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NGO HYDROECOLOGY OF MONTENEGRO

Environmental risk assessment of the Morača dams: fish fauna of Morača river canyon and Skadar Lake

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Skadar Lake and Morača River are two functional parts of one water system – the Skadar Lake system. Morača River is the biggest tributary of the Lake contributing with 62 % of the total water flowing into Skadar Lake (Lasca et al., 1981.). The total drainage area of Skadar Lake is 5490 km^2, of which 4460 km^2 are in Montenegro and 1030 km^2 are in Albania.

The total length of Morača River (from the spring to Skadar Lake) is 97km. The spring area of Morača River (several small streams which join together and form Morača River) lies at nearly 1000m altitude and the average slope of whole Morača River is near 10m per km of flow (near 10% slope). Morača River can divided in three parts by environmental conditions (physical-chemical environmental parameters) : the upper part (from the spring to Medjuriječje), the middle part from (from Medjuriječje to Podgorica) and the lower part (from Podgorica to Skadar Lake).

Skadar lake, with an average surface of 372,3 km^2 is the biggest lake in the Balkan peninsula. The Lake is located on Montenegro-Albania border (1/3 of lake is in Albania) in a karst terrain surrounded by the Dinaric mountains. The main lake inlet is Morača River and Bojana River is main Lake outlet.

According to Knežević (1985), who listed the fish species of the Skadar Lake system, there are 17 families, 38 genus and 45 fish species. Marić (1995) emphasizes two newly-described species: *Chondrostoma scodrensis* and *Rutilus prespensis vukovici*. The latest literature data indicates the final (current) number of species, of which three are newly-described species (*Pomatoschistus montenegrensis,* Miller & Šanda, 2008.; *Knipowitschia montenegrina*, Kovačić & Šanda, 2007.; *Scardinius knezevici*, Bianco & Kottelat, 2005.) as follows: 17 families ,38 genus, 50 species (Table 3.)

Of these 50 species, 31 are endemic species with an Adriatic – Ionian distribution (Table 4.), which means that they are endemic of the Adriatic – Ionian sub-province of the Mediterranean zoo-geographical province (Banarescu, 1992). This shows that 62 % of the species of Skadar lake system are endemic (Figure 3). If we then exclude the introduced species (thirteen of them, table 5.) and analyze the original fish fauna of this area, 84 % of species are endemic of the Adriatic – Ionian region. Of this 31 endemic species, 8 are endemic of Skadar Lake system (meaning that they exist only in this water system) which makes 16 % of ichthyic-fauna endemic only of this area (if we exclude the introduced

species, the original percentage of endemic ichthyic-fauna endemic only for this system is 22 %).

The fish resource of Skadar Lake represents more than 95 % of the total fresh water fishery in Montenegro. Skadar Lake has far higher values than other karst lakes in the Balkan Peninsula in terms of fish production and fish biomass. Based on statistical data of annual catch, fish production in Skadar Lake is 80 kg/ha (8000 kg/km^2, data related to the Montenegrin part of lake). As in other large-surface lakes, only a restricted number of fish species dominate hence representing most of the catch of the lake. In Skadar Lake arp (*Cyprinus carpio*) and bleak (*Alburnus alburnus alborella*) represent more than 70% of the total catch. Beside these two species, *Alosa fallax nilotica*, *Anguilla anguilla*, *Chondrostoma nasus*, *Leuciscus cephalus albus*, *Scardinus erythrophtalamus scardafa*, *Rutilus basak ohridanus*, *Mugil cephalus* are also significant for fishery.

This study estimated that at least 300 families directly depend on the fish stock as their main source of income. An additional 300 families depend indirectly on fishery activity, so that a realistic estimate is that approximately 600 families depend on fish as their main income-generating resource. The study estimated that the economy based on fish as a main resource (fishing, fish processing, restaurants, sport fishing) is worth at least 4.250.000 € per year.

The study made by Knežević (2009) simulated the water regime variation in Skadar lake due to the construction of four dams on Morača River. This findings were used to predict the changes in the fish habitats of Skadar lake and Morača River paying particular attention to the key fish ecological requirement of fish, the spawning habitat. It is widely known in fact that the most vulnerable part of the year for all fish species is the spawning period.

Of the two most important fishery species, carp and bleak, the carp uses a special and temporary habitat for spawning, created by spring flood events, so that it migrates from the deeper water habitats in the lake into the shallow flooded areas that are overgrown by macrophytic vegetation.

Kneževic (2009) calculated that if water is loaded in the dam reservoirs during spring months (April, May and June) this will cause a decrease in the water level of Skadar lake in April of approximately 63cm, meaning that the lake's surface will decrease by 12.6km^2. The lost surface corresponds to the spawning ground of carp. The data for May and June are similar: in May the water level will decrease by 64cm causing a decrease in the lake surface of 12.8km^2 , while in June the water level will decrease by 65cm which will result in a decrease of the lake surface of 15.8 km^2. If this happens the fertilized eggs or the carp's larva would perish.

We estimated that such scenario will impact on the population number of fishery important species (in first line bleak and carp) with an estimated decrease of maximum 30 % which will imply an economic loss of 1.416.666 € on an yearly basis.

As the dams on Morača river will be installed in the medium course we can expect a strong negative impact on the trout population living there. Brown trout, the most abundant trout species, will face population fragmentation. In the upper part of the river (downstream of the dams) brown trout individuals will be isolated and the genetic diversity survival will rely on isolated individuals.

The brown trout from the lower stretch will lose spawning ground, located in the upper part of the drainage, which will become unreachable due to the barrier posed by the dams.

The marble trout will be also negatively affected because the medium course of Morača river, where this species is more abundant, will be completely changed. We can expect that the number of marble trout individuals will dramatically decrease and this is of particular concern as the species is already at a critically low number compared to 25 years ago.

1. Fish fauna of Morača River and Skadar Lake

1.1. Environmental characteristic of Morača River and Skadar Lake

Skadar Lake and Morača River are two functional parts of one water system – the Skadar Lake system. Morača River is the biggest tributary of the Lake contributing 62 % of the total water flowing into Skadar Lake (Lasca et al., 1981.). The total drainage area of Skadar Lake is 5490 km^2, of which 4460 km^2 are in Montenegro and 1030 km^2 are in Albania. Of this 4460 km^2, two-thirds is the drainage area of Morača River. The total length of Morača River (from spring area to Skadar Lake) is 97km. The spring area of Morača River (several small streams which join together and form Morača River) lies at nearly 1000m altitude and the average slope of whole Morača River is near 10m per km of flow (near 10% slope). By the environmental conditions (physical-chemical environmental parameters) the whole course of Morača River is divided in three sectors: upper part (from spring area to Medjuriječje), middle part from (Medjuriječje to Podgorica) and lower part (from Podgorica to Skadar Lake). All those parts are characterized by different altitude and slope, and related to this, with different water temperature, climate and fish species composition (different fish species with different abundance).

Morača River in the upper part has an average slope of 26,6% and average annual temperature about 8^o C. The average amount of dissolved oxygen is 12 g/l. In the middle part the average slope is 4,12%, average annual temperature is about 15 ^{o} C and average amount of dissolved oxygen is 10g/l. In lower part the slope is 1,5%, average annual temperature is 17 ^{o} C and average amount of oxygen is 9 g/l (Graphic 1.1. and Table 1.)

Morača River flows through humid mountains, modified Mediterranean and typical Mediterranean climate (Table 1.). The amount of water (m^3/s) also increases with distance from source with maximum average in position of Delta on Skadar Lake (annual average 202,63 m^3/s). The biggest tributary is Zeta River which joins the Morača above Podgorica. In this point Zeta river brings more water than Morača. The Zeta River water-mass is more than half of total Morača River water-mass downstream of Podgorica. Other important tributaries are: Mrtvica River, Sjevernica River, Mala River and Cijevna River. The last two of them, in their lower parts, are out of water for two summer months (July and August, depending on precipitation schedule). Morača River is Dinaric torrent water flow characterized by high variation in amount of water. For instance, in position of Morača delta, there are two maximums in April and December (330 m^3/s and 380 m^3/s), and one minimum in August (30 m^3/s) (Lasca, N. et al. 1981). During whole year (same position) Morača River have higher flow than average during seven and a half months (second half of October, November, December, January, February, March, April and May) while lower flow than average occurs during for and a half months (June, July, August, September and first half of October) (Lasca, N. et al. 1981).

Figure 1. Slope profile of Morača River flow, blue line – upper part, red line – middle part, green line – lower part.

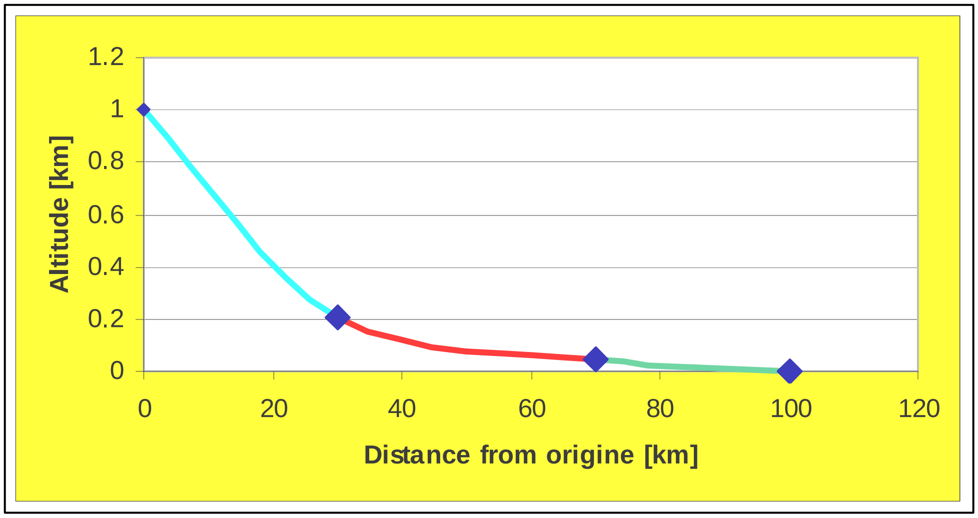


Table 1. Climate, temperature, precipitation and chemical water parameters for different localities (upper, middle and lower part) on Morača River, according to Drecun et al., 1985.

	Dragovića polje	Manastir Morača	Medjurječje	Bioče	Duklja	Botun	Adžove vrbe
	Upper part			middle part		lower part	
Mean year temperature (^{o}C)	6	10	10	14	16	17	17
Mean number of days with temperature below O^{o} C	30	10	10	5	0	0	0
Mean number of summer days (Tmax $\geq 25\ ^{o}C$)	40	50	50	100	130	130	130
Precipitation (mm)	1970	2153	2370	1909	1838	2000	2250
Dissolved oxygen (mg/l)	12.05	11.84	11.78	11.43	10.49	9.2	9.9
Usage of BPK5 (mg/l)	1.4	1.63	1.57	1.65	2.24	3.93	4,2
pH	8.12	8.18	8.25	8.2	8	8.45	8
HCO2 (mg/l)	8.85	9.4	10.2	9.45	7.8	11.4	11,2
HCO3 (mg/l)	133.41	131.76	128.02	139.95	165.66	158.9	145
KMnO4 (mg/l)	2.24	2.41	2.71	3.2	6.2	9.81	15.37

Sulfates (mg/l)	**14.35**	**15.2**	**15.05**	**14.96**	**16.03**	**16.12**	**27**
Chlorides (mg/l)	**5.45**	**5.05**	**5.8**	**5.5**	**5.7**	**6.05**	**6.1**
Nitrates (mg/l)	**0.98**	**0.85**	**0.92**	**1.15**	**1.24**	**1.42**	**1.6**
Nitrites (mg/l)	**0**	**0**	**0**	**0**	**0.002**	**0.003**	**0.005**
Ca (mg/l)	**43.2**	**44.27**	**44**	**41.64**	**47.4**	**47.9**	**47.8**
Mg (mg/l)	**8.68**	**7.57**	**6.21**	**7.72**	**16.61**	**15.57**	**15.67**
SiO2 (mg/l)	**1.95**	**1.87**	**2.03**	**2.14**	**2.1**	**2.12**	**2.15**
Volatile Phenols (mg/l)	**0**	**0**	**0**	**0**	**0.001**	**0.003**	**0.01**
Dray remnant on 105 C (mg/l)	**158.2**	**162.3**	**148.2**	**168.6**	**164.2**	**169.5**	**169.8**
Free CO2 (mg/l)	**0**	**0**	**0**	**0**	**3.3**	**3**	**3.5**
Na (mg/l)	**1.82**	**1.82**	**1.82**	**1.85**	**1.86**	**1.86**	**1.86**
K (mg/l)	**0.51**	**0.51**	**0.49**	**0.53**	**0.75**	**0.75**	**0.75**

All those variations in Morača River flow and in drainage area (different geographical features, different geological substrates, high mountains, narrow canyons, narrow basins and wide valleys, different climates, different steep angles, different amount of water flow) is reason for presence of all possible river habitats and bio-tops. There are rapid river parts (small and large water flow) with constant and low water temperature or with wider water temperature variation. Deep slow parts (pools) variable by water temperature and by water-flow, deep fast parts and numerous waterfalls and cascades. All kind of river bottoms and sediments are present, big monolith rocks, all kind and all size boulder and gravel and finest sand and mud. In lower part, through Zeta valley, Moraca River is wide meandering lowland river surrounded by flooded terrain (meadows, forests). In lake estuary area, Morača forms two-fork delta covered with river and lake vegetation (bushes, trees, rush…) which is most complex ecosystem (in spatial terms) with numerous canals, pools and underwater labyrinths.

Skadar lake, with the average surface of 372,3 km^2 is the biggest lake in Balkan peninsula. The Lake is located on Montenegro-Albania border (1/3 of lake is in Albania) in karst terrain surrounded with Dinaric mountains. The main lake inlet is Morača River (average 202,63 m^3/s) and Bojana River is main Lake outlet (average 310 m^3/s). The rest (110 m^3/s) comes from precipitation and underwater karst springs called "vrulja" placed in Lake. The Skadar Lake is relatively shallow with a mean depth of 5,01m but there are locations where Lake depth go to 60m (Raduško oko) in small deep bays called "oka". The lake bottom is about 6 meters above sea level and the lake coast line (with islands) is 207 km. The Bojana river (Lake outlet) is wide lowland river with length of 40 km which forms a huge estuary delta on Adriatic coast (near Ulcinj city).

The Lake is placed in Mediterranean climate with average number of 130 "summer days" (days with temperature equal to or higher than 25^o C). Mean value for precipitation is 2250mm and there are no winter days (days with temperature equal or below 0^o C). The southern and south-western coast (as well as narrow north-eastern part towards Rijeka Crnojevića) are steep mountains and hills slopes while northern and north-eastern coast is wide lowland area (swamps, flooded meadows, lowland forests).

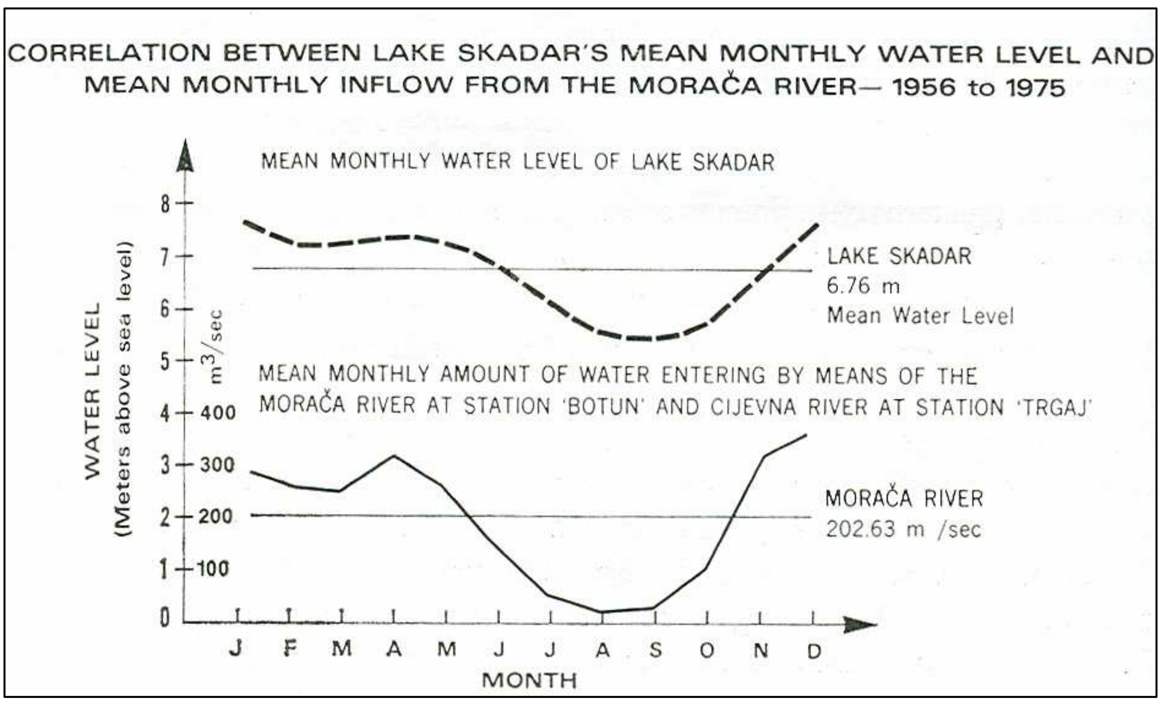
Table 2. Climate, water temperature, precipitation and chemical water parameters for Skadar Lake. according to Rakočević, 2007.

	Value	Range
Precipitation (mm)	2250	2000 - 2500
Mean winter temperature of Lake water [^{o}C]	8	4,4-30.1
Mean summer temperature of Lake water [^{o}C]	24,5	
Mean number of days with temperature below O^{o} C	0	
Mean number of summer days (Tmax ≥25 ^{o}C)	130	
Dissolved Oxygen, mean summer value (mg/l)	8,8	5,7 - 14
Dissolved Oxygen, mean winter value (mg/l)	11	
Total Phosphorus, mean winter value (µg /l)	5	5 - 60
Total Phosphorus, mean summer value (µg /l)	20	
Total Nitrogen, mean winter value (mg/l)	0,1	0,1-1,32
Total Nitrogen, mean summer value (mg/l)	0,45	
pH, mean winter value	7,1	
pH, mean summer valu	8,9	

The Lake water temperature shows no stratification on vertical plane (except in "oka") and very small horizontal variation (in Lake part near Morača River delta temperature is 2-4 degrees lower than in rest of the Lake). Mean winter water temperature is 8^{o} C and mean summer water temperature was 24,5 (Table 2.). The water of Skadar Lake has a high amount of dissolved oxygen during whole year with mean winter and summer values of 8,8 mg/l and 11 mg/l (Table 2.). With mean value of 12 µg/l for Phosphorus, Skadar lake goes under middle-trophic lake types (by OECD criteria; OECD, 1982). But the fact is that water masses of Skadar Lake, for longer period of year have extremely oligotrophic character and that during summer period water-masses quality moves toward eutrophic conditions (Table 2.). The total Nitrogen shows increases in last 25 years (comparing to 1981 data set; Petrović, G. 1981) and total Nitrogen/total Phosphorus ratio (TN/TP ratio) shows that nowadays Phosphorus is limiting factor for bioproduction (25 years ago limiting factor was Nitrogen) (Rakočević, 2007). The pH value of Skadar lake water-masses is stable on vertical plane and show almost no variation with depth. On horizontal plane pH value show some variation during summer months. The mean pH value for winter part of year was 7,1 and for summer part of year was 8,9 (Rakočević, 2007).

The water level in Skadar lake varies dramatically during one year cycle. On long time-scale (data serial for period 1951-1976) the highest water level at Plavnica station was recorded in 1963 with value 9.84 m (Lasca et al., 1981). The lowest recorded water level was in summer of 1952 with value of 4,67 m (Lasca et al., 1981). Mean water level for this period was 6,76 m while mean high water level was 8,72 m and mean low water level was 5,21m. There is strong correlation between Morača River water level variation and Skadar Lake water level variation during one year cycle (Figure 2.).

