

## HISTORY OF AQUACULTURE RESEARCH IN ESTONIA

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Received 11 June 2001

**Abstract.** Fish farming was initiated in Estonia in the 1890s by German landowners, who reared brown trout and common carp in ponds. Development towards intensive fish farming began in the 1960s. The Department of Fish Farming of the Estonian Institute of Animal Breeding and Veterinary Science carried out applied research on problems related to freshwater pond farming. The main topics of the research included technology of carp culture under the climatic conditions of Estonia, improvement of the performance of carp strains by selective breeding, measures of treatment of fish against parasitary diseases, and problems of rainbow trout farming in fresh water. The Laboratory of Marine Fish Rearing of the Tallinn Department of the Baltic Fishery Research Institute dealt with a broad range of topics of fish farming in sea water, feed composition and quality, fish physiology and diseases, construction of recirculation systems, etc. in the 1970s–80s. The Department of Hydrobiology of the Institute of Zoology and Botany of the Estonian Academy of Sciences carried out studies on the genetics, physiology, morphology, and parasitology of carp and rainbow trout.

**Key words:** aquaculture, research history, common carp, rainbow trout.

### EARLY HISTORY OF AQUACULTURE RESEARCH

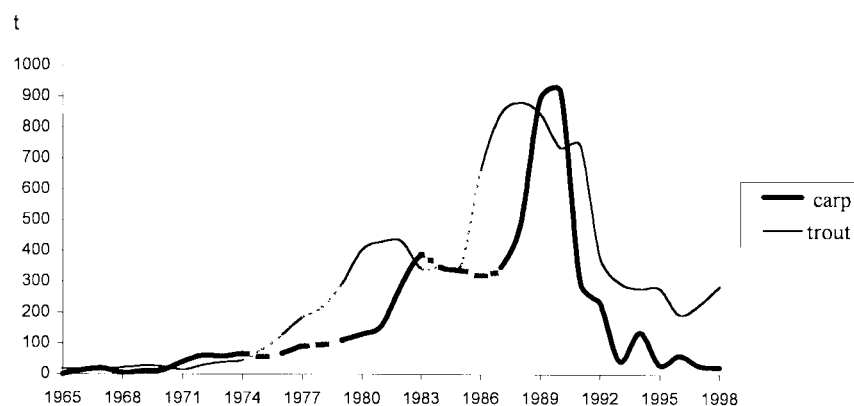
The development of fish farming and research in this field have been closely linked. Fish farming began in Estonia in the 1890s. German landowners initiated farming of brown trout (*Salmo trutta fario*) and common carp (*Cyprinus carpio*) in ponds and developed it into a profitable branch of economy. Professors of the University of Tartu J. Kennel and M. Braun and other scientists (M. v. z. Mühlen, A. v. Middendorf) made experiments of hatching brown trout and whitefish (*Coregonus lavaretus*). Trials to improve the technology of pond farming were carried out by owners of fish farms, e.g. St. v. Holstein (Antsla fish farm) and Fr. Berg (Sangaste fish farm). Fr. Berg, who was known as

an enthusiast of progressive methods of agriculture, wrote also much about the problems of pond fish farming and his experience of solving them (Tohvert, 1995).

World War I and the Russian revolution had a devastating effect on the fish farming in Estonia. Between the two world wars the production of fish farming for fish consumption was small in the Republic of Estonia (Tohvert & Paaver, 1999). The term “fish farming” was used in the meaning of hatching of larvae of salmon, trout, and whitefish for releases. Also some trials to hatch fry of pikeperch were carried out in Sindi hatchery by E. Reinvaldt. The production of commercial fish farming remained small and rearing technology old fashioned and primitive until the 1960s.

