CARASSIUS AURATUS S. *LATO* IN VARIOUS TYPES OF AQUATIC ECOSYSTEMS FROM THE PRUT RIVER BASIN

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Abstract: The present paper describes some peculiarities of the growth and reproduction of *Carassius auratus* s. *lato* from the ecosystems of Lower Prut and Beleu Lake. This taxon is characterized by asynchronic development of oocytes and lying of three portions of eggs during the reproductive cycle. The histological analysis of the ovaries of *Carassius auratus* s. *lato* in these ecosystem types during the inter-reproductive period has revealed some differences in the development of future generations of oocytes. The oogenesis process in females from Beleu Lake is more intense and the value of gonado-somatic index is higher.

Keywords: bio-invasion, ecosystem, eurytopic, expansion, gametogenesis, idio-adaptation, reproduction, taxon

Introduction:

The *Carassius auratus* s. *lato* is a taxon native from Far East, exactly from the Amur river basin (Kottelat and Freyhof 2007; Abramenco 2011). Introduced in Europe in XVII century by the Portuguese as decorative fish, around 1730 it was already widespread among European aquarists (Skolka and Gomoiu 2004; Iacob and Petrescu-Mag 2008).

Not only through the individuals escaped from aquariums and by the dissemination and exchange of fishing material, but as well due to a self-expansion process, have the species spread throughout Europe in a short time period and at present it features a cosmopolite distribution (including in water basins of North America) (FishBase, online).

For these reasons, it is practically impossible to reconstitute the historical map of the spread of this taxon. Its expansion was in great measure reliant on anthropochore activities and on the high ability of self-expansion in new territories. But, certainly, it is the first allogenic species of fish pervading in the Republic of Moldova that provoked an invasive effect.

At present, due to exceptional hydrobiotopic and competitive potential, it is a common species in the whole hydrographic network.

Despite numerous scientific papers dedicated to the biology of *Carassius auratus* s. *lato* (over 500 in Russian scientific literature), at present the taxonomic status of the species remains a mystery to the researchers (Vehov 2013). There are several considerations in this regard. One of them claims that the genus Carassius Nilson

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comprises only two taxa with the rank of species: *Carassius carassius* L. – Crucian Carp and *C. auratus* L. - European Goldfish. The latter, however, forms two subspecies: *C. auratus gibelio* Bloch – Prussian Carp and *C. auratus auratus* – Common Goldfish with terra typica of the south of Amur basin, which includes a large variety of ornamental forms of Golden Fish known by aquarists everywhere. This classification is largely met in the works of Berg 1949; Bănărescu 1964; Popa 1977; Dolghii 1993; Apalikova et. al. 2011; Reshetnikov 1998; Vasilieva 1999.

Another classification is based on the works of Kottelat and Freyhof (2007), where the taxonomic status of the Crucian carp is unchanged, while the Prussian Carp and the Common Goldfish are at the top rank of species: *C. gibelio* Bloch and respectively *C. auratus* L. At present this classification is adopted by many taxonomists, ecologists and geneticians (Bogutskaia and Naseka 2004; Diripasco et al. 2011), including by the authors of the present paper.

Some researchers (Golovinskaya et al. 1965; Vasiliev 1985; Cerfas 1987; Abramenko 2011) stated that unisexual polyploid Crucian Carp (3n=135-165) – *Carassius gibelio* Bloch, 1782 was pervasive in the water basins of Europe from the XIXth century till the beginning of the 60s of the XXth century, and it was the only identified form. Later, however, as result of massive works of acclimatization the second species became suffusing – the bisexual and amphidiploid Common Golden fish (2n = 98-100) - *Carassius auratus* Linnaeus, 1758 - in which both sexes are represented in population roughly equal and that invaded shortly the whole Ponto-Caspian basin (Vehov 2007; Mejerin and Kokodii 2009; Abramenko 2011).

The comparative morphological analysis of bisexual and unisexual populations of Silver Carp (Vasilieva 1999) demonstrated that reliable differentiation is not found in most of characters, which allows the validation of their diagnosis by classical methods as separate taxonomic entities. No morphometric distinctive characters supported by Kottelat and Freyhof (2007) are deliberative, being based more on body color (the Common Goldfish has mostly golden coloration) and on the number of lateral line scales (26-31 in Common Goldfish and 29-33 in Crucian Carp). Also, Mejerin and Kokodii (2009) argues that the separation of these taxa can only be rendered using genetic markers, because of the quick transgression of most morphometric distinctive characters (although some trends in spatial separation of these biotypes are observed).

Moreover, the possibility of using genetic markers has revealed the presence in nature of numerous prolific hybrids between Silver Carp and Crucian Carp (Hänfling et al. 2005) and even between Silver Carp and Common Carp (Haynes et al. 2012).