Figure 2. Correlation between lake Skadar's mean monthly water level and mean monthly inflow from the Morača River – 1956 to 1975



From all those parameters and facts that are emphasized in previous part, it is easy to conclude that condition for ichthyic-fauna in Skadar Lake are more than excellent. There are all kind of biotopes, lake has high level of bio-production (thanks to shallow bottom almost all lake water-mass are in photic zone) and high level of oxygen. Although the lake temperature is very variable (8-24^{o} C) there are locations where temperature of deeper part is more constant (Skadar Lake "oka") what provides environment to steno-thermal organisms. The lake bottom is mainly covered by mud but there are locations (especially along coast) where bottom is of stone, gravel or rocks. During high water-levels lake water floods lowland area on northern coast forming huge space of swamp, flooded meadows and flooded lowland forests (average Skadar Lake surface is 372,3 km^2 but during high water levels the Lake surface increases to 525 km^2). According to Lakušić (1983) there are three main Skadar lake ecosystems:

1. Ecosystem of deep Lake water mass (except Lake "oka"): 3m-8m water depth, water temperature in range 7-27^oC with mean annual temperature of 15^oC, main producers are submersed plants (species from genus *Chara*, *Nitella*, *Najas* in deepest parts and species from genus *Potamogeton*, *Vallisneria*, *Ceratophyllium*, *Myriophyllum* and *Ranunculus* in 3m-6m water depth) and phytoplankton algae (*Bacillaraiophyta* -157 species, *Cyanophyta* – 60 species, *Pyrophyta* – 13 species and *Chlorophyta* – 377 species).

2. Ecosystem of shallow Lake water mass: 1m -3m water depth, water temperature in range of 0 – 30^oC with mean annual temperature of 16^oC, main producers are floating plants (species from genus: *Nymphaea*, *Nuphar*, *Trapa*, *Potamogeton*, *Polygonum*, *Nymphoides*, *Marsilea*, *Lamnea* and *Ranunculus*).

3. Ecosystem of emerged vegetation: 0 - 1 m depth during floods, main producers are emerged plants (species from genus: *Phragmites*, *Typha*, *Schoenoplectus*, *Pycerus*, *Bolboschoenus*, *Cladium*, *Holoschoenus*, *Dichostylis*, *Butomus*, *Alysma*, *Iris*, *Euphorbia*, *Polygonum*, *Gliceria*, *Equisetum*, *Mentha*, *Ludwigia*, *Roripa*). This ecosystem is placed in surrounding zone and every year, during high water level, this ecosystem floods by Lake water.

1.2. Ichthyofauna of Moarača River and Skadar Lake

The Tertiary origin of Skadar Lake system ichthyofauna is proven by the fact that there is no non-salmonid predatory species (pike and perch) in this system. Until introduction of perch (during early 1980s) only predatory species in this system were endemic salmonids (*Salmo trutta*, *Salmo marmoratus*, *Salmothymus obtusirostris zetensis*) and eel, which enter in to system from Adriatic Sea through Bojana River. The presence of endemic salmonid species indicates to their late Tertiary (Eocene – Miocene) isolation from Balkan Peninsula hinterland by Dinaric mountains rising, which is confirmed by presence of other endemic taxa. Nevertheless the presence of similar ichthyofauna in other Adriatic water systems (Ohrid Lake, Prespa Lake, Neretva River, etc.) signify the pre-glacial and glacial (Pleistocene) connection between those water systems. This probably results in divergence of common species on subspecies/species level (common for different Adriatic water system and common for Adriatic and Black sea drainage). But the fact that other Adriatic rivers (western Balkan rivers, Neretva, Krka, Soča and rivers with underground flow in Slovenia, Lika, and Herzegovina) have more specific ichthyofauna with higher level of endemism and with significant paleo-endemism, indicate that Skadar Lake system for longer time was without of any connection with them. Fauna elements which are common for Skadar Lake system and other western Balkan drainage areas (the endemic trout *Salmo farioides*, *Salmo marmoratus*, *Salmothymus obtusirostris*) point to their previous most probably pre-Miocene connection. This connection could exist as Adriatic branch of ancient Thetis sea (the source of present Mediterranean Sea) when ancestral trout taxa were anadromus (like Salmon, migrate from rivers in to marine habitat). In late Miocene the whole Mediterranean basin was desiccated (so called "late Miocene crisis") and trout stayed captured in terrestrial water systems where they, perhaps, still tried to simulate the habits of "normal" life cycle by performing the interdromus migration from rivers in to lake basins and back to lake tributaries. In present time, two Skadar Lake system trout species perform this interdromus migration, *Salmo dentex* ("strun") and *Salmo marmoratus* ("glavatica").

The other hypothetical reason of ichthyofauna similarity between Skadar Lake system and other western-Balkan river systems is possibility of connection through one central river basin in period of Adriatic bay regression. It is highly possible that similarity of present endemic fauna (for example *Alburnus alburnus alborella*, *Rutilus basak*…) is consequence of early Pliocene Thetis regression. The sea level decreased to 200 m and regression disappeared to present Jabuka Depth in Adriatic basin. In such condition river Po (Italy) became central river basin for Adriatic region and its tributaries were precursors of present rivers in Balkan and Apennine peninsula.

Third, but less possible hypothesis, is based on fact that with rising of Dinaric mountains (from Oligocene to the end of Neogene) basins of numerous Balkan rivers changed their flow direction or water simply disappeared in numerous profundities. The evidence of those events are numerous karstic fields that once were bottom of lakes. Such karstic fields are present in Lika, Herzegovina and in Montenegro. It is highly possible that in those times, binding water-flows that connect those lakes basins were present which gives opportunity for ichthyofauna migration and mixing.

According to different types of endemism (paleo- and neo-endemism) and different taxonomical level of endemism (sub-species, species or genus level) the most possible situation is that all of those three scenarios (in different moments of geological history of Mediterranean basin) were affective on present Skadar lake basin zoogeographical status.

The number of fish species in Skadar Lake system rose in last 40 years because of uncontrolled stocking of allochthonous fish species which were originally from Black Sea drainage area (*Hypophthalmichthys molitrix, Thymallus thymallus*, *Carassius auratus gibelio*, *Perca fluviatilis*). But beside those introductions, the Skadar lake system (Sakadar Lake and rivers in this water basin) is home to several endemic species from families *Salmonidae*, *Cyprinidae*, *Gobiidae* and *Cobitidae*. The Lake is also spawning and growing zone for several andromus and katadromus (migratory) fish species (e.g. *Alosa falax nilotica*, *Anguilla anguill*a) as well as for estuary fish species (*Dicentrarchus labarx*, *Saprus aurata*, *Platichthys flessus*). The taxonomical, faunistical and ecological structure of the Lake and whole system is unique in Mediterranean region thus this System, with a fish assemblage combined with wide range of all kind of water habitats, is area of high importance for biodiversity conservation in whole eastern Adriatic region.

According to list of fish species that inhabit Skadar Lake system (Knežević, 1985.) there are 17 families, 38 genus and 45 fish species. Marić (1995) emphasizes two newly-described species: *Chondrostoma scodrensis* and *Rutilus prespensis vukovici*. The latest literature data, three newly-described species (*Pomatoschistus montenegrensis,* Miller & Šanda, 2008.; *Knipowitschia montenegrina*, Kovačić & Šanda, 2007.; *Scardinius knezevici*, Bianco & Kottelat, 2005.), indicate the final (present) number of species: number of families – 17, number of genus 38, number of species 50 (Table 3.)

Table 3. Ichthyic-fauna of Skadar Lake and its drainage area, according to Knežević (1981), modified.

FAMILY	**SPECES – SUBSPECIES**
Petromyzonidae	*Petromyzon marinus*
	Lampertra fluviatilis
	Lampetra planeri
Acienseridae	*Acipenser sturio*
	Acipenser naccarii
Anguillidae	*Anguilla anguilla*
Clupeidae	*Alosa fallax nilotica*
Salmonidae	*Salmo farioides*
	Salmo dentex
	Salmo marmoratus
	Salmo montenegrinus
	Oncorhynchus mykiss
	Salmothymus obtusirostris zetensis
Thymallidae	*Thymallus thymallus*

Cyprinidae	*Rutilus basak*
	Rutilus prespensis vukovici
	Pachychilon pictum
	Leuciscus cephalus albus
	Leuciscus souffia montenegrinus
	Phoxinus phoxinus
	Scardinius erythrohthalmus scardafa
	Scardinius knezevici
	Chondrostoma nasus ohridanum
	Chondrostoma scodrensis
	Gobio gobio lepidolaemus
	Alburnus alburnus alborella
	Alburnoides bipunctatus ohridanus
	Megalobrama terminalis
	Hypophthalmichthys mollitrix
	Aristichthys nobilis
	Ctenoharyngodon idella
	Carassius auratus gibelio
	Pseudorasbora parva
	Rhodeus sericeus amarus
	Cyprinus carpio
Cobitidae	*Barbatula barbatula sturanyi*
	Cobitis taenia ohridana
Ictaluridae	*Ictalurus nebulosus*
Gasterosteidae	*Gasterosteus aculeatus*
Poecilidae	*Gambusia affinis holbrooki*
Mugilidae	*Mugil cephalus*
	Liza ramada
Percidae	*Perca fluviatilis*
Moronidae	*Dicentrarchus labrax*
Blennnidae	*Blennius fluviatilis*
Gobiidae	*Padogbius pannizai*
	Pomatoschistus montenegrensis
	Knipowitschia montenegrina
Pleuronectidae	*Platichthys flessus*
Cithatidae	*Citharus linguatula*

Of these 50 species, 31 of them are endemic species with Adriatic – Ionian distribution (Table 4.), endemic for Adriatic – Ionian sub-province of Mediterranean zoo-geographical province (Banarescu, 1992). This shows that 62

% of species in Skadar lake system are endemic (Figure 3) and if we exclude the introduced species (thirteen of them, table 5.) and analyze the original fish fauna of this area, 84 % of species are endemic for Adriatic – Ionian region. Of this 31 endemic species, 8 of them are endemic for Sakdar Lake system (they inhabit only this water system) what makes 16 % of ichthyic-fauna endemic only for this area (if we exclude the introduced species, the original percentage of endemic ichthyic-fauna endemic only for this system is 22 %).

Table 4. An overview of endemic fish taxa with different level of endemism, according to Marić (1995), supplemented with a newly-described fish taxa (the star "*" marks taxa with narrow geographical dissemination within Skadar Lake drainage area)

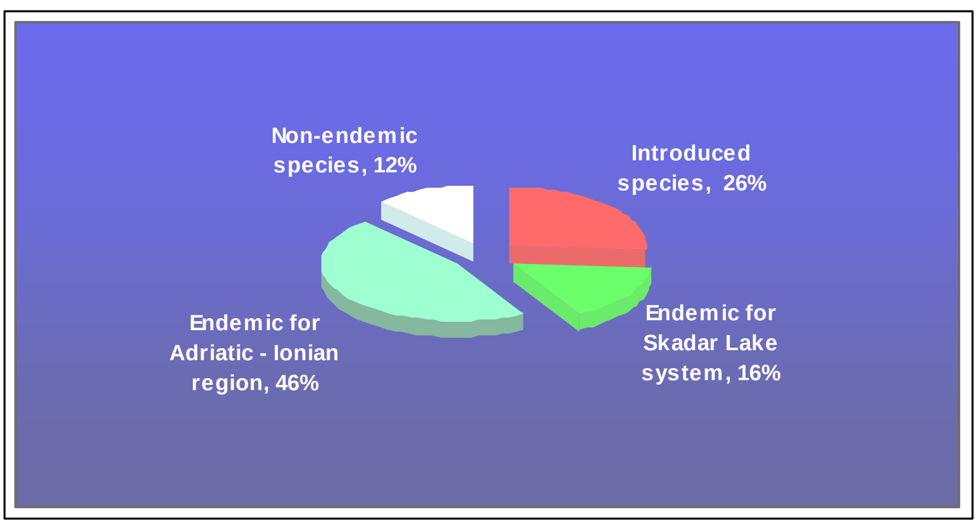
SPECIES – SUBSPECIES
Petromyzon marinus
Lampetra fluviatilis
Lampetra planeri
Acipenser naccarii
Acipenser sturio
Allosa fallax nilotica
Salmo dentex
Salmo farioides
Salmo marmoratus
*Salmo montenegrinus**
*Salmothymus obtusirostris zetensis**
Alburnoides bipunctatus ohridanus
Alburnus alburnus alborella
Barbus peloponnesius
Chondrostoma nasus ohridanus
*Chondrostoma scodrensis**
Gobio gobio lepidolaemus
Leuciscus cephalus albus
*Leuciscus souffia montenegrinus**
Pachychilon pictum
*Phoxinellus stimphalicus montenegrinus**
Rutilus basak ohridanus
Rutilus prespensis vukovici
Scardinius erythrophthalmus scardafa
*Scardinius knezevici**
Cobitis taenia ohridana
Barbatula barbatula sturanyi

Blennius fluviatilis
Padogobius panizzai
*Pomatoschistus montenegrensis**
*Knipowitschia montenegrina**

Table 5. An overview of introduced fish species in Skadar Lake system, according to Knežević (1985), modified.

SPECIES – SUBSPECIES
Hypophthalmichthys molitrix
Oncorhynchus mykiss
Thymallus thymallus
Salmo trutta (Black sea and Atlantic linage)
Megalobrama terminalis
Hypophthalmichthys mollitrix
Aristichthys nobilis
Ctenoharyngodon idella
Carassius auratus gibelio
Pseudorasbora parva
Ictalurus nebulosus
Gambusia affinis holbrooki
Perca fluviatilis

Figure 3. The composition of Skadar lake system fish fauna



From biodiversity point of view, it is hard to say which are the most important fish species from Skadar Lake system. The potential candidates are, with no doubt, the endemic species but the fact is that in this system lives species with different level of endemism (local endemic species, species that are endemic for Adriatic-Ionian region, species that are endemic for eastern Mediterranean). The second parameter should be the level of threat for individual taxa according to IUCN red list classification, and the third parameter can be the size of Sakdar Lake system compared with whole living area of each endemic species.

Of thirty one endemic species, eight are exclusively endemic only for this area. Two of those eight species have unclear systematic status and their presence (after finding and description) has never been confirmed again (*Salmo montenegrinus* and *Chondrostoma scodrensis*). Two of three newly-described species (*Pomatoschistus montenegrensis* and *Knipowitschia montenegrina*) are small fish species that inhabits lake shore and shallow part of lake tributaries (flooded areas). The following species are potential candidates for most important fish species from biodiversity point of view: *Salmothymus obtusirostris zetensis*, *Leuciscus souffia montenegrinus*, *Phoxinellus stimphalicus montenegrinus*, *Scardinius knezevici* (Skadar lake system endemism), *Acipenser naccarii*, *Acipenser sturio*, *Allosa fallax nilotica*, *Salmo dentex*, *Salmo marmoratus*, *Alburnoides bipunctatus ohridanus* , *Alburnus alburnus alborella*, *Barbus peloponnesius*, *Chondrostoma nasus ohridanus*, *Pachychilon pictum*, *Rutilus basak ohridanus*, *Scardinius erythrophthalmus scardafa*, *Barbatula barbatula sturanyi* and *Padogobius panizzai* (Adriatic-Ionian endemisam).

Table 6. Skadar lake system selected endemic fish species and their UICN conservation status

SPECIES - SUBSPECIES	IUCN Red List Category
Salmothymus obtusirostris zetensis	**EN B2ab**
Leuciscus souffia montenegrinus	**LR/lc**
Phoxinellus stimphalicus montenegrinus	**no data**
Scardinius knezevici	**no data**
Acipenser naccarii	**VU A1ac**
Acipenser sturio	**CR A2d**
Allosa fallax nilotica	**DD**
Salmo dentex	**DD**
Salmo marmoratus	**LC**
Alburnoides bipunctatus ohridanus	**LR/lc**
Alburnus alburnus alborella	**no data**
Barbus peloponnesius	**LC**
Chondrostoma nasus ohridanus	**LR/lc**

Pachychilon pictum	**LC**
Rutilus basak ohridanus	**LC**
Scardinius erythrophthalmus scardafa	**CR A3e**
Barbatula barbatula sturanyi	**LR/lc**
Padogobius panizzai	**LC**

And finally, using IUCN red list categorization and relative importance of Skadar Lake system area (comparing with whole living area), following fish species are the most important from a biodiversity point of view:

1. *Salmothymus obtusirostris zetensis*, inhabits deep slow parts (pools) of Zeta and Morača River in their lower parts of flow. Other three subspecies of this complex species live only in Adriatic Basin Rivers Neretva, Krka, Zrmanja and Žrnovnica. The population of this species is very low (it remains in few locations) and decreasing.

2. *Salmo marmoratus*, inhabits fast (rapids) as well as deep slow (pools) parts of Zeta, Morača and Cijevna Rivers and entered Skadar Lake where it was relatively common catch (in nets) during the 1970s and 1980s. This fish inhabits Adriatic Basin Rivers Neretva, Soča and River Po in Italy. The population trend of this fish is decreasing in Morača River and is relatively stable (but low) in rivers Zeta and Cijevna. In last 20 years there was no data of this fish catching in Skadar Lake.

3. *Acipenser sturio*, which entered Skadar Lake for spawning from Adriatic Sea through Bojana River. This fish was really common in Skadar Lake and it was important for fishing activities. As in other Adriatic rivers, the population of this fish dramatically decreased (in last 10-20 years there was no catch of this fish in Skadar Lake) and considering the importance of Skadar lake (the biggest lake in Adriatic region) as spawning place, this fish is on the list of most important species.

4. *Alburnoides bipunctatus ohridanus*, is endemic fish species for Ohrid – Skadar lake system and half of the entire population live in Skadar Lake system.

5. *Chondrostoma nasus ohridanus*, is endemic fish species for Ohrid – Skadar Lake system and half of the entire population live in Skadar Lake system. This fish population dramatically decreased in whole Skadar Lake system in last 20 years (only in river Zeta this fish is still relatively abundant) and is now a rare catch in Skadar Lake although it was significant catch until the 1980s.

6. *Pachychilon pictum* is endemic fish species for Ohrid – Skadar Lake system and half of the entire population live in Skadar Lake system.

7. *Rutilus basak ohridanus* is endemic fish species for Ohrid – Skadar Lake system and half of the entire population live in Skadar Lake system.
8. *Scardinius erythrophthalmus scardafa* is endemic fish species of Adriatic region with disjunction in living area (Italy, Dalmatian rivers, Skadar Lake). The species is critically endangered (by IUCN categorization) but not in Skaadar lake system where almost 1/3 of the entire population live.

9. *Alburnus alburnus alborella* is endemic fish species for Ohrid – Skadar lake system, Neretva and Krka River, almost 1/3 of the entire population live in Skadar lake system. The species is of great importance in fishery, and in Skadar lake Adriatic bleak represent more than half of total annual catch.

2. Commercial fish stock

The fish resource of Skadar Lake represents more than 95 % of total fresh water fishery in Montenegro. By fish production and fish biomass Skadar Lake is far from other karst lakes on Balkan Peninsula. Based on statistical data of annual catch, fish production in Skadar Lake is 80 kg/ha (8000 kg/km^2, data related to Montenegrin part of lake) (Drecun, 1983.). By this level of fish production, Skadar Lake is almost equal to some eutrophic lakes. As well as in other bigger lakes, only restricted number of fish species dominates in normal fish production. Those fish species represent most of the catch in Lake. In Skadar Lake carp (*Cyprinus carpio*) and bleak (*Alburnus alburnus alborella*) represent more than 70% of total catch. *Alosa fallax nilotica*, *Anguilla anguilla*, *Chondrostoma nasus*, *Leuciscus cephalus albus*, *Scardinus erythrophtalamus scardafa*, *Rutilus basak ohridanus*, *Mugil cephalus* are also part of the catch (Table 7.).

