

MIGRATION OF FISHES IN ROMANIAN DANUBE RIVER (Nº 1)

A. CIOLAC

e-mail: andrei.ciolac@ugal.ro

*“Dunarea de Jos” University of Galati
Fishing and Aquaculture Department
Domneasca Street, 47, Galati 6200, Romania
(Phone: +40-236-415641; fax: +40-236-401353)*

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Abstract. Present review paper tries to show the main aspects of migration of fishes in Romanian sector of Danube River. The Danube River has a large hydrographical basin, being the second largest river in Europe. The main channel flows through seven European countries. There are many species of fish that annually or seasonally migrate either for reproduction or feeding in different areas of Danube and its main tributaries.

Keywords: migration, fish, capture dynamic, Danube, Fulton factor, protection

Introduction

Some recent studies [8] have increasingly demonstrated the widespread existence of spatial and temporal variations in the abundance and distribution of the populations of freshwater fishes, many of them previously assumed not to move between habitats. These movements are based on seasonal or ontogenetic causes, for spawning, feeding and refuge, and in many cases are crucial for the successful completion of the fish life-cycles [15]. This text tries to cover the incidence and types of migration exhibited by the freshwater and anadromous fishes in the Romanian Danube River and their different capacity and stimulus related to the migration.

The Danube River has a large hydrographical basin, wide of about 817000 km², being the second largest river in Europe. The main channel flows through seven European countries. A large part of its lower sector flows either nearby or into Romanian territory where it forms a large delta (Danube Delta) before reaching Black Sea. The ecological importance of Danube is underlined by the new studies or monitoring programs driven by international organizations or associations such as International Commission for the Protection of Danube River (ICPDR) and International Association for Danube Research (IAD).

Into the Danube River basin, fish fauna is still quite well represented by more than 100 fish species among 69 species in the main channel of Lower Danube. A percentage of about 75% fish species is still the main object of activities for the local fisheries.

The fish migration in Danube River is a common biological phenomenon. There are many species of fish that annually or seasonally migrate either for reproduction or feeding in different areas of Danube and its main tributaries. Usually, the fishes migrate from delta and main channel to the recently flooded plains of Lower Danube, especially for spawning. There is also a migration from delta to some particular places in the Black Sea

- the area of Danube River Mouths, where the water salinity is diluted by the fresh water supply. The fishes migrate in these marine areas probably for taking advantage of the characteristic richness of these waters due to the large amount of nutrients that the Danube is carrying out. In this off shore zones it is a common fact to find many species of the native fresh water fishes, which migrate in for feeding.

The migration of the fresh water fish species is usually a seasonal event. The fishes migrate in the spring for spawning in the most naturally protected areas. In these places the offspring find out the best conditions to grow up at least in their first months and even in their first year of life. After the spawning time, the fishes usually swim back into the feeding areas. These places are the riparian zones of Danube River that include, beside some permanent lakes and small swamps, also some similar spots in the main tributaries such as River Prut, River Siret, River Arges and River Olt).

The main fresh water species that perform that type of migration belong to the following families: Cyprinidae and Percidae (*Aspius aspius* L., *Leuciscus idus* L., *Cyprinus carpio* L., *Scardinius erythrophthalmus* L., *Rutilus rutilus carpathorossicus* Vlad., *Stizostedion lucioperca* L., *Perca fluviatilis* L. and *Silurus glanis* L.)

Migration of the fishes in the flooding areas

The seasonal migration of fresh water fish is very close related, beside the water temperature, to the hydrological regime of Danube River that determinates the characteristics of the flooding areas. It has been estimated in the middle of the last century a huge wetland area of about 800000 ha, including Danube Delta (about 400000 ha), which were potentially flooded or benefited of the water supply provided yearly by Danube River.

The connection between main channel of the river and the flooding plains was generally assured through many small creeks and the natural morphology of the relief (e.g. ground depressions). Similar formations are also usual into the Danube Delta where they provide the water supply. The flood is regularly producing every spring and its intensity depends on the amount of the melted snow and spring precipitations, mainly from the hydrographical basin of the Lower Danube River.

The ecological richness of these areas could be explained by the large amount of nutrients Danube River is carrying out and depositing on the flooding plains and its delta. The annual average of the transported alluvia in Danube River is 57 - 83 million tons per year with an average debit up to 2200 kg/sec [5]. The other general characteristics of flooding area such as the geo-morphological aspects that provides heterogeneous habitats with an average water level of 0.5 m to 2 m, many shelters and plenty of food, make these zones a real paradise for the spawners of many migratory fishes and their offspring.



Figure 1. Romanian Danube River from Iron Gates dams to Black Sea. Source: The Research Institute for Danube Delta.

At this time, the status of the Romanian Danube River flooding zone (Figure 1) is dramatically changed. First, because the building of Iron Gates I dam and, situated 80 km downstream, Iron Gates II dam. Second, do to the former Romanian management policy regarding the agricultural activities in flooding planes. Many specific constructions dammed the most of Romanian Danube river's banks preventing natural flooding and reducing drastically former wetland areas. Whether in 1921 to 1 km of river corresponded 612 ha floodplain, in the middle of 70ies the corresponding area for 1 km of river was only about 120 ha [2].

Actually, with some small exceptions (i.e. Little Island of Braila and "The Little Delta" of Somova-Parches area), most of Romanian sector of the Danube River is dammed along its banks. Excepting the Danube Delta, only few and small flooding plains have remained. One significant example is the sector of about 23.8 km, situated on the right bank and roughly located between Iascea and Tulcea Town. In this area, the seasonal flood facilitates the persistence of some complex aquatic ecosystems included into a characteristic wetland formed by marshes, small lakes and creeks, known as Somova-Parches Complex.

Along the Romanian sector of the Danube, there are some differences concerning the structure of fresh water fish populations. In the upper sector of the river, the fish fauna consists mainly in small cyprinids, breams and perches. Some species as *Perca fluviatilis*, *Stizostedion lucioperca* and *Silurus glanis* are quite well represented.

The lower sector of the river, which includes the main stream, branches, no dammed pools, lakes and Danube Delta has, beside a similar fish fauna, bigger cyprinids such as the common (European) carp (*Cyprinus carpio*) and the Asian carps. The other species that populate those habitats are *Silurus glanis*, *Esox lucius*, *Tinca tinca*, *Carassius auratus gibelio*, *Stizostedion lucioperca*. The capture studies show in these locations the permanent presence of large individuals, medium size and younger individuals along. These sites are considered main areas for adult fishes feeding.

In the lowest part of Danube Delta (Figure 2), some fresh water tolerant marine species mainly belonging to the Clupeidae, Gasterosteidae, Atherinidae and Gobiidae families, seasonally enter into the delta from Black Sea. Some scientists consider that at least Gobiidae family play actually a very important role in the energetic balance of the local ecosystems, as a very important input of food resource for many indigenous carnivore species [3].