### **AQUACULTURE RESEARCH IN THE PERIOD OF INTENSIVE FISH FARMING**

Since the end of the 1960s the production of farmed for consumption fish began to rise and the process accelerated in the 1970s (Fig. 1). It was the time when the bases of contemporary industrial fish farming were formed in Europe. Feeding with formulated dry feeds by means of automatic feeders, mariculture of salmonids in net pens, and vaccination of fish spread widely. Recirculation systems were developed and warm effluent water of power plants was used to prolong the growth period of fish. A marked increase in the production of fish in ponds and cages in Estonia could not be achieved without significant support of applied research in this field. At that time the applied aquaculture research in Estonia kept pace with the development of fish farming in Europe. The North European model of intensive rainbow trout farming and East European technology of efficient carp farming were adjusted to the conditions of Estonia. However, the results of local research projects were mostly applied into practice directly by fish farming enterprises or transferred to fisheries authorities and central research institutes of the Soviet Union in the form of manuscripts. On the basis of some investigations guidelines for practical fish farming were issued (e.g. Erm, 1973). Other results were published either in Estonian in local journals or in Russian in proceedings of scientific conferences held in the Soviet Union. The decline of the production of commercial fish farming in the 1990s (Fig. 1) caused significant changes also in the research profile. Projects of applied research oriented to the development of large-scale intensive fish farming were cancelled. Currently only the Department of Fish Farming of the Institute of Animal Science of the Estonian Agricultural University carries out research in the field of aquaculture. Priority is given to studies of environmental and quality problems such as the impact of fish farming and stocking on the genetic diversity of fish species, efficiency of stocking of natural waters, or impact of eating farmed fish on human health. These are questions which have risen in all North European countries due to explosive development of aquaculture and Estonia has been carrying out high level research in these fields.



**Fig. 1.** Dynamics of aquaculture production in Estonia in 1965–98 by species. Dotted line marks extrapolation of data for periods when official statistics was not available.

## INVESTIGATIONS AT MAIN CENTRES OF AQUACULTURE RESEARCH IN ESTONIA

**Department of Fish Farming of the Estonian Institute of Animal  
Breeding and Veterinary Science (since 1994 the Institute of Animal  
Science of the Estonian Agricultural University)**

The department was established in 1961 as the Department of Sheep and Fish Farming. Since 1964 the Department of Fish Farming exists as a separate unit. A large fish farm (125 ha of ponds) was built in central Estonia in Ilmatsalu in the 1970s as an experimental base of the Department to promote the development of inland fish farming. The simultaneous steering of both the Ilmatsalu experimental pond farm and the research department by Mare Puhk in the 1970s–80s was especially fruitful from the aspect of the development of carp farming. It enabled application of the results of research projects immediately into practice in the Ilmatsalu fish farm and use of its facilities for experiments. The research programme of the Department included four main directions:

### *1. Improvement of the technology of common carp farming*

First (1964–71) the development level of rearing methods in Estonian fish farms was estimated and problems were identified (Jaama & Puhk, 1966; Puhk, 1970, 1971). Then (1972–80) fish farming technology suitable for local conditions was worked out. Standards for carp rearing were developed and a new price system was suggested. Feeding technology (construction of demand feeders) and diurnal variation in feeding activity (Puhk, 1983b; Puhk & Kurtch, 1983; Puhk & Tohver, 1985b, 1987) were studied and recipes of dry feeds were composed. Methods of induced spawning and a technology of incubation of eggs were developed (Puhk & Tohver, 1976a) to produce fry in desired quantities and at a

fixed date. It also helped to get rid of parasites that contaminated larvae in the spawning ponds. A three summer rearing cycle was introduced to produce large, over 1 kg carp instead of two summer old small (400 g) fish which had no demand on the market. The quality of carp (dress-out percentage, biochemical composition of flesh, etc.) was estimated (Puhk & Tohvert, 1984).

#### *2. Selective breeding of common carp*

Broodstock consisting of different strains (local Antsla strain, Ropsha strain, German mirror carp) and interstrain crosses was formed (Puhk, 1973, 1983a; Puhk & Tohvert, 1985a, 1986; Tohvert et al., 1998). Strains were characterized by several traits such as performance, morphology, genetic variability of allozymes, and biochemical composition (Tohvert & Puhk, 1989; Gross et al., 1989; Paaver & Gross, 1990; Gross, 1991; Gross, 1992; Gross & Wohlfarth, 1994). Selective breeding was carried out to improve the growth and survival of the fish. Tagging experiments were made to find methods for individual marking of broodstock and group marking of test fish. Dye insertion and finclipping were found to be the most suitable methods (Puhk & Tohvert, 1981). As a result of selective breeding and better reproduction technology the productivity of the brood fish (number of progeny per female) increased significantly (Puhk & Tohvert, 1983; Tohvert, 1992).

#### *3. Parasitology of pond fish and antiparasitary treatment of fish*

The parasite fauna of Estonian fish farms was studied and problems caused by parasitary diseases (chilodonellosis, ichthyophthiriosis, dactylogyrosis, trichodinosis, and diplostomatosis) were identified (Kasesalu, 1970, 1971, 1974, 1982; Kasesalu & Laius, 1990). A scheme of prophylactic treatment of fish and ponds against parasites was suggested. Losses of fish during overwintering were estimated and a technology of keeping fish during winter in tanks and troughs was developed (Puhk & Tohvert, 1976b; Laius, 1989, 1990).

