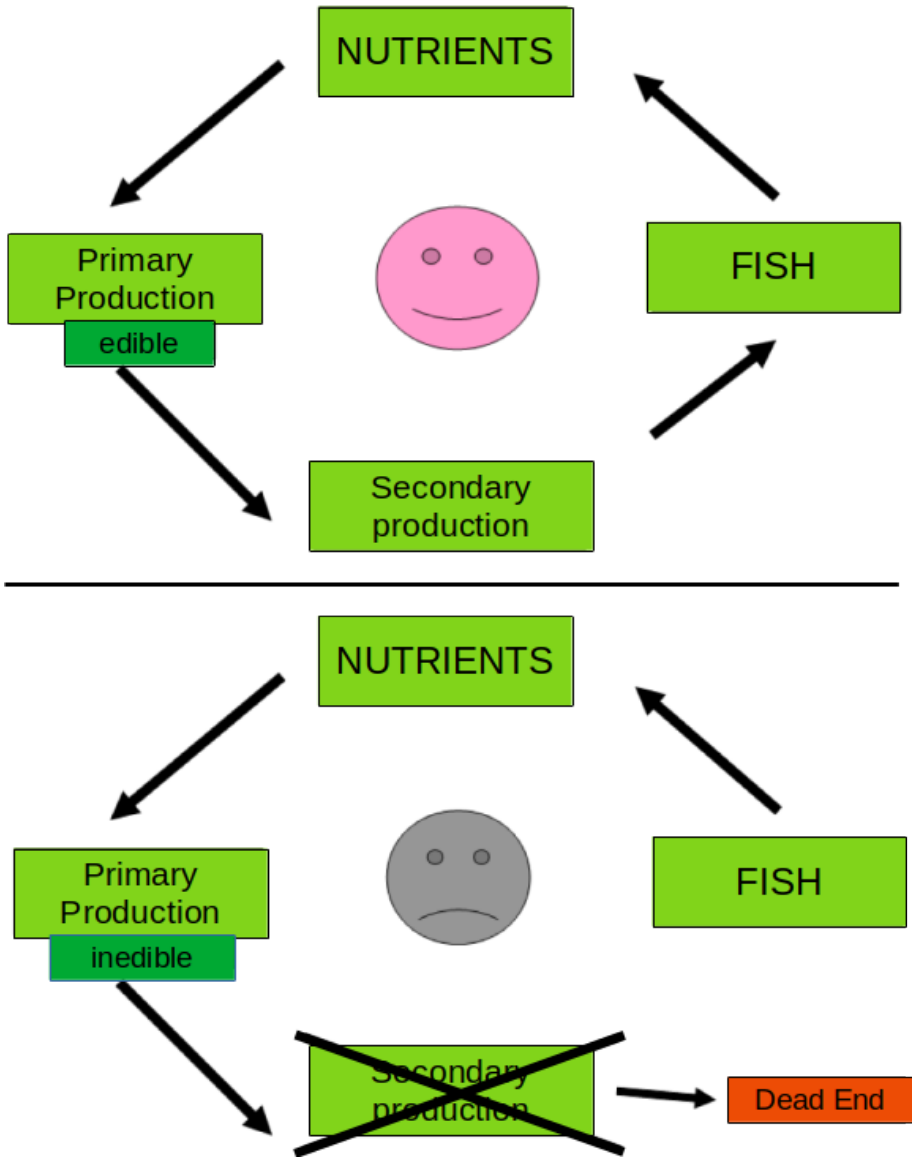

Figure 2.2: Sustainable pond management avoids the formation of a dead end. Figure: BAW

If the fish population density and feeding are in balance, a reproductive daphnia population and a phytoplankton population consisting mainly of edible algae will develop. If the fish population is too low, an overpopulation may occur as a result of insufficient use of the daphnia, leading to a high visibility depth and thus increased plant growth (aquatic plants, reeds, etc.). Siltation of the pond is the result (Fig. 2.5).

To optimise water quality, the continuity of the food chain MUST be maintained throughout the production period!!!

A good measure of the natural food available is the individual density of Daphnia >1 mm [17] in size. The pond manager is therefore faced with the challenge of keeping the natural food stock as stable as possible. The results of many practical studies show that the number of Daphnia >1 mm should be between 20 and 40 ind./l [18].

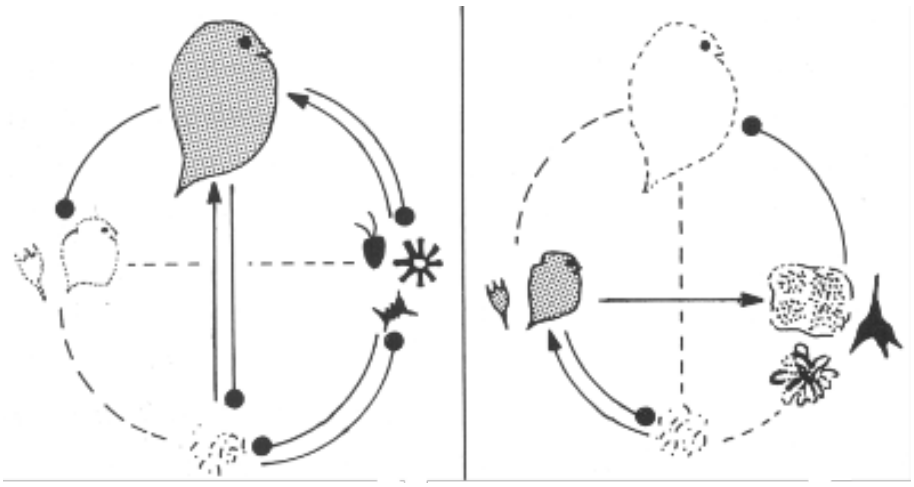

Figure 2.3: Formation of algal blooms in the absence of large daphnia. Figure modified according to [22].

The following daphnia density limits can be used for *NURSING NATURAL FOOD*.

- 20 - 40 Ind./l: Ideal level for sustainable reproduction of daphnia populations in Waldviertler ponds.
- <20 Ind./l: There is a risk of overexploitation of the daphnia stock, the reproductive capability is not guaranteed.
- >40 Ind./l: The daphnia stock is under-utilised, overpopulation is possible, negative consequences such as oxygen depletion etc. may occur.

The results of many years of research in this area are in stark contrast to most feeding recommendations [5, 13].

It is assumed that the development of plankton (phyto- and zooplankton) follows a certain schematic development pattern. However, this view is taken from lake science [10] and is therefore not at all applicable to drainable shallow waters with completely different environmental conditions and fish densities.

Similarly, the requirement that half of the increase in carp biomass must come from natural diets [13] is unlikely to be met by current practices.

Figure 2.6 shows the individual daphnia densities recorded in three consecutive years in a larger grow out pond. The extremely low daphnia density in 1998 (red line) is accompanied by results that are completely incompatible with the objectives of sustainable pond management. In this case, the cause of this poor result is clearly the excessively high fish density. A high proportion of cyanobacteria (blue-green algae) indicates that the direct food chain has been disrupted, with the associated consequences of high total phosphorus, low visibility and high pH (Tab. 2.2).

In the interests of truly sustainable pond management, care should be taken to avoid such developments. This could also create the conditions for improving fish health and product quality.

	End of the 19th century	Thirties	Sixties and Seventies	Nineties until today
Nutrient input	Low	Increasing	High	High
Phytoplankton	Low production	Increasing biomass of edible algae	Average biomass and production	Inedibe algae dominate
Zooplankton	Low biomass	Big daphnia predominate	Big daphnia	Zooplankton with low filtration rate predominate
Fish stock	Very low 40 Ind./ha	Low 100 Ind./ha	Up to 500 Ind./ha	High 700 – 1000 Ind./ha

Figure 2.4: Development of Czech ponds with increasing nutrient supply. Figure: BAW according to [12]