The spatial distribution and the migration of fishes in the flooding plains of Romanian Danube River were not rigorously studied. However, fish distribution and density in various food plain habitats depend on the local water level, flooded vegetation and the major biological needs of fishes as feeding and reproducing. The amount of fish that remains for some reasons in the floodplain pools over the year and the seasonal intensity of migration of fish coming in here from the main channel should be also considered.

The earliest stage of the spring migration for reproduction starts in February or March, depending on the water temperature. Usually, the fresh water fish species such as *Silurus glanis*, *Leuciscus idus*, *Stizostedion lucioperca* and *Pelecus cultratus* leave their winter shelters from the main channel of Danube for entering into the spawning areas when water temperature is about 4 - 6°C.



Figure 2. The network of channels, creeks, pools and lakes in Danube Delta. Source: The Research Institute for Danube Delta.

In the spring, when water temperature is about 10°C – 14°C, the other group of fishes becomes to head to the flooding areas for spawning. They are the main species of Cyprinids (common carp, breams and goldfish) which crowd at this time the fresh flooded areas of the banks, entering also into the similar places on the lower sectors of the main tributaries of Danube such as Prut River, Siret River, Arges River and Olt River.

After the reproduction, in the same time with the water retreat, the spawners migrate to the deeper pools or lakes. In the mean time the offspring goes to the not so deep areas using the network of small creeks and channels of flooded plain.

The offspring stay in these places, for feeding and growing, until the next flood occurs. Many times, the communication ways between those places and the main channel disappear because the decreasing of the water level in the main channel of Danube

River. Some times, mainly in the droughty summers, a large amount of juveniles dies because the lack of the water and solved oxygen. This way, many of the remaining flooding areas become a deadly trap for the offspring.

Migration of the common carp

The common carp (*Cyprinus carpio* L.) is quantitatively one of the most important species of the fresh water fishes in lower section of Danube River. Its migration could be representative for many other related species. The density and the dispersal of the carp populations in Danube are certainly depending on the way that the migration and the reproduction is occurring. There is a supposition that a migration of carp from Danube Delta areas to the recent flooded plains upstream located is a yearly event.

Even there are not clearly scientific proved, some local observations over a large period of time bring out the idea that this particular migration of carps is a real fact, its intensity being related to the water level evolution. When the water level in Danube Delta are not too high and, as a result, the local reproduction places become less available and not appropriate for reproduction, the carps intensely migrate to the Danube flooding plains. In the years with more convenient water level, when a large area of delta is flooded and many places become more acceptable for reproduction, the upstream migration of common carp is not as intense as usual.

Either less or more intense, the carp migration from delta to main channel and nearby flooding areas is a permanent process, probably due also to the lack of the convenient conditions for the offspring survival and development in the Danube Delta.

How long is the way of common carp migration from the delta to up stream place of reproduction is still a sensitive issue to be investigated, because there is not relevant experimental data. The best way to perform this research is of course the tagging methods that suppose catching, tagging and recapture of tagged fish. Probably because the high costs in time and money supposed by the use of these more precise methods, there are not recent rigorous studies concerning any migratory fish species in Romanian Danube River. The older studies on 130000 individuals of adult carps in Danube Delta and some upstream locations [10], that included tagging methods, did not offer any conclusive result concerning the real intensity of the carps migration.

However, the increased abundance of the common carp into the main channel in spring mounts versus other seasons can be a good indicator that the carp migration for spawning either from delta or similar places is a real event. The carp migration usually starts in April when the water temperature is about 12°C and it has the highest intensity in Mai when the water temperature is around 16°C. The water temperature of 18°C to 20°C is the optimum for spawning.

The biology of common carp is quite well known mainly because the importance of this species in some Central and Eastern European countries that have developed an intensive fishculture based on the genetically selected races of cyprinids. There are not recent studies on similar aspects regarding bio-ecology of the wild carp in the Danube River. Therefore, some results of our research in middle 90ies concerning the common carp in the area before the Danube Delta could bring out some interesting issues.

The common carp becomes sexually mature in the Romanian Danube River at the age of 3 years for males and 4 years for females. There is information that some times, in special situation (in the seasons warmer than usual) the males became sexually devel-

oped even at the age of 2 years old [4]. Our studies on the carp population in the Lower Danube did not confirm that supposition that could be explained by some accidental errors involved by the age determination methods.

The males-females ratio (M/F) calculated in 1996 in different locations on more than 200 adult individuals was of 0.42 to 0.65, a value of about 0.5 being considered as a normal ratio for the common carp. The average fecundity of the females was estimated at about 85000 follicles but the fecundity could be very variable depending on the age and the size of each adult female.

The yearly growth rate of common carps in Lower Danube River could be an indicator of the environmental conditions for their natural development. Comparing the carp size at different ages from different ecosystems we observe many similarities (*Table 1*).

For a better evidence of the natural life conditions of the common carp in Danube River, we have calculated also the values of Fulton isometric conditional factor (*a*) for different age classes (*Table 2*). As shown, the values for the different ages are relatively close and quite high, indicating a really good condition of the carp development and growth.

Table 1. Size of the common carp at different ages in some ecosystems.

Ecosystems	Average values of total body length (cm) at the age of year:						
	1	2	3	4	5	6	7
Central Danube River [1]	13.6	22.2	30.1	36.2	41.5	47.2	54.3
Central Volga River [7]	8.9	19.8	28.9	37.2	43.6	48.1	52.9
Azovean Sea [5]	13.0	24.5	34.9	41.0	45.5	48.0	-
Lower Danube River [6]	13.5	23.8	30.5	37.5	44.6	48.0	53.3

Table 2. Fulton isometric conditional factor calculated for different ages of the common carp in Romanian Danube River (*W*: body weight, *L*: body length).

Elements of calculus and Fulton factor (<i>a</i>)	Classes of age (years)								
	1	2	3	4	5	6	7	8	9
W (g)	61	290	580	1200	2250	2450	3350	4750	6200
L (cm)	13.5	23.8	30.5	37.5	44.6	48.0	53.3	58.0	63.6
Fulton factor ($a = W/L^3$)	0.0247	0.021	0.02	0.0227	0.0253	0.022	0.02	0.0243	0.024

The stock of common carp in Danube River has significant decreased in the last time. The main reason is the reducing area of the flooding plains the restraint of the best places for carps spawning. The overfishing and a very high level of the poaching, especially in the migration time, contribute also to the decline of the carp populations. As a result a lot of large adults are caught in the small lakes and pools using traps, nets and other gears either in the time of spawning or on their return way to the main channel after the spawning period of time.