Table 7. Most common fish species in Skadar Lake catch

Species – subspecies	English name
Alburnus alburnus alborella	Adriatic bleak
Cyprinus carpio	carp
Alosa fallax nilotica	shad
Anguilla anguilla	eel
Chondrostoma nasus	nase
Mugil cephalus	gray mullet
Leuciscus cephalus albus	chub
Scardinus erythrophtalamus scardafa	rudd
Acipenser nacarii	Adriatic sturgeon
Pachyhilon pictum	moranec

Rutilus basak ohridanus	Adriatic roach
Carassius auratus gibelio (introduced)	prussian carp (introduced)
Perca fluviatilis (introduced)	perch (introduced)
Salmo mormoratus	marble trout
Salmo farioides	Brown trout

In Skadar Lake most of the fish is caught in fishing areas in northwestern parts, in shallow coastal parts, in flooded area and in sublacustric springs (lake "oka"). All fishing efforts are in high concordance with each fish species ecological requirement. Fisheries have already recognized seasonal movement patterns. In spring, most fish move into littoral and flooded zones to spawn (cyprinid fish species). After spawning period, majority of fish move from this flooded and littoral area into the deeper pelagic region of lake, presumably for feeding. With the approach of autumn majority of bleak begin migration to their wintering habitats. During winter large concentration of fish are in wintering habitats, lake "oka" (sublacutstric springs, cryptodepressions) where they spend winter.

The majority of catch is taken with nylon gill nets with different mesh sizes (bleak nets, carp nets, nase nets), with beach seines and with coops. Large beach seines are almost exclusively used for fishing in lake "oka" along lake shore. Gill nets and coops are used for fishing in littoral and pelagic zone of the lake. Usually, heavy exploitation of fish occurs during shoaling period and in places where fish is concentrated. Maximum yield of bleak is during winter in lake "oka" and catch in that period (October – March) represents 76 % of total annual *Alburnus* catch (Stein et al., 1981). Until the 1980s when government proclaimed Skadar Lake a National Park, maximum catch of *Cyprinus* occurred during March – May period (spawning time) in flooded and littoral lake areas where this species spawns.

The precise statistic of catch in Skadar Lake for last 30 years is completely absent but there are relatively confident data for catch in 1947-1976 period. In this period the total catch varies from 353 to 1311 thousands of kg (Figure 5.). The average annual catch for 1953-1962 periods was 1141 tonnes. This numbers should be increased for 10-15 % because there are no data related to other catch than from registered fisherman who worked for public cooperative company. In this 1141 tonnes of annual catch, bleak was 570 tonnes, carp was 230 tonnes, shad around 35 tonnes, eel trout and mullet 25 tonnes, nase (*Chondrostoma*) was 30 tonnes while all other fish species were around 251 tonnes (Figure 4).

Figure 4. Mean proportion of major fish species in total annual catch for period 1947 - 1976

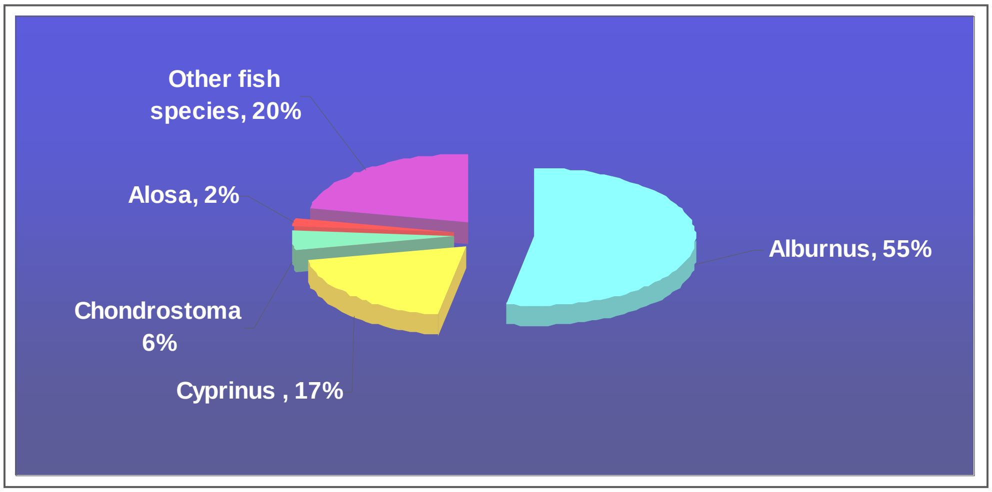
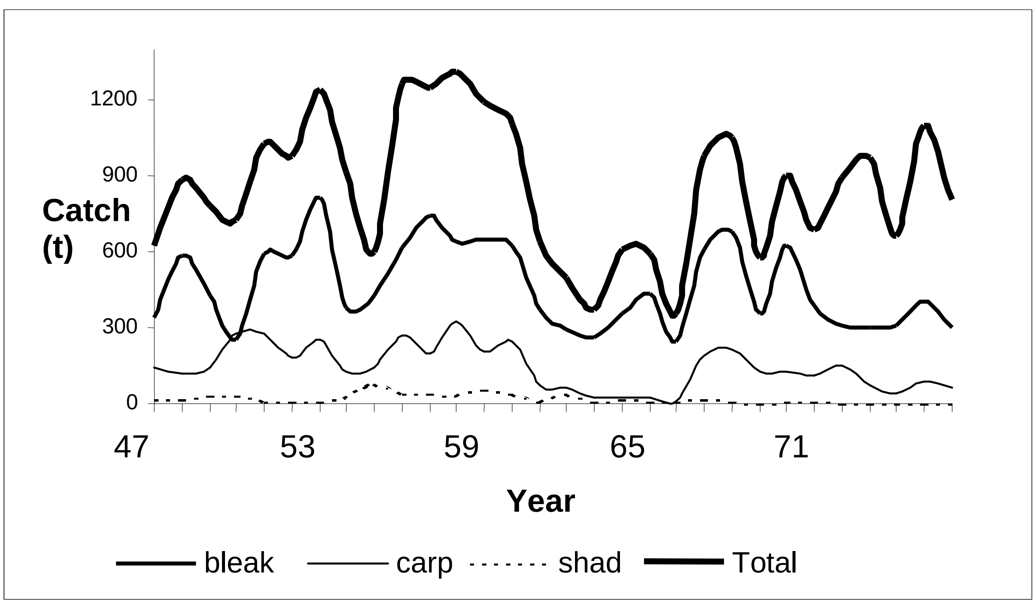


Figure 5. Mean annual catch in Skadar Lake according to Stein et al., 1981.



During the past 50 years not only total amount of catch varied and changed, participation of individual fish species in total catch also shifted. This particularly related to proportional representation of two of four major species (*Alosa fallax nilotica*, *Chondrostoma nasus*) and to proportional representation of minor (in fishery terms) species (*Anguilla*, *Scardinius*, *Mugil*, *Leuciscus*, *Salmo* and *Acipenser*) (Table 8.).

Table 8. Catch of major species (in tonnes) during two periods (1947-1966 and 1967-1976) and change in catch in percentage

Species	**1947-1966 period**	**1967-1976 Period**	**Changes in %**
Chondrostoma	63	12	↓ 81%
Alosa	23	4	↓ 83 %
Anguilla	10	1	↓ 90 %
Mugil	3	1	↓ 66 %
Salmo	2	1	↓ 50%
Acipenser	2	-	↓ 100 %
Leuciscus	3	8	↑ 166 %
Scardinius	8	37	↑ 362 %
Scrap fish (mainly *Rutilus* and *Pachychilon*)	112	238	↑ 112 %

From previous table it is obvious that in second period catch dramatically decreased for migratory species (migration from sea to lake). In 1960, the Albanian government constructed a stationary fish weir to harvest fish migrating up the Bojana River from Adriatic Sea into Lake Skadar. This was the main reason for dramatically decreasing of those species catch in Skadar Lake. Until late 1980's and during 1990's, Albanian government controlled this fish weir. After dramatic socio-political changes in Albania in 1990's until present time, those "gates" mainly remain closed and controlled by local Albanian families without any institutional control and rules. As consequence, the catch of those migratory species remain low and not statistically significant even today. The decreasing of *Chondrostoma* catch is a consequence of this species over fishing. Main catch of this fish was in March-May during spawn when this species migrates to littoral and flooded areas. As a consequence of this change, the catch of fish with lower price, smaller in growth and with lower quality of meat (*Leuciscus*, *Scardinius*, *Rutilus* and *Pachychilon*) dramatically increased.

During 1970's two new (introduced) fish species were noticed for Skadar Lake, prussian carp (*Carassius auratus gibelio*) (Vuković *et al*., 1975.) and perch (*Perca fluviatilis*) (Knežević, 1979.). The population of prussian carp «exploded» during 1980's and 1990's when this fish became a statistically significant part of total catch. Unfortunately, the exact data of this species catch is missing but local fishermen are of the opinion that this fish, now, is third in total annual catch. Even more, some of those fishermen suppose that in 1985-1992 period prussian carp was more numerous than common Skadar lake carp. In present time, the population of prussian carp is stabilized on significant lower level than during 1990's and this fish has taken the place of nase (*Chondrostoma nasus*) or even more, in Skadar lake total annual catch.

The perch now represents the main predatory species in Skadar Lake littoral area. After introduction, this fish species found free ecological niche in Skadar Lake littoral area (before the introduction, only predatory species in Skadar Lake were salmonids and eel). The perch population grows dramatically and nowadays it is one of the most numerous fish species in Lake littoral parts. In the last two decades of 20^{th} century the new species was considered "scrap" fish without strong market demands. That was because perch had never lived in Lake and people preferred to buy and eat domestic species (carp, bleak, chub, rudd, roac, etc.). In last 10 years people have become familiar with perch and have started to consume this species, that produce market demands for this fish. Some presumption is that this fish nowadays take place of shad (*Alosa fallax*) in total Skadar Lake catch.

As we mentioned previously, the data related to total catch for last 25 years is completely absent. This happened due to socio-economic crisis in whole Balkan Peninsula that occurs during last decade of 20^{th} century. In that period the public company "Industriaimport" (a fishing cooperative which were the most important fish buyers) went bankrupt and with this company disappeared the only trustful register of Skadar Lake catch. The cannery "Ribarstvo" in Rijeka Crnojevića survived the dramatic period and it was privatized several years ago. This factory continues with production of smoked carp and bleak cans but in smaller amounts than before. Nowadays this factory mainly produces sardines.

In last 20 years there was no well organized research on fishery issue and no continues monitoring of Skadar lake catch. In this period there were only individual research mainly related to fish taxonomy. During the 1990's fishing activities on Skadar Lake were without any restriction (there was positive legislation related to fishing activities, mesh size, forbidden fishing during spawn period, forbidden fishing tools, etc. but there was almost no implementation of this). In last five years the management of National Park "Skadarsko Jezero" strictly put in use all fishery legislation and rules. They again reestablish fishing licenses (for recreational and professional anglers) and start with controlling and arresting of poachers. But again there is no data related to catch.

At the end of this chapter we make an estimation but only based on previous data and on some hypothesis. Without any doubt we can stress that *Chondrostoma nasus* has become so rare in Skadar Lake that the catch of this species is not statistically significant (comparing to total Lake catch). There is a similar situation with *Alosa fallax*, *Mugil cephalus* and trout. Increasing catch of *Leuciscus*, *Scardinius* and "scrap" fish species is continuous trend and in worst case it stay in detected level from 1976 (Table 8.). Two new species in Skadar

Lake, perch and Prussian carp have become so abundant in last 25 years that they represent the most significant part of total catch in Lake. Those two species have become normal part of offer at fish market places. In last 25 years technology has advanced dramatically so nowadays all fishing tools are better and have better fishing results. The fishermen now have echo-sounders (fish-finders), fast boats or faster motors on their traditional boats, the nets are now made of better nylon and ropes, better artificial bait and better communication, which results in bigger catch for less fishing time. In the last five years tourism has become one of the best national products and we have continuous economic growth in this branch. This is particularly related to Adriatic coast and Skadar Lake and as consequence; now there is ten times more restaurants with Skadar Lake fish (carp, bleak and eel) on their menu. The number of recreational anglers has also increased while number of professional fisherman probably stays on same level or decreased by a maximum 20%. We can presume that 1/3 of fisherman are still not registered (that still angle without license in period of year when there is strong market demand for fish). This happens because of Skadar Lake size and relatively dismembered coast covered with dense vegetation and due to strong fishing tradition in surrounding villages. If we calculated the total fish production (for Montenegrin part of lake with surface of 230 km^2) based on production level of 8 t/km^2 (Drecun, 1983), we would get the total amount of 1840 tonnes of fish annually. We can assume that nowadays total annual catch in Skadar Lake should be around 1953-1979 mean value of near 1000 tonnes of fish, what is still under sustainable yield. More precise estimations and calculations are shown in further parts of this study.

3. Socio-economical activities related to fish as a resource

3.1. Fishing gears used for fishing in Skadar Lake

The population of wide Skadar Lake coastal zone has been oriented to fishing activities from the distant past. Favourable natural conditions of the Lake with the high abundance of the fish have been compensation for relatively unfavourable living circumstances in the surrounding karst hinterland. Towards permanent use of the lake as a wealthy resource of nourishment, the population has, through making of fishing gears and their use, through the manner of fishing and fish storage, and especially through social organization – mainly collective organization of fishing and distribution of catch, developed such forms of fishing which have attained the character of constitutive traditional life and work of people in this area.

The fishing gears that were (and some of them still are) applied in Skadar lake, were made of materials and resources from the natural environment. The zone of emerged and periodically submerged vegetation provides resources for manufacturing various wooden fishing gears and devices. The boats ("čun" - traditional boat) were made from bigger trees while several types of fishing gears were made of elastic brushwood. The oldest fishing gear was coop (basket like fish trap) that was made osier brushwood and branch. The coop was primary used for fishing of bleak. The oldest fishing gear made of iron is harpoon that was primary used for carp fishing especially during spawning period under gas lamps (during the night). Among older fishing gears that were in use until recent times (and some are still in use but made of contemporary materials) the most effective and most common were:

"Vrša" – the pear like coop made of thin osier branch. It has two openings, smaller one for fish entrance and bigger one (with cover) for taking out fish. The length is 1-1,20 m and circumference is 0,50 – 0,60 m. It was primary used for fishing of bleak but also for eel and chub.

"Vršica" – is made of same material as "vrša" but different in size and shape. It is lengthened gear 1m long and 0,30 cm wide and primary used for eel fishing.

"Koš" – one meter long fish tarp with latitude of 0,80 – 0,90 m. It is used for chub and smaller carp fishing.

"Košić" – similar to previous fish trap but with smaller latitude. It is made of thicker osier brunch and used for nase fishing.

"Karić" – smaller square shape net (3 x 3 m) made of flax, cotton, silk or nylon rope. Mesh corner are fixed to opposite and downward curved wooden sticks that are positioned on long rod. This gear is used for fishing of smaller littoral fish as well as for bleak during winter shoaling.

"Kalimera" – the same construction as "karić" but bigger (mesh size is 5 x 5 m). It is fixed fishing tool and the rod perform as winch. This gear is mainly placed in area where fish is shoaling in large mass. This gear is also primary used for bleak fishing.

"Pari" – made of long and strong rope (150m – 200m). On every 1 – 1,5m the lateral rope with hook on the free end are attached. This fishing gear is primary used for eel fishing but the carp also angle on it.

"Ošće" – metal made harpoon with five long sharp prongs from same metal basis. The middle prong called "kalauz" is the longest one. The "ošće" are placed on the 4-5m long wooden rood (handle). This gear is primary used for carp fishing (recently Prussian carp also) during the night (under gas lamp) while carp is spawning in shallow parts of the Lake. By this tool it is easy to catch the biggest carp specimens (5-20 kg).

Big "grib" – the biggest net for bleak fishing. It can be 200-300 m long and 16-20 m high. In the middle part is the biggest and called "vreća" (sack) and it has two "wings" where height of "grib" is 2-3m. It is used for massive catch of bleak and other fish in Lake cryptodepressions (Lake "oka").

Small “grib” – completely similar to big “grib” but smaller in size. It is 150 -200m long with sack height of 10 and “wing” height of 1-2m. It is primarily used for fishing in shallow part of the Lake and for catching of nase but also carp and trout.

Of those fishing gears nowadays are still in use (but made of iron rings, and nylon rope and line) “koš”, “karić”, “kalimera”, “pari”, “ošće”, big and small “grib”.

Beside those tools, different types of fixed nets (which are fixed with lead or stone anchors in pelagic and deeper littoral zone or with ropes attached to trees, bush or stone on shore in shallow littoral and flooded area) were and still are used for fishing. Those nets have their names according to fish species for which they are used. They are mainly same in general size, long 30-80 m and with height of 2-4 m, but different in mesh size. Thus, we have “ukljevna” (bleak) net with mesh size of 16 mm, “skobaljna” (nase) net with mesh size of 38 mm and “krapnjača” (carp) net with mesh size of 65 mm (this net is also used for fishing of trout). In the past those nets were made of flax line, then cotton and silk line (in surrounding villages, silkworm was farmed before World War II and silk line was used for net making) and nowadays those nets are made of nylon line and ropes. There are two types of each net, depending on position in water column, fixed ones which lower rope lies on bottom and floating net which upper rope floats on water surface.

3.2. Fishing of economically important species

Bleak and carp represent more than 70 % of total annual catch (Figure 4.) and together with shad (Alosa fallax) and nase (Chondrostoma nasus) it was more than 80% of total annual catch in Skadar Lake (data for 1947-1979 period). Nowadays shad and nase, as we mentioned before, become really rare catch and they are replaced in total catch with two introduced species, prussian carp (*Carassius auratus gibelio*) and perch (*Perca fluviatilis*).

The fishing season on Skadar Lake lasts almost for whole year but there are some restrictions according to species. Fishing season for bleak is from 31st of October until 15th of March (four and a half months or 135 days of which 30% of the days are unfavourable for fishing so the real number of fishing days is 95), during bleak autumn migration to their wintering habitats and during bleak wintering in Lake “oka” (Lake cryptodepressions) and other deeper part of the lake under strong influence of fresh water with relatively constant temperature. In other part of the year fishing of bleak is forbidden. Carp and all other species fishing season is from 1st of June until 1st of March (fishing of carp and all other fish species is forbidden for three months, March, April and May during spawning period) and season last for 9 months or 270 days. During this period 30% of the days are unfavourable for fishing (heavy rains in autumn and winter followed by strong north wind during autumn, winter and first month of spring). So the real number of fishing days is around 190 days.

Bleak (*Alburnus alburnus alborella*) is dominant fish species in Skadar Lake total catch with participation of 54%. Fishing season runs for 135 days in late autumn and during whole winter. Bleak is mainly fished in Skadar Lake cryptodepressions (alke "oka") Raduš, Karuč, Volač, Ranj. In this period of year bleak forms huge schools in those areas and all Skadar Lake bleak population (or populations, some believes that bleak in Skadar Lake exist in few populations) is wintering in 10-15 huge schools. The most effective way of bleak fishing is by using big "grib" and "kalimera". Big "grib" was dominant fishing tool during past and even now those nets are still in use in some Lake parts. Handling with this net demands participation of 30-200 fishermen (mainly from one village or Lake region) and 5-10 boats. In this operation all anglers have their precise job. One of them, commonly the oldest fisherman with the greatest experience, stands on hump and steers with "grib" positioning. He observes the bleak shoal movement and navigates fishermen in boats in order to put them in best possible position for overtaking as much as possible. He decides when bleak school is most dense and in center of fishing area and gives the command for "grib" to be dropped in water. In this moment, as fast as it is possible, fishermen in boats surround the bleak school in a semicircle (first from the side where fish can easily escape). While "grib" (the upper ridge) is attached to boats prows the fisherman on the shore starts pulling out of "grib" and overtaking bleak from bottom. Then, the boats approach the shore and whole "grib" is pulled out (upper and bottom ridge) with bigger part of bleak school. By this tool it is possible to catch up to 50 tonnes of bleak in one pulling (Lopičić, 1931), but standard catch was 5-20 tonnes of bleak depending on fishermen's agility and bleak school size.

