ON THE DOWNSTREAM MIGRATION OF ICHTHYOPLANKTON ALONG THE BULGARIAN SHORE OF THE DANUBE RIVER

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MIGRATION EN AVAL
ICHTHYOPLANCTON
DÉVELOPPEMENT PRÉCOCE
DYNAMIQUE DIURNE
ET MENSUELLE
DANUBE

RÉSUMÉ – Nous avons identifié 29 espèces d'ichthyoplankton migratoire, appartenant à 4 familles. Les Cyprinidae et les Gobiidae sont dominants. La grande majorité des migrateurs se trouve à la phase III du développement (post-larves). La distribution de l'ichthyoplankton en aval est irrégulière. La majeure partie des migrateurs est concentrée dans la couche d'eau superficielle : Cyprinidae – 82,8 %, Cobitidae – 100 %, Percidae – 75 %, Gobiidae – 64,7 %. La dynamique journalière de la migration montre un maximum nocturne : 92,5 % des migrateurs. L'intensité mensuelle et annuelle de la migration et la richesse spécifique des migrateurs sont très variables.

DOWNSTREAM MIGRATION
ICHTHYOPLANKTON
EARLY STAGES OF DEVELOPMENT
DIURNAL AND MONTHLY DYNAMICS
DANUBE

ABSTRACT – 29 species of migratory ichthyoplankton along the shore have been identified. Representatives of Cyprinidae and Gobiidae are dominant. Among migrants post larvae (stage III) predominate. Both intensity of migration and species diversity are not uniform along the shore investigated. The main part of the ichthyoplankton migrates close to the surface : Cyprinidae 82.8 %, Cobitidae 100 %, Percidae 75 % and Gobiidae 64.7 %. A diurnal dynamics of downstream migration is well expressed. On the average 92.5 % of larvae and young fishes migrate during the night. The total intensity of migration as well as species composition vary during the months and the years.

INTRODUCTION

Researches on the migration of ichthyoplankton in the Danube River are scanty and only concern the Danube Kilia arm. Liashenko (1953) gave some information about distribution and migration of larvae of the Black sea shad *Alosa pontica pontica* (Eichwald). Vladimirov (1953) noted their migration towards the Black Sea, where they died because of the high salinity. Zambriborsht & Chin (1973) investigated the drift of the fish larvae from the Kilia arm towards the Black Sea. They believe that the presence of lakes, inlets, floods and marshes can delay the migration of larvae for several months. The young fishes are more resistant to salinity change and their survival would be considerably higher. Tkatschenko (1984) found 46 species of young fishes in the Kilia arm.

The present paper considers results of the first more complete investigations on the downstream migration of ichthyoplankton in the Low Danube. The parameters of migration as species-sizes composition of migrants, stages of ontogenesis, spatio-temporal structure of migration were examined.

* rkm (River kilometer – The distance to the Black Sea.

MATERIAL AND METHODS

The points of sampling in the study area are shown in Fig. 1. Material was collected as follows :

1. In June and July 1989 at Baikal (641 rkm*).
2. In June 1991 at : Vidin (790 rkm), Lom (743 rkm), Baikal (641 rkm) and Tutrakan (433 rkm).
3. During May to July 1992 at Baikal (641 rkm).

The migratory ichthyoplankton was caught at the pontoons by ichtyoplanktonic nets with an opening of 0.2 m^2 and 1.0 mm mesh, at surface and bottom. The optimum exposition of nets was 15 to 20 minutes. Larvae and young fishes were caught close to the shore by fry drag-net (4 m long) with 1.0 mm mesh. All collected samples were preserved in 4 % formalin. Notochord length (NL) or standard length (SL) were measured depending on the larval stage.

The species of fish larvae and their stages of development were defined according to the guide of Koblitskaia (1981). The ontogenesis of larvae and young fishes is divided into 4 basic stages : I – embryos, pre-larvae (with substages A and B) : From hatching till resorption of yolk sac ;

Table I. – Species-sizes composition and stages of development of migratory ichthyoplankton.