Even the last rules and regulations concerning the fishing activities in the Romanian Danube River have improved, the management of these fisheries is still inadequate and the common carp stocks protection need more attention from the official institutions that coordinate the Romanian fisheries.

The existing programs related to the establishing of few more protected areas, not only in the Danube Delta but also upstream, in the areas of the flooding planes must be implemented in a daring manner. It should be also considered the opportunity of some fish repopulation plans in diverse appropriate areas of the river.

Migration of other fish species

There is a similar situation also for other fish species. The environmental changes related to the damming of the major part of the Danube River in the last time had the most important contribution to the decreasing number of fish in many other fish populations. That situation can be observed studying the evolution of the yearly amount and the structure of the captures in *Table 3*.

We can see that some species not very sensitive at the environment degradation as *Carassius auratus gibelio* Bloch, 1783 or other species which are comfortable in main channel, as Asian carps, became more present in the captures than others species as *Tinca tinca* (tench).

Table 3. Yearly capture of the fresh water fish species in the Romanian Danube River from 1991 to 1999.

Fish species	Annual capture (tons)								
	1991	1992	1993	1994	1995	1996	1997	1998	1999
<i>Acipenser ruthenus</i>	-	0.2	0.03	0.03	0.3	0.3	-	0.32	0.50
<i>Cyprinus carpio</i>	6.5	5.3	21.8	29.8	26.0	14.2	26.0	20.4	83.18
<i>Abramis brama</i>	21.5	51.4	59.8	64.9	127.7	72.7	140.8	33.52	22.17
<i>Blicca bjoerkna</i>	16.2	13.1	9.3	6.85	9.01	1.88	12.58	7.52	16.72
<i>Stiostedion lucioperca</i>	0.27	3.04	3.08	3.54	9.93	17.05	9.81	29.97	33.65
<i>Silurus glanis</i>	16.1	5.58	5.81	7.27	4.35	6.4	5.90	16.09	43.47
<i>Asian carps</i>	16.30	49.38	75.11	89.29	102.3	101.4	72.99	20.75	91.30
<i>Esox lucius</i>	-	-	1.13	0.68	1.63	1.39	1.29	4.86	9.4
<i>Rutilus rutilus carpatho-rossiucus</i>	7.71	13.95	37.06	22.98	10.20	14.36	35.8	31.90	8.0
<i>Carassius auratus</i>	33.08	66.97	107.6	197.0	262.6	177.7	113.9	102.8	142.0
<i>Perca fluviatilis</i>	2.30	0.12	5.70	46	1.69	0.22	0.625	0.46	0.8
<i>Tinca tinca</i>	-	0.05	-	-	-	-	-	0.32	0.42
<i>Barbus barbus</i>	5.15	8.09	6.20	15.95	21.72	21.70	6.05	0.14	1.26
<i>Aspius aspius</i>	0.07	0.90	6.88	0.65	2.01	6.22	2.03	1.27	4.04
<i>Alburnus alburnus</i>	9.10	8.89	10.24	26.13	13.88	14.45	4.41	0.78	10.76
<i>Pelecus cultratus</i>	0.01	0.10	-	0.32	1.32	0.048	3.65	2.07	2.83
<i>Alias sp.</i>	8.10	44.70	5.18	19.2	18.81	20.70	9.00	6.51	28.13

The evolution of the annual amount of capture is better shown in *Table 4*. Covering a larger interval of time, and presenting separate data from the Danube Delta area and the upstream sectors of the Danube River (main channel), the table show obviously the decreasing level of the captures in ones of the last twenty years.

If considering an almost constant fishing effort during the investigated period of time, which is not quite real because we do have information that the fishing effort has significantly increased in 1990ies, we observe that in 1982 was officially registered the largest capture ever, of almost 12000 tons. This amount of the capture is more than twice higher than the average capture over twenty years (about 4994 tons) and more than 22 times higher than the smallest ever level of capture (approximately 531 tons) in 1999.

Even the official statistic data cannot be truly considered as the most accurate information, for some years (form 1990 to 1999) there is the evidence of the dramatically decreasing of the capture, indicating a proportional fish stock decrease.

Table 4. Fish capture evolution in different sectors of the Danube River from 1980 to 1999.

Year	Danube Delta		Main channel of Danube River		Total Romanian Danube River	
	Tons	%	Tons	%	Tons	%
1980	6683.0	76.7	2035.0	23.3	8718.0	100
1981	8834.4	79.8	2035.0	20.2	10069.4	100
1982	9494.8	80.0	2330.3	20.2	11825.1	100
1983	7603.0	84.6	1388.3	15.4	8991.3	100
1984	6578.9	67.8	3124.7	32.2	9703.6	100
1985	7461.8	80.6	1772.8	19.2	9234.6	100
1986	7565.6	89.2	913.5	10.8	8479.1	100
1987	5870.6	82.2	1268.9	17.8	7139.5	100
1988	6822.6	88.2	908.9	11.8	7731.5	100
1989	4481.6	89.8	505.9	10.2	4987.5	100
1990	4281.6	98.2	76.2	1.8	4357.7	100
1991	388.4	68.61	176.214	31.39	564.7	100
1992	936.0	84.89	166.635	15.11	1102.7	100
1993	633.3	81.41	144.681	18.59	778.0	100
1994	1179.5	79.78	298.888	20.22	1478.4	100
1995	930.8	72.0	361.9	28.0	1292.7	100
1996	655.4	66.57	329.1	33.43	981.5	100
1997	970.3	81.04	237.2	18.96	1207.5	100
1998	521.5	69.84	225.3	30.16	746.8	100
1999	436.58	82.22	94.46	17.78	531.04	100

The Asian carps

One of the most interesting issues of the ecology of fishes in the Danube River and particularly in the Romanian Danube River is the presence of some relatively new acclimated fish species, so called “Asian carps” which include three species: the grass carp (*Ctenopharyngodon idella* Vallenciennes, 1844), (*Figure 3*), the silver carp (*Hypophthalmichthys molitrix* Vallenciennes, 1844) (*Figure 4*) and the big head (*Aristichthys nobilis* Richardson, 1845) (*Figure 5*).

The story of the acclimatization of the Asian carps in Romania starts in 1957 when 100 young individuals of grass carp have been imported form former USSR. That action continued in the early 1960ies by the introducing of the young individuals of the other species brought in from the People Republic of China. These species were introduced first in some fish culture research facilities and the fish farms located in Western and Central Romania, as well as few fish farms from Danube Delta [9].

The acclimatization of the Asian carps has been considered successful and positive

for the fish farming production, even in the local climate, these species still require a hormonal stimulation, the artificial fecundation and incubation for obtaining the offspring.