#### *4. Technology of farming rainbow trout in fresh water*

Possibilities of increasing the intensity of rearing trout were studied, feeding trials with different wet and dry feeds were carried out, and recipes for dry feeds were composed (Post, 1975). The reproduction technology was improved (Novozhenin et al., 1991) by introducing application of anaesthetics, fertilization in physiological solution, new hatching equipment, and a vacuum driven system for cleaning eggs.

The staff of the Department was 7–9 persons during peak periods, including 3–5 scientists and 2–5 technicians. The technical staff of Ilmatsalu experimental pond farm was of great support in carp farming trials.

Four persons (M. Puhk, I. Post, J. Kasesalu, and R. Gross) were awarded a candidate of science (Ph.D.) degree in the field of fish farming. The list of scientific publications on fish farming by staff members of the Department in the period 1961–90 included about 160 titles. The booklet *Kalakasvatus* was issued (7 issues), where the results of research projects were published and explained in popular form in Estonian.

**Laboratory of Marine Fish Rearing (1988–98 the Laboratory of Coastal Fishery) of the Tallinn Department of the Baltic Fishery Research Institute (often its abbreviated Russian form BaltNIIRKh is used)**

Research in marine aquaculture was initiated in Estonia at the beginning of the 1970s. An experimental station with fish cages was founded in Kõiguste Bight in the southeastern part of Saaremaa Island in 1972.

Investigations were carried out in three main directions:

1. *Problems of commercial fish farming in the Baltic Sea (mainly rainbow trout in marine net cages)*

Problems of the construction of rearing facilities (Sõrmus, 1974), antifouling protection of cages (in cooperation with a plant manufacturing ship paints in Riga), feeding and feed composition (Sirak et al., 1976; Kangur et al., 1977a; Tanner et al., 1987), physiological condition of fish (Kangur, M. & Kangur, A., 1978; Kangur, A. K. & Kangur, M. L., 1982a), the need of cage reared trout for contact with air (Kangur, M. et al., 1977b) were studied. Much attention was paid to diseases (Õun & Shchukina, 1976, 1979; Jõgis & Turovski, 1979; Veldre et al., 1980; Õun & Kadakas, 1982; Vismanis et al., 1984; Lullu et al., 1986), especially to vibriosis and immunization of rainbow trout against it. The study included working out and testing a vaccine on the basis of local strains of *Vibrio anguillarum*. Toxicity assessment of feeds was made (Tanner et al., 1983; Veldre & Tanner, 1984). Growth, survival, and recapture rate of fish reared in semiclosed Undu and Arju bays (Saaremaa) and the impact of damming on ambient environmental conditions were studied (Kangur, M. et al., 1982). Commercial farming of carp in marine cages was tested (Kangur, 1985).

2. *Rearing of fish juveniles for releases into natural waters*

The studies of rearing pike-perch included development of methods for collecting eggs using hormonal injections or artificial nests, incubation of eggs in water saturated air (Wojnarovitch method), rearing summerlings in fresh and brackish water ponds (Erm, 1985, 1987). Many experiments were made on pike rearing and a manual was published for fish farmers on this matter (Erm, 1973). Rearing of juveniles of whitefish in fresh- and brackish water earthen ponds, in temporal water bodies, in net cages in a lake and coastal bays, and in tanks with artificial feeding and also the efficiency of releases of whitefish were studied (Sõrmus, 1975, 1979). Rearing of sea trout and salmon in net cages in the sea (Arman & Shchukina, 1976) and rearing and overwintering of salmon smolts in the cooling water of a power plant were also investigated.

3. *Introduction of non-native fish species into aquaculture in Estonia*

Opportunities to rear coho salmon *Oncorhynchus kizutsch* in Estonia were tested (Kangur, M. L. et al., 1985). An interesting finding was survival of some males of coho salmon in cages after maturation. Returns of mature coho salmon to the outlet of the fish farm from which they had escaped to the Baltic Sea were detected (Kangur, A. K. & Kangur, M. L., 1982b). Experiments of rearing pink

salmon (*Oncorhynchus gorbusha*), a sturgeon hybrid bester (Romanycheva & Kangur, 1980), and hybrids of rainbow trout with coho salmon in marine net cages were carried out (Kangur, M. L. et al., 1981).

Attempts at sex reversal of rainbow trout by feeding the fish with steroids and management of rainbow trout released into the open bay by acoustic signals (Volovova & Järvik, 1981) did not give applicable results. Results of sea ranching of carp were more promising.