This phenomenon is a clear example of free hybridization between bisexual Silver Carp and Crucian Carp, where the subsequently obtained descendants can freely interbreed with the triploid form of Prussian Carp, generating an impressive genetic diversity: in addition to the three registered parental taxa (Common Goldfish, Prussian Carp, Crucian Carp) there are 5 more different hybrid biotypes with different rank of genome ploidisation (Mejerin and Kokodii 2009).

Moreover, some actual genetic studies demonstrate that both Common Goldfish and Crucian Carp can separately form diploid-polyploid complexes and the haplotypes of both studied taxa across China are recognized through genetic markers as genotypes of Common Goldfish and of Crucian Carp (Rylkova et al. 2010).

Other cyto-genetic and molecular studies established that the triploid form Prussian Carp females (3n = 150) can reproduce ameiotically gynogenetic as well as sexually by meiosis (Fan and Shen 1990). The odd polyploid organism may have the set of XXX or XXY sex chromosomes, where Y-heterochromosome is in repressive state (as recessive gene), and phenotypically manifested only in gynogenetic form. The intensification of anthropogenic pressure and the environmental factors' instability cause the "passing" of ameiotic gynogenetic form of Prussian carp into the meiotic bisexual, where triploid males may appear with XYY allosome set (Abramenko 2011). The research in the field has shown that between triploid and diploid forms there is an exchange of genetic material with current trend of unidirectional transformation of gynogenetic triploid form into diploid bisexual (Apalikova 2011).

All these results, on the one hand suggest that the biology of Prussian Carp is still far from being fully elucidated and most of the present populations represent a "genetic mix of predecessors pervaded from various regions" in some cases being more correct to mention the taxa as *Carassius auratus* s. *lato* or *Carassius auratus* - complex (Fig. 1).

Figure no. 1 *Carassius auratus* s. *lato* – the first allogenic specimen naturalized in the conditions of the Republic of Moldova, the taxonomic status which is still not definitively elucidated

Therefore, as the first step in this paper, we proposed the aim of enlightening the ecological-reproductive peculiarities which contributed to the obvious biological progression of the taxon within the limits of the Republic of Moldova**;** and subsequently, with the accumulation of sufficient ichthyologic material, a series of genetic – molecular comparative studies of individuals from different points of distribution area will be performed.

As it is known, the number of fish population depends largely on conditions of reproduction and on the state of the reproductive system. The changes of fish inhabiting conditions in water basins negatively affect the reproduction, the seasonal process of gametogenesis and reproduction rhythm (Kazanskii 1975; Koshelev 1984). *Carassius gibelio* is one fish species with an asynchronous development of oocytes and portion spawning. In the water bodies of the Dniester and Prut rivers in females during the reproductive cycle there form three generations of eggs, but, depending on the environmental conditions in different years, there are changes in the amount of spawning portion.

The studies conducted in the Dubasari Reservoir and the lower sector of the Nistru River was until the year 1986, when there were registered three portions of spawning in *Carassius gibelio* during the spawning season (Statova 1970; Fulga and Bodareu 1992). The construction of the dam of the Dniester HES has fundamentally changed the dynamics of annual water flow, of the natural course of floods and the physico-chemical regime of the river (Rusev et al. 2004; Shevtsova et. al. 2004). After the launch of the Novo-Dnestrovsk Hydroelectric Station in 1986, due to the lack of environmental conditions for spawning, the females in these waters, spawned only two portions of eggs (Fulga et al. 1994; Fulga et al. 1999; Fulga and Bulat 2010).

During the period of existence of the Cuciurgan cooling reservoir, significant changes in its thermal regime have been recorded. The studies performed by the scientists of the Institute of Zoology of Academy of Sciences of Moldova, throughout the period of weak impact of wastewater from the hydroelectric station, as well as under conditions of increased termofication in the cooling reservoir. There have revealed changes in the fish growth rate, as well as in the development of the reproductive system and of the reaction of reproductive cells in the females of *Carassius gibelio* depending on the temperature factor in the reservoir (Vladimirov et al. 1973; Statova 1973; Statova 1985; Karlov and Krepis 1988; Statova et al. 1988).

Throughout the entire period of the reproductive system study in females of *Carassius gibelio* in Prut river, it was established that individuals, because of the lack of environmental conditions for the third spawning, throughout the whole period of spawning lay two portions of eggs (Fulga et al. 2006; Fulga 2011). The studies on gonad development during the annual reproductive cycle in females of *Carassius gibelio* in the Beleu Lake have been performed for the first time.

In this paper there are purveyed biological characteristics of *Carassius gibelio* and the morpho-functional condition of the reproductive system of females inhabiting the lower course of Prut River and Beleu Lake.

Materials and methods:

The ichthyologic material was collected in-between the years 2004-2014 from different natural aquatic ecosystems of the basin of Nistru and Prut rivers. Fish species were collected using stationary nets (dimensions 15 mm × 15 mm; 50 mm × 50 mm) and trawl for juveniles (l = 6 m and 20 m). Most of the caught individuals were returned alive to the water. For laboratory study, a part of individuals were fixed in 4% formalin solution. The analysis of ichthyologic material was performed by conventional classical and ichthyologic methods (Kottelat and Freyhof 2007; Năvodaru 2008; Koshelev 1984; Lakin 1980; Pravdin 1966).