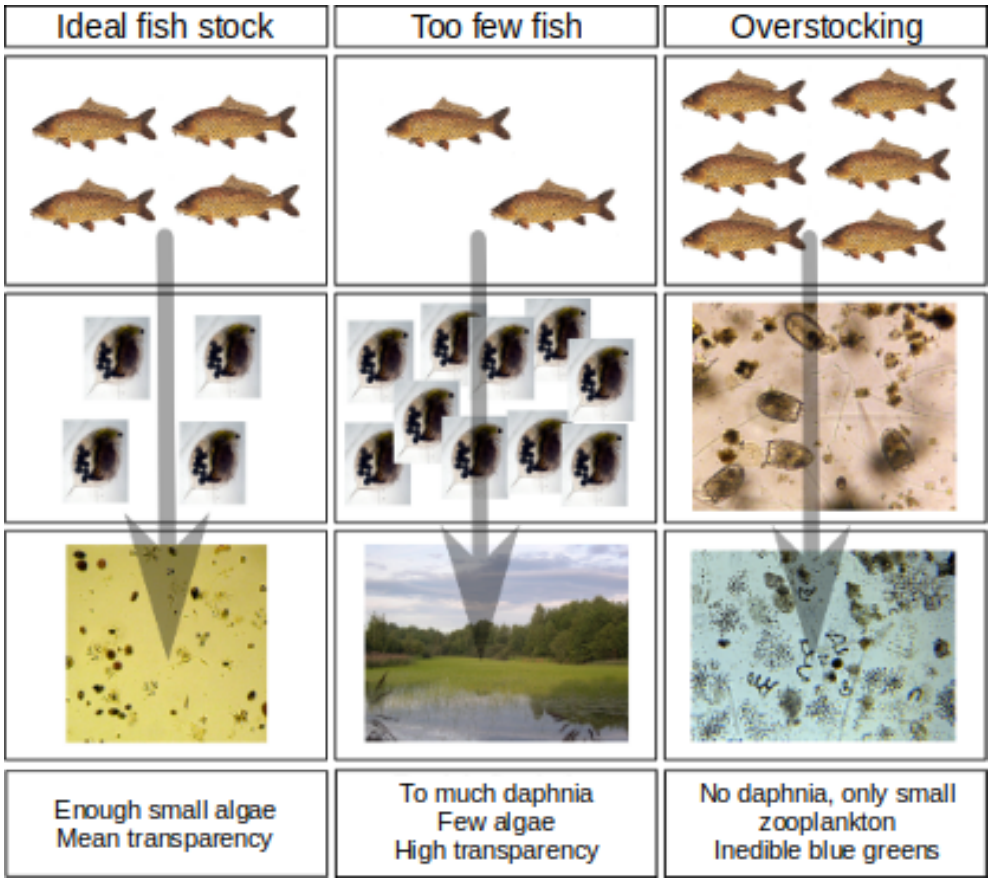

Figure 2.5: The pond ecosystem at different fish density. Figure: BAW

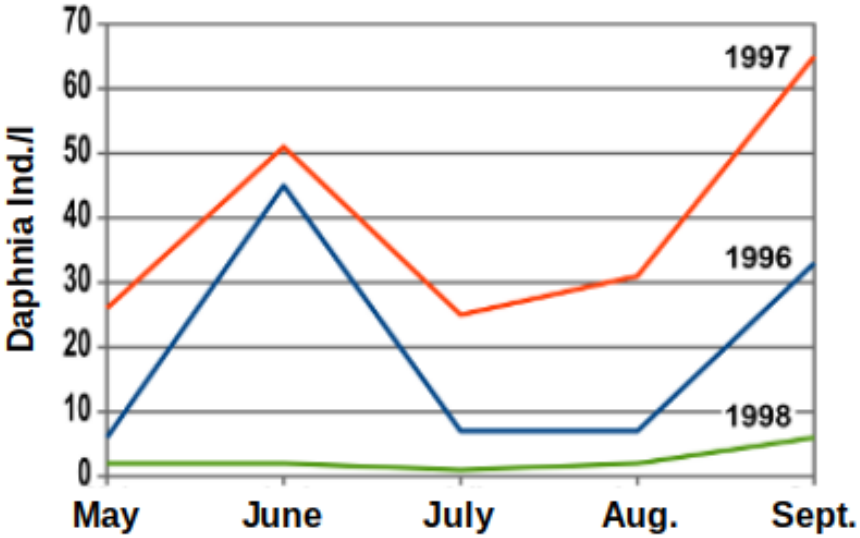

Figure 2.6: Monthly mean values of the density [Ind./l] of daphnia >1 mm. Figure: BAW

Table 2.2: Comparison of the production years 1996 - 1998.

Year	pH max.	Ptot [µg/l] max.	Water transp. [m] August	Cyanobact. % Biomass	Fish prod. [kg/ha]	Carp [Ind./ha]
1996	8,9	276	0,45	43	450	615
1997	7,7	345	0,70	32	310	567
1998	9,0	757	0,20	83	381	4437

3 Natural food and supplementary feeding

Karin Schlott, Günther Schlott & Günther Gratzl

3.1 What is natural food?

Natural food is generally defined as the animal organisms in the pond that are eaten by the fish (common carp). In addition to zooplankton, small bottom-dwelling and plant-dwelling animals (mud worms, insects and their larvae, etc.) also play a role. However, zooplankton organisms can be considered as the most important component of the natural food. Especially those larger than 1 mm, the large daphnids (water fleas) and copepods play an important role (Fig. 3.1).

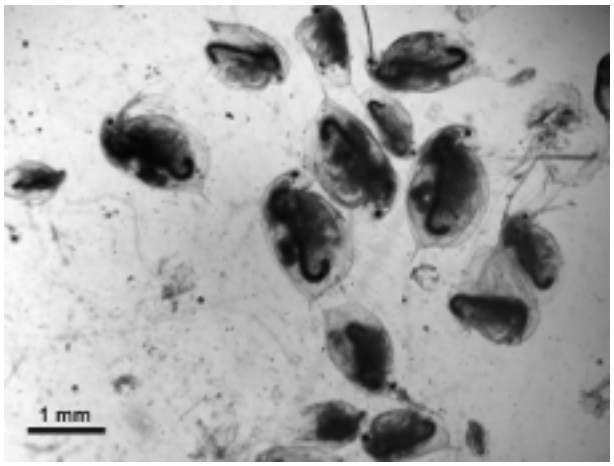

Figure 3.1: Daphnia are the natural food par excellence. Specimens >1 mm are of particular importance. Figure: BAW

The fundamental importance of natural food for fish farming was recognized early on [24, 25]. Walter wrote as early as 1899: *Plankton is a major component of fish food. Whether a body of water is poor or rich in fish, whether it produces a large or small increase in fish meat, depends mainly on the larger or smaller amount of plankton stored in its waters. We cannot increase the fish population in our waters unless we improve the food source of the same* [25].

What is natural food? How are natural foods developed? How do you encourage the development of natural foods? Why is natural food important?

These and similar questions occupy a pond keeper when he wants to make the management of his ponds close to nature, ecological and sustainable. This is definitely not an easy task! First of all, it must be clearly understood that the relationship between natural food and fish is much more complicated than, for example, the relationship between grazing animals and their natural environment. One of the main differences is that natural food in a pond can hardly be seen with the naked eye and therefore the amount present at any given time cannot be estimated directly. Only very experienced and skilled observers are able to make even an approximate estimate of the natural food situation on site.

A good introduction to the subject of natural food in ponds can be found in the volume on *The Planktic Natural Food* in the series of publications of the Federal Agency for Water Management [17].

3.1.1 The role of large daphnia

That daphnia is the most important food for carp has already been established [24, 27]. Up to 27,000 daphnia were found in the intestine of three year old carp [8]. In the ponds of the

Waldviertel[1], the cladocerans, the group to which daphnids belong, are the most important component of the zooplankton with a share of about 2/3 of the biomass in summer [20].

In order to approach the required coordination of supplemental feeding and natural food in pond management practice, it is necessary to define a reference value for the amount of natural food available at a given point in time. Long-term data series collected in practical research projects can be used for this purpose. The sampling and evaluation methodology used is summarized in SYNOPSE 2000 [18]. The monthly mean daphnia values shown in Figure 3.2 thus provide a means of quantitatively estimating the amount of natural food. The underlying Daphnia abundances must be considered as a result of fish feeding pressure and the bonity-dependent production potential of Daphnia.

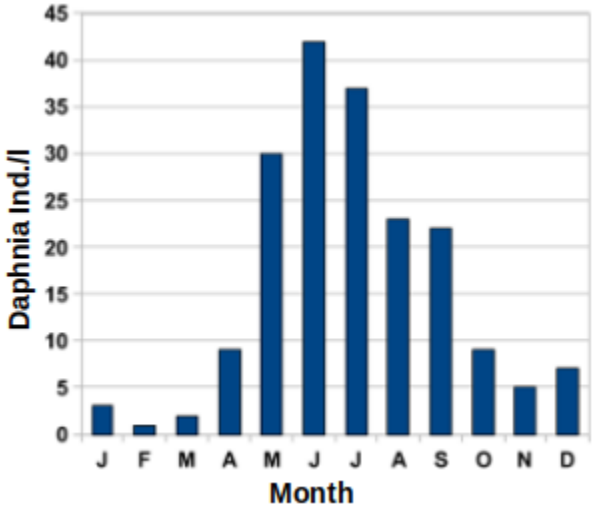

Figure 3.2: Monthly mean values of Daphnia >1 mm in Waldviertler ponds. (n=1.438) Figure: BAW

Large and prolonged deviations from the reference values shown in Figure 3.2 indicate imbalances in the interactions between fish density, natural food and supplemental feeding, which have negative ecological and economic consequences. In practice, this means trying to influence the feeding pressure on the daphnids by providing a diet that is flexible in terms of quantity and quality. It can be assumed that increasing the amount of food will reduce the feeding pressure on the daphnia and increase their reproductive potential. On the other hand, a reduction or complete cessation of supplemental feeding should result in a reduction of the daphnia population by increasing the feeding pressure.

In principle, it is known that fish can influence zooplankton. Benndorf, for example, writes *A reasonable fish feeding pressure can also promote the stability of a Daphnia population by avoiding starvation of the same or oxygen deprivation as a result of overpopulation* [1]. Hrbaček also points to the influence of fish stocking, noting that at higher fish densities, zooplankton evolve toward smaller zooplankton species that are no longer useful to the fish [7]. However, a quantitative evaluation seemed too costly for fishing practice.