The number of people engaged in aquaculture research was about 25 in the peak period of activities of the laboratory. About 90 papers were published and their temporal distribution (10% before 1976, 43% in 1976–80, 28% in 1981–85, 19% in 1986–90) reflects quite well changes of effort in different periods.

**Department of Hydrobiology of the Institute of Zoology and Botany  
of the Academy of Sciences of the Estonian SSR (at the Limnology  
Station at L. Võrtsjärv)**

A project of fundamental research in production biology of fish, which included farmed fish (carp and rainbow trout), was initiated around 1965 to reveal the factors determining the productivity of fish by means of complex analysis of many characteristics. Although this final goal was not achieved and the project was cancelled around 1990, some important results were obtained in the field of fish biology. Strains and stocks of carp and rainbow trout were genetically characterized by means of allozyme markers (Paaver, 1983, 1988; Krause & Paaver, 1988; Paaver & Gross, 1990). Experiments on genome manipulation were made to produce triploid rainbow trout by means of heat shock (Paaver & Palm, 1990; Tambets et al., 1991). Seasonal variation of metabolism in fish liver was studied. It was discovered that during transfer from summer to winter regime or back the balance of lipid–glycogen assimilation in the liver of carp and trout changes, which must be taken into account by feeding in different seasons or transfer of fish between fish farms. Morphological and physiological traits of different stocks of carp and trout reared in Estonia and neighbouring countries were measured.

The staff of the group was around 12 persons including 6 scientists (H. Haberman, K. Laugaste, A. Kirsipuu, T. Paaver, T. Noorits, and H. Tell-Tünder) in the peak time. However, only a few of them were directly involved in aquaculture research. The number of publications dealing with the biology of farmed fish was around 30. Two important symposiums were held in Tartu on the initiative of this Laboratory in cooperation with the Department of Fish Farming of the Institute of Animal Breeding and Veterinary Science. The symposium on fish genetics, hybridization, and cytology, bringing together all scientists in this field in the USSR, took place in 1986. The first in the USSR symposium on genetic manipulations of fish was held in 1988.

### **Contribution of the other research institutions**

In the 1970s–80s the contribution of the University of Tartu to the development of aquaculture consisted in educating fish farmers. Over 20 students wrote diploma papers about fish farming, including the technology of rearing and feeding carp and rainbow trout, fish diseases and parasites, etc. In the middle of the 1980s studies of the embryology of carp were made by Prof. T. Saat in cooperation with the All-Union Research Institute of Pond Fish Farming (VNIIPRKh). Central institutes of applied science of the Soviet Union often used Estonian fish farms as research bases for experiments in aquaculture. The State Research Institute of River and Lake Fisheries (GosNIORKh) carried out trials of rearing coregonids (e.g. “Iudoga whitefish”) in Haaslava fish farm. Rearing of different fishes in sea cages was investigated by the All-Union Research Institute of Marine Fisheries and Oceanography (VNIRO) at Tõstamaa and in some other places. Experiments of rearing salmon, rainbow trout, and carp in the heated outflow water of a power plant in Narva were made by GosNIORKh. Innovative experiments on gene transfer were carried out in Aravuse trout farm by scientists of Moscow University and VNIIPRKh.

Fishing cooperatives (kolkhozes) and other enterprises carried out applied research in their own interests (often in cooperation with some Estonian research institute). Experiments on rearing different fish species – sturgeons (Herman, 1975), eel, Pacific salmon, and several strains of rainbow trout were made in the Kirov Fishing Cooperative. The same enterprise developed in cooperation with the Tallinn Department of BaltNIIRKh (O. Leino) and Tallinn Technical University a model of recirculation system (Biorek) for rainbow trout rearing (Asi, 1980).

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Research projects of Estonian scientists covered a broad range of questions and had significant practical outputs. Modern intensive farming of rainbow trout could not be developed in Estonia without the contribution of the Laboratory of Marine Fish Rearing of the Tallinn Department of the Baltic Fishery Research Institute and the Department of Fish Farming of the Estonian Institute of Animal Breeding and Veterinary Science. Efficient carp farming in relatively unfavourable for this fish climate of Estonia was built up by efforts of scientists of the Department of Fish Farming of the Estonian Institute of Animal Breeding and Veterinary Science. The academic research carried out at the Institute of Zoology and Botany in the 1970s–80s in farmed fish genetics was ahead of similar research in Europe of that time.