Histological investigations were performed on ovaries of adult individuals of Prussian Carp, 34 individuals from Lower Prut sector and 41 individuals from Beleu Lake. Ovary samples were fixed in 4% formalin solution with further processing according to widely recognized classical methods. The stage of maturation of the ovaries was determined after Meitn (1939), with some specifications by Sacun and Butskoy (1963) and the state of the oocytes development – according to the classification of Kazanskii (1949). Ovary sections of 7µm thickness were stained by the method Mallory (Roskin and Livenson 1957). The gonado-somatic index (GSI) was determined by the ratio of the weight of ovaries to the body weight (without viscera). All obtained data are a summary of statistical processing using STATISTICA 6.0 and Excel programs - 2007. The microphotographs were obtained with a microscope supplied with photo camera AxioImagerA2.

Results and discussion:

The statements about "double" entering of Prussian Carp in Moldova can be also sustained by the fact that up to the XX century the species was an incidental one in industrial catches and mainly in 1962. Due to its exceptional ecological plasticity, of the 16 small rivers investigated in Moldova the Prussian Carp was reported in eight of them (Tomnatic et al. 1962), whereas its production in fish ponds in the country in 1964 was already of 334,900 kg, and as for the lake catches in Ghidighici its share reached 42.4% (Statova 1966).

The same observations were reported by other researchers in some water basins of the Europe. Thus, if in the Danube basin the Prusian Carp was known only from the inferior course (covering 90% of the surface), then at the end of the 70s of the past century this species had already overlaid 59% of the basin surface and at the begining of the 60s till mid-70s the industrial catches grew by 7 times, from 0.6 thousand tonnes to 4.7 thousand tonnes (Holčic 1980).

In some natural ecosystems in the country (lower Nistru and Prut floodplains, river bed lakes etc.) the Prussian Carp proliferated to such an extent that it has undermined the nutritional basis of economically valuable fish species, which led to a diminishing of fishery resources and, thus, had a negative impact on the results of industrial fishing. Moreover, the Prussian Carp, along with stone moroko, had a significant contribution to the extinction of autochthone fish species, such as Crucian Carp, Tench, European Mudminnow and European Weatherfish from natural lakes and ponds. Nevertheless, it was found that in the aquatic ecosystems which are more complex in structural terms (for ex. Nistru and Prut rivers), owing to the great potential of preserving the intra-biocenotic balance, in the species permeated from abroad relevant cases of short-time expansion and rapid proliferating are not recorded, each native taxon being perfectly integrated in the ichthyocenotic structure, acquired during the intense struggle for existence and natural selection, and any change cushioned by the representatives of secondary positions with close biological needs (through intra-biocenotic links multiple provided and duplicated in "weaker points").

In the Dubasari reservoir in the first years of its creation (1955) the ratio of Prussian Carp (together with Crucian Carp) constituted 1.08% (Statova 1966), in 1998 – 1.8% (Usatii 2004), and in-between 2000 and 2012 it increased to 8.0% (The laboratory report of Ichthyology and Aquaculture for 2012). This alarming dynamics, on the one hand confirms the hypothesis regarding the consecutive entering of Prussian Carp and Common Goldfish, and on the other hand it indicates the trend of resistance weakening of the ecosystem of Dubasari reservoir toward the influence of external destabilizing factors.

The status is even more alarming in natural ecosystems of lake, swamp and small rivers of Moldova, the quantitative indicators of Prussian Carp values being extremely high, far exceeding the critical allowable level, in most of them being a multi-dominant representative (Bulat et al. 2014). These negative consequences of Prussian Carp bio-invasion can be explained by the fact that in these small and relatively isolated ecosystems a very poor biodiversity has formed, but with narrower specialized representatives (stenobionts), each taxon becoming important both as a structural and functional (few intra-biocenotic connections, but essentially and functionally unrepeatable) component. Under the conditions when impact factors (such as multiple fragmentation of hydro-biotops with rapid effects of eutrophication, clogging and heating) cause the extinction of such key species, negative consequences occur immediately at all levels of bio-ecological organization.

Depending on the specific environmental peculiarities established in the ecosystem, the ecological valence range of the species is manifested by the appearance of an expressed ecological polymorphism. The biotypes are different, firstly concerning the population structure (genetics, age, sex), then the niche occupied in space, growth rhythm, sexual maturation period, fecundity, amount of spawning, competitive and hydro-biotopic capacity etc.

In the Beleu Lake and small rivers of the Republic of Moldova, the Prussian Carp forms well differentiated ecophenes allowing it to survive, and even prevail in unfavorable environmental conditions.