Thus, assuming that the amount of daphnia or daphnia density is a suitable parameter for estimating natural food, the question arises of a relatively simple and practical method that allows the pond keeper to approximate the amount of natural food present directly at the pond. Such a method is presented in Chapter 4. But first, the feeding of carp and the concept of *demand-oriented feeding* are specified.

3.2 How to feed carp?

When it comes to feeding in pond management, it is more accurate to speak of supplemental feeding or feed. It is generally assumed that most of the protein requirement should be met by the natural feed, while the supplemental feed provides the necessary carbohydrates. In Austria, the most important feeds are barley, wheat and rye. Increasingly, other feeds

[1] The Waldviertel (Forest Quarter) is the northwestern region of the northeast Austrian state of Lower Austria. https://en.wikipedia.org/w/index.php?title=Waldviertel&oldid=1163030432, 2023-08-01

are being used or experimented with, such as oil press cake. Commercial extruded feeds (pellets) are only used in certain situations, such as condition feeding. Therefore, the following comments refer to supplemental grain feeding.

In addition to the classics [14], more recent textbooks and manuals on carp pond management usually assume that the amount of feed to be given is based on the weight of the fish and the production target e.g. [4, 5]. The feed conversion ratio (FCR) is usually used to calculate how much feed is needed during the season. It is common to use an FCR of 2[2] [4, 5]. The administration of the calculated amount of feed is done according to a so-called feeding plan. Table 3.1 gives an overview of different feeding schedules. According to the authors, all of them more or less aim at providing the pond keeper with a relatively simple principle for the optimal use of the calculated amount of feed. The water temperature, the natural food and the feeding desire of the fish should also be taken into account.

Table 3.1: Monthly amount of feed to be given in % of the total amount of feed, according to various authors. K...condition feeding with commercial extruded feed, A...Compensatory feeding, only when the weight of the animal is not sufficient for the market.

	April	**May**	**June**	**July**	**August**	**Sept.**	**Oct.**
Walter [26]	-	10	20	30	30	10	-
Schäperclaus [13]	-	-	15	25-30	40-45	10-25	-
Hofmann [6]	-	10	20	30	30	10	-
Steffens [23]	-	5	15	25	40	15	-
Proske [15]							
Rearing pond	K	10	20	30	25+K	15+K (+A)	K
Growout pond	K	5	25	40-45	20(+A)	5-10(+A)	-
Füllner et al. [4]							
K1 to K2	-	max. 5	10	20	45	20	(Rest)
K2 to K3	-	5	15	25	40	15	-

Although the above-mentioned textbooks and reference books point out that this feeding concept should not be understood as a rigid corset and that it is the responsibility of the pond keeper to react to the respective situation in the pond. It is tempting to rely on this scheme alone, and at most to take into account the oxygen content of the water in high summer. The warning that grain can never be a substitute for natural food, and the quite correct advice to avoid overuse of natural food, are related to the difficulty of correctly assessing natural food without much effort. Instructions for this are not available, so this task is left to the experience of the pond keeper. Years of experience can be very helpful, especially if the pond keeper is a good observer and knows his ponds. Nevertheless, it would be desirable for him, as well as for the beginner, to have a method that allows him to roughly determine the natural food present in the pond and to adjust the feeding accordingly. This adapted feeding, based on the natural food, will be called *demand-oriented feeding* and will be discussed in the following section.

3.3 Demand-oriented feeding

Contrary to the more or less rigid feeding plans described above, the *demand-oriented feeding* is based on a real and direct coordination of the feeding strategy with the natural

[2] FCR 2 = 2 kg of feed for 1 kg of growth

food. The goal of feeding is to optimize the use of the natural food and to increase yield and reduce nutrient load in the pond. This sounds easier than it is, and this is also the biggest problem in implementing pond management practices. Demand-oriented feeding requires regular monitoring of the natural food supply and adjusting the feeding strategy accordingly. A relatively rigid feeding schedule will only work to a limited extent.

In natural food, all nutrients are present in ideal proportions and in sufficient quantities. Therefore, it is important to pay special attention to the preservation and promotion of natural food. In order for the carp to grow well on grain feed and not to accumulate unwanted fat, natural food must always be available in sufficient quantities, as natural food contains a very high proportion of essential amino acids needed for muscle development.

Simply put, the trick is to reduce supplemental grain feeding when there is plenty of natural food available so that the fish can concentrate on the valuable free food in the pond. As soon as the natural food is depleted but not overused, increase the grain feeding to relieve the pressure on the natural food. Because carp are also comfortable and prefer to eat something that does not require them to hunt, search and gather, but rather is practically available in a pile. This is an attempt to achieve a balance between proteins from the natural food and carbohydrates from the supplementary food. Thus, if the population of Daphnia in a pond has completely collapsed, feeding a mixed diet would be necessary purely for nutritional reasons. However, since such a condition may indicate far-reaching undesirable developments in the pond ecosystem and associated possible extremes in important environmental parameters (e.g. oxygen, pH, ammonium), a more detailed chemical and biological water analysis is urgently required in such a case. In such a case, it is advisable to consult a specialist and it is also required by some quality guidelines.

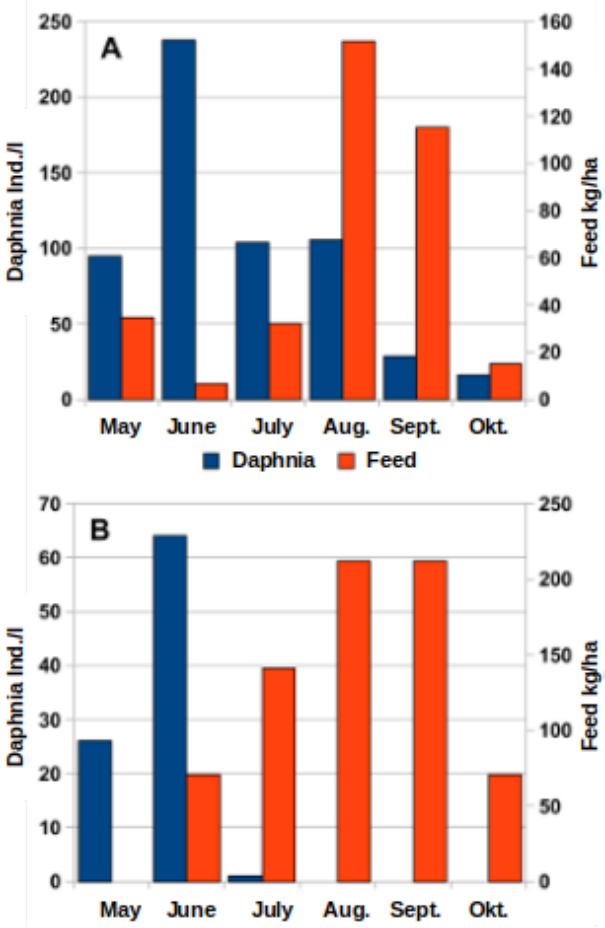

Figure 3.3: Mean values of Daphnia and food consumption. **A:** Feeding with consideration of natural food. **B:** Feeding without considering the natural food. Figure: BAW

To make this easier to understand, two examples are given here, each of which represents an extreme variant in a wide range of possibilities.

Figure 3.3A shows a demand-oriented feeding strategy. Care has always been taken to ensure that the natural food is not unduly consumed by the hungry fish, but on the other hand, not wasted unused. The result is a low consumption of supplemental feed and a good food conversion ratio: supplemental feed: 393 kg/ha, production: 334 kg/ha, FCR 1.2. Figure 3.3B shows a feeding strategy following a stubborn scheme. It was fed without regard to the natural food. As a result, natural food was initially overused and the stock of Daphnia was unable to recover. Despite the use of large amounts of supplemental feed, it was not possible

to compensate for the loss of protein-rich natural feed. The result is a high consumption of supplemental feed with low production and a correspondingly poor FCR: supplemental feed: 707 kg/ha, production. 162 kg/ha, FCR 4.4.

The method is based on the possibility to quantify the available natural food and to draw the right conclusions for the required feeding strategy. That this is possible in principle has already been shown several times [17]. In the following chapters, a practical method will be presented that allows anyone to estimate the available natural food directly at the pond relatively easily, as well as the theoretical background of this method. In addition, sampling devices are presented that can be made inexpensively with materials available at hardware stores.

4 The settling volume

Karin Schlott, Martin Fichtenbauer & Christian Bauer

4.1 Daphnia density

If it was mentioned in Chapter 3 that feeding should be done in such a way that the natural food is neither overused nor underused, then the question arises in what range the amount of natural food should be. As already mentioned, zooplankton organisms larger than 1 mm are of special importance for carp farming. Based on many years of research, it can be assumed that the amount of large daphnids should always be between 20 and 40 individuals per liter of pond water [18]. A smaller number increases the risk that the reproductive capacity is no longer sufficient. Here the pond keeper must try to compensate for this lack of natural food by increased feeding. At densities well above 40 individuals per liter, feeding should be reduced or even discontinued, as the natural food is not being adequately utilized.

The evaluation of the natural food with the help of professional collecting devices and a microscope in the laboratory [17] is time-consuming and therefore not suitable for use at the pond. A volumetric determination of the plankton via the so-called settling volume, on the other hand, has the potential to replace this counting method.