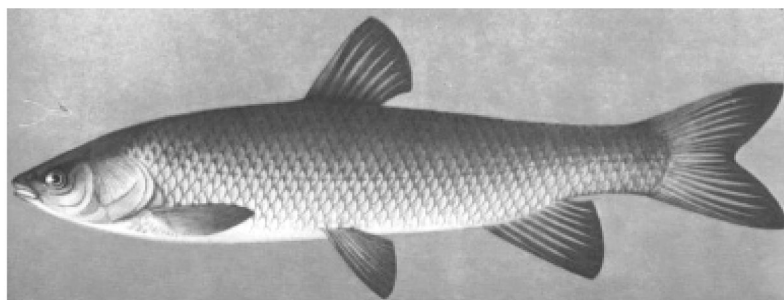


Figure 3. Grass carp (*Ctenopharyngodon idella* Vallenciennes, 1844). Source: Manea, 1985.

The juvenile Asian carps probably enter the natural environment accidentally, by escaping from some fish farms, either directly in Danube River or in its main tributaries. Nobody knows certainly the dates of the event or how many individuals have escaped in the wild. Some of these accidents could be related to the large floods occurred in the middle 70ies. However, at the end of 1970ies, the Asian carps start to be an increasing part of the capture in Danube Delta and the upper sectors of the Romanian Danube River. Their weigh in the structure of the total yearly capture arrives at more than 100 tons in the middle of 1990ies (Table 5).

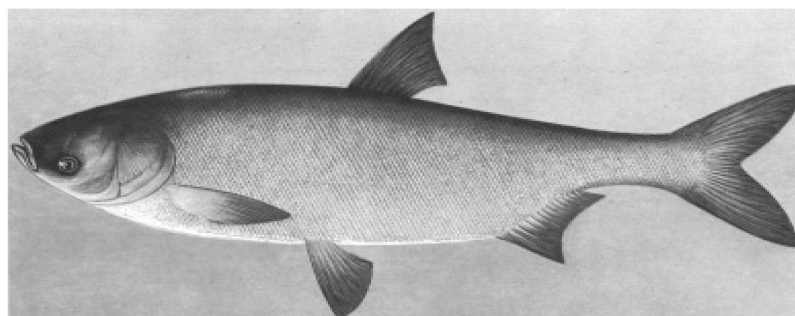


Figure 4. Silver carp (*Hypophthalmichthys molitrix* Vallenciennes, 1844). Source: Manea, 1985.

One of the main bio-ecological issues concerning the Asian carps is still the possibility of the natural reproduction of those alien species in the Danube River. There is an opinion that does not recognize the eventuality for the Asian carps naturally reproduce in the new habitats. The meaning of that is the unsuccessful acclimatization of these species. So, it is supposing that the presence of the Asian carps in the Danube is only related to the escape events of the small individuals from the fish farms facilities.

On the other side, the idea of an existing process of reproduction of the Asian carps in Danube River is confirmed by the information related to the capture of the individuals in their first stages of development. Unfortunately, we do not have yet any scientific prove concerning the presence of the roes or the embryos of Asian carps in Danube River, even there are some unpublished information about.

However, the increasing number of the adult individuals caught in the last decade and also some biological and ecological characteristics of these species could confirm their real acclimatization in Danube River.

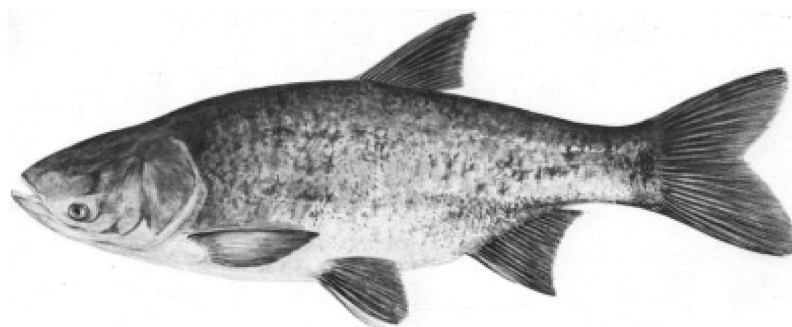


Figure 5. Big head (*Aristichthys nobilis* Richardson, 1845). Source: Manea, 1985.

First, the evolution of the captures in the last time shows, with few exceptions, the annual amount of the annual capture is of about 100 tons. It is hard to believe that the increased number of fish in natural populations could be sustained only by the accidentally escapes from fish farms.

Table 5. Dynamics of the Asian carps capture in the Romanian Danube River from 1991 to 1999.

Year	Danube Delta (tons)	Danube River (tons)	Total (tons)
1991	0.221	34.123	34.304
1992	25.368	24.020	49.388
1993	56.785	18.432	75.217
1994	60.079	29.211	89.290
1995	64.929	37.680	102.609
1996	33.560	67.857	101.407
1997	22.960	70.696	72.992
1998	5.891	14.866	20.757
1999	3.313	87.980	91.293

Second, even the biology of the Asian carps in the fish farms, closely related to their artificial reproduction, is well known, there is a lack of information regarding their behaviour in Danube River.

In their endemic habitats in the Asian rivers these species of fish need some particular environmental conditions to be accomplished for having a normal reproduction. The most important of these conditions are concerning the following aspects:

- The water temperature stabilized for a relatively large period of time in the interval of 18°C to at least 22°C.
- The existence and the persistence of the increasing water level.
- The water flow up to 3m per second.
- A certain degree of water turbidity.
- The appropriate places for the offspring development and growing up, similar to the Danube River native cyprinids.

All these conditions must be accomplished for a successful spawning, which includes the gonads maturation, the stimulation of the spawning and a good offspring survival.

In Danube River these requirements are basically accomplished in some specific locations. Even the opinion supposing the action of a limitative factor, such as the concentration of the solid water suspensions of about 1.2 kg/m³ [10], necessary for the big head

and silver carp spawning stimulation is true, that condition is also accomplished. As a result, there is not significant motivation, regarding the environmental conditions, for the Asian carps not to spawn in Danube River.

A study of the capture performed over ten years (*Table 5*) shows a relative equilibrium between the capture amount of the Asian carps in Danube Delta and the total capture in the main channel of the river. This is an indicator either for a quite uniform distribution of the fish population in this environment or, the most probably, for the manifestation of a real migration for reproduction of the adult Asian carps from lower sector of the river to the upstream areas, where they are finding appropriate places for spawning. The migration of the Asian carps occurs usually in June. This fact is obvious even in some years such as 1998, when the adult flocks had a reduced number of individuals (*Table 6*). The result of an experimental fishing campaign in some places situated upstream Danube Delta, which registered only the individuals bigger than 4 kg (potential spawners) put in evidence the massive presence of the Asian carps in the migration time.