Bleak Fishing with "kalimera" gear is characteristic for cryptodepressions but yet for estuariess of lake tributaries (streams and rivers), their banks and for entering region of lake bays and inlets. Big fixed "kalimera" (30 m x 30 m net size) are placed on bank of Lake "oka" Raduš and Karuč while for fishing in other lake habitats it is used smaller movable "kalimera" (up to 5 m x 5m net size). Fishing with "kalimera" tool performs during day and night but the best catch is during high water level with muddy water. Small movable "kalimera" are placed in water for 1-3 hours and then "kalimera" is pulled out catching the fish that are on top of the net. With this small "kalimera", on well-selected fishing place, it is possible to catch 400-500 kg of bleak (and some other "scrap" species) for one night of fishing. Principle of fishing with big "kalimera" is the same except that this tool is fixed and instead of man power electrical motors are used. This gear is used for day as well as for night fishing. The "kalimera" net spends a few hours in water and is then pulled out catching all bleak above. In one catch it is usual to take 0,5 - 4 tonnes of bleak (and some small "scrap" fish, small carps and perch which represent 30% of catch) but the catch can be up to 10 tonnes in one fishing. This gear is related to industrial fishing in Skadar "oka" (Raduš, Karuč) only.

Bleak is also caught with "ukljevna" (bleak) gill net with mesh size of 16 mm in diameter. Traditional boats "čun" are used for positioning of bleak gill net. The net is left for whole night in water. In morning net is taken out with catch in it, but also net can be checked and cleaned out of fish several times per night. This bleak gill net can be floating and used for fishing of bleak in places where bleak masses (deeper coastal water) or in pelagic lake parts. The so-called "standing" gill net is used for fishing of bleak in shallow littoral parts, in streams and river estuaries and in flooded areas among osier trees. Almost all professional anglers from Skadar lake use these kind of nets as a dominant fishing gear for bleak fishing. The catch with those nets depends on net size and angler experience and, for net long 80 m and 2 m height, it can be up to 100 kg per night but the average catch is about 20 kg per night.

Sport and recreational fisherman also fish bleak as one of their favorite catch. They use long rods with nylon line, several hooks (5-10) and float in order to position the hooks with bait in middle part of water column. For bait they use live worms (fly worm) and on every hook they attached one worm. Sport and recreational fisherman mainly angle in shallow coastal Lake zone, in deeper coastal zone or in lake "oka". For one day of fishing (eight hours) they can easily catch up to 15 kg of bleak, especially during winter. Someone also use small artificial fly for bleak fishing but this bait is not so efficient as live worms.

Carp (*Cyprinus carpio*) is second dominant fish species in Skadar lake total catch (17 % of total catch, mean value around 200 tonnes per year). The fishing season for carp runs from 1^{st} of June until 1^{st} of March (270 days). In the past the main gear for carp fishing was "osti" (harpoon). During spawning period, carp migrate in to shallow flooded areas. This gear is used by night, one fisherman drives boat and other stand on prow, where is gas lamp, handling with harpoon. Gas lamp illuminate water in front of boat so the fisherman in front can sea carps in water. When he noticed the fish he throws "osti" in order to stab a gear in fish. This is the most effective way of carp fishing. Two anglers, for one night during carp spawning period, can catch up to 100 kg of carp. This gear is forbidden in last 30 years but because of facts that this was traditional way of fishing for centuries, because this is most effective way of fishing of big carps (3 -20 kg of weight) and thanks to Scadar lake littoral and flooded areas which are wide and complex system, this fishing mode still exist on Skadar lake. It is hard to say how much carp, anglers still is caught by this gear, but on annual level this percent shouldn't be les than 20 %.

The main gear of professional Skadar lake fisherman, for carp fishing, is "krapnjača" (carp) gill net. Like for other nets, this net type is different in general size (different in length and height) but the mesh size is standard - 65 mm in diameter. Carp gill net is mainly "standing" type and used for shallow coastal region, for rivers and streams estuarys, entering in Lake bays and inlets and for flooded areas. The net is mainly positioning in dusk and taking out in dawn but it can be used during the daylight also. The main catch occurs during wintering migration of carps in to spawning habitats and during their way back to summering habitats. The fishermen put the nets different places in order to locks fish passages during carp seasonal or diurnal migrations. Main fishing areas for carp are northern, north eastern and eastern coastal zone of Skadar lake. The nets are not so selective so fishermen catch both, small and big fish. The catch varies according to their size and angler experience. During winter, by this gear, the fisherman can catch up to 20 kg of carp per night per one net, but the average catch is about 2 kg of carp per one net per night of fishing. Skadar lake fishermen generally have 2-4 carp gill nets so the average catch of carp is about 5 kg. During summer, when carp is in deeper part of Skadar lake with colder water, fisherman pose the carp gill nets in pelagic central part of the lake but the fishing is not so effective like in winter part of fishing season.

Professional fisherman on Skadar Lake also fish carp using of "pari" fishing gear (long rope line with 50-100 hooks attached on it with lateral nylon line). "Pari" are putted down on bottom (with stone anchors on both ends) during the night. For bait fishermen attach live lake snail (*Limnea sp.*) without of shell. In the morning they pull out "pari" with carps (and eels) which are caught on hooks during the night. This is not so effective gear for carp but it contributes with 10 % in total carp catch.

Carp is the most attractive species for sport fishermen. They fished carp in both, deep and shallow waters, near stream and rivers estuaries, in cryptodepressions (Lake "oka") and around lake isles. For carp fishing they use rood with nylon line and hook. For bait they use corn seed or ball of paste with artificial smell and taste which is made for carp fishing (so called "boil" bait). The hook is weighted with small lead parts so the bait is on the bottom. In the fishing area, before fishing, fishermen drop cooked corn in order to attract the carps. Every fisherman has 3-5 roods (average) and for one night of fishing it is normal to catch 3 kg of carp (mainly 0,5-1,5 kg of weight).

The introduced species which is very abundant in Skadar Lake, Prussian carp (*Carassius auratus gibelio*), is fished using the same fishing gears and in the same habitats as «normal» carp (*Cyprinus carpio*).

Perch (*Perca fluviatillis*) is fished in shallow littoral parts along whole Skadar lake coast. The main fishing gear for perch fishing are gill nets (usually 38 mm mesh size) which are placed among littoral vegetation during night but also it can be used during daylight. The perch is also caught using of "pari" with fish parts, worms or meet parts on hooks as bait.

Sport fisherman fish perch with root, nylon line and hook. They use the same bait as professionals use for "pari" and they fish perch in coastal littoral part of the lake, in rivers and streams estuary and in cryptodepressions. One sport fisherman can easily fish up to 10 kg of perch per one day of fishing.

3.3. Estimation of number of families living out of fishing

The total number of people that lives on Skadar Lake coast or in Lake hinterland and who are versed to Skadar Lake resources is not more than 8000 people. Those people mainly live in small coastal villages, in one urban center (Rijeka Crnojevića) and one bigger village in Skadar Lake hinterland (Golubovci). Through history those people were mainly oriented to animal farming (mainly ships, goats and cows for their own needs mainly) and to agriculture and fishing (for producing of excesses and selling them on market).

Jovićević (1928) stressed that in 1928 in area of Ceklin (north-eastern part of Skadar Lake coast) there were 1200 fishermen/shareholders in their fishermen's association. In those years the fishery on Lake was organized in territorial manner so all coastal territories such are Ceklin, Ljubotin, Dupilo and others, hade their fishing territories, well organized collective fishing, strong rules for catch sharing and strong rules for sharing of time and space for fishing. In order to have as mush reliable fish selling as it is possible (and also bleak scale selling; in those years in Rijeka Crnojevica it woks French factory for production of artificial pearls made of bleak scale – "*essence d'Orient*") the fisherman from Ceklin territory were organized in association. Jovićević (1928) estimated that in 1928th production of bleak scale exceeded 20 000 kg. Lopičić (1928) written that in this year fishermen from Ceklin association produce 6 000 kg of bleak scale. From those data it is easy to estimate that in those years (30's of 20th century) there were at least 3000 fisherman on Skadar Lake who somehow (directly or indirectly) depends on fishing. This implies that almost all families that lived in Skadar lake coast or nearest hinterland depended on fishing in some part of the year.

After the World War II the complete socio-economical climate in Montenegro has changed. This was the time of intensive industrialization and strong migration of population from villages in to the towns. The cities of Podgorcia, Cetinje and Bar (which are closest to Skadar lake) were intensively populated with people from Skadar lake region. Those people found jobs in cities and they leaved fishing as a profession or mode for relatively sure and fast way for money earning. But beside those transitions fishing still was present as a profession on Skadar lake. In 1967th government of the Republic of Montenegro establish complete control under Skadar lake fishing as government fishery. Because of possibility for secured and guaranteed catch sell, private fishermen were attracted to fishing cooperative and fishery grows. In 1967th the number of fulltime fishermen was 590, in 1972nd this number increases to maximal 666 of fulltime fishermen and by the end of 70's this number varies between 450-500 (Stein et al., 1981). Even in this period there were fisherman who didn't wish to become a part of government fishery (fluctuation in number of full-time fishermen), and who still sold their catch in marketplaces, directly to people, or to restaurants. According to this data, we can give the estimation that during 60's, 70's and 80's at least 500 families directly depend on fishing in Skadar lake.

During Balkan crisis in 90's there were no data or registry related to number of fisherman on Skadar lake. In those years a majority of people were with almost no financial incomes from factories, companies and public sector they worked for. People which origins are from Skadar lake region turned to fishery in order to supply theirs families with fresh fish proteins or to earn some money from fish selling on market places or to restaurants. This particularly happened during high market demand for fish in winter months (November and December) during orthodox families celebrations. As we mentioned before, in last five years, management of National Park "Skadar Lake", re-established control under Skadar lake fishery and start with fishing license selling. By annual financial report of NP "Skadar Lake" for years of 2005th and 2006th we have some clue about the number of fisherman who are full-time fisherman on Skadar lake (Table 9.)

Table 9. Number of fishermen on Skadar Lake according to NP "Skadar Lake" management annual report (2005th and 2006th)

Catgory	**number of licence in 2005th**	**number of licence in 2006th**
Economic fishing of all kind of fish	171	165
Economic fishing of eel	29	7
Economic fishing of bleak	10	11
Economic fishing with "pari" tool	14	11
TOTAL	**224**	**194**
Number of annual licence for sport fishing	273	391
Number of fisherman who were caught in economic fishing without license	25	109

* The requested report from SLNP for 2007th was not ready before submission of this part of the report

** The requested exact price of permission (for economic and sport fishing) as well as price of concession for industrial catch of bleak was not in the report from NPSL

By this data (Table 9.) the number of full-time fisherman on Skadar Lake is about 200, but still there are fishermen who are not in any kind of register. Some of them were caught during their activities without licence (in 2005, 25 of them; in 2006, 109 of them, Table 9.) but the others escape or avoid the Lake guards. They remains their gears and guards confiscated 1 368 nets, 16 coops and 2 400 "pari" in 2005 and 1 483 nets, 10 coops and 50 "pari" in 2006.

All those data shows that still significant number of fishermen angle without any permissions. Even more, during high market demand for fish (carp and bleak) when fish price is highest (during winter months November and December) there is strong fishing pressure on Skadar Lake fish stock with all kind of tools. In this period, some significant number of people who lives in Skadar Lake area, deal with fishing, fish processing and fish selling. Due to fact that fish market is still under minor control (fish origin, way of fishing of sold fish, etc.) the full-time and periodical fisherman have no problem with fish sallying. We can estimate that 1/3 of fisherman is still under no control and out of any kind of register. All this bring as to estimate number of 300 fishermen who totally or mainly depends on fishing in Skadar Lake. This give as possibility to conclude, with high level of confidence, that in Skadar Lake region at least 300 families (250 families depending on private fishing and fish selling and 50 families depending through working in "Ribarstvo" cannery and in Raduš and Karuč fishing concessions) economically depend on Skadar lake stock. The number of families who indirectly depend on Skadar Lake fishing (restaurants, fish processing, periodically fishermen, etc.) is hard to determine but this number is, with no doubt, around the same number as for families who directly depend on fishing in Skadar Lake. Finally we can give estimation that total number of families who directly or indirectly depend on Skadar Lake fish stock is about 600.

3.4. Estimation of generated income for fisherman families

The Skadar lake fisherman weren't willing to give us an answer on questionnaire related to their annual catch. Probably they were afraid of establishment of annual government tax (they are now fishing without paying of any tax to government, selling of fish is still in "grey" zone of economy without any taxes) for their fishing activities. The ones, who were willing to answer, gave us completely unusable and unbelievable data. If calculate those data, the fishing on Skadar Lake is completely unsustainable activates that only cover fisherman expenses for fishing gear and fuel purchasing, almost without any significant profit.

Because of this we are forced to do some estimation in order to have any clue about total catch per fisherman per year. First we will present the calculation of total fisherman catch per species per year. In this calculation we'll use data for number of fishing days, average catch with most common gear and number of estimated fishermen on Skadar Lake.

The fishing season for bleak last four and a half months (from 31st of October until 15th of March) or 135 days. In this late autumn and winter period we'll calculate that there is 30 % days which are not favourable for fishing, what bring us to number of 95 days that are favourable for fishing of bleak. The main fishing gear for bleak is "bleak" gill net. The average catch with this gear for one day of fishing is 20 kg of fish. The total estimated number of fishermen on Skadar Lake is 300 and for handling of bleak gill net one or two fishermen is needed. All this gives further calculations of lowest annual catch of bleak:

(**95** of fishing days) x (**20 kg** average daily catch) x (**150 fishermen**, two fishermen for one fishing) = **285 000 kg** of fish per season

If we take the other calculation, if we made a presumption that one fisherman take help of somebody from his family to drive a boat while he pose the bleak gill net or he can do it alone (the experienced ones), we'll get this number of highest catch:

(**95** of fishing days) x (**20 kg** average daily catch) x (**300 fishermen**, one fisherman for one fishing) = **570 000 kg** of fish per season

The mean value (the estimated catch range from 285 000 kg to 570 000 kg) is **427 500 kg** of fish using of bleak gill nets on annual level. The bleak gill net catch not only the bleak, they catch all other smaller fish species which are in the same habitats as bleak (mainly "scrap" fish). If we presume that 30 % of fish is other species (not bleak), the total annual catch of bleak by Skadar lake fishermen is **299 250 kg** (300 tonnes of bleak). This further means that one fisherman for one season catches almost **1 000 kg** (**997,5 kg**) of bleak or **10,5 kg** of bleak per one fishing day.

Carp fishing season last for 9 months, from 1st of June until 1st of March, or 270 days. If we calculated that there is 30 % of days which are not favorable for fishing, we'll get number of 190 fishing days for carp fishing. The main (legal) fishing gear for carp is "carp" gill net. The average catch with this gear for one day of fishing is 7 kg of fish. The total estimated number of fisherman on Skadar lake is 300 and for handling of carp gill net, one or two fishermen is needed. All this gives further calculations of lowest annual catch of carp:

(**190** of fishing days) x (**5 kg** average daily catch) x (**150** fisherman, two fisherman for one fishing) = **142 500 kg** of fish

If we take the other calculation, if we made a presumption that one fisherman take help of somebody from his family to drive a boat while he pose the bleak gill net or he can do it alone (the experienced ones), we'll get this number of highest catch:

(**190** of fishing days) x (**5 kg** average daily catch) x (**300** fisherman, one fisherman for one fishing) = **285 000 kg** of fish per season

The mean value (the estimated catch range from 142 500 to 285 000 kg) is **213 750 kg** of fish using of carp gill nets on annual level. The carp gill net has biggest mesh size (64 mm) of all nets that are used in Skadar lake fishery. This net is highly selective for smaller fish so only species which have bigger growth (prussian carp, bigger perch, bigger chub and bigger shad) can be netted. Some estimation is that 10 % of fish in carp gill net is other than carp so the total annual catch of carp (by carp gill net) is **192 375 kg**. This further means that one fisherman for one season catches **641,25 kg** of carp or **3,4 kg** of carp per one fishing day.

Bleak and carp represent 70 % of total catch in Skadar Lake. Catch of other species is hard to estimate, especially catch of eel (the most expensive fish species from Skadar Lake which price is 12 € - 15 € / kg). Perch, prussian carp, chub and "scrap" species are near 30 % of catch but the present exact numbers and proportions are completely unknown (there are statistical data related to previous period 1956-1976). So, we'll do the estimation of total weight according to fact that this species represent 30 % of catch.

The price of carp varies due to period of the year and due to the size of the fish. Smaller carps (1-3 kg of weight) have price 3-5 € and bigger ones vary between 5-10 €. Fresh bleak price varies between 1 and 3 € per kg. Price of both species increases with processing (smoked fish). Price of smoked bleak is 5 € per kilogram and price of smoked carp varies from 10 to 18 € per kilo (in November and December during orthodox family celebrations). Smoked fish lose up to 40% of weight (water evaporation) and the price calculation is obvious. Because of bleak massive fishing there is strong need for processing (in order to preserve fish meat) and 70 % of catch is smoked. This percentage is lower for carp and about 30 % of total catch is smoked. The average annual financial income of fisherman (bleak and carp) is sown in table 10.

Table 10. The average annual financial income per fisherman

	Bleak		Carp	
Total catch/year [kg]	1000		641	
	Fresh	**smoked**	**Fresh**	**smoked**
weight [kg]	300	420*	448	115**
average price [€]	2	5	5	13
income [€]	600	2100	2240	1495
Subtotal [€]	**2700**		**3735**	
Total [€]	**6435**			

* 70 % of total catch is 700 kg and smoked fish lose 40% of weight (water); **30 % of total catch is 192 kg and smoked fish lose 40% weight (water)

Because of small "scrap" and other fish price, 1-2 €/kg, and extremely low market demand (unsafe selling of fish) we didn't calculate the additional amount of 600 kg of other fish. The total average annual income of fisherman is about **6400 €**. The average income per family depends on number of anglers in family but mainly there is one professional (full-time) fisherman in one family.

3.5. Estimation of generated income of the sold fisherman licenses

In further chapter will be cited the official data from Montenegro National Parks financial report (National Park Skadar Lake). The data for 2005 and 2006 financial year follows in next table (Table 11.).

Table 11. Official data of financial income based on sold licences for economical, industrial and sport fishing (2005 and 2006)

	2005	**2006**
Income by fishing licence (sport and economical) [€]	53 967	59 090
Income by concession for bleak harvest (Industrial fish in lake "oka") [€]	18 448	26 800
Total [€]	**72 415**	**85 890**

In 2005 total income by licence for Skadar Lake fish stock usage was 72415 € while in 2005 it was 85890 €. Public company "National Parks of Montenegro,- Skadar Lake National Park" collect money from fishing licences.

4. Habitat changing and fish

4.1. Ecological needs of all fish species

All fish, regardless of species, have similar basic ecological needs. First is water and second is available food. Precise ecological needs, however, vary according to species. For instance combination of water temperature, water speed, dissolved oxygen in water and water habitats dominantly define species that inhabits particular water ecosystems. Organisms (phytoplankton, zooplankton, algae, plants, worms, mollusks, crustaceans, insects, amphibians, reptiles, birds and mammals) together with fish, form complex feeding chains and they interact constantly. Environmental parameters define available food in some ecosystems and different fish use different food items (they have different position in food chain) or, if they use similar food, they are feeding at different times of day.

For instance, ecological needs of brown trout and carp are completely different but this doesn't mean that those two species can't be found in same water (this is particularly important for big specimens). Brown trout inhabits clear, fast water with high amount of oxygen which temperature never goes over 21^{o}C. The waters with those characteristics mainly exist in upper river region, but regarding to Morača River, such conditions exist in whole course except in lowest part in middle of summer. Those conditions determine the other organisms that inhabit that water so the trout food item is also determined by the environmental parameters. As predatory species, trout eats almost all animals from river, mainly insects (flies, midges and larva that live on bottom) and fish (bigger trout prey on bigger fish) but also worms, crustaceans (especially amphipods) and amphibians. As for all other fish species the most important happening in trout life is spawning period. In this period different fish species use different habitats in different parts of year as their spawning ground (the fish have external fertilization and they pose eggs on gravel, rocks, underwater vegetation or they leave fertilized eggs in free pelagic water layer). The trout pose eggs on gravel river bottom, mainly near river banks (depending on rivers) in upper part of river course. Some trout completely change their original habitats during spawning period, they migrate upstream (similar migrations like salmon does) in order to reach spawning ground. As individual predatory species, they spend solitary life, but during spawn they gather in spawning areas. After spawn they either migrate downstream or stay in spawning areas.