## REFERENCES

- Arman, J. K. & Shchukina, I. N. 1976. Rearing of sea trout in sea cages. In *Fishery Research in the Baltic Sea*, Vol. 12, pp. 145–152. Zvaigzne, Riga (in Russian).
- Asi, A. 1980. Experimental recirculation system for rearing of trout. *Rybn khoz.*, 2, 30–31 (in Russian).
- Erm, V. 1973. *Haugi marja inkubeerimise ja vastsete kasvatamise juhend*. Eesti Kalurikolhooside Vabariiklik Liit, Tallinn.
- Erm, V. 1985. Koha noorjarkude kasvatamisest polükultuuris Võiste riimveelises rannikutiigis. *Abiks Kalurile*, 2, 2–8.
- Erm, V. A. 1987. Efficiency of artificial spawning nests of pike-perch in Pärnu Bay. In *Abstracts of All-Union Conference "Artificial Reefs for Fishery"*, pp. 115–117. Moskva (in Russian).
- Gross, R. 1991. Characterization of genetic, morphological and performance traits in common carp strains in Estonia and the results of commercial crossings. Cand. Sci. Thesis. Tartu (in Russian).
- Gross, R. 1992. Strain differences in performance of two- and three-summer old common carp in Estonia. *ELVI teaduslike tööde kogumik. Loomakasvatust*, 63, 118–125.
- Gross, R. & Wohlfarth, G. W. 1994. Use of genetic markers in growth testing of common carp, *Cyprinus carpio* L., carried out over 2 or 3 year cycles. *Aquacult. Fish. Manage.*, 25, 585–599.
- Gross, R., Puhk, M. & Tohver, T. 1989. Estimation of some genetic and fish farming traits of initial material for selection of Estonian carp. In *Genetics in Aquaculture. Materials of 3rd All-Union Symposium on Genetics, Selection and Hybridization of Fish*, pp. 196–206. Nauka, Leningrad (in Russian).
- Herman, A. 1975. Bestrist ja bestri kasvatamisest S. M. Kirovi nimelises kalurikolhoosis. *Abiks Kalurile*, 1, 15–18.
- Jaama, K. & Puhk, M. 1966. Põllumajandusliku kalakasvatuse organiseerimine ja tiigimajanduse alustest Eesti NSV-s. Manuscript in the library of Inst. Animal Sci. of Estonian Agricultural University, Tartu.
- Jõgis, V. & Turovski, A. M. 1979. Diseases of salmonid fish in seawater fish farms of the ESSR. *Rybn. khoz.*, 10, 23–24 (in Russian).
- Kangur, A. K. & Kangur, M. L. 1982a. Diagnostic value of some indices of blood serum of rainbow trout. In *All-Union Conference of Ecological Physiology and Biochemistry of Fish. Abstracts 3*, pp. 54–55. Naukova Dumka, Kiev (in Russian).
- Kangur, A. K. & Kangur, M. L. 1982b. Development of gonads of coho salmon in conditions of rearing in sea cages. *All-Union Conference of Ecological Physiology and Biochemistry of Fish. Abstracts 3*, pp. 56–57. Naukova Dumka, Kiev (in Russian).
- Kangur, M. 1985. Karpkala kasvatamisest meres. *Teaduse saavutusi ja eesrindlikke kogemusi põllumajanduses. Kalakasvatust*. Tallinn, 22, 8–15.
- Kangur, M. & Kangur, A. 1978. Variability of some physiological traits of rainbow trout by rearing in sea cages. *Fischerei-Forschung* (Rostock), 16, 35–40 (in Russian).
- Kangur, M., Kangur, A., Roosma, A. & Shchukina, I. 1977a. Growth and physiological condition of rainbow trout in sea cages at different feeding regimes. In *Biological Bases of Feeding of Fish in Industrial Rearing*, pp. 100–108. Leningrad (in Russian).
- Kangur, M., Kangur, A., Shchukina, I. & Sõrmus, I. 1977b. Physiological condition of rainbow trout in sea cages isolated of water surface in winter. In *Abstracts of 6th Soviet–Japanese Symposium on Questions of Aquaculture and Increasing of Biological Productivity of World Ocean*, pp. 54–56. Moskva (in Russian).
- Kangur, M. L., Kolk, J. V., Turovski, A. M., Kangur, A. K., Shchukina, I. N. & Makarov, I. M. 1981. About hybrids of rainbow trout with coho salmon. In *Genetics, Selection and Hybridization of Fish. Abstracts of II All-Union Symposium*, pp. 174–175. Rostov-na-Donu (in Russian).