The slow growth in Prussian Carp in small rivers of Moldova allow this opportunistic species (euritherm, eurioxibiont, mixohaline, euriphagous, polyphilic) to resist and even to proliferate rapidly in austere environmental conditions (Bulat et al. 2014). Also, this adaptive variability of the species, displayed in different ecosystems and various environmental conditions, is meant to serve as an important object in the study of bio-indication of environmental quality.

In such conditions, the structural-functional analysis of the population status of Prussian Carp caught in the Beleu Lake in summer (when the local population becomes isolated spatially and ecologically) has revealed a number of biological features.

The estimation of gravimetric values of Prussian Carp individuals from Beleu Lake during unfavorable period stated the presence of ecophene with slow growth rate (Tab. 1).

Table no. 1 Empiric gravi-dimensional values and growth parameters of the ecological for *Carassius auratus* s. *lato* with slow growth rhythm in the ecosystem of Beleu Lake

t (x)	$l(t)$	$\ln(l_\infty - l_t)$ (y)	$w(t)$	$\ln(w_\infty^{1/3} - {}_t^{1/3})$ (y)	$lgw(t)=a+b\,lgl(t)$ lgl(t), (x)	lgl(w), (y)
0+	4.9±0.11	2.69	3±0.12	1.49	0.69	0.48
1+	10.6±0.14	2.19	31±1.45	1.01	1.03	1.49
2+	13.0±0.24	1.88	57±1.76	0.72	1.11	1.76
3+	14.5±0.15	1.62	95±4.21	0.29	1.16	1.98
4+	17.5±0.39	0.72	138±5.27	- 0.32	1.24	2.14
	a=6.993	t_0= -0.442	a=2.086	t_0= -0.386	a=-1.635±0.092	
n =69	b=0.642	k=0.442	b=0.646	k=0.436	b=3.06±0.098	
	c=3.169	l_∞=19.561	c=1.942	w_∞=204.98	r_{xy}=0.998±0.001	
	$l=19.561\,(1-e^{-0.442(t+0.442)})$		$W=204.98\,(1-e^{-0.436(t+0.386)})^3$		lgW=(-1.635±0.09)+(3.060±0.09)lgl	

Legend: l(t)-average standart length (cm); w(t)-average weight (g); growth parameters: l_∞-asymptotic length, w_∞- asymptotic weight, k-growth constant, t_0-theoretical age; a, b- regression constants; r_{xy}-correlation coefficient.

The analysis of the mathematic model of length and weight growth in the local population of *Carassius auratus* s. *lato* of the Beleu Lake (Tab. 1), indicate that the parameter k has an increased value (k for length - 0.442, k for weight – 0.436), particular for the species with a short life cycle and high growth rate in the first age groups, necessary for reaching in a short-time period the maximum physiological size (l_∞ = 19.561 cm, w_∞ = 204.98 g).

According to Bertalanffy model, the *Carassius auratus* s. *lato* ecotype from the Beleu Lake ecosystem behaves as a species featuring a short-life cycle, small-sized simple structure of age groups, demonstrating a phenomenal adaptive potential toward the large variations of abiotic gradient factors. This species' small size and its high abundance in the lake have become crucial conditions for its species to be an important trophic object for a variety of ichthyophagous species (catfish, pike, perch, asp). Even despite some conflicting considerations regarding the accessibility and low preferentiality of *Carassius auratus* s. *lato* as prey for perch in the Beleu Lake in the autumn of 2014, there was registered a special affinity for this trophic object (with a frequency of 82.35%).

The *Carassius auratus* s. *lato* from Beleu Lake in the first summer of its life (0+) has the mean standard length of 4.9 cm and the body weight of 3.0 g, whilst in the next summer it is characterized by the mean standard length of 10.6 cm and the body weight of 31 g, at 2+ - the mean body weight of 57 g and standard length (l) – 13.0 cm, then at 3 + - the weight of 95 g and the length of 14.5 cm, and at 4 + - mean body weight of 138 g, and the body length of 17.5 cm.

Considering the length-weight correlation analysis, it can be observed the value of b = 3.061 revealing an increase of isometric character in length and weight, which suggests that the slow-growing ecotype fits perfectly in severe environmental conditions established in the ecosystem, efficiently mobilizing the energetic resources accumulated to face the weather.

Within the age structure of the *Carassius auratus* s. *lato* ecotype from Lake Beleu the maximum ratio is held by the individuals aged 2+, reaching 68.2%.

The comparison of the gravi-dimensional growth rate of the local ecologic form of *Carassius auratus* s. *lato* found in Beleu Lake along with individuals from other aquatic ecosystems of the Republic of Moldova shows a more slowed growth in the river bed of Nistru, Prut, also in lake river beds, being slightly faster than in small rivers from Moldova (Bulat 2014; Usatii 2004; Dolghii 1993).