4.2 Settling volume

Since the settling volume of plankton plays a certain role in production biology [9], it was obvious to use this method also for quantitative and, above all, practical estimation of the natural food available for carp and other fish in ponds. First attempts in this respect were made in 1984 in Austria [21]. For practical use, it is important to choose the mesh size (500 µm) of the plankton net so that the large zooplankton are caught but everything else is washed through.

The question remains whether the settling volume allows a reliable conclusion on the number of individuals per liter of water. To test this, 174 plankton samples were taken from four ponds (0.38, 0.23, 0.18 and 0.1 ha) during two production years. The samples were counted under a microscope as described in [17] and the settling volume was also determined. Figure 4.1 shows the values of count and settling volume plotted against each other. A high correlation is shown and Spearman's rs[1] is 0.95, indicating that the *settling volume is a sufficiently accurate method for estimating available natural food for pond management practice.*

However, there are limitations. For example, contamination of the sample by seeds, or the presence of large algae such as Volvox, can falsify the result. However, such problems occurred in less than 10% of the samples and can hardly be overlooked. Glassworms (larvae of chaoborus), which can also occur in higher densities, are not a problem because at low doses of formaldehyde they are still alive while the zooplankton sink to the bottom. Especially in spring, large copepods rather than daphnids may dominate the plankton and thus the settling

[1] Spearman's rank correlation coefficient is a measure of the relationship between two variables. A value of 1 indicates a perfect correlation

volume. This is not a falsification, however, as large copepods are also eaten by carp as a substitute for daphnia. [27].

Furthermore, it remains to be seen whether in larger ponds sampling at the monk is sufficient to make a statement about the natural food in the whole pond. Earlier experiments [16] in a pond of 18 ha show that the results are the same for samples distributed over the pond, but it is still recommended for ponds >than 2 ha to take mixed samples (5 l by boat at 4 different locations).

4.3 Feeding according to the settling volume

4.3.1 Interpretation of the settling volume

So how can the Settling Volume (SV) result be interpreted and used to adjust supplemental feeding? Table 4.1 shows the interpretations and practical conclusions that can be drawn from past experience.

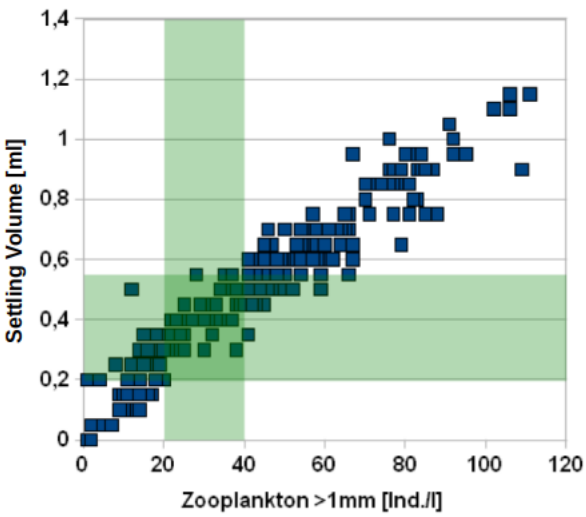

Figure 4.1: Counted plankton samples plotted against sedimentation volume. There is a clear correlation, Spearman's rs = 0.96 (n = 261). Figure: BAW

A SV of less than 0.2 ml, i.e. less than 20 ind./l (Fig. 4.1), indicates a lack of natural food. To prevent the population from collapsing, the feeding pressure from the fish must be limited as much as possible. On the other hand, the missing protein source for the fish must be replaced. However, the lack of natural food cannot be compensated by grain [4]. Therefore, in such a situation, commercial extruded feed must be used. This measure simultaneously causes indirect fertilization and promotes algae growth as a food source for the daphnia. However, the use of these high quality foods must be done with caution and with regard to the oxygen content of the water.

If the SV is between 0.2 ml and 0.55 ml, the natural food is available at an ideal level. The purpose of supplemental feeding is to maintain this level and to ensure constant availability. Therefore, feed normally according to the calculations (see 4.3.2) and the carps receive a balanced diet of protein-rich natural food and carbohydrate-containing cereals.

With SV above 0.55 to 0.8 ml, the amount of natural food is above average. This means that the carp are not using it enough. To achieve a better utilization of natural food, reduce the amount of supplemental feed by half.

If the SV exceeds 0.8 ml, the population of natural food is much too high. It is necessary to pay attention to the fact that the feeding pressure of the carp on the natural food should be strongly increased in order to reduce the population. The supplemental feeding should be stopped completely! If the natural food gets out of control, it is not only a waste of money, but can also lead to problems. Excessive amounts of zooplankton organisms have a high oxygen demand and there are situations where this can lead to a lack of oxygen in the pond.

Especially the last two measures, reducing or stopping the feeding, are difficult to understand, especially when they are done at high water temperatures and the fish accept the grain

perfectly. But do not worry, you will not miss any increase. On the contrary, you would be giving away free natural food and possibly harming the quality of the meat. Sufficient natural food is a guarantee for carp with optimal fat content [4].

Table 4.1: Goals and measures associated with the respective settling volume (SV).

SV [ml]	**Natural food**	**Goal**	**measure**
<0,2	Shortage	Spare natural food Protein deficiency compensate	commercial feed (Indirect fertilization)
0,2 - 0,55	Sufficient	Maintaining the state	Feed according to calculate
>0,55 - 0,8	Above average	Increased usage	Feed reduction by half
>0,8	Excess	Reduction	Stop feeding

4.3.2 Feed calculation

Section 3.2 showed how to determine the amount of grain needed and how to distribute it over the production period. Another way to manage the feed is to make the application of the feed dependent on the weight of the fish and the water temperature, which requires sample fishings or at least an estimation of the current weight of the fish. This method was originally intended for use with commercial extruded feed. At a water temperature of 20 °C and good oxygen conditions, the following daily feed rates can be administered in % of fish live weight: Kv-K1 5-10%, K1-K2 3-5%, and K2-K3 2-3% [3, 5].

This method has been adapted for grain feeding. The following principles were considered:

☞ Feed grain only when water temperature is above 14 °C

☞ Feeding stops when the oxygen level drops below 4 mg/l.

☞ DFeeding occurs on Monday, Wednesday and Friday

☞ The SV is determined on Monday and the week's feeding was based on it.

☞ In 2009, up to 4% of fish weight was fed per day (see chapter 7.2).

☞ In 2010, up to 2% of fish weight was fed per day (see chapter 7.3).

☞ The actual amount of feed administered was based on the SV (Table 4.1).

However, before we take a look at the 2009 and 2010 management results, a low-cost do-it-yourself sampling kit and the sampling itself will be presented.

5 Sampling kit

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5.1 Fichtenbauer-Sampler

To determine the settling volume of planktonic natural food in a carp pond, 20 liters of pond water are needed, taken from four locations at five liters each [19]. Usually water samples for such studies are taken with a professional scientific sampler (e.g. Schindler sampler). However, as this is relatively expensive and also relatively susceptible to damage in the rough and tumble of everyday life on a loading platform between feed sacks and shovels, it was necessary to construct a robust, inexpensive, yet relatively accurate and reliable alternative. The result of these efforts is the *Fichtenbauer sampler* (Fig. 5.3). The components and their respective costs are listed in Table 5.1. All of the materials for the sampler are available from home centers, hardware stores, or plumbing supply companies. The total cost of materials for the homemade bailer was about € 61 (as of 2011).

Building instructions Fichtenbauer-sampler

The first step is to fit a pipe plug to the house sewer pipe. The plug is greased with soft soap and the pipe is sealed with the plug. Then 5 liters of water are poured into the plugged pipe and cut off directly at the 5 liter water level mark. An opening is cut out of the plug to allow the water sample to flow in and out when the sampler is immersed.
Cut out a piece from the bottom of a second pipe plug, which will later serve as a hinged cover for the lower opening and is attached to the cut-out pipe plug with a hinge. The entire bottom of another pipe plug is cut off and attached to the house sewer pipe with a rolled hinge as the upper lid. The handle of the sampler is most conveniently formed from a sheet metal strip and mounted on the upper end of the sewer pipe. To ensure that the sampler sinks quickly, suitable weights (heavier metal parts) should be attached to the sampler, but they must not interfere with the flaps.

5.2 Plankton net

A plankton net is required to filter the zooplankton from the water sample taken with the sampler. This can also be made relatively easily for pond management purposes (Figure 5.3). There is no need to resort to expensive scientific equipment. A net made of commercially available fine window blinds will do. Only the 500 µm net needs to be purchased from a specialist retailer. Table 5.2 gives an overview of the materials needed and their cost. The total amount of materials for the homemade plankton net is about € 68 (as of 2011).

Table 5.1: List of materials and costs for the Fichtenbauer-sampler (as of 2011).

Material	Costs
1 Sewer pipe DN 150 500 mm	€ 14,11
3 Sewer pipe plug DN 150	€ 28,35
1 Rolled hinge 30 x 100 mm	€ 1,49
1 Galvanized hinge	€ 1,79
18 Nuts and bolts	€ 2,96
2 Sheet metal, aluminum blank 0.5 m	€ 2,77
Window sealing tape approx. 0.4 m	approx. € 10,00 (one roll)
Total cost	**approx. € 61,50**

Table 5.2: List of materials and costs for the plankton net (as of 2011).