- Kangur, M., Annist, J., Kotta, I., Lumberg, A. & Turovski, A. 1982. Impact of isolation from open sea on the hydrochemical regime and hydrobionts in some bights of Saaremaa Island. In *Eesti II vabariikliku ökoloogiakonverentsi teesid*, p. 116. Tartu (in Russian).
- Kangur, M. L., Kangur, A. K., Kolk, J. V., Turovski, A. M. & Shchukina, I. N. 1985. Rearing of coho salmon in the Baltic region. In *Biological Bases of Aquaculture in the Seas of the European Part of the USSR*, pp. 139–151. Moskva (in Russian).
- Kasesalu, J. 1970. On the parasite fauna of carp in Estonian fish farms. *Collection of Scientific Papers of Estonian Agricultural Academy*, **70**, 133–136 (in Russian).
- Kasesalu, J. 1971. Ihtüoparasitaarne olukord ja kalade haigused Eesti NSV tiigimajandeis. Cand. Sci. Thesis. Tartu.
- Kasesalu, J. 1974. Karpkala parasitofauna vanuselisest ja sesoonsesest dünaamikast Eesti NSV-s. *ELVI teaduslike tööde kogumik. Veterinaaria*, **32**, 70–74.
- Kasesalu, J. 1982. Karpkala protozoofauna dünaamika esimesel eluaastal. *ELVI teaduslike tööde kogumik. Veterinaaria*, **53**, 132–140.
- Kasesalu, J. & Laius, A. 1990. Karpkala ujupõiehaigusest Eestis. *Teaduse saavutusi ja eesrindlikke kogemusi põllumajanduses. Väikeloomad*. Tallinn, **11/90**, 63–67.
- Krause, T. & Paaver, T. 1988. Morphological and genetic characterization of Donaldson trout and Finnish trout in recirculation system Biorek (ESSR). *Izv. GosNIORKh*, 276, 94–99 (in Russian).
- Laius, A. 1989. About different wintering technologies of carp (*Cyprinus carpio* L.). In *Collected Materials of Scientific Meeting "Sustainable Technologies in Fish Farming"*, pp. 203–211. Stara Zagora.
- Laius, A. 1990. Unterschiedliche Überwinterungstechnologien für einsömmerige Karpfen (*Cyprinus carpio*) in Estland. *Z. Binnenfisch.*, **37**, 215–218.
- Lullu, A. V., Kokarev, A. V., Kadakas, V. V., Semenov, A. C., Manushkin, A. A. & Paalme, T. G. 1986. Flexibacteriosis of juvenile rainbow trout in the heated water fish farm. In *Abstracts of I All-Union Symposium on Diseases of Marine Hydrobionts, Bol'shoi Utrishch*, pp. 27–29. Moskva (in Russian).
- Novozhenin, N. P., Linnik, A. B. & Tenson, R. O. 1991. Incubation of trout eggs. *Rybn. khoz.*, 10, 27–31 (in Russian).
- Õun, A. I. & Kadakas, V. V. 1982. On the vibriosis in the rainbow trout in Estonian fish farms and the diagnostics of the disease. In *II Symposium on Marine Aquaculture*, pp. 23–24. Odessa (in Russian).
- Õun, A. & Shchukina, I. 1976. Vikerforellide vibrioosist meresumpades. *Abiks Kalurile*, 3, 34–40.
- Õun, A. I., & Shchukina, I. N. 1979. Diagnostics of vibriosis of fish. *Veterinariya*, **2**, 40–44 (in Russian).
- Paaver, T. 1983. *Biochemical Genetics of Carp*. Valgus, Tallinn (in Russian).
- Paaver, T. 1988. Electrophoretic variability of proteins and genetic characterization of cultivated in USSR strains of rainbow trout *Salmo gairdneri*. *Vopr. ikhtiol.*, **28**, 595–603 (in Russian).
- Paaver, T. & Gross, R. 1990. Genetic variation in carp *Cyprinus carpio* L. strains reared in Estonia. *Genetika*, **26**, 1269–1278 (in Russian).
- Paaver, T. & Palm, A. 1990. Chromosomal variability in rainbow trout stocks in Estonia. *Proc. Estonian Acad. Sci. Biol.*, **39**, 165–169.
- Post, I. 1975. Vikerforell Eesti NSV tiigimajandeis. Cand. Sci. Thesis. Tartu.
- Puhk, M. 1970. Karpkalakasvatuse bioloogilistest alustest Eestis. *ELVI teaduslike tööde kogumik. Zootehnika*, **22**, 155–162.
- Puhk, M. 1971. Karpkala Eesti NSV tiigimajandeis. Cand. Sci. Thesis. Tartu.
- Puhk, M. 1973. Karpkala tõugruppidest ja nende mõningatest kalamajanduslikest omadustest Eesti NSV tiigimajandeis. *Soovitusi teaduse ja tehnika saavutuste rakendamiseks põllumajanduses*. Tallinn, **29**, 54–58.
- Puhk, M. 1983a. Karpkalatõugudest ja majanduslikest omadustest Eesti NSV-s. *ELVI teadlaste soovitused tootmisele*. Tallinn, 59–64.