The analysis at the population level indicates deviations in sex structure as well, where the conspicuous predominance of males in the population has been registered (60.8%). The study carried out in 1988 in the Lower Danube confirms the permanent changes in the sex structure of populations of this taxon, the male ratio reaching 40.6% (Goncearenko 2001).

It is believed that in a population with both forms of reproduction in unstable environmental conditions, it is more convenient if individuals are present in diploid bisexual forms, actively using the genetic recombination process. In addition, they are independent of the presence of other male-donor species of Cyprinidae (necessary to stimulate gynogenetic reproduction) in which, because of the instability of environmental gradients, the reproductive period may not coincide with that of *Carassius auratus* s. *lato*, or they may not have access to spawning places. In the population with sexuate meiotic reproduction the presence of diploid males of *Carassius auratus* s. *lato* always ensures the successful fertilization of eggs, and the diversity of recombinations in meiosis phases creates (and subsequently select) the most appropriate genotypes (Abramenko 2011).

This adaptation reaction at population level is also observed in other natural water ecosystems of the Republic of Moldova. For example, in Ghidighici reservoir the ratio of the males in population reaches the value of 15.7%, in Prut river bed of 22.3%, while in Byc river it is already 30.96% (Bulat 2014).

Thus, the sex structure of *Carassius auratus* s. *lato* populations serves as an important support for the bio-indication of environmental quality and the species show a pronounced ecological polymorphism on various levels of integration and organization.

Also under the actual conditions of "supersaturated" number, the small number of females in Beleu Lake restrains the population prolificacy value, participating indirectly in diminishing the annual number increases, and thus, in attenuation of intra- and interspecific fierce competition.

The capturing of *Carassius auratus* s. *lato* directly from Prut river bed reveals significant differences in the population structure and individual growth rhythm.

The gravimetric values and the character of growth in *Carassius auratus* s. *lato* from Prut river bed are shown in Table 2.

Table no. 2 Gravimetric values and growth parameters in *Carassius auratus* s. *lato* from Prut river bed

t (x)	l (t)	ln(l_∞-l_t) (y)	w (t)	ln($w_\infty^{1/3}$-$_t^{1/3}$) (y)	lgw(t)=a+b lgl(t) lgl(t), (x)	Lg wl(t), (y)
0+	5.6±0.61	3.41	6.7±0.93	2.23	0.75	0.83
1+	11.2±0.16	3.20	68±2.54	1.97	1.05	1.83
2+	16.5±0.15	2.96	125±3.34	1.83	1.22	2.10
3+	18.1±0.22	2.87	193±4.52	1.69	1.26	2.29
4+	21.0±0.38	2.70	251±5.86	1.59	1.32	2.40
5+	23.0±0.14	2.55	359±11.61	1.41	1.36	2.56
6+	24.0±0.44	2.47	491±22.06	1.20	1.38	2.69
7+	25.5±0.92	2.33	582±31.97	1.05	1.41	2.76
8+	30.0±1.41	1.28	850±21.21	0.56	1.48	2.93
n=70	a= 6.17 b= 0.827 c= 3.676	t_0= -0.518 k= 0.189 l_∞= 5.814	a= 1.963 b= 0.824 c= 2.418	t_0= -0.004 k= 0.19 w_∞=411.98	a= -1.258±0.113 b= 2.825±0.143 r_{xy}= 0.994±0.003	
$l = 35.814(1-e^{-0.189(t+0.518)})$			$W = 1411.98(1-e^{-0.19(t+0.004)})^3$		lgW=(-1.258±0.113) + (2.825±0.143)lg l	

Legend: l(t)-average standart length (cm); w(t)-average weight (g); growth parameters: l_∞-asymptotic length, w_∞- asymptotic weight, k-growth constant, t_0-theoretical age; a, b- regression constants; r_{xy}-correlation coefficient.

Application of Bertalanffy model for *Carassius auratus* s. *lato* from Prut river bed conveys a similar growth rate as for large species with complex population structure (k length - 0.189 and k weight - 0.192) in which the attainment of maximum physiological values (l_∞ = 35,814 cm, w_∞ = 1411,98 g) is even in all age groups, the determining factor being the characteristics of abiotic gradients of hydrobiotop.

In the first summer of life the *Carassius auratus* s. *lato* reaches the mean length (l) of 5.6 cm and mean weight of 6.7 g. In the second summer (1+) - the mean length of 11.2 cm and mean weight of 68 g, at 2+ – standard length of 16.5 cm and weight of 125 g, at 3+ – 18.1 cm and 193 g, at 4+ - 21.0 cm and 251 g, at 5+ years – 23.0 cm and 359 g, at 6+ - 24.0 cm and 491 g, at 7+ - mean length of 25.5 cm and mean weight of 582 g, and at the age 8+ it was captured an individual with the length of 32.2 cm and weight of 850 g.