Material	Costs
1 Sewer pipe plug DN 250 mm - Rohr	€ 37,32
1 Sewer coupler DN 50 mm	€ 2,20
1 Sewer pipe plug DN 50 mm	€ 2,64
1 Sewer pipe DN 50/250 mm	€ 2,64
1 Fast clamp DN 250 mm	€ 12,96
Window blind	approx. € 10,00 (1 linear meter)
Total cost	**approx. € 68,00**

Building instructions plankton net

Simply transfer the pattern Figure 5.1 for the plankton net onto wrapping paper or the like using the dimensions given, then cut the window blind to size and sew it together. The sewn together plankton net is attached with the wide opening to a 250 mm pipe plug with the help of a fast clamp. At the bottom narrow end of the net, a 50 mm pipe plug is mounted. The bottom was previously cut out of both pipe plugs. The sewer coupler, fitted with a pipe seal, is pushed onto the small pipe plug on the plankton net. This sewer coupler is to receive the shortened HT pipe, which is provided with a 500 mm net at one end and serves as a collection container for the zooplankton.

5.3 Other equipment

In addition to the sampler, plankton net and bucket, other utensils are needed (Fig. 5.2). In addition to a glass vessel to rinse the plankton net and to hold the sample, a squirt bottle and a small funnel are useful.In the 2011 and 2017 German editions, formalin 20-25 % is used to fix the zooplankton. For health reasons we now recommend the use of 95 % ethanol [2]. A tube sealed at one end with a 500 µm net, which can be easily made by the user, is used together with the squirt bottle to clean the sample from formaldehyde/ethanol. The measuring tube or graduated cylinder should be neither too large nor too small. A capacity of at least 10-15 ml is useful. Various models (plastic, glass, different graduations) are available from laboratory suppliers. For a model without a stand, a stand is useful, which can be easily made from a wooden cube.

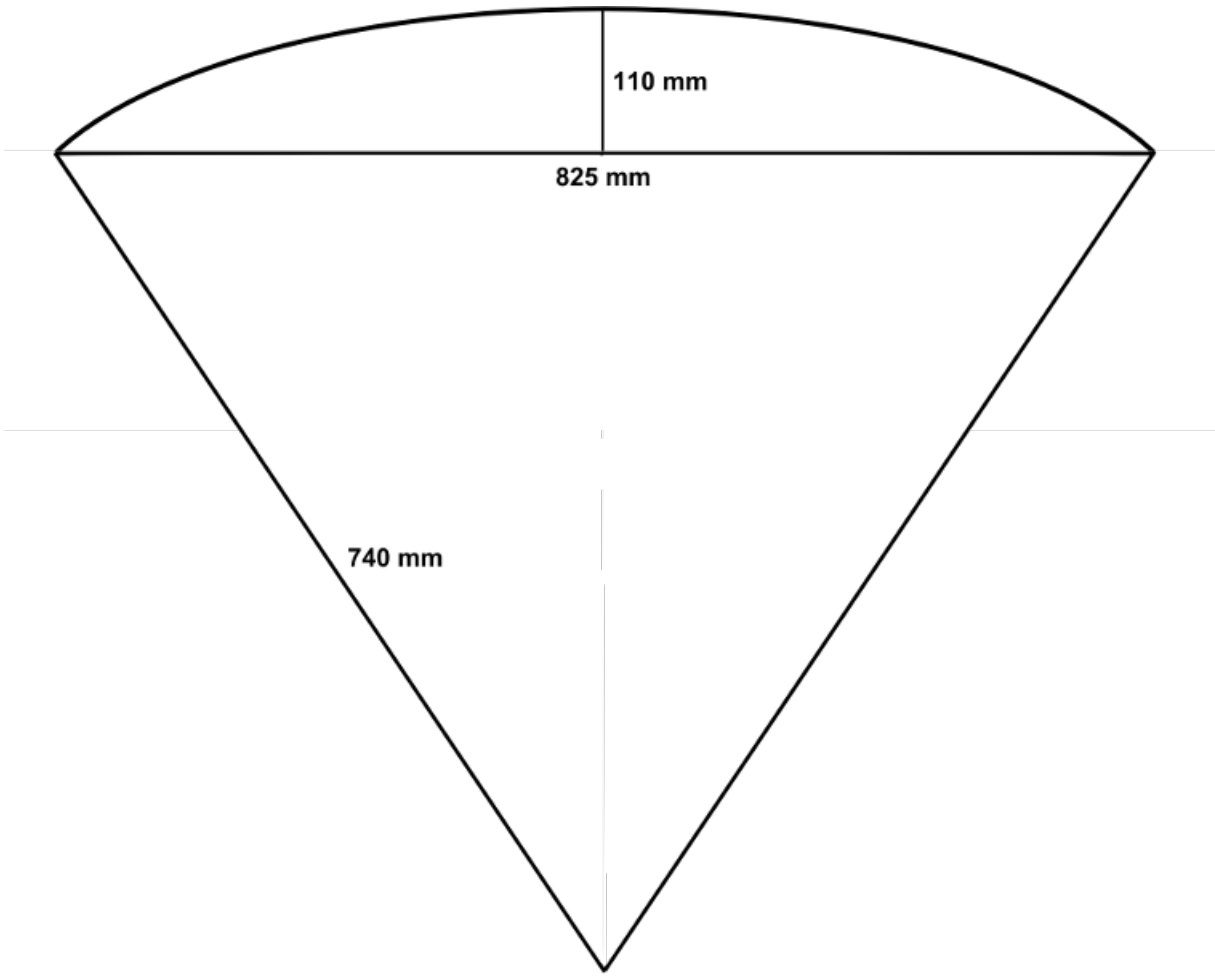

Figure 5.1: Transfer the pattern and assemble the sewn net with the other pieces according to the instructions. Figure: BAW

Figure 5.2: Other equipment: Measuring Tube [1], Stand [2], Pipe with 500 µm net [3], Funnel [4], Squirt bottle [5], Ethanol 95 % [6], sample vessel [7]. Figure: BAW

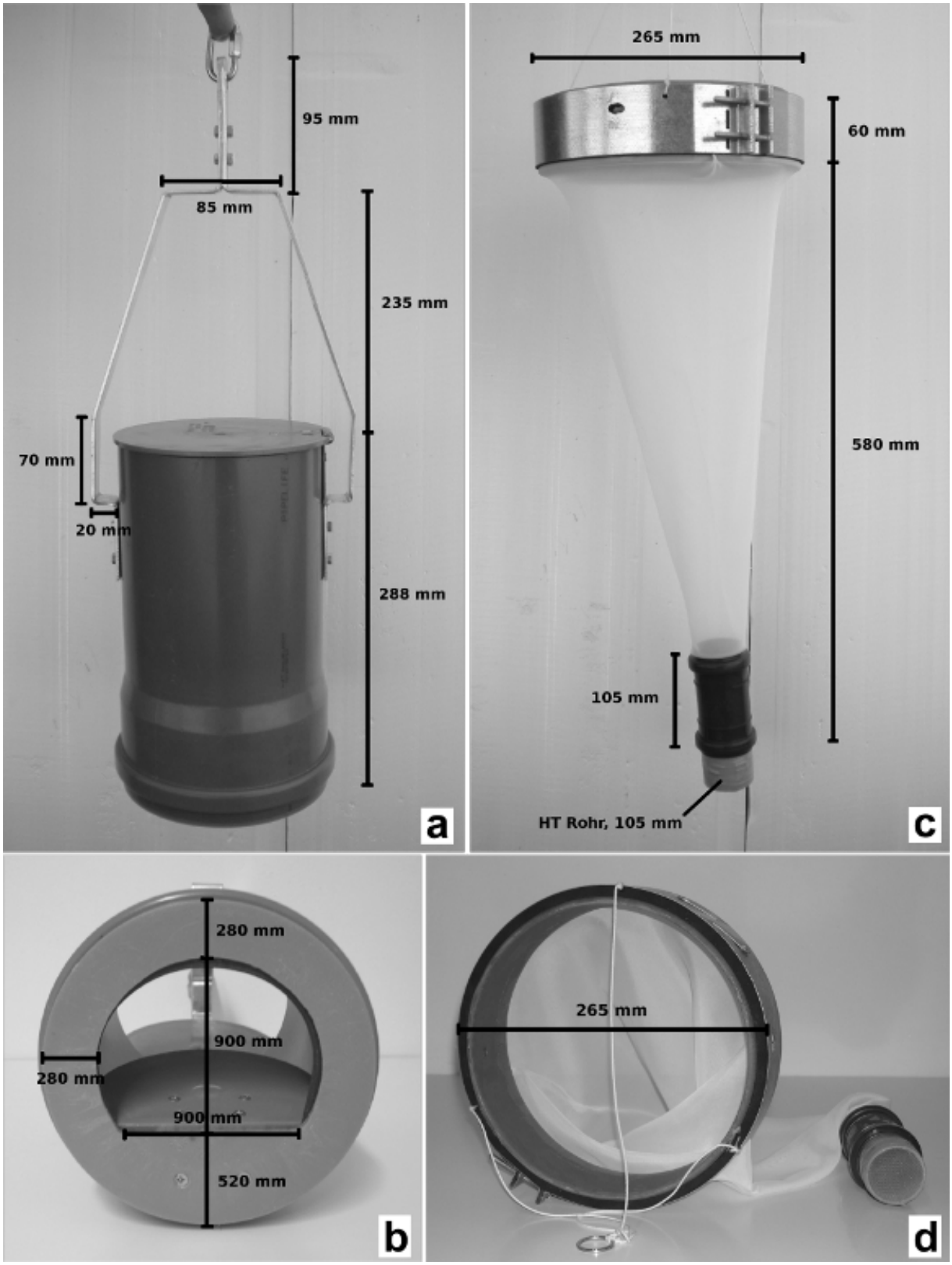

Figure 5.3: View and dimensions of the Fichtenbauer-sampler [a,b] and the plankton net [c,d].
Figure: BAW