Carp for instance can live in muddy waters with almost no oxygen dissolved in it. This species has special tissue adaptation in upper wall of mouth that allows this species to use oxygen from air. During summer months, carps are near water surface (or they frequently move to surface), they emerge their mouths and it looks like they are swallowing the air. Carp prefer lake water habitat or slow moving, deep river waters. This is not a fish of fast water courses. As omnivore species with big growth, carp eat everything that they can find in their habitats. They mainly feed from bottom and in different times of year they use different food items. For Skadar lake carp, Janković (1981) points out that during winter months diet consisted of Entomostraca (crustaceans), Chironomidae (worms), plant seeds as well as other insects and their water larva. In spring, diet mainly consists of clams, snails, plant fragments and variety of other water organisms while in summer main food items were snails and plants (Janković, 1981). Spawning for carp, as for other fish species, is central happening and it happens during April and May (some small percentage of individuals spawn yet in March while other small percentage of individuals spawn during late May and June). For spawn and eggs development ideal temperature range from 15,5-20.0^{o}C (Janković, 1981). As trout and almost all other fish species, carp for spawning use different habitats than for living. In late spring they undertake migrations from deeper lake water habitats in to the shallow flooded areas that are overgrown by macrophytic vegetation. In those temporary habitats they gather in massive groups, they spawn and leave fertilized eggs on submersed vegetation. After spawn they back in to the lake habitats while some stay captured in pools and small lakes waiting for next flood.

During individual development (growing) fish also change their ecological preferences and as they grow they change habits, food and living place. In first days they still use yolk as a food, fish larva stay covered among vegetation or rocks in, as far as it is possible, calm water mass. For trout this means that their larvae live near river banks and in pools, hiding among vegetation or among tree branches caught in stones or river bank. Carp larvae remain on spawning places hiding among dense submersed vegetation. As fish larva become small juvenile individuals, they change habitat and start with feeding but first on smallest food items. For most fish this first food is similar and mainly contains zooplankton (mainly plankton crustaceans), microscopic benthic animals which livs on stone, gravel, mud and plants (mainly rotatoria) and microscopic benthic algae (mainly Bacillariophyta and Chlorophytae) that lives on same places as previous animal group. For trout this means that juveniles start with active moving, enter in faster river parts and start feeding on small benthic animals. With growing, juveniles gradually take over ecological niches of adults and start eating the same food items but smaller in size. The carp juveniles move toward lake banks and stay in shallow littoral parts among dense vegetation and start feeding on zooplankton, benthic and epiphyte algae. Growing juveniles move into deeper Lake parts and as they move they start feeding on same diet as adults and take over their characteristic ecological niche.

The general conclusion is that fish undertake two types of habitat changes (changing of ecological needs). The first is irreversible and occurs during individual development (eggs → larva → juvenile → adult) and second type is cyclic (reversible), characteristic for adults (mature fish) and happens every year during spawning period.

4.2. Influence of water regime fluctuation on commercial fish stock

The karst rivers and lake systems are characterized by high fluctuation in river flow during year seasons so the fish species are already evolved in direction to minimize this negative impact (otherwise they will become extinct). Since the water-flow of Morača River and Skadar Lake level are in high correlation (60 % of Lake water enters from Morača River) building of dams and hydro plants (4 of them) on Morača River middle and upper course will for sure have effects on Morača and Skadar Lake water regime. Fluctuations in Skadar Lake generally shouldn't affect adult part of fish stock but the changing water regime during carp spawning period can have a strong negative impact on carp population in the Lake. If Skadar Lake water level is significantly lower than usual for period of year in April and May the food could be much lower and smaller surface of land will be covered with water. This will reduce carp spawning area and as consequence the carp population will decrease in few years. It could be an even more dramatic scenario if Skadar Lake level dramatically decreased in middle of spawning period, which could destroy the majority of next generation. As bleak use exclusively lake habitats (mainly pelagic or free water mass in littoral) the eventual negative influence on this commercial species shouldn't be as high as for carp. There will be almost no direct negative influences but if some basic chemical water parameter changed value this could have effects on bleak. With changing of whole system the Lake production can alternate and populations of all fish will be affected (some negatively and some positively).

With modification of almost whole Morača River middle part this ecosystem will be changed in essence. The annual water level fluctuations will be changed and stabilized on new high level (by this plan only small parts between artificial lakes will be in original shape). This will submerge almost all trout spawning area in Morača middle course and in Mala rijeka, Sjecernica and Mrtvica River. Beside brown trout, this will especially affect the Adriatic basin endemic marble trout (*Salmo marmoratus*) that doesn't inhabit upper course of Morača River. The whole karst river ecosystem (in this part of Morača) will be changed in to lake ecosystem characterized by relative cold (except surface layer, temperature of deeper layers shouldn't goes over 20^{o}C) and rich in oxygen waters. By default this water condition is excellent for trout species but their spawning areas will be deep on lakes bottom and without constructing of spawning places and spawning of wild fish the brown and marble trout populations will decrease.

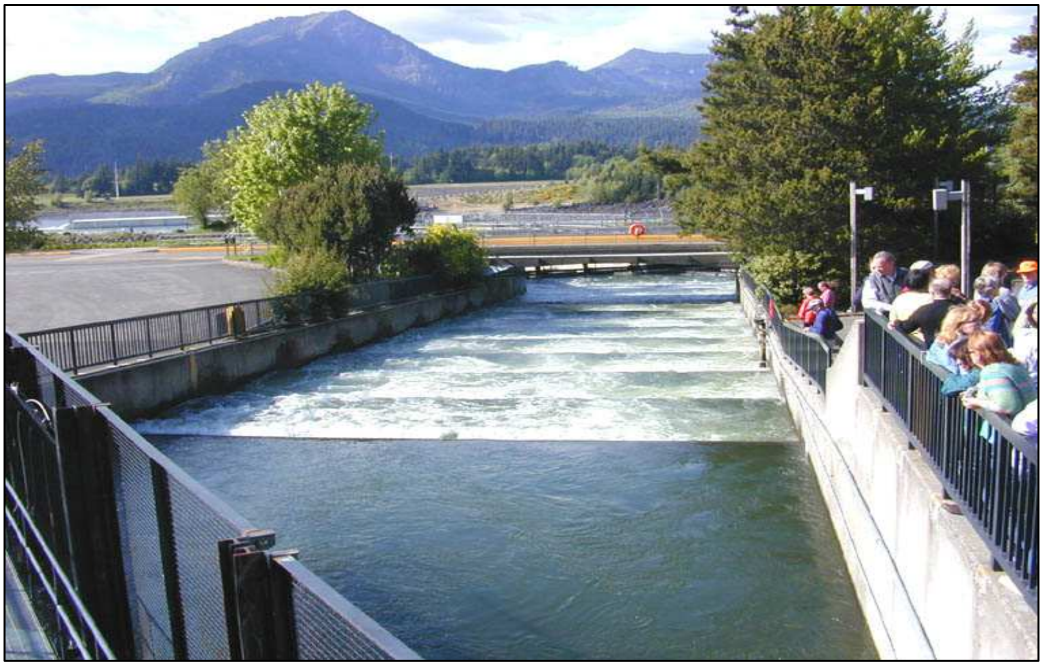
Dams and hydro-plants will alter normal fish migrations during year (mainly upstream in spring and downstream in autumn). Even with building of fish passages, fish leaders and fish passes those migrations will be significantly lower in number so this will have direct negative effect on almost all fish species. The other thing that could also have negative effect on fish downstream of hydro-plants is low water level during spawn or during summer months. By regulation of water outlet on last dam (correlate water outlet with average Morača flow for selected "hot" period) it would be easy to minimize this impact.

4.3. Recommendation for dams construction in terms of fish passes to maintain river connectivity

Building of 4 dams (hydro-plants) on Morača River will disturb normal life cycle of fish. Dams will stop upstream and downstream migrations of fish which occurs every year (spring and autumn). In Morača river system not only salmonid species migrate, cyprinid species also have similar behaviour. In spring they migrate upstream of the Morača River in middle and even in upper part of Morača. All those migrations will stop if dam constructors do not include measurements for negative impact minimization. Without any doubt there is no way to maintain previous connectivity but there are some measures that can help to minimize this effect.

Constructing of fish-ways together with dams should be an obligatory request from future dam investors. Those fish-ways are also known as fish ladders and represent structures on or around artificial barriers (such as dams and weirs) to facilitate fish natural migration. Most fish-ways enable fish to pass around the barriers by swimming and leaping up a series of relatively low steps (hence the term ladder) into the waters on the other side. The velocity of water falling over the steps has to be great enough to attract the fish to the ladder, but it cannot be so great that it washes fish back downstream or exhausts them to the point of inability to continue their journey upriver.

Figure 6. Bonneville fish ladder (Bonneville dam on Columbia River, USA)



Fish ladders are very effective and relatively old device mentioned for first time in France during 17th century. One version of fish ladder was patented in 1837 by Richard McFarlan from Bathurst, New Brunswick who designed a fish-way to bypass dam at his water-powered lumber mill. There are five main types of fishways: Rock-ramp fishway, Pool and weir, Vertical-slot fish passage, Baffle fishway and Fish elevator.

Rock-ramp fishway uses large rocks and timbers to create pools and small falls that mimic natural structures. Because of the length of the channel needed for the ladder, such structures are most appropriate for relatively short barriers.

Pool and weir is one of the oldest styles of fish ladders. It uses a series of small dams and pools of regular length to create a long, sloping channel for fish to travel around the obstruction. The channel acts as a fixed lock to gradually step down the water level; to head upstream, fish must jump over from box to box in the ladder.

Figure 7. Pool and weir fish ladders (at Berrien Springs Dam, St. Joseph River, Berrien County, USA)

Vertical-slot fish passage is similar to a pool-and-weir system, except that each "dam" has a narrow slot in it near the channel wall. This allows fish to swim upstream without leaping over an obstacle. Vertical-slot fish passages also tend to handle reasonably well the seasonal fluctuation in water levels on each side of the barrier.

Baffle fishway uses a series of symmetrical close-spaced baffles in a channel to redirect the flow of water, allowing fish to swim around the barrier. Baffle fishways need not have resting areas, although pools can be included to provide a resting area or to reduce the velocity of the flow. Such fishways can be built with switchbacks to minimize the space needed for their construction. Baffles come in variety of designs. The original design for a Denil fishway was developed in 1909 by a Belgian scientist, G. Denil; it has since been adjusted and adapted in many ways. The Alaskan Steeppass, for example, is a modular prefabricated Denil-fishway variant originally designed for remote areas of Alaska.

Fish elevator or **fish lift**, as its name implies, breaks with the ladder design by providing a sort of elevator to carry fish over a barrier. It is well suited to tall barriers. With a fish elevator, fish swim into a collection area at the base of the obstruction. When enough fish accumulate in the collection area, they are nudged into a hopper that carries them into a flume that empties into the river above the barrier.

Figure 8. Salmon fish-ladder at Capilano River Regional Park, Canada

Which type of fish ladders is the best solution for dams on Morača River (in terms of distances, elevations, canyon type and dam spacing) is difficult to define without precise dams constructing plans. There is strong need for hydrologist and construction engineer to work together, in order to define type of fish ladders and in order to put the most suitable solution in construction plan. Only by doing this is it guaranteed that those fish passages will be incorporated in dam project with the best possible results for fish fauna and for river connectivity, for this concrete water flow. After production and reading of hydrological study, it will be easier to define the type of fish passages, but the construction and implementation of precise fish ladders (for each dam) have to be done together with hydrologist and dam constructors. In final ichthyological study, depending on hydrological study, more precise data and estimations will be stressed.

5. Potential impact of dams on the ichthyofauna of Moraca River and Skadar Lake

In this chapter we will try to explain how dams, which are planned on Morača River, can impact on fish fauna of the whole Morača – Skadar Lake system. First of all we have to divide the whole System into two subunits because one part (**Morača river-flow**) will be faced with direct impact while the other unit (**Skadar Lake**) will confront an indirect impact.

Here we wish to emphasize, without any doubt that all changes will impact on fish fauna. There is no need to be an expert on biological and environmental issues to understand this. The dams that are planned for Morača river will change the natural water level fluctuation in both parts, in river flow and in Skadar lake. It is natural that all water habitat species adapt to natural water level fluctuation and will be affected by any change in the natural dynamics of water ecosystems. Logically, if something is changed in the ecosystem, the components of this system will react. Those reactions should be channelled towards minimizing change and reestablishing a new balance in the ecosystem. As the water environment is a restricted living area, changes in water mass will produce changes in fish populations and communities. For example, if some water flow or lake "supports" a certain biomass of fish (restricted food resource and restricted space in water mass as a resource), the dwindling of water-mass will produce declining fish bio-mass.

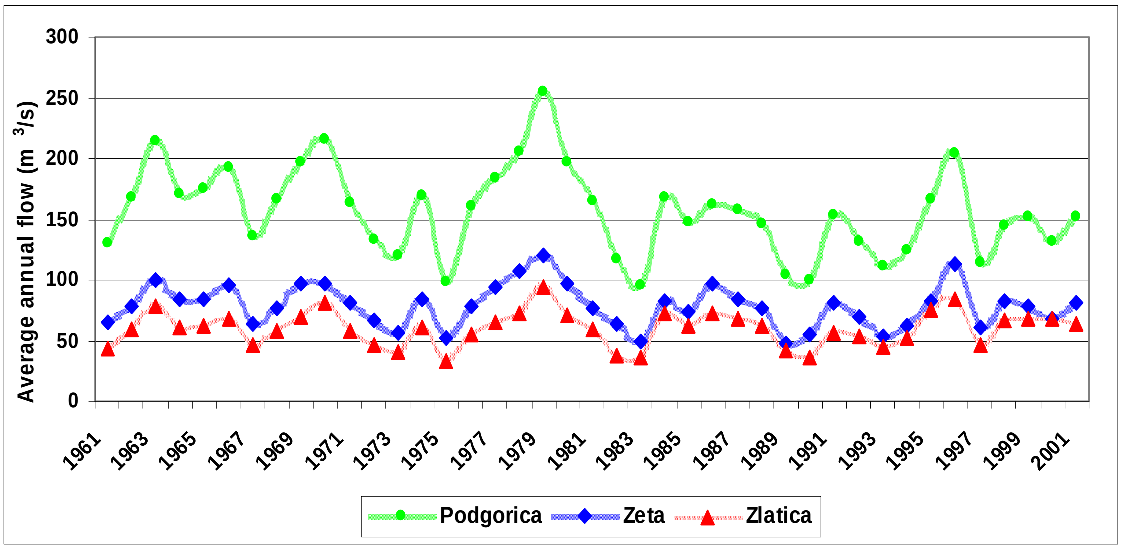
Possible impacts should be analysed through two groups. First will be the direct impact on fish populations and communities and second as indirect impacts on fish populations and communities.

Morača river flow – As dams are planned in the middle part of Morača river (the first will be at the beginning of the canyon „Platije" while the last one before the city of Podgorica) the whole river-flow will be transformed in three relatively separate parts. The upper part of Morača river will preserve its present and natural shape and this part, in an environmental sense, will have almost no impact as a result of dam building. This means that this upper part of Morača will not "suffer" from changes to the natural water level fluctuation and other related environmental parameters. Related to this, there will be no indirect impacts on fish fauna in this area, no changes in environmental parameters, no changes of water habitats. But fish populations, in this part, will be affected by direct impacts. Namely, the upper part of Morača river (and her tributaries, Mrtvica, Sjevernica, Ibrištica) is a spawning region for at least two trout species, brown and marble trout. The dams will be an impassable barrier for them unless fish-stairs are installed. This further means that natural and annual migration of fish, as described in previous chapters, will be reduced despite the installation of fish-stairs. The number of trout individuals, which in spring and early summer migrate to the upper parts of the river following small cyprinid fish and their own natural instinct, in the spawning period will dramatically decrease and the whole trout population (brown and marble trout) of this part will predominantly depend on fish stock which stay "captured" in this upper part of the flow. A new situation will affect on small cyprinids on similar way because those fish also undertake upstream migration during spring time. Dams will dramatically reduce the number of migrants and cyprinid populations in Moraca river upper course will depend on population remain that stay in this part of river. As this part, as whole Morača river course, has minor importance for fishery eventual changes in fish stock will not affect this branch. This part of the river is attractive for sport fishing which, if developed as a tourist attraction, would provide welcome income to the local community.

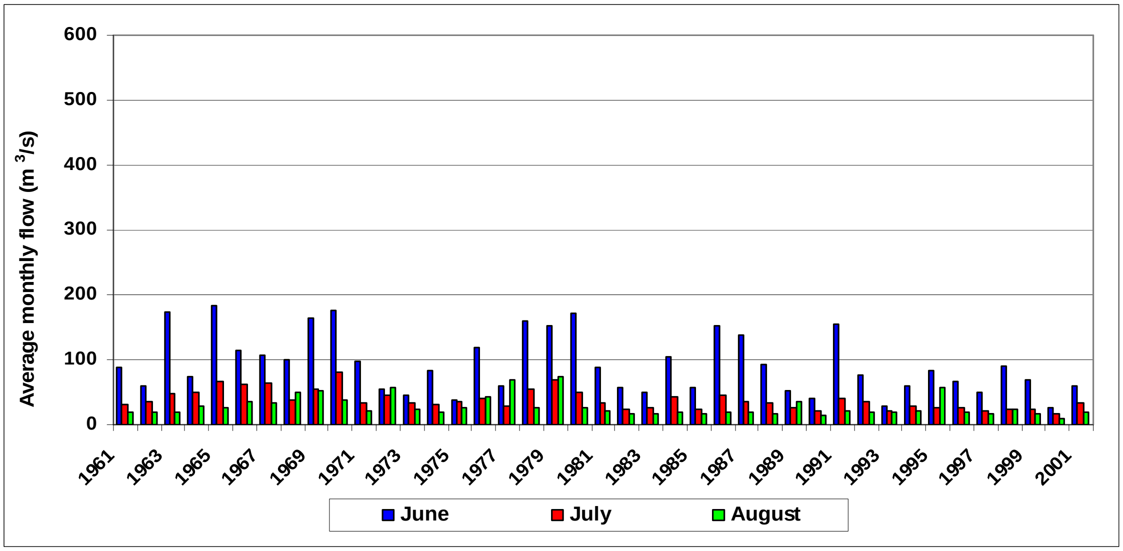
The middle part of Morača, from Medjurijecje to Podgorica, will be dramatically changed by the construction of dams. The entire middle part of the fast river-flow will be transformed into four artificial lakes habitats which will cause transformation of fish communities. The rest of the Morača river, between the first and fourth dam, will be too short and under strong and more frequent water level fluctuation. In the newly-created artificial lakes cyprinids will have a better habitat and are likely to multiply (when compared to intact river-flow) due to the higher productivity of the lake ecosystem and increased organic matter in it. Trout will be also part of this new ecosystem, they will become smaller in number but bigger in size. They will have difficulty finding spawning grounds but we can expect them to adapt whilst never achieving their previous abundance. This new balance can be expected 10-15 years after the dams construction. In the rest of the Morača river (between dams), the violent water-flow with frequent level fluctuation will favour trout species. The biomass of trout in this modified river-flow will be less than in intact river. Although fishery wouldn't be affected by those impacts, important river habitats will be destroyed. Destruction in the middle part will dramatically affect the population of marble trout (*Salmo marmoratus*) because this part of the river is the sector where this species is numerous. We suppose that this is also the most important spawning ground for this species, at least for the Morača river population. The environmental **impacts** in the middle course of Moarača river will be so dramatic that the whole fish fauna will be dramatically changed.