	Family / Species	Lmm	stage	n
	Cyprinidae			
1.	*Leuciscus cephalus* L.	12.0-15.6	IIID2-E	2
2.	*Leuciscus idus* L.	11.0-12.4	IIID2-E	3
3.	*Scardinius erythrophthalmus* L.	9.3-15.0	IID1-IIIE	11
4.	*Aspius aspius* L.	14.5-16.8	IIIE	3
5.	*Leucaspius delineatus* Heckel	9.0-12.0	IIID-E	10
6.	*Chondrostoma nasus* L.	12.0-14.0	IIID2-E	7
7.	*Gobio gobio* L.	10.0	IIID2	1
8.	*Barbus barbus* L.	10.4-13.0	IIID2	9
9.	*Alburnus alburnus* L.	8.8-20.2	IID1-IV	26
10.	*Blicca bjoerkna* L.	11.5-12.6	IIID2-E	2
11.	*Abramis brama* L.	13.0-23.0	IIID2-IV	3
12.	*Abramis ballerus* L.	12.3	IIID2	1
13.	*Abramis sapa* Pallas	18.8	IIIF-G	1
14.	*Vimba vimba carinata* Pallas	11.5	IIID2	1
15.	*Pelecus cultratus* L.	8.5-14.0	IIC2-IIID2	5
16.	*Rhodeus sericeus amarus* Bloch	8.1-9.5	IIID2	21
17.	*Carassius carassius* L.	13.1	IIIE-F	1
18.	*Cyprinus carpio* L.	11.0-20.0	IID1-IIIG	12
	Cobitidae			
19.	*Cobitis aurata bulgarica* Drensky	10.5	IIID2	1
	Percidae			
20.	*Perca fluviatilis* L.	10.0	IIID2	1
21.	*Stizostedion volgensis* Gmelin	15.0	IIIF	1
22.	*Stizostedion lucioperca* L.	10.4	IIID2	1
23.	*Aspro streber* Siebold	12.6	IIIE	1
	Gobiidae			
24.	*Neogobius melanostomus* Pallas	5.0-11.7	IIID2-IV	56
25.	*Neogobius fluviatilis* Pallas	4.7-7.8	IID1-IIIE	78
26.	*Neogobius gymnotrachelus* Kessler	6.0-6.2	IIIE	2
27.	*Neogobius kessleri* Gunther	5.6-9.0	IIID2-F	2
28.	*Protherorhinus marmoratus* Pallas	5.0-16.2	IIID2-IV	3
29.	*Benthophilus stellatus* Sauvage	6.0	IIIE	1

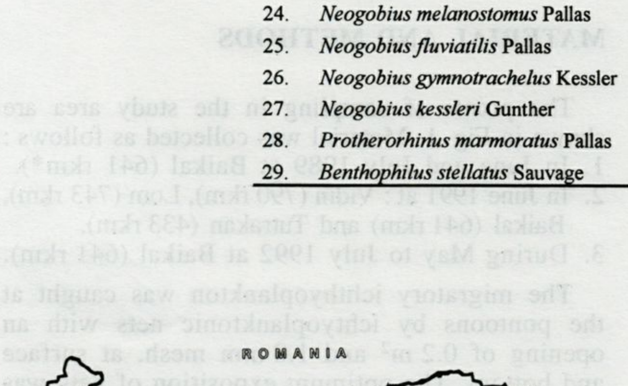

Fig. 1. – Map of Bulgaria with the points of sampling in the study area (Vidin, Lom, Baikal, Tutrakan).