5.4 Accuracy test

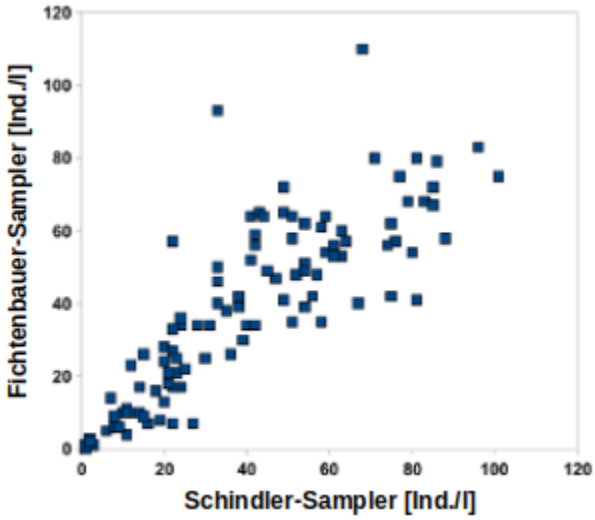

Figure 5.4: The comparison of the Fichtenbauer-sampler with the commercial Schindler-sampler shows a high conformity. Figure: BAW

In order for the homemade devices to be used in daily practice to determine the settling volume and thus to feed according to demand, it must be ensured that they provide sufficiently accurate results. To determine this, a total of 105 plankton samples were taken in parallel from several ponds during the 2009 production year using both the homemade kit and the commercial devices. The zooplankton organisms larger than 1 mm of each sample were counted under binoculars in the laboratory. Unsuitable samples were discarded (see Chapter 4). Using the count results plotted against each other (Figure 5.4) and Spearman's rs[1] = 0.87, it can be shown that the do-it-yourself kit provides sufficiently accurate results for pondkeeping practice when compared to professional commercial equipment.

[1]Spearman's rank correlation coefficient is a measure of the relationship between two variables. A value of 1 indicates perfect correlation. Read more about it on the web: https://en.wikipedia.org/w/index.php?title=Rank_correlation&oldid=1123335196, 2023-07-28.

6 Sampling

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Water samples are taken at the monk or drain (Fig. 6.1a). At each of four different locations (Fig. 6.1b), 5 litres of water are taken with the sampler from a depth of approximately 0.5 m below the water surface and immediately after sampling poured through the plankton net into a bucket. At the bottom of the plankton net is the 500 µm net, which retains the largest plankton organisms. After the fourth sample, the net is carefully rinsed into the bucket with pre-filtered water to ensure that all plankton organisms are collected in the collection cup of the plankton net (Figure 6.1c). For a small pond and in calm weather, sampling at the monk is sufficient. For a larger pond, the individual samples must be taken at four different locations in the pond using a boat. As a total of four samples of five litres are taken, the total sample volume is 20 litres. The zooplankton organisms remaining in the net during filtration are collected with a small amount of water in a glass jar (Fig. 6.2a), killed and fixed in ethanol (96 %) (Fig. 6.2b).

Figure 6.1: Collection and preparation of the zooplankton sample: [a,b] collection with the Fichtenbauer-sampler at four sites around the monk; [c] careful rinsing of the net with already filtered water. Figures: BAW

After a short wait of about 1 minute, the sample is filtered again through a *tube* with a 500 µmesh at the bottom to remove the fixative (Fig. 6.2c). Then, using a funnel and water

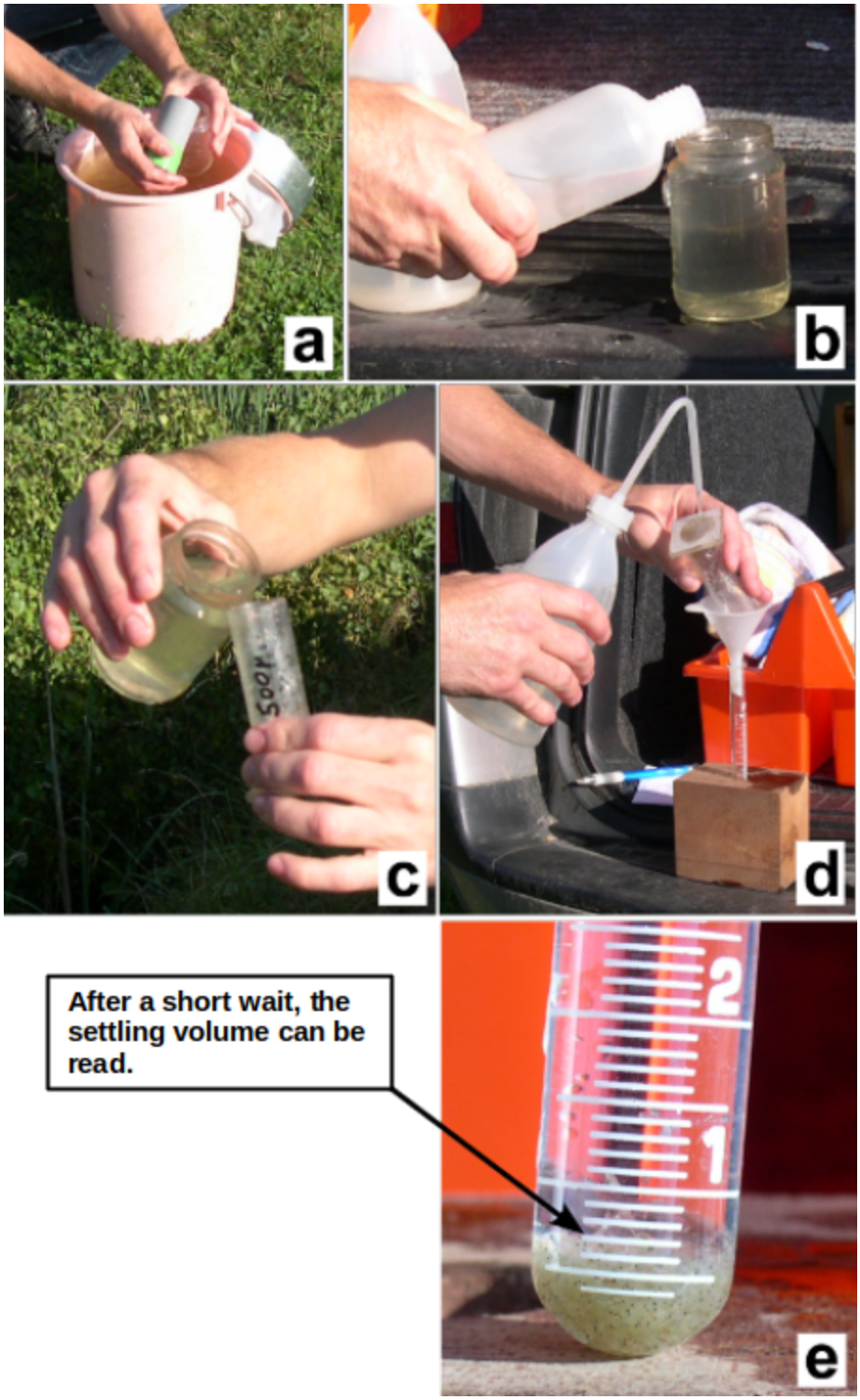

Figure 6.2: Processing the collected zooplankton sample: [a] load the sample; [b] add the fixative; [c] wash out the fixative; [d] rinse the sample into the measuring tube; [e] read the sedimentation volume. Figures: BAW

bottle, rinse the zooplankton in the tube into a glass tube with a millilitre scale (Fig. 6.2d). Care should be taken not to use too much water for rinsing, otherwise the sample tube will overflow and the zooplankton will be lost. After a short time the zooplankton will settle to the bottom of the tube and the volume in ml can be read from the scale (Fig. 6.2e). The procedure described so far is carried out directly at the pond and the pond keeper can quickly estimate how much feedable zooplankton is present in the pond. He can then adjust the feeding to the natural food supply via the sedimentation volume. Settling volume was measured at every second feeding in 2009 (twice a week) and once a week in 2010. A record was kept of the results of the settling volume measurements and feed administration. Figure 6.3 shows an extract from this record.