Table 6. The amount of the adult Asian carps captures in 1998.

Area	Monthly amount of capture (kg)						
	Mars	April	May	June	July	August	September
Isaccea	12	56	212	945	230	124	56
Galati	43	94	198	1008	357	60	20
Braila	45	101	202	1122	157	45	12

Analysing the monthly capture for a larger period of time we observe a specific seasonal behaviour of these species, which consist in the following aspects:

- In March and April, there is a timid presence of the spawners in the different sectors of the lower Danube River.
- In May, there is an increasing amount of the adults, probably as a result of the start of the crowding process that usually precedes the upstream migration.
- In June, the capture was the largest one; it signalises the peak of the migration. The water temperature is of 19°C to 24°C.
- In July, there is a decreasing presence of the adults; there is possibly to find the evidence of their offspring presence.
- Most of the caught individuals weighted 6 kg-12 kg; this size is a characteristic of the sexually mature individuals.

In some other ecosystems the natural reproduction of the Asian carps is certified. In Amu-Daria River and Kuban River in the former USSR, Asian carps are certainly acclimatized in similar environment [10].

In fact, there is information that in Danube River the Asian carps could reach their sexual maturity even one or two years earlier than the similar individuals from fish farms [7]. A comparative study of the average growing rates of the grass carp in captivity versus natural ecosystems of the Danube River (*Figure 6*) sustain the validity of that information.

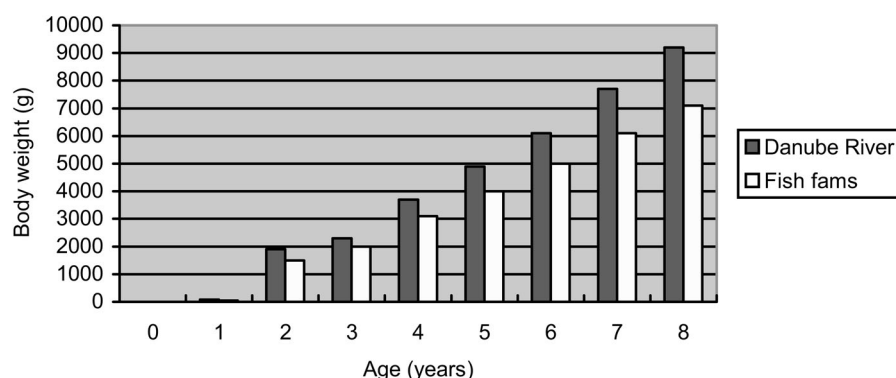


Figure 6. The grass carp dynamic of the growth in the fish farms and Danube River.

The other biological information regarding some large spawners of about 12 kg, which have completely developed gonads and a quite high gonad-mass ratio of 6.41 to 9.2, confirm again the possibility for the grass carp to reproduce in Danube River.

Some scattered observations related to the specific behaviour of the Asian carps, regarding the reproduction process, such as the crowding, indicated few particularly spots in Danube River which are considered the preferred places for spawning. There are few differences concerning the specific biology of each species of Asian carps, depending of the environmental conditions, such as the water temperature and the water deep. The grass carp spawns earlier, at a lower water temperature than silver carp and big head. Also, the silver carp and the grass carp seem to prefer the superficial waters as well as the big had stay in the deeper horizons of the water.

The main characteristic of the fresh water fish migration in Romanian Danube River is supposing to be the relative short migration way trough the ecosystems with similar environmental conditions. The few differences regard some parameters such as the water temperature and the amount of the solved oxygen, but only in some particular situations.

The fishes migrations depend not only of the needs related to reproduction but also of the need to assure the nutritional basis for the offspring and the availability of food for them self after a sensitive and high consumption of energy demanded by their movement and spawning A different type of migration, not yet studied in Danube River, could happen in the late fall and in the early winter when some species such as *Cyprinus carpio*, *Silurus glanis* and few other species crowd, for wintering, in some particular habitats with deep waters and reduced water flow.

The fish wintering is a very interesting adaptation of certain species that allow them to spend the cold season by reducing their metabolic rate and living mainly on their fat reserves cumulated in the warm seasons. That is an interesting modality to avoid the lack of food in winter and preserve the energy, common to many poikilothermous (cold-blooded) species.

The commercial fishermen, who know well the fish behaviours use some specially designed gears for fishing into the particular spots where the fish is crowded in the winter (which is not a normal fishing season in Danube River).

Typical migration of fishes

Most of biologists consider the migration of fresh water fish is in fact a semi-migration, mainly because the relatively short migration way and the little differences between the ecosystems they use to leave or to enter. As a result, these species of fish are often called the semi-migratory fishes.

The real or the typical migratory fishes are considered those species of fish that perform a long migration into the marine ecosystems or from marine to fresh water environments, either for spawning or feeding. These species are usually named the typical migratory fishes.

There are two categories of fish that perform long migrations to or from large rivers. The first category includes the catadromous fishes that spawn in the marine environment and spend most of their life for feeding and growing up in fresh water ecosystems at least until they reach the sexual maturity age. The second includes the anadromous migratory fishes, which spend most of their lifetime in seas or oceans and migrate to spawn in the fresh water environment.

In Danube River both catadromous and anadromous migratory fish species are present in certain period of time. The only one catadromous fish in Danube River is the eel (*Anguilla anguilla* L.).

At this time the number of the eels caught in Romanian Danube River is so less, as well as one individual every two or three years. There is the idea supposing the eel does not enter any more the river from the Atlantic Ocean in natural way but is still present in a few places as a result of the stocking with elvers.

Much better represented in Danube River is the group of the anadromous migratory fishes which include mainly two fish families: Acipenseridae (sturgeons) and Clupeidae (shads).

The Sturgeons

The most important marine migratory sturgeons in Danube River belong to two genders: Huso, which is represented by beluga (*H. huso* Linnaeus, 1758) and Acipenser having two, quantitatively, more representative species: Russian sturgeon (*A. guldensstaedti* Brandt, 1833) and stellate sturgeon (*A. stellatus* Pallas, 1771). These species are common to the ecosystems of the Black Sea, Caspian Sea and Azovian Sea, being considered a relict species remained after the old Sarmatian Sea that formed before a huge marine basin, disappeared in the Pliocene.

Beluga (Huso huso L.)

Beluga (*Figure 7*) is the largest migratory sturgeon in Danube River. Its huge size became legendary. The oldest data recorded in 1827 show one beluga of 1500 kg caught in Caspian Sea. The other data shows also few individuals weighting up to 1200 kg. In 1922 a female individual caught in the lower sector of the Volga River weighted 1220 kg. In 1924 another female caught in almost same place weighted almost 1228 kg and had 246 kg of roes (about 7.5 millions follicles) [16]. An individual caught in the Azovian Sea had an estimate age of 58 years old and weighted 640 g [4].