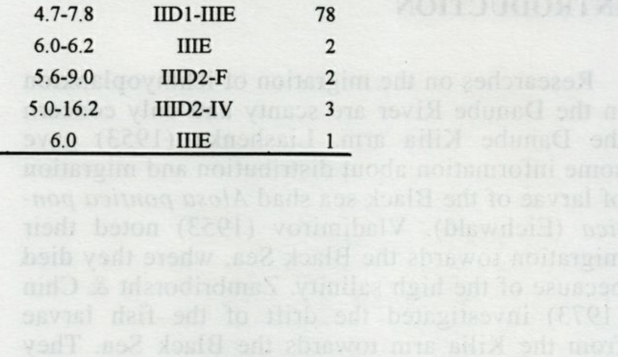

Fig. 2. – Downstream distribution of migratory ichthyoplankton.

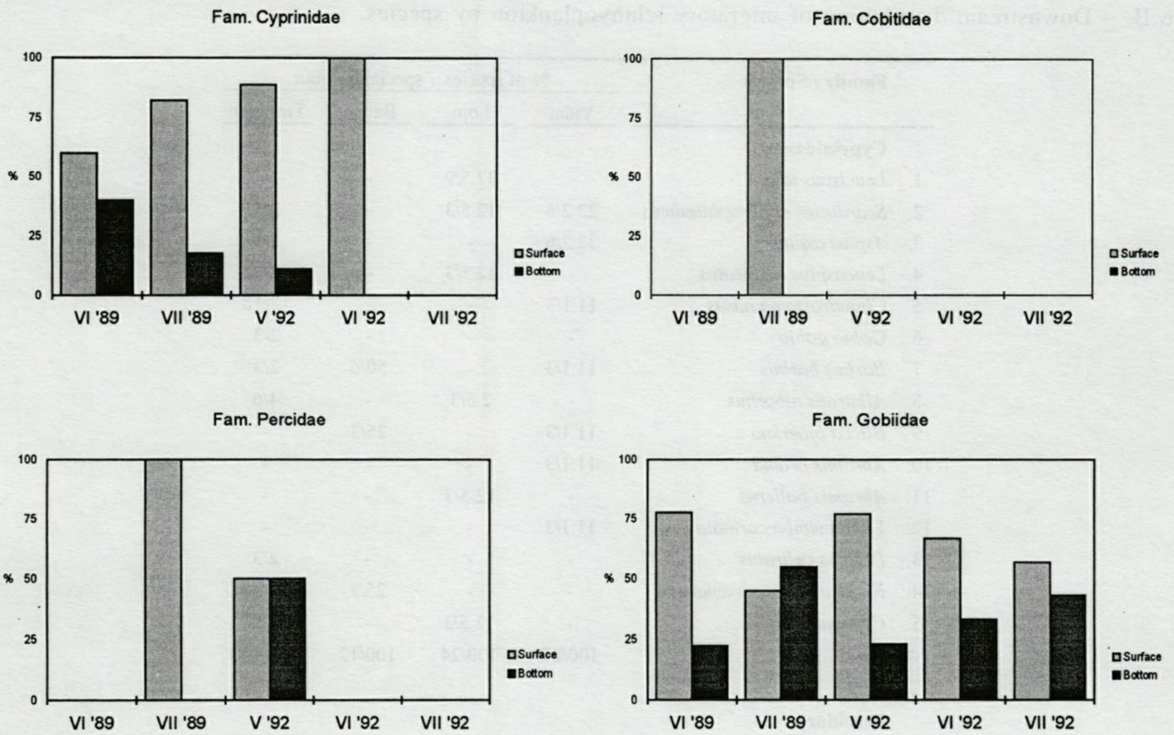

Fig. 3. – Vertical distribution of migratory ichthyoplankton for different families.

II – early larvae (substages C1, C2 and D1) : without yolk sac, appearance of mesenchyme rays and bone rays in the caudal fin toward the end of stage; III – post-larvae (substages D2, E, F and G): complete formation of the fins, appearance of scales; and IV – young fish : complete formation of body, distinguished from adults by proportions only.