The lower part of Morača river, from Podgorica to Skadar lake, will stay relatively preserved with slight ecological impacts. Zeta river, which flows into the Morača just before Podgorica, brings more water mass than Morača so the water level fluctuation of Morača below Podgorica will be minimized (Graph 3.1). This doesn't mean there will be no frequent changes of river flow, it means that those peaks will be smaller. Due to the production of electric power or water loading, the lower course of Morača river will be much more stable. This means that during periods of high waters, the river level will be lower and during low waters periods, the river level will be higher. During autumn/winter floods, we can predict that the water level of Morača river, below Podgorica, will be lower than usual. This will happen because of dam water-flow installation. With full electric power production, 120 m^3/s of water can pass through a turbine. Regarding that, this is a cold period with high demand for electric power (and there is no problem with filling dams reservoirs), so we can assume that in this period as much electricity as is needed will be produced. In the winter season, when there is still strong demand for electric power, the water level of Morača river downstream of Podgorica will be higher than usual. This is due to the fact that in this period the water level of rivers is relatively low (a lot of water is bounded in the mountain region in the form of snow) so the production of electric power will raise the water level significantly. In spring time, the second flood period, Morača river water-level will be lower than usual for the same reasons as the autumn flood period. During summer, regarding electric power production, the water level of Morača downstream of Podgorica could be even doubled (Graph 5.2.).

Graph 5.1. Average annual flow (m^3/s) of Morača river at stations Zlatica and Podgorica and of Zeta river at station Danilovgrad (Knežević, 2009)



Graph 5.2. Average monthly flow (m^3/s) of Morača river at station Podgorica (Knežević, 2009)



Here we hypothesized with general impacts on seasonal scale because it is impossible to give the exact prediction. All those water level changes will have their daily cycle, regarding electric power production, and the water level will go up and down during 24 hours. We have to be honest and to emphasize that those water level fluctuations wouldn't be so dramatic in all other periods than in summer. There will be 20-50cm of amplitude and will not directly affect the fish populations which live in Morača river. On the other hand, during winter and spring when the majority of fish spawn (salmonid species spawn in winter while cyprinids spawn in spring) it is of major importance that the water level doesn't decrease dramatically. This could result in emersion of fertile fish eggs and their destruction. As spawning is the most crucial and most vulnerable period for fish, the whole next generation of fish and the whole fish population healthiness depend on spawn efficiency.

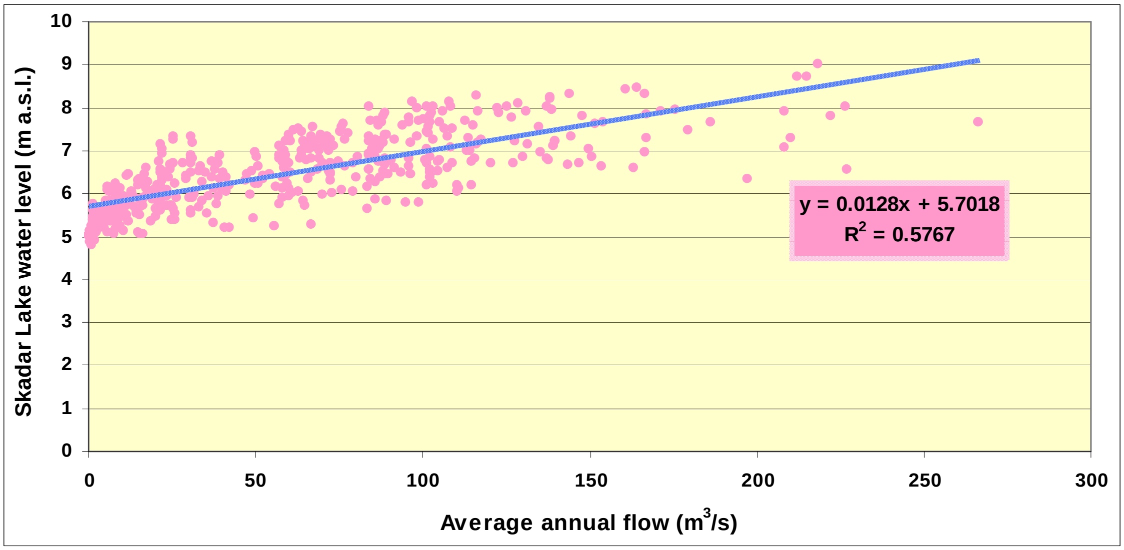
The whole Morača course, as well as fish populations in it, will be divided in two separate parts. The fish population in the lower part will be in a better position because of Lake Skadar. This is especially the case for cyprinids as Skadar Lake is one big reservoir for them (in term of habitats, food and genetic diversity). The dams will block upstream migration so we can expect that they will, in the lower part of course, become more numerous than they are now. As of the majority of trout populations will stay in the lower course (below dams), they will lose the majority of their spawning grounds due to dams, and in the first few years after dam building this part of population will confront the problem of finding new places to spawn. We can expect that in 5-10 years after dams construction, trout (all three species) will adapt to the new situation. As confirmation of previous thesis we can take Zeta river (the lower course through

Bjelopavlići valley) as an example. Namely, at the source of the Zeta river a hydro-electric plant has been installed for 30 years. This plant produces electricity and sluices a large amount of water in Zeta river almost every day (except during turbine reconstruction periods). Nevertheless, trout and cyprinids adapt to this everyday water level fluctuation (up to 50cm), and both groups are still relatively numerous in this river. We believe that something similar can be expected for the lower course of Morača river, if dams are installed.

As for the two previous parts of Morača flow, for the lower part we can also say that there is a minor importance in terms of fishery so eventual changes wouldn't affect this activity on an annual scale.

Skadar lake – all Montenegrin Adriatic drainage, sooner or later, will run into Skadar lake due to Morača river flow. In her course Morača receive numerous water flows but only a few of them have a significant impact on the total water mass that runs into the Lake. In this study it is of great interest to find out how much water flow in position of last dam (Zlatica locality) contributes to the total inflow in Skadar lake at the mouth of the river. The average annual water flow of Morača river in position of Zlatica is 59.84 m^3/s while the average water flow in position of Morača river mouth (Skadar lake) is 210 m^3/s (Knežević, 2009). From previous data we can calculate that water of Morača river upstream of Zlatica contributes 27,8 % of the total water mass which runs in to Skadar lake. This highly significant impact is also confirmed in "Study of water regime of river Morača and Skadar Lake" (Knežević, 2009) where a high correlation is shown between the water flow of Morača river in Zlatica locality and the water level of Skadar lake (Graph 5.3.)

Graph 5.3. Correlation of water flow of river Morača in Zlatica position and water level of Skadar Lake



This provides further support, even without massive calculations, to state that changing of water flow in position of Zlatica will, for sure, change water level of Skadar lake (in terms of changing of natural water level). Without any doubt those changes of natural water level of Lake will have impact on fish populations that inhabit it.

Skadar leke, as all other lakes, has its own and natural variation of water level. Due to the Mediterranean climate and the characteristic distribution of precipitation, Skadar lake has two maximal water level on annual scale. After dry summer and first half of autumn, in November and December we have period of heavy rains that caused winter maximum of Lake level. It is well described (Knežević, 2009) that in this period, during December and January, Skadar Lake has maximal water level. Second maximum (spring maximum) occurs during moths of April and May. During late spring and whole summer water level of Skadar lake decreases reaching a minimum most often in the end of August and in first half of September. By this simplified example uphold the thesis that there is a strong correlation between high water flow of Morača river and high water level of Skadar lake as previously described (Picture 2, this study)

It follows, then, that changing Morača river flow in position of last dam (Zlatica locality) will caused changes to Skadar lake level. The most dramatic and most negative impact will be changing of water flows which could cause a decrease in the natural water level of the Lake. This is especially related to spring maximum. In this period the whole lake physiology (in terms of ecosystem physiology, on first place Lake productivity) increases due to temperature increase and nutrient entering in system (nitrogen and phosphorus salt). From ecological point of view, the production of fish biomass, directly or indirectly, depends on primary ecosystem production. Plankton algae, that live in free water or others that are attached to submerged vegetation and submerged remains of vegetation, as well as submerged and emerged plants are primary producers of each water ecosystem. During spring floods they multiply photosynthesis or, those that spend winter season inactive, start again with biomass production. This spring explosion of life (April, May and June) is fundamental for whole annual production of lake. In this period lake almost doubles the surface (due to floods) and the whole productivity raise much more due to floods event. After flood period, waters return to Lake bringing nutrients which cause higher level of bio-production. This flood period is of great importance for carp population in Skadar lake. In late spring carp undertake migrations from deeper lake water habitats in to the shallow flooded areas that are overgrown by macrophytic vegetation. In those temporary habitats they gather in massive groups, spawn and leave fertilized eggs on submersed vegetation. After spawn they go back in to the lake habitats while their larvae stay in pools, channels and small lakes for grooving and developing.

6. Scenarios of impacts on fish fauna of Skadar Lake

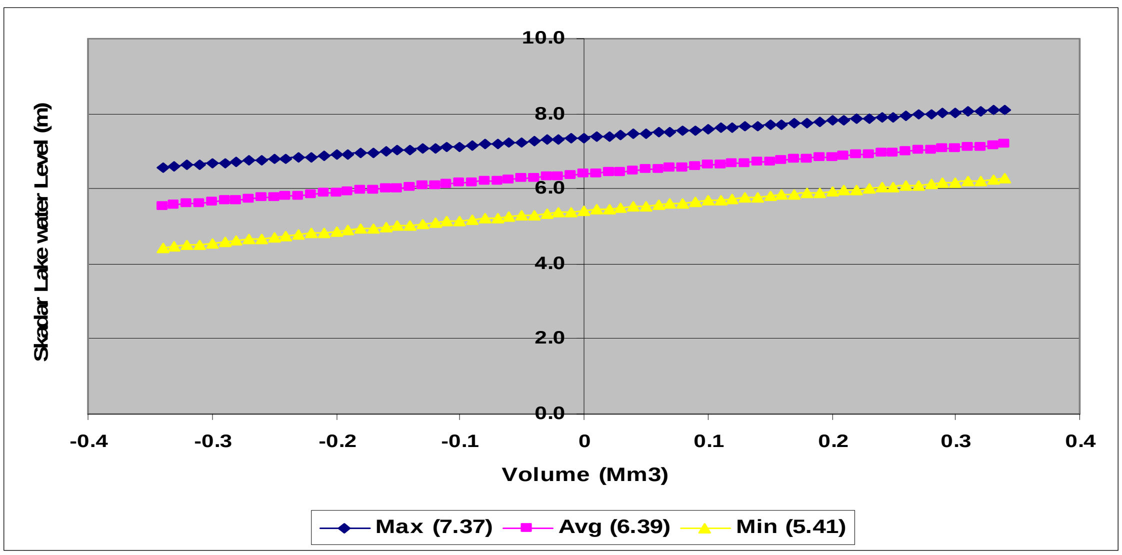
Under **direct impacts** we refer to impacts that are of consequence to changes in water level (water mass). We mentioned before that increasing and decreasing of water habitats (other than natural) have strong and direct influence on all aquatic life. As we don’t know the exact and precise working plan of dams it is impossible to predict exact changes to Lake water level. Here we attempt to do season by season analysis and to develop, for each season, two different scenarios. One: water level decreases (accumulation of dams reservoirs); and two: water level increases (emptying of dams reservoirs) compared to this period standard level.

Our referent study for prediction of Skadar lake water level (Knežević, 2009) takes into consideration dam reservoirs filling or discharging each month. The calculations were performed for average minimal, medium and maximal Skadar lake water level based on 40 years data series (1961-2001). In the same study (Knežević, 2009) author also gives data for maximal filing or discharging (gross capacity of dam reservoirs), filling or discharging of half capacity and filing or discharging of working capacity (in terms of electricity production). We decided to take into consideration calculations related to medium Lake water level each month combined with filling and discharging of working capacity of dams and to apply those data per season in order to develop different scenarios.

In **summer** period (July, August, September) Skadar lake has lowest water level, as does water flow of Morača river. Based on data series of average monthly Lake level (1961-2002) by Knežević (2009), average Skadar lake level for month July was 5,82 m for August it was 5,42 m and 5,44 for September. Same author stressed that average monthly flow of Morača river in position Zlatica for month July was 9,82 m^3/s, for August it was 5,76 m^3/s while in September it was 22,93 m^3/s.

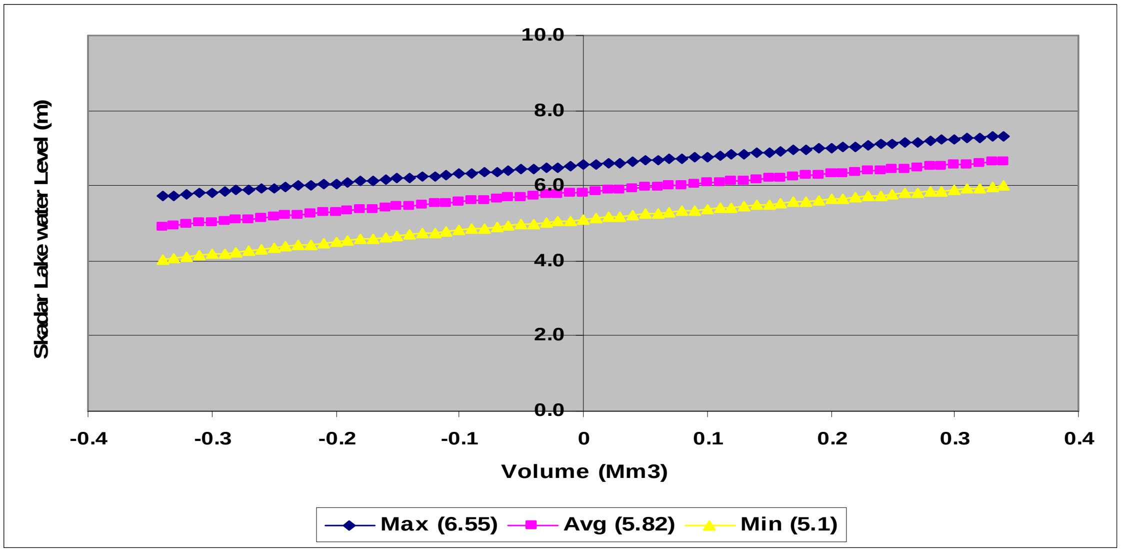
In July, loading of dams working capacity will produce decreasing of Skadar lake medium water level by 67 cm (Knežević, 2009). In terms of Lake surface this will produce decrease of 17,3 km^2. Variation of Lake water level due to water loading or discharging in July is shown on graph 6.1.

Graph 6.1. Variation of average maximal, middle and minimal water level of lake Skadar in July due to water loading or discharging (Knežević, 2009)



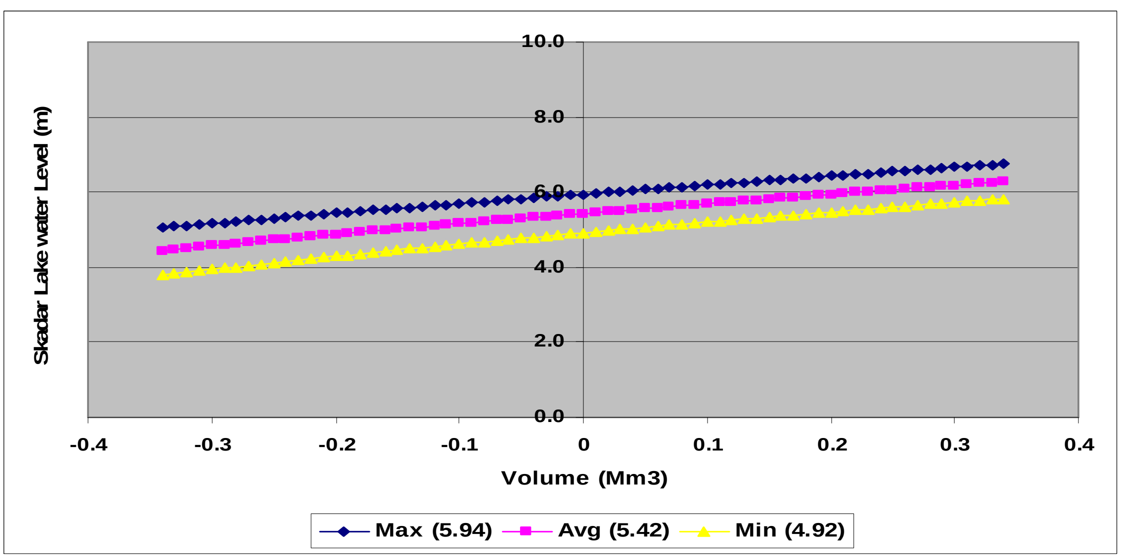
If dams load working capacity volume in August this will decrease Skadar lake medium water level for 73 cm causing decrease in Lake surface for 34,7 km^2 (Knežević, 2009). Variation of water level due to water loading or discharging in August is shown on graph 6.2.

Graph 6.2. Variation of average maximal, middle and minimal water level of lake Skadar in August due to water loading or discharging (Knežević, 2009)



In September loading of working capacity volume in dams on Morača river will produce decreasing of Lake medium water level for 74 cm and Lake surface will decrease by 30.5 km^2 (Knežević, 2009). Variation of water level due to water loading or discharging in September is shown on graph 6.3.

Graph 6.3. Variation of average maximal, middle and minimal water level of lake Skadar due to water loading or discharging, in September (Knežević, 2009).



In this period Lake normally has annual lowest water level and there is almost no water in surrounding flooded plain. This situation is characteristic for September and in this period we can find that Lake level exceeded 5,5 m of altitude only a few times during 40 analysed years (Kenžević, 2009). In July, August and September spawn of all cyprinids is finished and all species, in this period, are in their "normal" lake habitats, on their feeding grounds. By this period, most fish larvae and juveniles are in their nursery habitats which are mainly coastal littoral places between submerged and emerged vascular plants. Decreasing of water level by an additional 67-74 cm (depending on water-flow of Morača river in particular month) will produce decreasing of Lake surface by 17 – 34,7 km^2. According to Knežević (2009) surface of littoral swamp area, between 4,6 m and 5,5 m of Lake level, is 60,06 km^2. As littoral area goes up to 1-1,5 m of Lake depth, we can estimate that this area during summer months occupies at least 100 km^2. The loss of 17 – 34.7 km^2 of this habitat (decreasing for 17 – 34.7 %) is significant and fish larvae, juveniles and adults that inhabits such a niche will face problems. Of course, by this period of year cycle all fish larvae (juveniles) are active moving individuals so we can expect that they will retreat with water. We can also expect that those changes will produce an increase in mortality of fish larva (comparing to natural mortality at this stage of development) but how much exactly we can't predict. Here we can conclude that decreasing water levels will certainly have a negative impact on fish larva and juveniles due to loss of their living area. Consequences of such scenario will be visible two-three years after when those juveniles and larva become adults and when they become significant part of spawning population. Less spawning individuals will produce less fertile eggs, less larva and juveniles and eventually less adults in that generation. If this becomes standard event, we can expect that in 5-10 years we will be faced with decreasing fish populations affecting carp, chub, rudd, moronec and nase. We can't predict exactly but we can estimate, according to percentage of habitat loss, that population of these fish species could decrease at least 5%, but not more than 10 %, if this becomes new standard water level. Luckily, the population of bleak will not face described direct impacts because of bleak specific life cycle. Bleak larva is pelagic and will not suffer because of littoral habitats loss. Adult fish that inhabit this area, which are more durable and adaptable, will have slight problems which they will solve as they migrate in deeper part of littoral zone. Their main problem will be loss of some amount of food items (due to loss of habitats where they find food) but that will not caused some significant loss (significantly different than natural). Strongest negative impacts will have decreasing of Skadar lake water level in July while decreasing of Lake water level in September will have smallest negative impact on fish fauna in summer season (although it was calculated that in September decrease of Lake water level could be highest in summer season). At a glance this may not sound logical (smallest decrees – biggest negative impact and vice-versa) but here we have to take in consideration development of fish larva and juveniles. As cyprinids spawn in spring, larva and juveniles are bigger and more agile and adaptable in September than in July, causing such irregularity of negative impacts, on one side smallest decreasing of water volume while on the other side biggest negative impacts due to younger development stage of fish.