		Pond 1		Pond 2		Pond 3	
	Date	Feed kg (kg/ha)	SV	Feed kg (kg/ha)	SV	Feed kg (kg/ha)	SV
1	06.05.09	*2,43 (10,80)*	0,40	*4,10 (10,79)*	0,30	*1,94 (10,78)*	0,40
	08.05.09	*3,65 (16,22)*		*6,14 (16,16)*		*2,91 (16,17)*	
2	11.05.09	2,43 (10,80)	0,55	2,05 (5,39)	0,65	1,94 (10,78)	0,50
	13.05.09	2,43 (10,80)		2,05 (5,39)		1,94 (10,78)	
	15.05.09	3,65 (16,22)	0,50	6,14 (16,16)	0,20	1,45 (8,06)	0,75
	18.05.09	2,43 (10,80)		4,10 (10,79)		0,97 (5,39)	
	20.05.09	2,43 (10,80)	0,55	4,10 (10,79)	0,30	0,97 (5,39)	0,65
	22.05.09	3,65 (16,22)		6,14 (16,16)		1,45 (8,06)	
	25.05.09	1,20 (5,33)	0,70	4,10 (10,79)	0,35	0,97 (5,39)	0,70
	27.05.09	1,20 (5,33)		4,10 (10,79)		0,97 (5,39)	
	29.05.09	1,82 (8,09)	0,70	3,07 (8,08)	0,55	0,00 (0,00)	1,00
	02.06.09	1,20 (5,33)		2,05 (5,39)		0,00 (0,00)	
	03.06.09	1,20 (5,33)	0,70	0,00 (0,00)	0,45	0,00 (0,00)	0,80

Feed with commercial feed (2% of fish weight/day)
Feed with grain (4% of fish weight/day), Water temp. > 15 °C

½ Feed quantity
No feeding

Low $O_2 \leq 4$ mg/l
Stop feeding!!!

Figure 6.3: Explanatory protocol for recording settling volume (SV) and feed application in the three experimental ponds. Figure: BAW

7 Management examples

Martin Fichtenbauer & Christian Bauer

7.1 Experimental ponds

The ponds where the method of feeding by settling volume was developed are located in the northern Waldviertel (Lower Austria) between the towns of Litschau and Reitzenschlag at an altitude of about 580 m above sea level. The site comprises a total of 4 ponds and a spawning pool with a water surface area of approximately 1 ha. Ponds 1-3 were used for the investigations (Fig. 7.1). The ponds are fed by a ditch from which water is taken and which also acts as a diversion. To prevent the otter (*Lutra lutra*) from entering the ponds, each pond on the site was secured with an electric fence powered by a battery and a solar panel.

Figure 7.1: Aerial view of the experimental pond site in the northern Waldviertel. Of the 4 ponds, 3 were used for the experiments, pond 1: 0.23 ha, pond 2: 0.38 ha and pond 3: 0.18 ha. Aerial view from NÖ Atlas, © Land Niederösterreich, NÖ Atlas.

7.2 Economic data 2009 and 2010

7.2.1 Stocking and harvesting results

Stocking was carried out in spring with K2 (common carp of two years). In pond 1 and pond 2, additional grass carp (*Ctenopharyngodon idella*) were stocked to control aquatic vegetation. No other secondary fish were stocked. In particular, stocking of *whitefish*, which can quickly get out of control, would have a negative effect on zooplankton. In general, stocking rates must be adjusted to avoid over- or under-utilisation of natural food sources from the outset. Tables 7.1 and 7.2 give an overview of stocking, catches/harvest, production and losses in the three experimental ponds in 2009 and 2010.

Table 7.1: Stock, harvest and production 2009

Pond 1 (0,23 ha), Season 2009

Stocking 3.4.09 (gras carp 4.5.09)						Harvest 15.10.09							
Spec.	**Ind.**	**kg**	**kg/Ind.**	**Ind./ha**	**kg/ha**	**Spec.**	**Ind.**	**kg**	**kg/Ind.**	**Ind./ha**	**kg/ha**	**Prod.kg/ha**	**Losses%**
K2	79	60,80	0,77	351	270	K3	77	227,9	2,96	342	1013	743	2,5
Grass c.	14	10,50	0,75	62	47	Grass c.	13	28,9	2,22	58	128	82	7,1
Total	93	71,3		413	317		91	275		400	1141	825	

Pond 2 (0,38 ha), Season 2009

Stocking 3.4.09 (gras carp 4.5.09)						Harvest 8.10.09							
Spec.	**Ind.**	**kg**	**kg/Ind.**	**Ind./ha**	**kg/ha**	**Spec.**	**Ind.**	**kg**	**kg/Ind.**	**Ind./ha**	**kg/ha**	**Prod.kg/ha**	**Losses%**
K2	133	102,40	0,77	350	269	K3	119	333,2	2,80	313	877	607,4	10,5
Grass c.	24	18,00	0,75	63	47	Grass c.	22	45,1	2,05	58	119	71,3	8,3
Total	157	120,40		413	316		141	378,3		371	996	678,7	

Pond 3 (0,18 ha), Season 2009

Stocking 3.4.09						Harvest 7.10.09							
Spec.	**Ind.**	**kg**	**kg/Ind.**	**Ind./ha**	**kg/ha**	**Spec.**	**Ind.**	**kg**	**kg/Ind.**	**Ind./ha**	**kg/ha**	**Prod.kg/ha**	**Losses%**
K2	65	50	0,77	361	278	K3	64	177,4	2,77	356	986	707,8	1,5

Table 7.2: Stock, harvest and production 2010

Pond 1 (0,23 ha), Season 2010

Stocking 15.4.10 (grass carp 8.4.10)						Harvest 8.10.09							
Spec.	**Ind.**	**kg**	**kg/Ind.**	**Ind./ha**	**kg/ha**	**Spec.**	**Ind.**	**kg**	**kg/Ind.**	**Ind./ha**	**kg/ha**	**Prod.kg/ha**	**Losses%**
K2	90	51,10	0,57	400	227	K3	88	175,4	1,99	391	780	552	2,2
Grass c.	9	7,30	0,81	40	32	Grass c.	8	15,2	1,89	36	67	35	11,1
Summe	**99**	**58,4**		**440**	**260**		**96**	**191**		**427**	**847**	**587**	

Pond 2 (0,38 ha), Season 2010

Stocking 15.4.10 (grass carp 8.4.10)						Harvest 7.10.10							
Spec.	**Ind.**	**kg**	**kg/Ind.**	**Ind./ha**	**kg/ha**	**Spec.**	**Ind.**	**kg**	**kg/Ind.**	**Ind./ha**	**kg/ha**	**Prod.kg/ha**	**Losses%**
K2	152	86,3	0,57	400	227	K3	150	313,7	2,09	395	826	598	1,3
Grass c.	16	13,0	0,81	42	34	Grass c.	16	29,0	1,81	42	76	42	0
Total	**168**	**99,3**		**442**	**261**		**166**	**343**		**437**	**902**	**641**	

Pond 3 (0,18 ha), Season 2010

Stocking 15.4.10						Harvest 6.10.10							
Spec.	**Ind.**	**kg**	**kg/Ind.**	**Ind./ha**	**kg/ha**	**Spec.**	**Ind.**	**kg**	**kg/Ind.**	**Ind./ha**	**kg/ha**	**Prod.kg/ha**	**Losses%**
K2	72	40,9	0,57	400	227	K3	69	136,3	1,98	383	757	530	4,2

7.2.2 Feeding and feed consumption

The following tables provide an overview of key management data, calculated/imputed feed consumption, actual feed consumption and the resulting savings (both feed and monetary).

Table 7.3: Imputed and actual feed consumption and the costs 2009; Grain €0,20/kg, Commercial feed €0,67; Feeding: 0,5-4 % of fish weight (temperature dependent).

Imputed feed consumption (rounded) and costs 2009					
	Pond 1	**Pond 2**	**Pond 3**	**Total**	**per Hectare**
Grain kg	512	898	371	1782	2270
Comm. Feed kg	56	39	18	108	137
Total kg	**568**	**937**	**385**	**1890**	**2407**
Cost grain €	102,43	179,69	74,23	356,35	453,95
Cost comm. feed €	37,24	26,06	12,31	75,61	96,32
Total €	**139,67**	**205,75**	**86,54**	**431,96**	550,27

Actual feed consumption (rounded) and costs 2009					
	Pond 1	**Pond 2**	**Pond 3**	**Total**	**per Hectare**
Grain kg	403	554	226	1182	1506
Comm. feed kg	57	39	18	114	145
Total kg	**459**	**593**	**226**	**1278**	**1628**
Cost grain €	80,5	110,74	45,19	236,43	301,18
Cost comm. feed €	38,04	26,06	12,31	76,41	97,34
Total €	**118,54**	**136,8**	**57,5**	**312,84**	**398,52**

Savings compared to imputed costs 2009					
	Pond 1	**Pond 2**	**Pond 3**	**Total**	**per Hectare**
Grain kg	110	345	145	600	764
Comm. feed kg	-1	0	-5	-6	-8
Total kg	**108**	**345**	**113**	**567**	**722**
Cost grain €	21,93	68,95	29,04	119,92	152,76
Cost comm. feed €	-0,8	0	0	-0,8	-1,02
Total €	**21,13**	**68,95**	**29,04**	**119,12**	**151,75**

Table 7.4: Feeding on 65 days in 2009 and 67 days in 2010; 0.5 days are due to the fact that both commercial feed feed (CF) and grain (G) were fed once.