The results of downstream distribution of migratory ichthyoplankton are based on the investigations made during 1991. The researches on the vertical migration structure, its diurnal and monthly dynamics were carried out during 1989 and 1992. All results about intensity (1) of migration (specimens/h) are related to a surface of 0.2 m^2 (the opening of ichthyoplanktonic nets).

RESULTS

1. Species-size composition and stages of development of migratory ichthyoplankton

During the entire period of study, 29 species of migratory ichthyoplankton of 4 families were found (Table I), which represents 47.5 % of the whole ichthyofauna of the Bulgarian Danube stretch – 61 species (Marinov, 1978). The species catch for each family is : Cyprinidae – 72 %, Cobitidae – 33.3 %, Percidae, 57.1 % and Gobiidae – 85.7 %. According to similar data of downstream migration in the Upper Volga and the Ili River, the migrants were composed of 53.7 % and 100 %, respectively, of the whole ichthyofauna (Nezdolii, 1974; Pavlov *et al.*, 1981).

Among migrants, the Cyprinidae and the Gobiidae are dominant. The species of Cobitidae and Percidae are rare in the samples (Table I).

According to our results dominant migrants of Cyprinidae are the post-larvae (stage III) with 89.2 %. The early larvae (stage II) compose 5 %, the larvae between stages II and III 3.3 %, and young fishes (stage IV) – 2.5 % respectively. The embryos (stage I) were not always caught.

All migrants of Cobitidae and Percidae are in stage III. Migrants of Gobiidae of stage III are 95.8 %, between stages II and III 2.8 %, and in stage IV 1.4 %. Similar percentages of downstream migrants of Gobiidae in Low Volga were reported by Pavlov (1976).

2. Downstream distribution of migrants

The migratory ichthyoplankton (during 1991) was represented by 3 families (Fig. 2). The quantitative composition of species is given in Table II.

3. Vertical distribution of migrants

The results are based on the samples from surface (0 to 60 cm) and bottom (3.5 to 4.5 m). The distribution of families and species is given in Fig. 3 and Table III. The greater part of

Table II. – Downstream distribution of migratory ichthyoplankton by species.

Family / Species	% of species / specimens/hour			
	Vidin	Lom	Baikal	Tutrakan
Cyprinidae				
1. *Leuciscus idus*	-	37.5/9	-	-
2. *Scardinius erythrophthalmus*	22.2/6	12.5/3	-	2/3
3. *Aspius aspius*	22.2/6	-	-	2/3
4. *Leucaspius delineatus*	-	12.5/3	-	18/27
5. *Chondrostoma nasus*	11.1/3	-	-	12/18
6. *Gobio gobio*	-	-	-	2/3
7. *Barbus barbus*	11.1/3	-	50/6	2/3
8. *Alburnus alburnus*	-	2.5/3	-	4/6
9. *Blicca bjoerkna*	11.1/3	-	25/3	-
10. *Abramis brama*	11.1/3	-	-	-
11. *Abramis ballerus*	-	12.5/3	-	-
12. *Vimba vimba carinata*	11.1/3	-	-	-
13. *Pelecus cultratus*	-	-	-	2/3
14. *Rhodeus sericeus amarus*	-	-	25/3	32/48
15. *Cyprinus carpio*	-	12.5/3	-	24/36
Total	100/27	100/24	100/12	100/150
Percidae				
16. *Stizostedion volgensis*	-	-	-	100/3
Gobiidae				
17. *Neogobius melanostomus*	27.5/4.7	80/20	16.7/3	60.7/51
18. *Neogobius fluviatilis*	72.5/12.4	20/5	83.3/15	39.3/33
Total	100/17.1	100/25	100/18	100/84

downstream migrants were caught at the surface : Cyprinidae 82.8 %, Cobitidae 100 %, Percidae 75 % and Gobiidae 64.7 %.