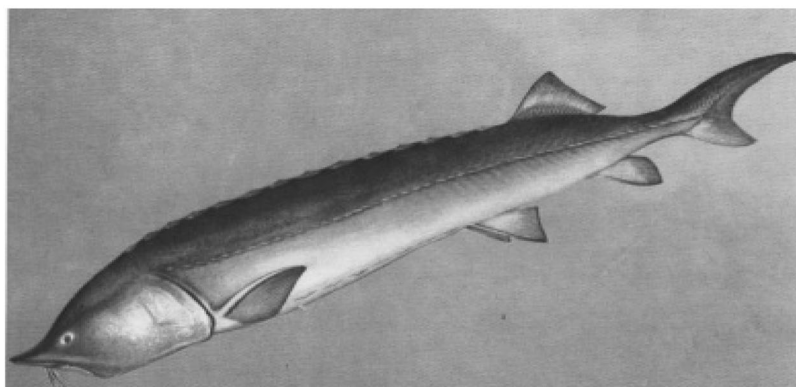


Figure 7. *Beluga (Huso huso Linnaeus, 1758). Source: Manea, 1980.*

There is also recorded information on very large individuals of beluga caught in Danube River. In 1890 has been caught in the Mouth of Saint George Branch of Danube one individual of 882 kg and later another one of 560 kg. The last one is preserved in Bucharest at the “Grigore Antipa” Natural History Museum. Some biologists consider credible captures of beluga individuals weighted up to 2000 kg and more than 6 m long [11]. The absolute longevity of beluga is also supposed to be up to 100 years. Beluga needs to live almost 75 years for reaching 1000 kg [12].

The adult individuals of beluga in Danube River usually size from 1.5 m to 3 m and weight from 45 kg to more than 100 kg. In the Black Sea belugas live in waters of 50 m to 100 m deep, some times deeper (up to 160 m).

The presence into the beluga stomach of certain amount of shells, mainly *Modiola phaseolina* that forms large populations on the bottom of sea at 60-70 m, could be a confirmation for the presence of beluga in these places. The belugas could be found also in certain places corresponding to some Romanian onshore localities at the Black Sea (Constanta Town, Agigea Town and Caliacra Cape) and even (less frequently) in some southern locations of the Bulgarian coasts. It is supposing that beluga is also wintering in similar places [5].

Beluga's nutritional spectrum in the marine environment is different depending on the individuals' age. In their very first age of life, the belugas feed mainly on the inferior crustaceans. At the age of 2 years old beluga starts to eat also some mollusks for after that to become mostly fish eater. More than 80% of their food may consist in diverse species of fish. The large adults feed on fishes (mainly clupeids and also cyprinids) to the exclusion of different food and occasionally they are capable of hunting bigger prey as young Caspian seals [16].

Frequently, the belugas follow the flocks of the pelagic fishes for feeding on them. Some accidental captures of beluga in marine fish traps, specially designed for small pelagic fish, confirm that behaviour.

When became sexually mature, at a certain stage of the maturation of gonads, in spring months (March-April) or even much earlier [13] and also in the fall (September-October), beluga starts to crowd in the front of the Mouths of Danube River and swims upstream a little bit later.

The migration of the beluga in Danube River may start earlier than usual if the water temperature is higher than normal, in the early spring or in warm winters. In these situ-

ations the beluga swims upstream in January. The beginning of the first period of migration (spring migration) in Danube River generally happen at the end of February when water temperature is about 4-5°C [14]. Beluga is the first migratory sturgeon, which starts to migrate in Danube River, in front of Russian sturgeon and stellate sturgeon.

The intensity of the migration slowly decreases until early July, when only very few individuals can be found in Danube, for rapidly disappearing in the middle of July or the first days of August.

The second migration of beluga has not the same intensity as the first one. It starts in late summer and has a maximum of the intensity in October and November. The fall migration is more specific to the younger spawners and to the other individuals, which not fully accomplished the gonads maturation process. These immature sturgeons remain in the river and spend the winter in deep location. They will spawn in the next spring season.

Even there are some suppositions concerning a different behaviour, characteristic to some other biological forms of beluga, which are capable to spend more than one year in Danube River, there is not any documented data to prove it. Also the idea of two existing biological forms of beluga, the first one migrating in the autumn and the second one in the spring, has not scientifically proved arguments.

The differences regarding the age and the degree of the maturation of gonads between the individuals that compose the flocks in the spring, respectively in fall, can be rather do to the different precocity. The belugas spawn in Danube River on the rocky or sandy bottoms placed in the deep locations of 8 to 20 m, in the late spring when the water temperature is 13°C or more. These favourable places for the beluga reproduction are usually located into the upper sector of the Romanian Danube River and even in the upper Danube.

After 8 or 9 days, depending on the water temperature the young hatches and after another 8 days they start to actively feed. The beluga offspring slowly returns to Black Sea in late summer and in the fall. They usually remain in the front of the Mouths of the Danube until the late fall when start to swim to the deeper waters of the Black Sea, along the continental platform, for wintering.

Russian sturgeon (Acipenser güldenstaedti Brandt, 1833)

The second large species of sturgeon that migrates for spawning in Danube River is the Russian sturgeon (*Figure 8*). It has up to 2.4 m and weights 80-100 kg. Usually, the adult individuals size 101.5 m and weight 8-25 kg. Similar to beluga, the Russian sturgeon needs long time to become sexually mature: 8-12 years for males and 12-15 years for females.

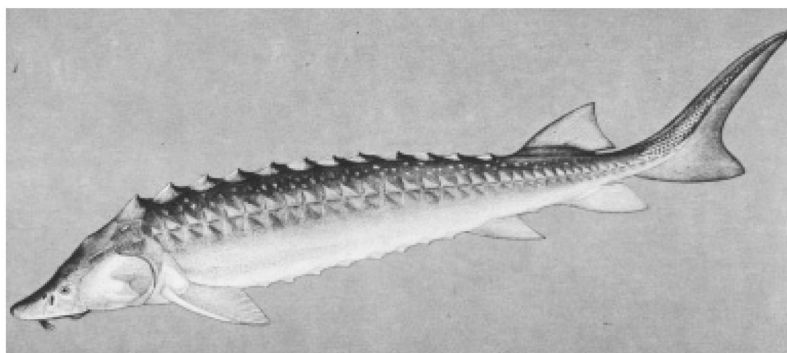


Figure 8 . Russian sturgeon (*Acipenser güldenstaedti* Brandt, 1833). Source: Manea, 1980.