When comparing the growth rate of *Carassius auratus* s. *lato* of this ecosystem with other aquatic ecosystems of the Republic of Moldova, there is a significantly slower growing rhythm than in Cuciurgan (2+ - 338.5 g, 3+ - 677.7g, 4+ - 830.0 g, 5+ - 1125.5 g) and Dubasari (2+ - 390.0 g, 3+ - 506.0 g, 4+ - 773 g), similar to that from the lower sector of Nistru river (2+ – 180 g and l – 18.05 cm, at 3+ – 245 g and 19.7 cm, 4+ – 540.6 g and 24.5 cm) and in accordance with that reported for the entire area of the species (Usatii 2004).

The exceptional adaptive variability of *Carassius auratus* s. *lato* in different aquatic ecosystems of the Republic of Moldova can cause a great plasticity of the species, when choosing the population strategies depending on specific environmental conditions and opportunity requirements (type r and simple structure as in small rivers and Beleu Lake (Manta Lake) or type K and complex structure – as the river bed ecosystems of large rivers and reservoirs).

At the length-weight correlation analysis, we see the value of b = 2.825 $\pm$ 0.143, which indicates a pronounced negative allometry, favoring an increase in length compared to the weight. This value is caused primarily by the peculiarities of the biotope of Prut River, with faster water flow, low transparency and lower values of primary and secondary production of nutritional hydrobionts (Ungureanu 2011).

There are also differences in sexual maturation period of these two ecological forms. The *Carassius auratus* s. *lato* from Prut river bed usually reaches sexual maturity at the age of 2+ years, while the ecological form from Beleu Lake reaches sexual maturity mostly at 1+ years, frequently being captured mature females with standard length below 9.2 cm and body weight of 23.0 g.

In this way, it can be concluded with certainty that in lower Prut macroecosystem two forms of *Carassius auratus* s. *lato* are present:

- a quick growing rhythm inhabiting mainly the Prut river bed (and entering for reproduction in Beleu and Manta lakes);
- a local opportunistic ecological form, with a slower pace of growth that permanently inhabits Beleu Lake.

These forms featuring a major adaptation potential (slowed growth, sexually reproducing mode, the predominance of males in the population, early maturity, simplified age structure etc.) in extreme environmental conditions (alternations of temperature and depth, deficit of solved oxygen during droughts, unstable food resources etc.).

The analysis of the reproductive system in *Carassius auratus* s. *lato* from various natural aquatic ecosystems of the Republic of Moldova confirms the presence of high adaptive plasticity of this taxon in different ecological conditions.

In spring, when the water temperature in the lower sector of the Prut River and Beleu Lake reaches the spawning threshold for the carp (in the 3rd decade of April) the oocytes of phase E enter in the maturation period and transit to the phase F. Throughout this period in fish from rivers and lakes the size composition of germ cells that have completed the vitellogenesis is fairly uniform, averaging between 841 ± 9.3 mkm and 849 ± 17.0 mkm respectively. Regarding females in pre-spawning condition there are numerous oocytes present in the gonads in different phases of maturation, the characteristic being the different location of the nucleus concerning the animal pole. The fish caught in Beleu Lake on 26-27 April had the gonads on Vth, respectively on VI-IV_2 stages of maturity. In females' spawned ovary there are empty follicular membranes, as well as oocytes of next generation in the phase of vitellogenesis and vacuolization (Fig. 2).

In females from the lower course of Prut River the process of oocyte maturation with subsequent spawning of the first portion of eggs occurs in the same time period as in Beleu Lake in the third decade of April. We have to mention that the beginning of the spawning season in individuals from rivers did not change in comparison with the previous years (Fulga and Kiseliova 2007). After the first spawning the gonads pass into the VI-IV_2 stages of maturity. The older generation of oocytes is in phase D_5. The gonado-somatic index dwindles, but its values in the spawning females' ovaries from both water basins do not differ significantly ($P \leq 0.95$), (Tab. 1). After the first spawning, in the gonads, along with the resorption of the remaining elements, the development of the second generation of oocytes springs from the subsequent spawning in the given reproductive season.

Further on, when the decline in water level in the Prut River ensues, the Beleu Lake separates from the lower portion of the river that leads to the rapid heating of its water surface. Consequenty, the processes of intense vitellogenesis and maturation of oocytes in females from the lake occur faster than in the river. In early May, the resorption of residual elements from the previous spawning is over, and the next generation of eggs is preparing for new spawning. In the second decade of May the carp ovaries pass into the IV_2-V stage of maturity that is characteristic for the fish before releasing the second portion of eggs.

Figure no. 2 Detail of the ovary after spawning the first portion of eggs in the female from Beleu Lake

Note: a-Empty follicular membranes; b-Oocyte in the phase of vacuolization; c-Oocyte in the phase of vitellogenesis.