4. Diurnal dynamics of downstream migration

Changes of total migration intensity during a twenty-four hour period are given in Fig. 4. On the average 92.5 % of larvae and young fishes migrate at night. Among day migrants, species of Cyprinidae and Percidae are noted. The migrants of Cobitidae and Gobiidae are recorded at night only.

The duration of the basic migratory process at night was about 7 hours. Larvae could cover a distance of 12.6 km during this time at a measured mean velocity of 50 cm/sec.

5. Monthly and annual dynamics of downstream migration

The data of total intensity of both monthly and annual dynamics of migration and the distribution of migrants by families are given in Fig. 5 and 6 respectively. The quantitative change of species during the different months and years is given in Table IV.

DISCUSSION

The species diversity of downstream migrants from a given area is in accordance with the reproduction of the fishes. The zone along the shore is where the Cyprinidae, Cobitidae and Gobiidae spawn, while the respective Percidae spawn far from the shore in deeper water (Belii, 1963 ; Setsko & Feoktistov, 1976 ; Vassilev, 1986).

The majority of Cyprinidae embryos are stuck to submerged vegetation. Their downstream migration usually starts after they leave the substratum, at about the end of stage I.

Larvae of Cobitidae have negative phototaxis and settled in the ground near to the shore. This is the most probable reason of their minimal participation in the downstream migration. Similar results were given by Pavlov *et al.* (1981) for the Volga and the Ili River.

The minimal participation of larvae of Percidae in the downstream migration cannot be explained. This is probably in accordance with the rather small number of Percidae in past years.

The absence of Acipenseridae in samples is most probably related to their reproductive bi-

Table III. – Vertical distribution of migratory ichthyoplankton by species.

Surface	sp/h	Bottom	sp/h
June 1989			
Surface	sp/h	Bottom	sp/h
Cyprinidae			
Alburnus alburnus	3	*Abramis sapa*	1.5
Abramis brama	1	*Pelecus cultratus*	2
Pelecus pultratus	2	*Carassius carassius*	1.5
Rhodeus sericeus amarus	1.5		
Total	7.5	Total	5
Gobiidae			
Neogobius melanostomus	7.5	*Neogobius melanostomus*	4
Neogobius fluviatilis	38	*Neogobius fluviatilis*	9
Total	45.5	Total	13
July 1989			
Surface	sp/h	Bottom	sp/h
Cyprinidae			
Barbus barbus	1.3	*Barbus barbus*	2.6
Alburnus alburnus	25.3	*Alburnus alburnus*	2.6
Pelecus cultratus	1.3	*Rhodeus sericeus amarus*	1.3
Rhodeus sericeus amarus	2.6		
Total	30.5	Total	6.5
Cobitidae			
Cobitis aurata bulgarica	1.3		
Percidae			
Stizostedion lucioperca	1.3		
Gobiidae			
Neogobius fluviatilis	5.4	*Neogobius fluviatilis*	5.3
		Neogobius melanostomus	1.3
Total	5.4	Total	6.6
May 1992			
Surface	sp/h	Bottom	sp/h
Cyprinidae			
Scardinius erythrophthalmus	12	*Leuciscus cephalus*	3
Barbus barbus	6		
Abramis brama	3		
Rhodeus sericeus amarus	3		
Total	24	Total	3
Percidae			
Perca fluviatilis	3	*Aspro sreber*	3
Gobiidae			
Neogobius melanostomus	9	*Neogobius melanostomus*	3
Neogobius fluviatilis	15	*Neogobius fluviatilis*	6
Protherorhius marmoratus	6		
Total	30	Total	9
June 1992			
Surface	sp/h	Bottom	sp/h
Cyprinidae			
Alburnus alburnus	3		
Gobiidae			
Neogobius melanostomus	9	*Neogobius melanostomus*	3
Neogobius fluviatilis	24	*Neogobius fluviatilis*	9
Neogobius gymnotrachelus	6	*Protherorhius marmoratus*	3
Neogobius kessleri	3	*Benthophilus stellatus*	6
Total	42	Total	21
July 1992			
Surface	sp/h	Bottom	sp/h
Gobiidae			
Neogobius fluviatilis	12	*Neogobius fluviatilis*	12
Neogobius kessleri	4		
Total	16	Total	12