Beside Black Sea, the Russian sturgeon can be found also in the Caspian Sea and Azovean Sea. Some biologists consider the existence of three subspecies and many biological forms [9]:

- *Acipenser güldenstaedti güldenstaedti* is considered the nominate form of this species, being common to the Northern Caspian Sea. It migrates for spawning in the Volga and Ural rivers.
- *Acipenser güldenstaedti persicus* lives the South of the Caspian Sea and migrates mainly into the Iranian rivers and Kura River.
- *Acipenser güldenstaedti colchinus* is the most frequent in Black Sea. It is supposing to have the following bio-morphological forms (natio): *A. güldenstaedti colchinus* natio colchica which migrates in the Caucasian rivers, *A. güldenstaedti natio tannaica* - the biological form of the Azovean Sea and *A. güldenstaedti colchinus natio danubicus* which migrates in Danube River.

The Russian sturgeon has also two periods of migration in Danube River, relatively balanced from the point of view of their intensity. In the spring, a maximum of the migration intensity is in April. In fall, the migration starts earlier and is the most intense in September.

The Russian sturgeons spawn in the late April or May and prefer for spawning the deep, rocky and sandy bottom places, similar to those of the beluga. There is some old information regarding the possibility for the Russian sturgeon to swim also into the main tributaries of the Danube, mainly in the Prut and Siret rivers [1].

After the reproduction period of time, the spawners head back to the Black Sea. The offspring feed on some aquatic worms and small crustaceans until they go back to the sea, in late summer. The nutritional spectrum of the adult individuals consist generally in molluscs up to 50%, crustaceans about 30% and fishes 20%.

Stellate sturgeon (Acipenser stellatus Pallas, 1771)

The stellate sturgeon (*Figure 9*) is the smaller marine sturgeon that migrates in Danube River. It is also the most frequent sturgeon in Danube and Black Sea. It can reach up to 1.1 m long and weights up to 30 kg. The stellate sturgeon may weight 60-70 kg.

There is the idea that stellate sturgeon has four subspecies:

- *Acipenser stellatus stellatus*, which can be found in the Northern areas of the Caspian Sea.
- *Acipenser stellatus natio cyrensis* located mainly in the Southern zones of the Caspian Sea.
- *Acipenser stellatus donensis*, which lives in the Azovean Sea and migrates for reproduction in the Don and Kuban rivers.
- *Acipenser stellatus ponticus* is a Black Sea endemic species, which include two populations with some distinct morphologic characters; the one migrates for spawning in the Dnepr River and the other one in the Danube River.

Into the Black Sea, the stellate sturgeon spends winter in not too deep locations, generally situated relatively close to the shore. It starts to migrate to Danube River in March or April when the water temperature is about 8°C. The maximum of the migration intensity is recorded generally in May. There is also a fall migration that has almost the same characteristics with the fall migration of the Russian sturgeon.

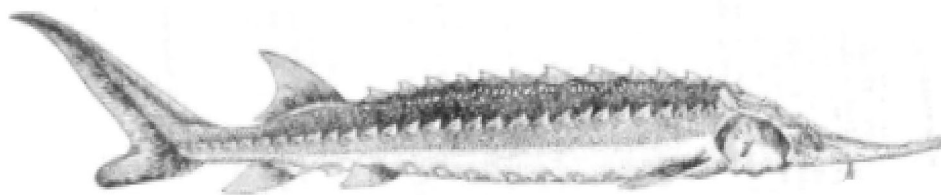


Figure 9. *Stellate sturgeon (Acipenser stellatus Pallas, 1771). Source: Rang et al., 2003.*

The stellate sturgeon spawns in almost the places similar to the other sturgeons: deep waters with the hard bottom and speedy water flow. Normally, the incubation of the roes takes 2-4 days, depending on the water temperature. The offspring remains in Danube River for feeding until the fall season when migrates to the Black Sea for wintering and growing up. Exceptionally, some young individuals can be found in the lower locations of the Romanian Danube River even in the winter. They may spend the winter in the river instead of the sea [5].

The sturgeons have complex life cycles that have been sporadically studied in the past 50 years. Their life cycle is reviewed in six stages: non-spawning adults, female spawners, male spawners, egg and larval, early juvenile, and late juvenile.

All species are long-lived, mature at advanced age. They have rapid and similar growth during the first few years of life and are feeding on similar taxa. They use deep river habitats for juvenile life stage deep marine locations for higher ages and have similar migratory patterns with seasonal concentration areas either in the sea before the moment of migration or in the river at the spawning time. These species of sturgeons differ however in ages and sizes at the maturity, in maximum size, time of spawning and migratory behaviours.

Their behaviour in marine habitats is still not very well known but it is probably to make some coastal migrations restricted to the Black Sea area. The juveniles reside in the riverine habitats along the coastal areas, in front of the Danube Delta and in the southern areas.

The Danube shad

Another interesting anadromous migratory fish in Danube River is the Danube shad (*Alosa pontica* Eichwald, 1838). Its migration is different than the sturgeons' migration, being more related to the environmental factors as the water temperature and levels. Also the way of the Danube shad migration up the river is shorter.

Generally, the shads are herring-like fishes with a few differences regarding their external aspect. Belonging to the Clupeidae family, they are old forms of fish, attested from the Tertiary Period. They have populated also the former Sarmatian Sea, that can explain the presence of some species and biological forms that migrate for reproduction in rivers (even if most of clupeids, herrings for example, remain all the time into the marine environment).

Among the relict clupeids in that old area there are those belonging to the Black Sea, Sea of Azov and Caspian Sea. However, only few species enter in Danube River for spawning: *Alosa pontica*, *Alosa maotica*, *Alosa nordmanni* and *Clupeonella delicatula*.

The Danube shad (*Figure 10*) lives in Black Sea. It is a pelagic species and prefers the Southern areas of the Black Sea. The adult individuals size about 40 cm and rarely weight more 1 kg.

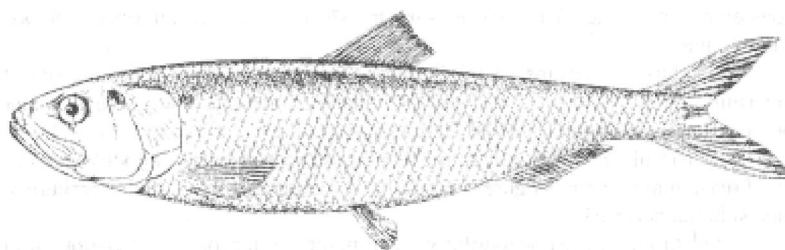


Figure 10. Danube shad (*Alosa pontica* Eichwald, 1838). Source: Rang et al., 2003.