The gonads of females in the lower section of the river Prut, as well as in Beleu Lake, in early May, also pass on IV_2 stage of maturity, but unlike the lake fish the further growth and development of oocytes slows down, continuing to accumulate yolk granules in the cytoplasm during the month of May. As a result, the second portion of egg spawning in females, inhabiting in different ecological conditions occur in a different time period. In Beleu Lake this process takes place at the end of the second decade of May. Shortly before spawning the gonads are at IV_2-V maturity stage, whereas the oocytes of older generation complete the accumulation of yolk granules (phase E) and pass into the maturation phase (F). In individuals from rivers, in this period, the gonads correspond to IV_2 maturity stage. By the beginning of the second decade of May, in females from lakes, an increase of gonado-somatic index is registered. Regarding river fish this parameter toward this time reaches significant lower values ($P \geq 0.95$), as in the composition of germ cells of the older generation, particular for the IV_2 maturity stage of the gonads, when the oocytes are in the final phase of vitellogenesis (D_6) (Tab. 3).

In the first decade of June, when carp females in lower Prut are preparing for the spawning of the second portion of eggs**,** the carp from the Beleu Lake already spawn for the third time (Tab. 4).

The past years' studies have pointed to the absence of the third portion of eggs spawning in carp from the lower section of Prut River (Fulga and Kiseliova 2007; Fulga 2011). Currently, the spawning of the third generation of eggs is registered in late June (Fig. 3). However, in catches it has been found that females bear in gonads -where there were only present, though- not spawned yolk oocytes is a state of resorption.

The process of non-ovulated eggs resorption occurs in parallel with the differentiation and growth of oocytes from the reserve fund.

The histological analysis of the gonads of females that completed the spawning season showed differences in the development of the new generation oocytes. In carp from Prut River, after the third spawning, the value of GSI proved significantly lower than that of the individuals from the Beleu Lake (P> 0.95) (Tab. 1). In the structure of germ cells in the older generation of the next year in females from Prut River, the oocytes are in the initial phase of vacuolization D_1 (Fig. 3). Regarding the lake individuals most of the cells are formed by oocytes at different stages of cytoplasm vacuolization (D_1-D_3) (Fig. 4), which explains the higher value of the GSI in the fish from this basin.

The difference in the development of oocytes in females from different populations can be as well traced in autumn. The older generation of oocytes of the next year the lake fish in October goes into the initial phase of accumulation of yolk granules, and their ovaries pass to the stage III-IV of maturity (Fig. 5).

The sexual cells of river fish in this period remain in the phases of vacuolization, which correspond to stage III of gonad maturity (Fig. 6) and only in November the oocytes of the new generation in the river fish pass to the beginning of vitellogenesis, and their gonads go into the III-IV maturity stage.

Table no. 3 Reproductive capacity of *Carassius auratus* s. *lato* females from different populations

Month	Stage of gonad maturity	Gonad weight (g)	GSI (%)	Development phase of oocytes of older generation
Beleu Lake				
April (3rd decade)				
	V; VI-IV_2	46.25±6.22	20.65±2.05	F
		19.60±2.85	9.40±1.28	D_5
May (2nd decade)				
	IV_2-V	24.00±3.25	19.35±1.42	E; F
June (1st decade)				
	III	5.10±0.36	2.34±0.18	D_1- D_3 Generation of next year
Lower Prut				
April (3rd decade)				
	VI-IV_2	17.52±1.75	8.73±1.14	D_5
May (2nd decade)				
	IV_2	19.87±1.71	11.80±1.29	D_6
June (3rd decade)				
	II –III	2.15±0.45	1.38±0.07	D_1 Generation of next year

Table no. 4 Time period of *Carassius auratus* s. *lato* spawning in the reproductive period

Generations of spawned oocytes	Beleu Lake	Lower Prut
I	IIIrd decade of April	IIIrd decade of April
II	IInd decade of May	Ist decade of June
III	Ist decade of June	IIIrd decade of June

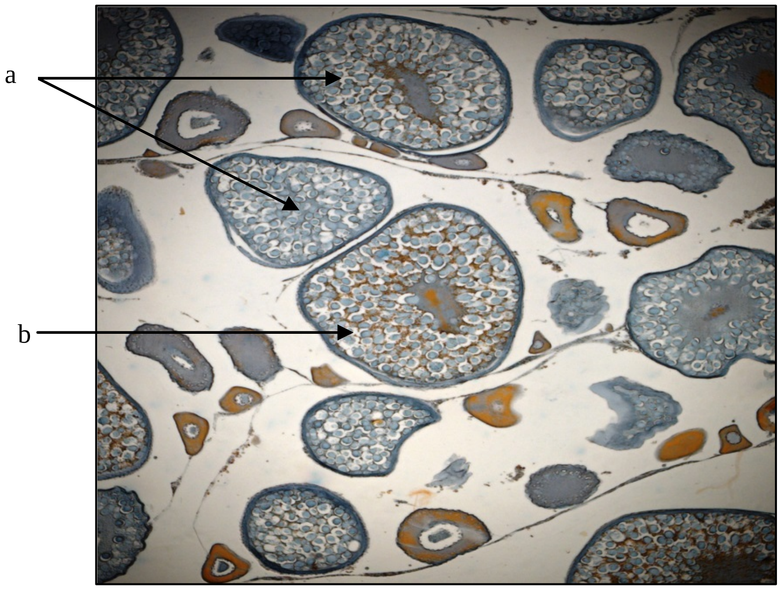
Figure no. 3 Oocyte of *Carassius auratus* s. *lato* from the lower course of Prut River after the spawning of the third generation of oocytes

Note: a-Empty follicular membranes; b-Oocyte of proto-plasmatic growth; c-Oocyte in the initial phase of cytoplasm vacuolization.