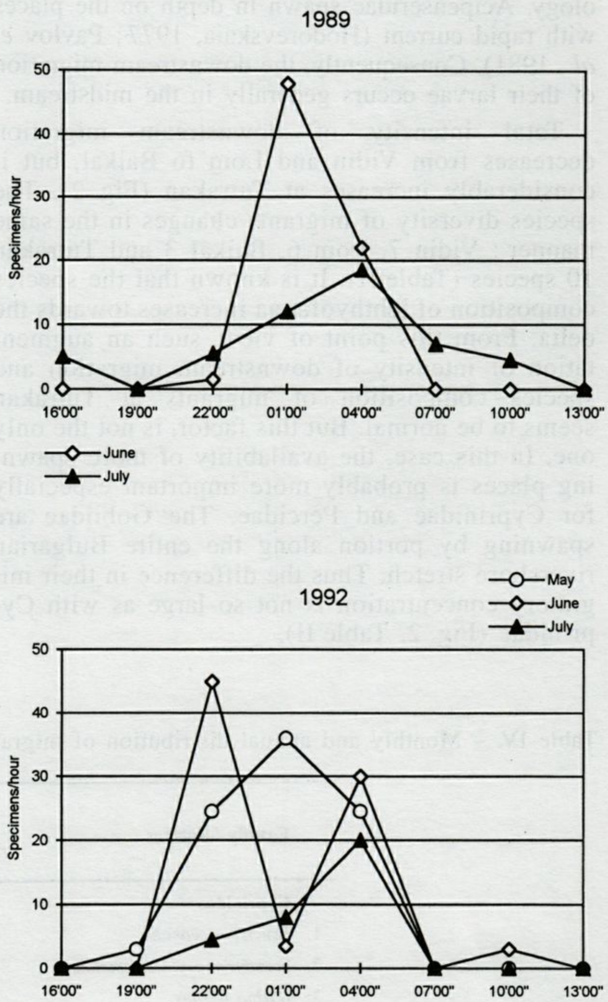

Fig. 4. – Diurnal dynamics of downstream migration.

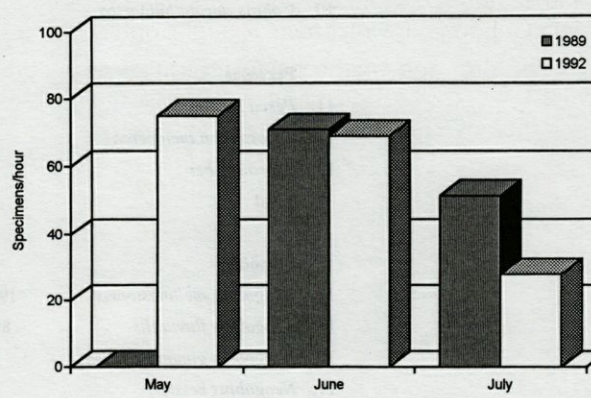

Fig. 5. – Total monthly and annual dynamics of downstream migration.

ology. Acipenseridae spawn in depth on the places with rapid current (Hodorevskaia, 1977; Pavlov *et al.*, 1981). Consequently, the downstream migration of their larvae occurs generally in the midstream.

Total intensity of downstream migration decreases from Vidin and Lom to Baikal, but it considerably increases at Tutrakan (Fig. 2). The species diversity of migrants changes in the same manner : Vidin 7, Lom 6, Baikal 3 and Tutrakan 10 species (Table II). It is known that the species composition of ichthyofauna increases towards the delta. From this point of view, such an augmentation of intensity of downstream migration and species composition of migrants at Tutrakan seems to be normal. But this factor, is not the only one. In this case, the availability of more spawning places is probably more important especially for Cyprinidae and Percidae. The Gobiidae are spawning by portion along the entire Bulgarian rivershore stretch. Thus the difference in their migratory concentration is not so large as with Cyprinidae (Fig. 2, Table II).