- Puhk, M. 1983b. Karpkala toitumisest, toitumisrütmidest ja nende tähtsusest söötmise organiseerimisel. *ELVI teadlaste soovitusel tootmisele*. Tallinn, 64–69.
- Puhk, M. & Kurtch, A. 1983. On the possibilities of improving the technology of feeding carp by producing market fish in Ilmatsalu experimental pond farm. *ELVI teaduslike tööde kogumik*, **54**, 143–149 (in Russian).
- Puhk, M. & Tohvert, T. 1976a. Karpkala taastootmise kunstlik meetod ning selle kalamajanduslik tähtsus. *ELVI teaduslike tööde kogumik*, **40**, 162–169.
- Puhk, M. & Tohvert, T. 1976b. Karpkala talvitumine. *Teaduse saavutusi ja eesrindlike kogemusi põllumajanduses. Loomakasvatus. Kalakasvatus*. Tallinn, **20**, 38–41.
- Puhk, M. & Tohvert, T. 1981. Remont- ja sugukarpkala märgistamise meetodid. *ELVI teadlaste soovitusel tootmisele*. Tallinn, 68–72.
- Puhk, M. & Tohvert, T. 1983. Karpkala produktiivomaduste parandamisest. *Kalakasvatus*. Tallinn, 19–24.
- Puhk, M. & Tohvert, T. 1984. Karpkala keemilise koostise ja energeetilise väärtuse sõltuvus kala vanusest. *Teaduse saavutusi ja eesrindlike kogemusi põllumajanduses. Kalakasvatus*. Tallinn, **20**, 3–8.
- Puhk, M. & Tohvert, T. 1985a. Saksa karpkala Eestis. *Teaduse saavutusi ja eesrindlike kogemusi põllumajanduses. Kalakasvatus*. Tallinn, **22**, 25–33.
- Puhk, M. & Tohvert, T. 1985b. Söödakulust karpkala kasvatamisel ja selle vähendamise võimalustest. *Teaduse saavutusi ja eesrindlike kogemusi põllumajanduses. Hobused ja väikeloomad*. Tallinn, **27**, 40–43.
- Puhk, M. & Tohvert, T. 1986. Ropša karpkalast ja tema kasutamisperspektiividest Eestis. *Teaduse saavutusi ja eesrindlike kogemusi põllumajanduses. Kalakasvatus*. Tallinn, **25**, 12–18.
- Puhk, M. & Tohvert, T. 1987. Efficiency of feeding of carp and factors influencing it. *ELVI teaduslike tööde kogumik*, **59**, 173–181 (in Russian).
- Romanycheva, O. D. & Kangur, M. L. 1980. Experimental and commercial rearing of salmonid and acipenserid fish in sea water. *Rybn. khoz.*, **2**, 25–27 (in Russian).
- Sirak, V. A., Sõrmus, I. P., Shchukina, I. N., Martinson, M. A., Aarik, M. I. & Tanner, R. H. 1976. Rearing of rainbow trout in sea cages by means of feeding with different fish feeds. In *Fishery Research in the Baltic Sea*, Vol. **12**, pp. 153–164. Zvaigzne, Riga (in Russian).
- Sõrmus, I. 1974. Sumbaparvedest. *Abiks Kalurile*, **1**, 27–33.
- Sõrmus, I. 1975. Merisiia elujõulise asustusmaterjali kasvatamise perspektiividest. *Abiks Kalurile*, **4**, 10–11.
- Sõrmus, I. P. 1979. Rearing of fry of sea spawning whitefish. In *Fishery Research in the Baltic Sea*, Vol. **14**, pp. 107–116. Zvaigzne, Riga (in Russian).
- Tambets, J., Paaver, T., Palm, A., Pihlak, A. & Gross, R. 1991. Variability of some cell parameters in di- and triploid rainbow trout, *Oncorhynchus mykiss*. *Proc. Estonian Acad. Sci. Biol.*, **40**, 129–135.
- Tanner, R. H., Iling, M. M., Kadakas, V. V. & Sergeev, B. L. 1983. Analysis of aflatoxins in feeds by means of high-efficiency chromatography in connection with development of liver tumors of rainbow trout in the ESSR. In *Tumors of Reared and Wild Fish – Reasons and Measures of Control*, pp. 52–57. Tallinn (in Russian).
- Tanner, R. H., Kivisilla, K. A., Iling, M. M., Prikk, M. A. & Turetski, V. I. 1987. To the question of unification of methods for revealing low quality of fish meals and dry feeds for fish. *Sb. nauchn. tr. VNIIPRKh*, 139–147 (in Russian).
- Tohvert, T. 1992. Productivity of female spawners of different strains of common carp in Estonia. *ELVI teaduslike tööde kogumik. Loomakasvatus*, **63**, 126–136 (in Russian).
- Tohvert, T. 1995. Krahv Friedrich Berg ja kalandus. In *150 aastat krahv Friedrich Bergi sünnist*, pp. 44–55. TÜ Kirjastus, Tartu.
- Tohvert, T. & Paaver, T. 1999. *Kalakasvatus Eestis*. Tartu.
- Tohvert, T. & Puhk, M. 1989. Tõulistest erinevustest samasuvise karpkala talvitumisel. *Teaduse saavutusi ja eesrindlike kogemusi põllumajanduses. Kalakasvatus*. Tallinn, **28/88**, 33–40.