Here we have to point out that this period is with lowest water flow on annual scale and we doubt that those months will be used for loading of dams reservoirs. Nevertheless, this is period of summer tourist season and consumption of electric energy is high due to air conditioning as well as full time working of all kinds of tourist structures (hotels, restaurants, cafes, discotheques, beach bars, apartments, rooms, booths) so we can assume that in this period dams will work and produce necessary electric power. This further means that water flow of Morača river will be higher than usual for this part of the year (discharging of previously accumulated water mass due to produce electric power) and in such situation we will not be faced with Lake level decreasing.

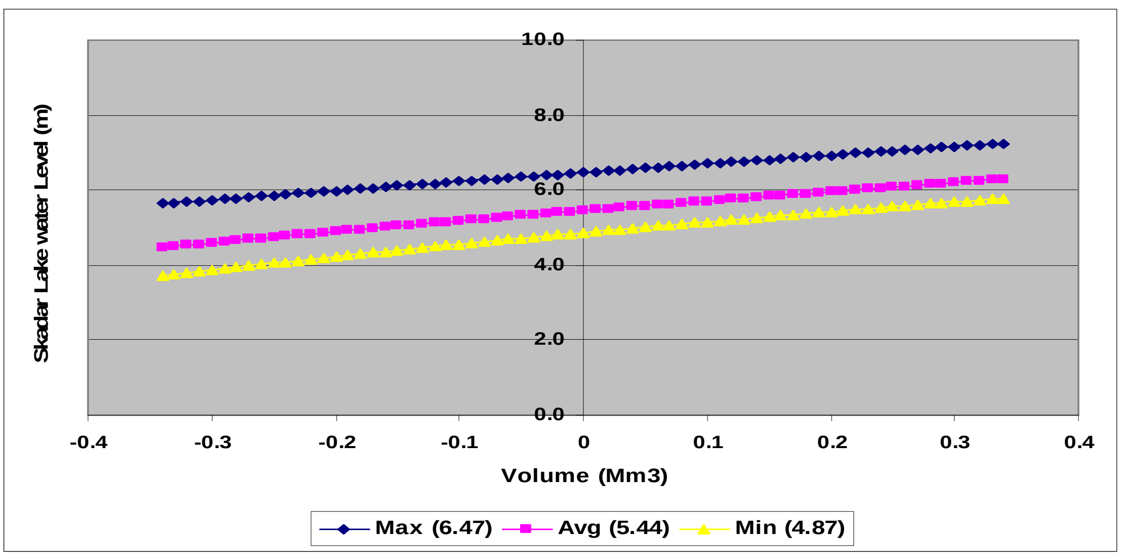
Discharging of working volume (effective volume) in July will produce an increase in Lake medium water level by 70 cm which will produce enlargement of this month average Lake surface for additional 26.1 km^2 (Knežević, 2009). Discharging of dams working volume in August will produce an increase in Skadar lake medium water level of 76 cm causing surface enlargement of additional 34.7 km^2, while discharging of working volume in September will increase Skadar lake medium water level for 76 cm causing surface enlargement of additional 34.2 km^2 (Knežević, 2009). This is shown on graphs 6.1., 6.2. and 6.3.

Development of second opposite scenario of impacts in summer season, which is based on an increase in Skadar lake water volume during summer season (July, August and September), is based on previous data. As we stressed before, this is period with lowest water level of Skadar lake (lowest water flow of Morača river). Regarding to this, an eventual increase in water level (and water volume) will provide more space for littoral habitat so we can conclude that this will produce almost no direct negative effects on Lake fish fauna. Nevertheless, this could have even positive impacts but only if there is no significant loss of littoral habitat in previous half of the year cycle. If we estimate only summer it could be concluded that production of electric power and discharging of working volume of dams theoretically will have positive effects on Skadar lake. This is without taking into consideration whole year and without considering where this water could come in to artificial lakes. Here we have to stress that there is no other chance than this water is loaded during previous spring season. Spring is most vulnerable part or the year for Lake fish fauna. This is spawning season and lack of water in Lake will produce strongest negative effects. If water level during summer is higher than usual this will not minimize negative effect from previous season so these slight and potentially positive impacts will have no long term effects. In the end, on the contrary, an increase in Lake level due to electric power production will have strong negative impact on fish fauna. Those effects will be even stronger and more negative than those produced by decreasing of Lake water level during summer.

In **autumn** period (October, November, December) water level in Skadar lake increases constantly and reaches maximal level in December/January. All this is due to high precipitation in this period, one of the Mediterranean climate characteristics. Based on data series of average monthly water level of Skadar lake (1961 - 2001) cited by Kenžević (2009), average Lake levels for each month was: October – 5.96 m, November – 6,63, December – 7,19. Same author stressed that average monthly flow of Morača river in position Zlatica for month October was 50,52 m^3/s, for November was 97,55 m^3/s while in December it was 98,21 m^3/s.

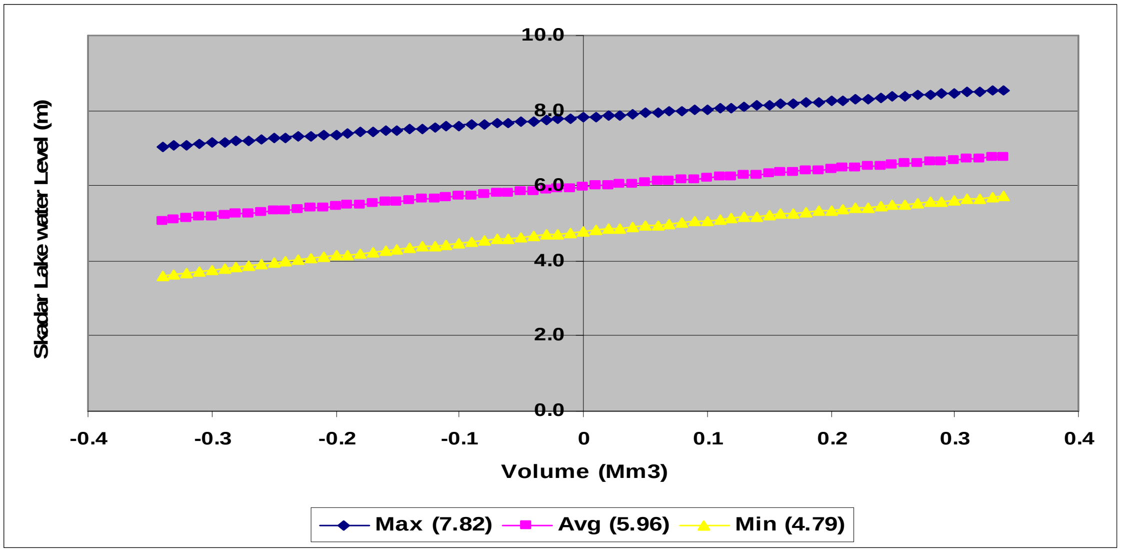
In October, loading of dams working capacity volume will produce decreasing of Skadar lake medium water level for 65 cm (Knežević, 2009). In terms of Lake surface this same author points out that this will produce decrease of 16.1 km^2. Variation of Lake water level due to water loading or discharging in Morača course in October is shown on graph 6.4.

Graph 6.4. Variation of average maximal, middle and minimal water level of lake Skadar due to water loading or discharging, in October (Knežević, 2009).



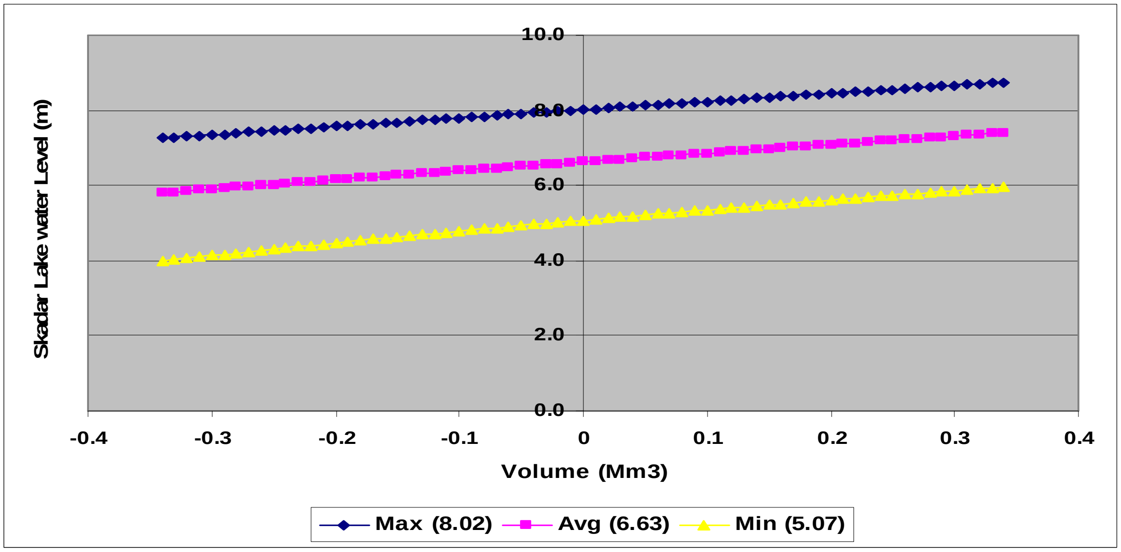
In November, loading of dams working capacity volume will produce decreasing of Skadar lake medium water level for 61 cm (Knežević, 2009). In terms of Lake surface this same author writes that this will produce decrease of 12.3 km^2. Variation of Lake water level due to water loading or discharging in Morača course in November is shown on graph 6.5.

Graph 6.5. Variation of average maximal, medium and minimal water level of lake Skadar due to water loading or discharging, in November (Knežević, 2009).



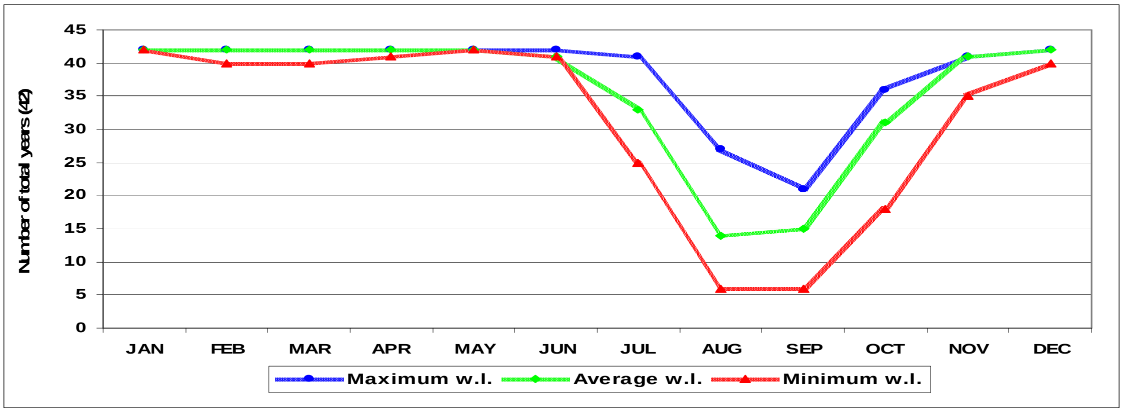
In December, loading of dams working capacity volume will produce decreasing of Skadar lake medium water level for 60 cm. (Knežević, 2009). In terms of Lake surface this same author write that this will produce decrease of -11.1 km^2. Variation of Lake water level due to water loading or discharging in Morača course in November is shown on graph 6.6.

Graph 6.6. Variation of average maximal, medium and minimal water level of lake Skadar due to water loading or discharging, in December (Knežević, 2009).

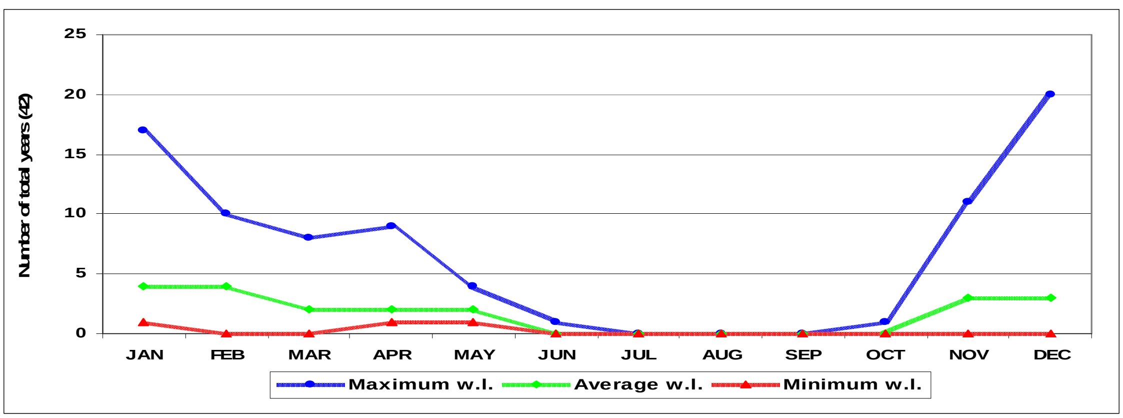


After dry summer period in autumn comes rainy season with maximal precipitation during whole year cycle. In this period water level in Skadar lake constantly increases and reaches maximum in December. Same situation is with Morača river flow that reaches winter maximum in same month. This rainy season is clearly visible from graph that illustrates how many times Lake water level exceeds 5,5 m and 8 m level, per each month during 40 years data series (Graphs 6.7. and 6.8.). During this period fish juveniles become fully developed and highly mobile for following flood. As water level increases, carp adults migrate to shallow Lake bays from where carps individuals will go to their spawning grounds (flooded plain during spring time). Bleak as second most important fish species (in terms of fishery), undertakes migration to deeper coastal zones with strong influence of fresh water wells (called "oka") where it will spend following winter. Production of Skadar lake ecosystem rapidly decreases and reaches minimum in December – January. In this period fish fauna, at least fishery important species, do not have special habitat demands that could be affected by decreases in Lake water level. This is particularly related to November and December. In those months eventual loading of dams working water volume will decrease Lake level by 65 cm (October) and 60 cm (December). If this scenario becomes real, Lake still will have flood level (in terms of average middle Lake level). Here we have to be careful in order not to be wrongly interpreted. In such situation eventual change will not have obvious and strong negative impacts but it doesn't mean that it will have any positive influences. Theoretically speaking, decreasing of water level of some lakes (comparing to natural fluctuation) will have negative impacts to all species that inhabit them, but it is hard to say what exactly. Some fish populations (individuals) will overcome this change by their own adaptation (they will find another close habitat that fits to them in this part of the year) and some will slightly decrease their number while others will not have any problems. Generally speaking, decreasing of Lake water level, during these three months will have minimal negative effects (on annual season scale) on fish fauna.

Graph 6.7. Appearance of maximum, average and minimum water level of Skadar Lake above 5,5 m a.s.l. (Knežević, 2009)



Graph 6.8. Appearance of maximum, average and minimum water level of Skadar Lake above 8 m a.s.l. (Knežević, 2009)



In this time of the year, first we have decreasing of electric energy consumptions (October) while in November and December we are faced with dramatic increasing due to cold weather. In such situation we can expect that dams will not produce power in October and we can expect that this period will be for loading of water. As by the end of October rains start, those impacts will be minimized in November and December when rain reaches maximum of precipitation.

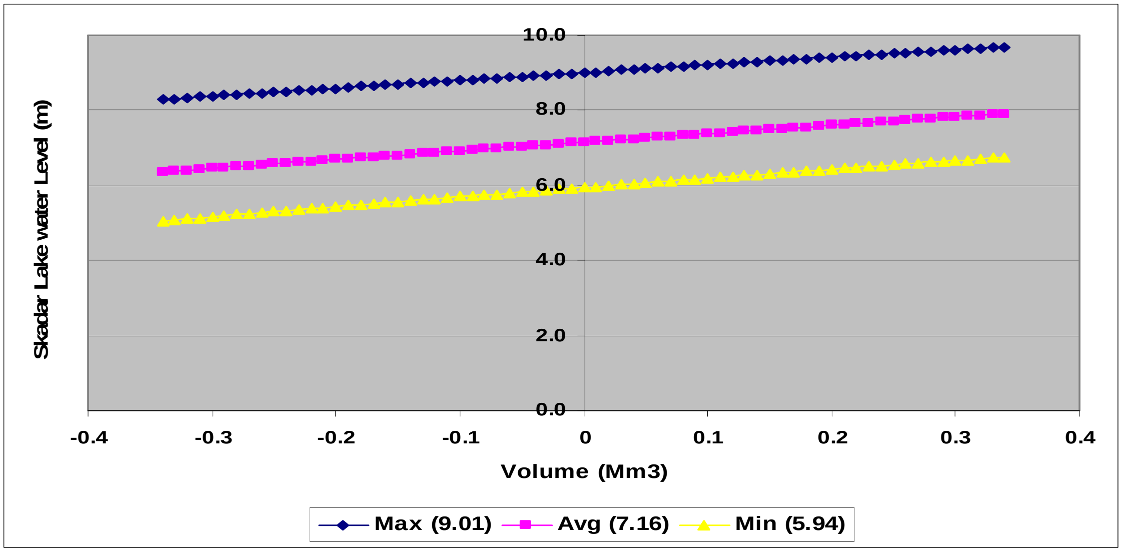
Discharging of working volume (effective volume) in October will produce an increase in Lake medium water level of 69 cm, producing an enlargement of this month's average Lake surface of an additional 23.8 km^2 (Knežević, 2009). Discharging of dams working volume in November will produce an increase in Skadar lake medium water level of 65 cm causing surface enlargement for additional 16 km^2, while discharging of working volume in December will increase Skadar lake medium water level by 64 cm, causing surface enlargement for additional 12,6 km^2 (Knežević, 2009). See graphs 6.4., 6.5. and 6.6.

According to such a scenario, an increase in Skadar Lake level during autumn months, will not have negative impact on fish fauna. According to these calculations variations are among maximal and minimal values so we can expect no negative influence, except for October. In October, upwelling of water will be without negative consequences for fish fauna while decreasing could have slightly negative impact.

In **winter** period (January, February, March) water level in Skadar lake stays on highest level with maximum in January. Based on data series of average monthly water level of Skadar lake (1961 - 2001) cited by Kenžević (2009), average Lake levels for each months was: January – 7,16 m, February – 6,92, March – 6,80. Same author stressed that average monthly flow of Morača river in position Zlatica for month January was 70,00 m^3/s, for February was 68,45 m^3/s while in March it was 69,69 m^3/s.

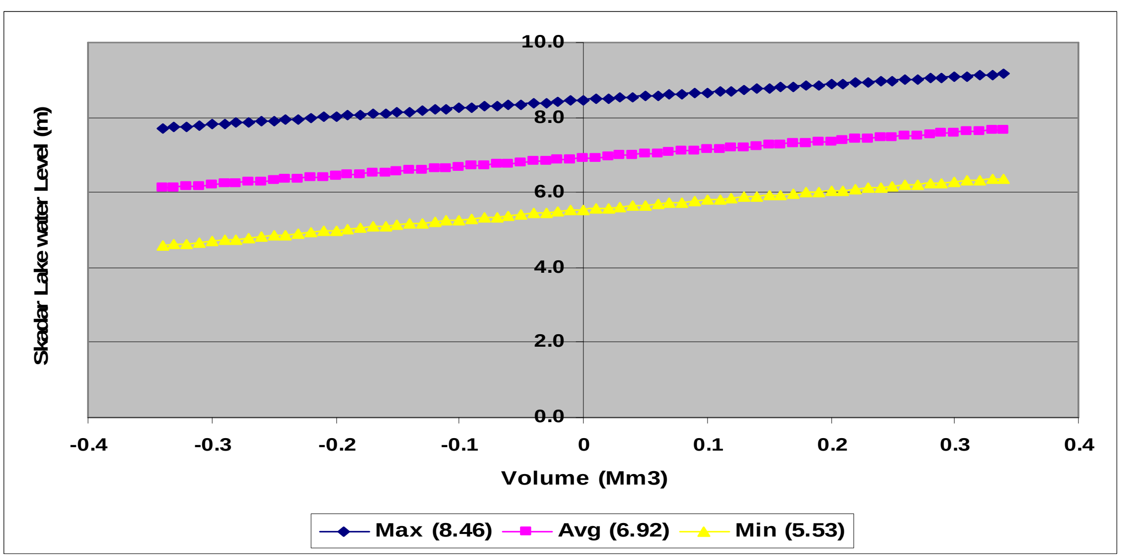
In January, loading of dams working capacity volume will produce decreasing of Skadar lake medium water level by 60 cm (Knežević, 2009). In terms of Lake surface this same author writes that this will produce decrease of 11,1 km^2. Variation of Lake water level due to water loading or discharging in Morača course in month October is shown on graph 6.9.