The structure of vertical distribution changes during the ontogenesis (Pavlov *et al.*, 1981). In our view, the stability of larvae in the water flow increases with their growth. In this way, the percentage of the « active moment » in the realization of downstream migration is increasing. In other words, young fishes are capable to change the vertical structure of migration more than are the larvae. According to our results, the post-larvae have greater numbers of migrants. After they fall within the watercourse with critical values of velocity, the passive downstream migration begins. The lowest velocity value we have measured was 40 cm/s, which considerably exceeded the critical velocity for larvae and young fishes (Pavlov, 1979). Under such conditions the vertical distribution of the migratory ichthyoplankton should depend mainly on the turbulences and the velocity gradient that increases from the bottom to the surface. Thus, the tendency for migrants is to ascend passively towards the surface. Under the given condition, biological and ecologi-

Table IV. – Monthly and annual distribution of migratory ichthyoplankton by species.

	Family / Species	% of species / specimens/hour				
		1989		1992		
		June	July	May	June	July
	Cyprinidae					
1.	*Leuciscus cephalus*	-	-	20/6	-	-
2.	*Scardinius erythrophthalmus*	-	-	40/12	-	-
3.	*Barbus barbus*	-	10.5/3.9	20/6	-	-
4.	*Alburnus alburnus*	24/3	75.5/27.9	-	100/3	-
5.	*Abramis brama*	8/1	-	10/3	-	-
6.	*Abramis sapa*	12/1.5	-	-	-	-
7.	*Pelecus cultratus*	32/4	3.5/1.3	-	-	-
8.	*Rhodeus sericeus amarus*	12/1.5	10.5/3.9	10/3	-	-
9.	*Carassius carassius*	12/1.5	-	-	-	-
	Total	100/12.5	100/37	100/30	100/3	-
	Cobitidae					
10.	*Cobitis aurata bulgarica*	-	100/1.3	-	-	-
	Percidae					
11.	*Perca fluviatilis*	-	-	50/3	-	-
12.	*Stizostedion lucioperca*	-	100/1.3	-	-	-
13.	*Aspro streber*	-	-	50/3	-	-
	Total	-	100/1.3	100/6	-	-
	Gobiidae					
14.	*Neogobius melanostomus*	19.7/11.5	10.8/1.3	30.8/12	18.2/12	-
15.	*Neogobius fluviatilis*	80.3/47	89.2/10.7	53.8/21	50/33	85.7/24
16.	*Neogobius gimnotrachelus*	-	-	-	9.1/6	-
17.	*Neogobius kessleri*	-	-	-	9.1/6	14.3/4
18.	*Protherorhinus marmoratus*	-	-	15.4/6	4.5/3	-
19.	*Benthophilus stellatus*	-	-	-	9.1/6	-
	Total	100/58.5	100/12	100/39	100/66	100/28

cal peculiarities of species have a secondary importance. It is well confirmed by the predominant surface downstream migration of both Cyprinidae and Gobiidae.