Figure no. 4 Oocyte of *Carassius auratus* s. *lato* from the Beleu Lake after the spawning of third portion of eggs

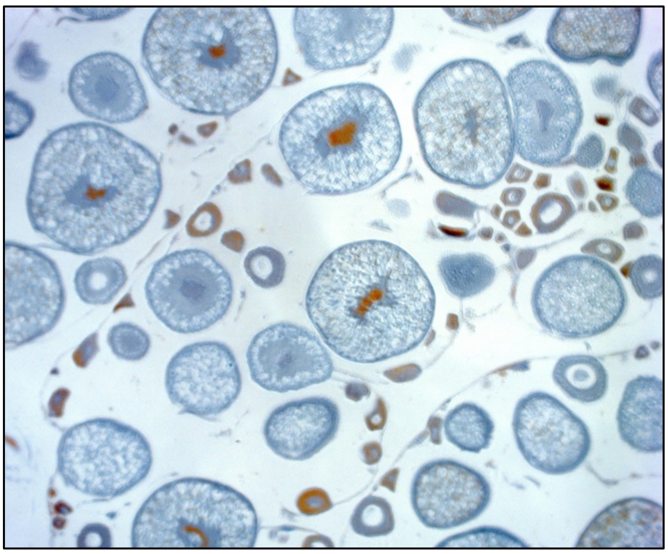
Note: a-Empty follicular membranes; b-Oocyte of proto-plasmatic growth; c-Oocyte in various phases of vacuolization.

Figure no. 5 Old generation of oocytes in *Carassius auratus* s. *lato* from Beleu Lake in the initial phase of yolk accumulation



Note: a-Oocytes that have completed the cytoplasm vacuolization; b-Oocytes in the initial phase of vitellogenesis.

Figure no. 6 Gonads of *Carassius auratus* s. *lato* from lower Prut. Oocytes in the phases of cytoplasm vacuolization



In winter time, it is noticeable a significant increase of gonadosomatic index, while in March its value in the females from Beleu Lake reaches 15.93%. This fact proves that in winter there occurs the accumulation of trophic substances in oocytes for the next breeding season.

In conclusion it can be assumed that *Carassius auratus* s. *lato* in the habitat conditions of the Republic of Moldova has reached optimum ecological status, demonstrating exceptional adaptive variability by involving structural and functional changes on various levels of bio-ecological organization.

Conclusions:

During spring floods, the Prut River forms a unique water system within the Beleu Lake. In these conditions the *Carassius auratus* s. *lato* from both biotypes lays the first portion of eggs in the same calendar terms (third decade of April).

In summer the environmental gradients from the Beleu Lake and Prut River differ significantly, causing changes in individual growth rates and reproductive ecology of the species. In individuals from the Beleu Lake the growth rhythm is significantly lower, and under circumstances of higher thermic regime, the oocyte growth of the second and third generation growth and development becomes shorter.

Investigations from previous years have revealed that in carp females from the lower sector of Prut River the portioned reproduction in three rates is absent, nevertheless, at present the third portion was recorded spawned at the end of June.

After the reproductive season the ovaries of *Carassius auratus* s. *lato* from Prut River pass into the stage II-III of sexual maturity, while the ovaries of individuals from the Beleu Lake go straight to the stage III of maturity, the gonadosomatic index having higher values.

Rezumat:

CARASSIUS AURATUS S. *LATO* ÎN DIVERSE TIPURI DE ECOSISTEME ACVATICE DIN BAZINUL RÂULUI PRUT

Lucrarea descrie unele particularități ale creșterii și reproducerii speciei *Carassius auratus* s. *lato* din ecosistemele acvatice ale Prutului de Jos și Lacului Beleu. Acest taxon este caracterizat de dezvoltarea asincronă a oocitelor și de depunerea a trei generații de ouă în timpul ciclului reproductiv. Analiza histologică a ovarelor speciei *Carassius auratus* s. *lato* din ecosistemele studiate pe parcursul perioadei inter-reproductive a demonstrat câteva diferențe în dezvoltarea viitoarelor generații de oocite. Oogeneza procesului la femelele din Lacul Beleu este mai intensă, iar valoarea indexului gonado-somatic este mai înaltă.

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