	2009			**2010**		
	Pond 1	**Pond 2**	**Pond 3**	**Pond 1**	**Pond 2**	**Pond 3**
CF, Temp. <14 °C	12	12	12	9,5	9,5	9,5
SV <0,2: CF	2	-	-	-	-	-
SV 0,2-0,55: G full	30	30	18	42,5	33,5	12,5
SV 0,55-0,8: G ½	21	15	24	15	21	38
SV >0,8: no feeding	-	7	11	-	3	6
no feeding O_2 Shortage	-	1	-	-	-	1

Table 7.5: Imputed and actual feed consumption and costs 2010; Grain €0,19/kg, Commercial feed €0,51; Feeding: 2 % of fish weight.

Imputed feed consumption (rounded) and costs 2010					
	Pond 1	**Pond 2**	**Pond 3**	**Total**	**per Hectare**
Grain kg	294	479	199	972	1238
Comm. feed kg	26	45	18	89	114
Total kg	**321**	**523**	**217**	**1061**	**1352**
Cost grain €	55,95	90,94	37,73	184,62	235,18
Cost comm. feed €	13,41	22,79	9,39	45,58	58,07
Total €	**69,35**	**113,72**	**47,12**	**230,20**	293,25

Actual feed consumption (rounded) and costs 2010					
	Pond 1	**Pond 2**	**Pond 3**	**Total**	**pre Hectare**
Grain kg	265	376	125	765	975
Comm. feed kg	26	45	18	89	114
Total kg	**291**	**420**	**144**	**855**	**1089**
Cost grain €	50,26	71,35	23,77	145,39	185,21
Cost comm. feed €	13,41	22,79	9,39	45,58	58,07
Total €	**63,67**	**94,14**	**33,16**	**190,97**	**243,27**

Savings compared to imputed costs 2010					
	Pond 1	**Pond 2**	**Pond 3**	**Total**	**per Hectare**
Grain kg	30	103	73	206	263
Comm. feed kg	0	0	0	0	0
Cost grain €	5,68	19,59	13,96	39,23	49,97
Cost comm. feed €	0	0	0	0	0

8 Fat content in fillet

As the fat content in carp fillet is generally considered to be a quality criterion, the range of fat contents that could be achieved by feeding according to settling volume in 2009 and 2010 should not be withheld. Figure 8.1 shows boxplots[1] for fat content in fillet. The graph shows the fat content determined for carps from the experimental ponds in 2009 and 2010 as well as the collected data of carps from the Waldviertel in 2006-2010. Table 8.1 shows mean values, minima and maxima for fat content in fillet from 2009 and 2010 as well as the long-term data from the Waldviertel.

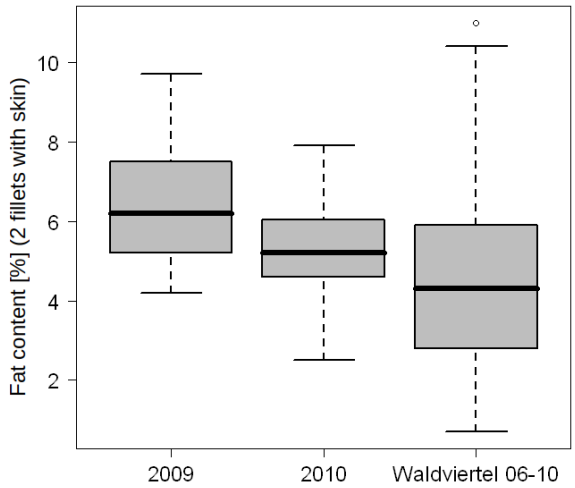

Figure 8.1: The fat content of carp fillets from the experimental ponds in 2009 and 2010 compared to the values from the Waldviertel from 2006 to 2010, plotted as a box plot.. Figure: BAW

Table 8.1: The fat content of carp fillets from the experimental ponds in 2009 and 2010 compared to the values from the Waldviertel in 2006 to 2010.

	n Samples	**average Fat cont.**	**min. Fat cont.**	**max. Fat cont.**
2009	19	6,6	4,2	9,7
2010	40	5,3	2,5	7,9
W4 06-10	333	4,5	0,7	11

[1]For interpretation of boxplots see https://en.wikipedia.org/w/index.php?title=Box_plot&oldid=1164969052, 2023-07-31.

Bibliography

[1] Benndorf, J.: Conditions for effective biomanipulation, conclusions derived from whole-lake experiments in Europe. In: *Hydrobiologia* 200/201 (1990), S. 187–203

[2] Black, R. A. ; Dodson, S. I.: Ethanol: a better preservation technique for Daphnia. In: *Limnology and Oceanography: Methods* 1 (2003), S. 45–50

[3] Bohl, M.: *Zucht und Produktion von Sü"swasserfischen.* Verlagsunion Agrar, 1999. – 720 S.

[4] Füllner, G. ; Pfeifer, M. ; Langer, N.: *Karpfenteichwirtschaft, Bewirtschaftung von Karpfenteichen, gute fachliche Praxis.* Sächsiche Landesanstalt für Landwirtschaft, 2007. – 129 S.

[5] Geldhauser, F. ; Gerstner, P.: *Der Teichwirt.* Parey Buchverlag, 2003. – 276 S.

[6] Hofmann, J.: *Der Teichwirt, Zucht und Haltung des Karpfens.* 5. Auflage. Paul Parey, 1979. – 332 S.

[7] Hrbaček, J.: Species composition and the amount of zooplankton in relation to the fish stock. In: *Rozpravy Czechoslovensko Akademie Ved.* 72 (1962), S. 1–116

[8] Koch, W. ; Bank, O. ; Jens, G.: *Fischzucht.* 5. Auflage. Paul Parey, 1982. – 235 S.

[9] Lillelund, K. ; Kinzer, J.: Absetz- und Verdrungsvolumen von Planktonproben. Untersuchungen zur Methodik. In: *internationale Revue der gesamten Hydrobiologie* 51 (1966), S. 757–774

[10] Odum, E. P.: *Fundamentals of ecology.* W.B. Sounders Company, 1959. – 546 S.

[11] Pechar, L.: Long-term changes in fish pond management as unplaned ecosystem experiment: importance of zooplankton structure, nutrients and light for species composition of cyanobacterial blooms. In: *Water Sciences and Technology* 32 (1995), S. 187–196

[12] Potužák, J. ; Hůda, J. ; Pechar, L.: Changes in fish production effectivity in eutrophic fishponds - impact of zooplankton structure. In: *Aquaculture International* 15 (2007), S. 201–210

[13] Schäperclaus, W.: *Lehrbuch der Teichwirtschaft.* 3. Paul Parey, 1967. – 582 S.

[14] Schäperclaus, W. ; Lukowicz, M. v.: *Lehrbuch der Teichwirtschaft.* 4. Auflage. Paul Parey, 1997. – 590 S.

[15] *Kapitel* PROSKE, C.: Sicherung und Steigerung der Erträge aus der Karpfenteichwirtschaft. In: Schäperclaus, W ; Lukowicz, M v.: *Lehrbuch der Teichwirtschaft.* 4. Auflage. Paul Parey, 1997, S. 267–303

[16] Schlott, G. ; Schlott, K.: Fütterungsprojekt Waldviertel - Abschlussbericht / Ökologische Station Waldviertel. 1994. – Forschungsbericht

[17] Schlott, K.: *Schriftenreihe.* Bd. 27: *Die planktische Naturnahrung und ihre Bedeutung für die Fischproduktion in Karpfenteichen.* Bundesamt für Wasserwirtschaft, 2007. – 41 S.

[18] Schlott, K. ; Schlott, G.: *Synopse 2000 - Ergebnisse aus Wissenschaft und Praxis.* BM f. Bildung, Wissenschaft und Kunst, 2001. – 94 S.

[19] Schlott, K. ; Schlott, G.: Das Absetzvolumen als Hilfe bei der naturnahrungsabhängigen Fütterung. In: *Österreichs Fischerei* 63 (2010), S. 265–269

[20] Schlott-Idl, K.: Development of zooplankton in fish ponds of the Waldviertel. In: *Journal of Applied Ichthyology* 7 (1991), S. 223–229

[21] Schlott-Idl, K. ; Schlott, G.: Das Absetzvolumen - ein Ma"s für die Zooplanktonmenge? In: *Österreichs Fischerei* 37 (1984), S. 147–150

[22] Sommer, U.: *Planktologie.* Springer Verlag, 1994. – 274 S.

[23] Steffens, W.: *Moderne Teichwirtschaft, Grundlagen und Praxis.* Neumann-Neudamm, 1979. – 375 S.

[24] Šusta: *Die Ernährung des Karpfens und seiner Teichgenossen.* Herrke & Lebeling, Stettin, 1887. – 251 S.

[25] Walter, E.: *Das Plankton und die praktisch verwendbaren Methoden der quantitativen Untersuchung der Fischnahrung.* Neudamm Verlag, 1899. – 44 S.

[26] Walter, E.: *Die Fischerei als Nebenbetrieb des Landwirtes und Forstmannes.* Neudamm Verlag, 1903. – 801 S.

[27] Wunder, W.: Das Plankton als wichtiger Bestandteil der Naturnahrung des Karpfens.-Methoden der Planktonvermehrung. In: *Österreichs Fischerei* 21 (1968), S. 97–103