This type of diurnal dynamics of downstream migration of ichthyoplankton is characteristic for rivers with water transparency of more than 30 cm by Secchi disk (Pavlov *et al.*, 1981). The considerable augmentation of intensity of downstream migration at night is closely connected with the loss of visual orientation of larvae and young fishes. Consequently they fall into the watercourse with critical values of velocity (Pavlov, 1979; Pavlov *et al.*, 1981). Our data of water transparency in the Bulgarian Danube stretch varied between 205 cm (Novo selo, 833 rkm) and 45 cm (Russe, 495 rkm). In the rivers with low water transparency such as Kuban and Ili (1 – 16 cm), the downstream migration has not been found maximum at night (Pavlov *et al.*, 1977; 1981). The absence of migrants of Cobitidae and Gobiidae during the daytime is most probably related to their bottom distribution, lower mobility and more strongly expressed positive tactile reaction (in comparison with Cyprinidae and Percidae). All these factors contribute to the better orientation of these species during the daytime and to their possibility to avoid the places with critical velocity of the watercourse. The catches carried out close to the shore with fry drag-net have demonstrated that the number of larvae and young fishes decreased 2 to 4 times. Similar results of «dispersal» of larvae at night were noted by other authors (Protasov, 1978; Pavlov *et al.*, 1981, 1988).

After the larvae have got into a watercourse with critical velocities during the night, they stop their migration during the daytime by a means that is still unclear. Doubtless, this process begins with recovery of their visual orientation (Pavlov, 1979; Pavlov *et al.*, 1981). The most probable mechanism is that larvae find the places with lower velocity of watercourse than critical (inlets, marshes, floods etc.).

The total intensity of downstream migration as well as of the species composition and quantity of migrants change during months and years. These changes can not be determined by a single factor. The dynamics of the migration are obviously connected with the influence of many abiotic and biotic factors of the environment. Among the abiotic factors the most important are hydrological (velocity, water level etc.). According to Pavlov (1984), the most important among the biological factors are the complex of innate behaviour reactions and morphological adaptations that regulate the spatio-temporal distribution of the larvae and the young fishes.

* rkm (River kilometer): the distance to the Black Sea.

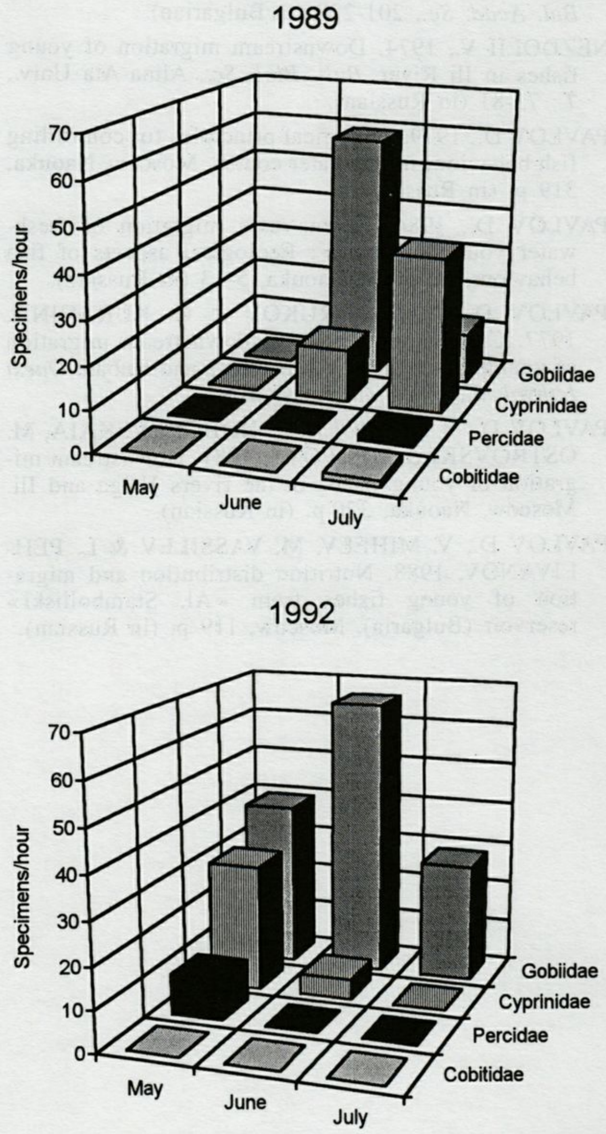

Fig. 6. – Monthly and annual distribution of migratory ichthyoplankton for different families.

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