- Tohvert, T., Gross, R. & Paaver, T. 1998. Karpkala sugukarja kujundamine ja valik Ilmatsalu kalakasvanduses 1971–1997. *EPMÜ LKI teadustöid*, **68**, 80–91.
- Veldre, L. & Tanner, R. 1984. Kalasöötade rääsumisproduktide toksilisusest ja selle hindamisest. *Abiks Kalurile*, **4**, 16–23.
- Veldre, I. A., Itra, A. P., Paalme, L. P. & Kangur, M. L. 1980. Accumulation of benz(a)pyrene in fish. *Vopr. onkol.*, **XXVI**, 80–82 (in Russian).
- Vismanis, K. O., Lullu, A. V., Jõgis, V. A., Turovski, A. M. & Õun, A. I. 1984. Diseases of salmonid fish in sea cages of the Baltic region and their prophylactic treatment. In *Biological Bases of Fish Farming: Parasites and Diseases of Fish*, pp. 54–63. Nauka, Moskva (in Russian).
- Volovova, L. & Järvik, A. 1981. Studies of attracting the fish to a source of sound. *Rybn. khoz.*, **7**, 44–45 (in Russian).

## EESTI KALAKASVATUSALASTE UURINGUTE AJALUGU

Tiit PAAVER, Tiiu TOHVERT ja Mart KANGUR

Kalakasvatusteadus on arenenud tihedas seoses tootmise taseme muutumisega selles valdkonnas. Kalakasvatus kujunes Eestis välja 1890. aastatel. Kalade paljundamise ja kasvatamise katseid tegid baltisaksa teadlased ja asjatundjad (J. Kennel, M. Braun, Fr. Berg jt.). Perioodil, kui kaubakala kasvatati vähe ja kalakasvatuse all mõeldi eeskätt noorkalade asustamist looduslikesse vetesse kalavarude suurendamiseks (1918–1960), olid ka uuringud väikesemahulised. Kalakasvatuse kiire edenemine 1970.–1980. aastatel tugines rakendusuuringutele, mida tehti Loomakasvatuse ja Veterinaaria Teadusliku Uurimise Instituudi kalakasvatuse osakonnas (M. Puhk, R. Gross, J. Kasesalu, T. Tohvert, I. Post jt.) ja Läänemere Kalandusinstituudi Tallinna osakonna merekalakasvatuse laboratooriumis (M. Kangur, V. Erm, I. Sõrmus jt.). Neist asutustest esimeses uuriti peamiselt karpkala ja vikerforelli mageveelist tiigikasvatust (kalakasvatuse tehnoloogia, söötmine, paljundamine, tõuaretus ja kalahaiguste tõrje), teises vikerforelli ja teiste kalaliikide merevees kasvatamist (sumbakalakasvatuse tehnoloogia, noorkalakasvatus kalavarude taastootmiseks, uute liikide kasvatamise võimalused, haiguste tõrje ja söötade kvaliteet). Kasvatatavate kalade geneetikat, füsioloogiat ja muid bioloogilisi probleeme vaadeldi Zooloogia ja Botaanika Instituudi hüdrobioloogia osakonnas (T. Paaver, K. Laugaste jt.). Olulise panuse kalakasvatuse arengusse andis kõrgema haridusega kalakasvatajate koolitamine Tartu Ülikoolis. Praegu tegeldakse kalakasvatuse uurimisega Eesti Põllumajandusülikooli loomakasvatusteadusliku instituudi kalakasvatuse osakonnas.