Its behaviour in the marine environment is not well studied but it is known that in the winter, the Danube shad can be found along the South-Eastern Coast of the Black Sea in the relative deep locations (more than 40 meters) [1].

As the water become warmer, the Danube shads crowd closer to the Romanian coasts of Black Sea in the less deep areas. They start to swim into the Danube River when the water temperature becomes relative stable in the interval of 5 to 6°C. This happens usually in the last decade of March and the beginning of April. The maximum intensity of the Danube shad migration is recorded in April-May when the water temperature is about 9-13°C [7].

In addition to the water temperature the other important ecological factors for the migration intensity are water turbidity and the amplitude of the water level oscillations. A high degree of the water turbidity, quite usual in spring, in Danube River, can delay the beginning of the Danube shad migration. Also the unusual low water level has a negative impact on the migration start and the migration intensity.

The lastingness of the Danube shad migration is between 100 days and 150 days, depending on the temperature evolution, frequently 120-130 days. The migration is almost finished in June when the water temperature is about 19-20°C. Being a pelagic species, the Danube shad lays the spawn in the mass of the water. Depending to the water temperature, the incubation of roes takes from 43 to 72 hours.

The offspring enters the flooded areas for feeding and developing and leaves those areas as soon as the water level starts to decrease. An important amount of the offspring can be found in the Mouths of the Danube River areas almost in the same time in which the spawners return to the Black Sea, after the reproduction.

The spawning areas into the Danube River are located mainly up to Calarasi Town (*Figure 1*). Even there are recordings on Danube shad captures upstream this particular location (until the Mouth of Timok River), these captures are less important.

The structure of the Danube shad flocks shows spawners with different ages. From this point of view, the individuals of 3 and 4 years old represent the core of flocks. Together, they mean up to 90% of all adults that migrate in Danube for reproduction. There are also few older individuals of 5, 6 and exceptionally 7 years old. The younger individuals of 2 years old can be found in certain years in a larger number than usual, as a result of their precocity in the sexual development (probably do to some better environmental conditions in the Black Sea).

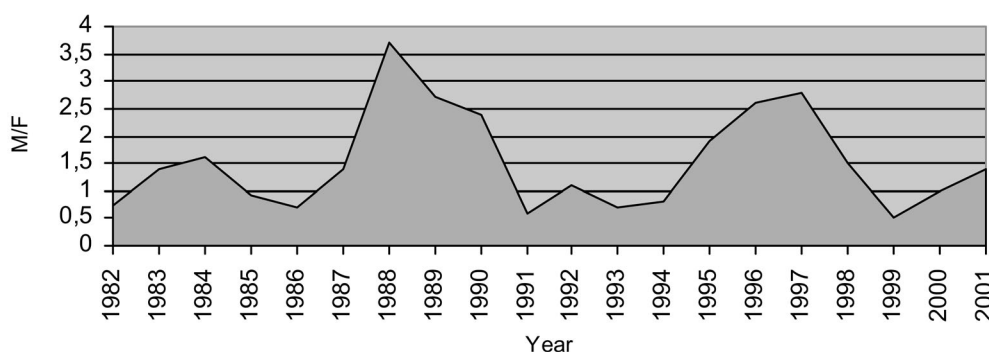
Based on these evaluations, most of the Danube shads are very possible to participate to the spawning process only once or twice. That could explain the reduced percentage

of the older individuals in the migratory flocks. Generally, an important number of older spawners may die after the reproduction, exhausted by the long way of the migration, some times more than 1200 km. Because the Danube shads do not feed themselves during the migration period of about two months, the old individuals finish their fat reserves and are not strong enough to return into the sea. However, even exhausted, the younger spawners come back to the Black Sea and they can be found in June, in the coastal areas of the Romanian Black Sea offshore.

The studies on the dynamic of the captures show some particular aspects related to the migration intensity. It decreases or increases following a quite precise cycle of about 10 to 12 years. Nobody knows what precisely ecological factors are responsible for. They could be related to some cyclic changes in the meteorological factors, which periodically affect either the Danube shad populations in Black Sea or the success of the reproduction and the offspring survival in Danube River.

The variability of the Danube shad amount that migrates yearly can be also a result of some biological factors such as the value of the males-females ratio (M/F). The normal value of the M/F ratio is around the unit. In fact, it is a very variable value in the interval of 0.38 to 3.72, most frequently of 0.9 to 2.77 (*Figure 11*). It means a large difference between the number of the Danube shad females which participate to the reproduction year by year and, as a result, a different amount of offspring that will size the number of potential spawners in the next 3 or 4 years.

Figure 11. Evolution of the Danube shad flocks M/F ratio from 1982 to 2001.



The Danube shad fishery is one of most important fisheries in the Romanian Danube River and the actual tendency of the decreasing number of shads that migrate for reproduction, respectively, the smaller captures recorded in the last time are good enough motivations for interested people to be concerned about, and to find out the real causes of this decline.

There are a couple of smaller clupeids that migrate also from Black Sea for spawning in Danube River. *Alosa caspia nordmanni* is a species of shad similar but smaller than the medium sized Danube shad. It has a maximum length of 22 cm and rarely weights more than 600 g. It prefers warmer waters and enters the Danube River about two weeks later than the Danube shad, generally in April when water temperature is 9-12°C. It could be found up to Iron Gates II Dam and uses for spawning (in May and first decade of June) many different location, even the pools and lakes of the Danube Delta. The offspring return to the marine environment in the late summer and crowds the Mouths of the Danube area.

The Caspian sprat (*Clupeonella delicatula*) is the smallest species of clupeids that migrate in Danube River. It is also common to the Caspian Sea where reach its maximum size of 17 cm. In Black Sea, Caspian sprat sizes no more than 12 cm, usually 6-8 cm. It spawns starting from its very first year of life in May and June, using the pools and lakes of the Danube Delta and the flooded areas up to Iron Gates dams.

Some times, the Caspian sprat remains in the fresh water environment for wintering in the appropriate spots. It is a quite important commercial fish, it being caught with the seine nets, mainly in the shallow water of the Black Sea. The Caspian sprat is in addition the main food source for the large shads in the Black Sea.

The last environmental changes occurred over all Lower Danube sectors [14] and particularly in the Romanian Danube River, especially as a result of dam constructions either for energetic (Iron Gates dams) or agricultural (flooding plains damming) purpose, have seriously shortened and damaged normal migratory pathways. Following their natural instinct, the migratory fishes still swim upstream but they find less appropriate opportunities for spawning, feeding and developing. As a result, the fish stocks in Danube River are decreasing year by year. Adding to this general picture of fish fauna status other human interventions such as the over fishing, the poaching and the accidental or permanent pollution of certain areas of the river, it should be easy to understanding the decline of the migratory fishes and the other species of fish in the Romanian Danube River.

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