Graph 6.9. Variation of average maximal, middle and minimal water level of lake Skadar due to water loading or discharging, in January (Knežević, 2009).



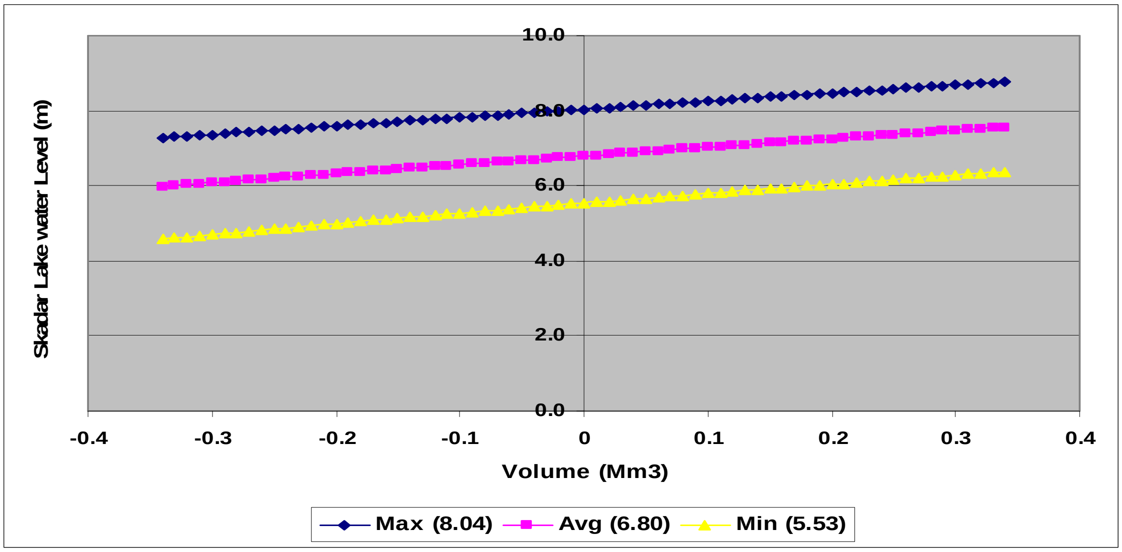
In February, loading of dams working capacity volume will produce decreasing of Skadar lake medium water level by 60 cm (Knežević, 2009). In terms of Lake surface this same author writes that this will produce decrease of 11,5 km^2. Variation of Lake water level due to water loading or discharging in Morača course in month October is shown on graph 6.10.

Graph 6.10. Variation of average maximal, middle and minimal water level of lake Skadar due to water loading or discharging, in February (Knežević, 2009).



In March, loading of dams working capacity volume will produce decreasing of Skadar lake medium water level by 61 cm (Knežević, 2009). In terms of Lake surface this same author writes that this will produce decrease of 11.8 km^2. Variation of Lake water level due to water loading or discharging in Morača course in month March is shown on graph 6.11.

Graph 6.11. Variation of average maximal, middle and minimal water level of lake Skadar due to water loading or discharging, in March (Knežević, 2009).



In winter period Skadar Lake keeps highest water level due to rains and snow melting in mountains. Similar situation is with Moraca river flow which stays on averagely highest level. Biological processes, during January February and March, in Lake are highly similar to those in November and December. Even Lake water level and Moraca river flow are highly similar. In environmental sense, temperature of the air (and Lake water) are slightly lower than in autumn and begin to increase by March. Physiology of lake is still on lowest level with slight increase in March which happens due to temperature increase. During winter period Lake level is of constantly high level which is highest on whole annual scale (Graph 6.7. and 6.8.). In January and February, decreasing of Lake water level will have almost the same results as for previous season. All fish species are in their wintering habitats (in terms of bleak it is Lake "oka", while for carp it is coastal Lake parts) which are mainly coastal area, lake bays, mouths of smaller tributaries. Decreasing of water level will not have significant negative effects on fish fauna, at least for carp and bleak, but it could affect some other members of Skadar lake ecosystem. In this place we could not say what exactly could go wrong and it is impossible to foresee it. Although decreasing of water level in March will not directly affect fish, this could have significant negative effect in next spring season. This decreasing in March will have cumulative effect in April and May, if the same happened in those two months (if water level decreases in April and May). This could result in more dramatic decrease of Skadar lake water level during spring months than calculated. As we mentioned before, this is spawning time of carp and spawning ground of this species are surrounding flooded areas of Lake. If water decreases the surface of this spawning ground will decrease too resulting in less effective spawning and decreasing carp population. Generally speaking, decreasing of water level will not have direct negative impacts on Lake fish fauna in January and February, while in March negative effects will be visible during next, spring season.

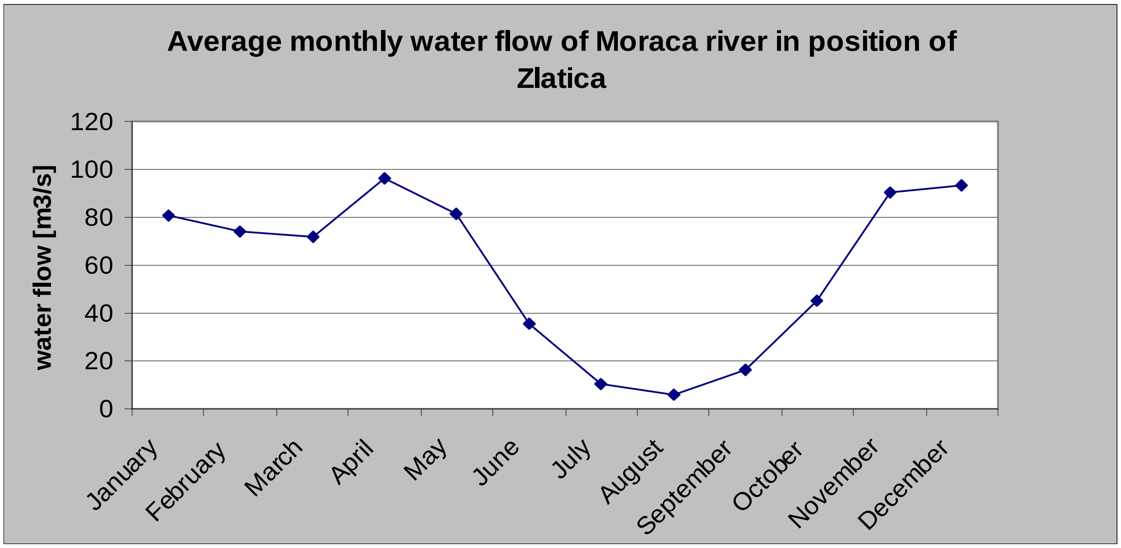
At this time of the year, we have constant and highest demand for electric power due to cold weather. In March those demands are still high but less than in previous months. In such situation we can expect that dams will not accumulate water, instead dams will probably work as much as water flow allows. We can predict that during winter time we will not be faced with Lake decreasing unless management of Electric Company decides otherwise. If this scenario becomes real this could even minimize or completely neutralize possible decreasing of Skadar Lake level in March (due to water loading in this month).

Discharging of working volume (effective volume) in January will produce an increase in Lake medium water level of 63 cm, increasing this month's average Lake surface by an additional 12,7 km^2 (Knežević, 2009). Discharging of dams working volume in February will produce an increase in Skadar lake medium water level for 65 cm causing surface enlargement for additional 14 km^2, while discharging of working volume in March will increase Skadar lake medium water level for 65 cm, for additional 14,7 km^2 (Knežević, 2009). See graphs 6.9., 6.10. and 6.11.

As for previous season, increasing of Skadar lake water level during winter season will not produce any negative effects on Lake fish fauna. No matter if water Level increases or decreases, this could not have any direct impact on fish fauna except in March (if the calculations are strict). In March, eventual decreasing of Lake water level will produce negative effects in next spring season as we explained before.

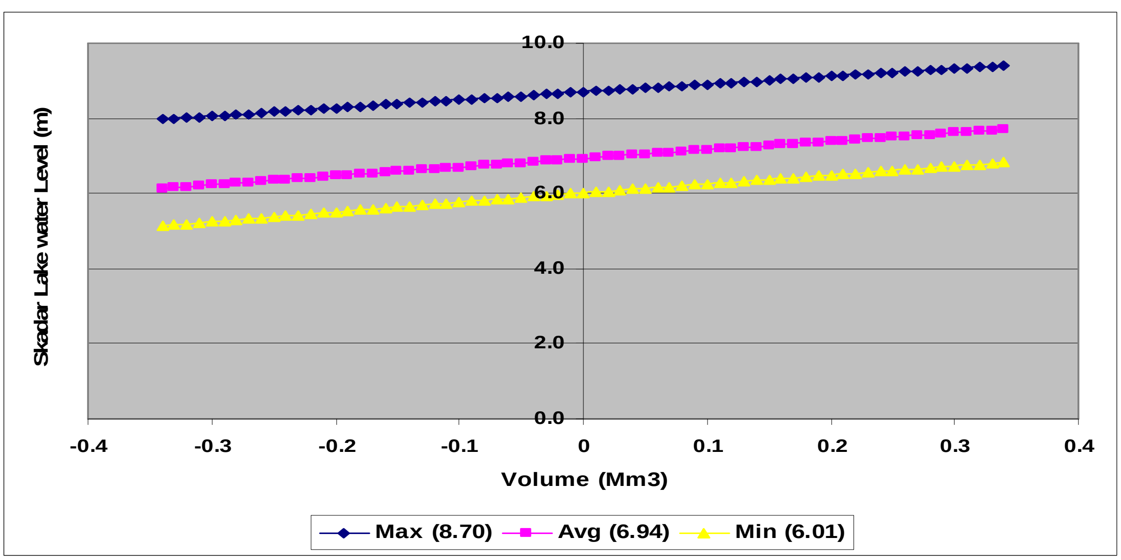
In **spring** period (April, May and June) water level of Skadar lake is still on high level but lower than during winter season. Based on data series of average monthly water monthly water level of Skadar lake (1961-2001) cited by Knežević (2009), average Lake level for each month was: April – 6.94, m, May – 6,88, June – 6,39. Same author stressed that average monthly flow of Morača river in position Zlatica for month April was 99,95 m^3/s, for May was 82,98 m^3/s while in June it was 35,45 m^3/s. Whole annual variation of Moraca river water flow in position of Zlatica is shown on graph 6.12. August, September October, November December

Graph 6.12. Average monthly water flow of Moraca river in position of Zlatica (Knežević, 2009)



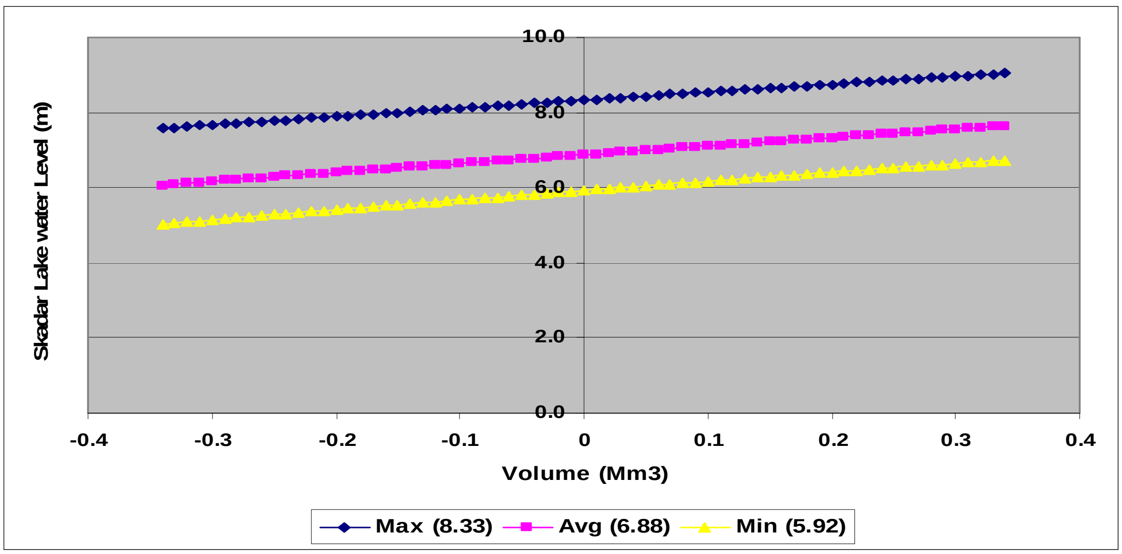
In April, loading of dams working capacity volume will produce decreasing of Skadar lake medium water level by 61 cm (Knežević, 2009). In terms of Lake surface this same author writes that this will produce decrease of 11.4 km^2. Variation of Lake water level due to water loading or discharging, in April is shown on graph 6.13.

Graph 6.13. Variation of average maximal, middle and minimal water level of lake Skadar due to water loading or discharging, in April (Knežević, 2009).



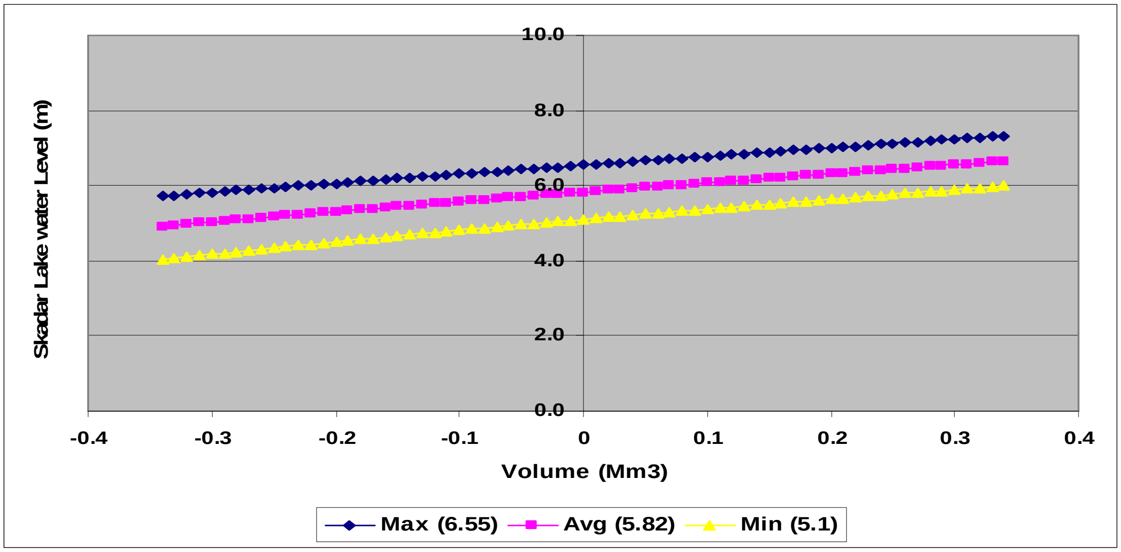
In May, loading of dams working capacity volume will produce decreasing of Skadar lake medium water level by 61 cm, (Knežević, 2009). In terms of Lake surface this same author write that this will produce decrease of 11.6 km^2. Variation of Lake water level due to water loading or discharging, in May is shown on graph 6.14.

Graph 6.14. Variation of average maximal, middle and minimal water level of lake Skadar due to water loading or discharging, in May (Knežević, 2009).



In June, loading of dams working capacity volume will produce decreasing of Skadar lake medium water level by 63 cm (Knežević, 2009). In terms of Lake surface this same author write that this will produce decrease of 13.3 km^2. Variation of Lake water level due to water loading or discharging, in June is shown on graph 6.15.

Graph 6.15. Variation of average maximal, middle and minimal water level of lake Skadar due to water loading or discharging, in June (Knežević, 2009).



During spring period Lake still has high water level and even increases size in April. This happens due to high precipitation in April and snow melting. That is why Moraca river has highest average flow in April (graph 6.12.). In May water level slightly decreases while it is at the lowest spring level in June. By this period all life in Skadar lake literally blooms, all photosynthesis increases and Skadar lake ecosystem reaches its maximum productivity by the end of June. Spring is also spawning time for almost all cyprinid species and it could occur in April or May depending on environmental conditions (more commonly in May). It seems that this April flood wave has some trigger function when fish spawn is about (together with length of photo-period, day light duration). As bleak spawn in open water here we will not take into consideration this species for estimation of eventual negative impacts. Of all other species, carp is most important in terms of fishery and will be discussed in detail. The most vulnerable part of the annual cycle for all kind of fish is spawning period and in Skadar lake (which is predominantly inhabited by Cyprinids) it is spring time when floods are present. During floods vast surrounding plane is covered with Lake water which forms additional and temporary habitats. Nevertheless carp use those special and temporary habitats to spawn. In spring carp undertake migrations from lake deep water habitats to the shallow flooded areas that are overgrown by macrophytic vegetation. In those temporary habitats they gather in massive groups, spawn and leave fertilized eggs on submersed vegetation. After spawning they return to the lake habitats while their eggs and following larvae stay in pools, channels and small lakes.

If dams load water in spring this could result in decreases to flooded areas of 12-15 km^2. According to Knežević (2009) flooded zone is between 5,5 m and 8 m (and more) of water level altitude, and this zone has a surface of 42,62 km^2 which gives an indication of how much (in percentage) of this area could disappear. This further means that, if this scenario of water loading during spring becomes real, this will cause a 28 % – 35% decrease of this important zone.

Loss of such area for fish is highly significant and if we know that those habitats are carp spawning ground the impact is clear. This will have strong negative effect on carp population and according to percentage of spawning ground that is lost we can make an estimation of the eventual decrease in carp population. Decreasing of spawning area by 30 % will decrease spawn efficiency by at least the same percentage. The effects will be even more negative if Skadar lake water level is on minimal average level for spring. In such conditions carp will lose almost 50 % of spawning ground. All this further means that in future generations there will be 30 % less juveniles. The visible effect will arrive as those generations grow, become adults and significant part of spawning individuals. It will result in fewer fertile eggs for at least same percentage (30%) even if water level in this year stays among natural fluctuation. If this becomes constant water level for spring season we can expect that in 3-10 years after dams installation, we will be faced with permanent decreasing of carp population by at least 30%. This scenario couldn't be avoided if in some of those months Lake water level is as natural. For instance, if we have normal Lake level in April and carp spawn and leave fertile eggs normally, decreasing of water level in May will affect hatching of those eggs and their destruction. It is therefore of greatest importance that Lake water level doesn't drop during spring season. The central aim of minimising negative effects should be fine balancing of water discharge during spring time (especially during April and May).

Discharging of working volume (effective volume) in April will produce an increase in Lake medium water level by 64 cm, which will produce enlargement of this month's average Lake surface by an additional 13,8 km^2 (Knežević, 2009). Discharging of dams working volume in May will produce an increase in Skadar lake medium water level of 64 cm causing surface enlargement of an additional 14,2 km^2, while discharging of working volume in June will increase Skadar lake medium water level by 66 cm, causing a surface increase of an additional 18,3 km^2 (Knežević, 2009). See graphs 6.12., 6.13. and 6.14.

As for all other months, but particularly spring months, an eventual increase in Skadar lake water level (higher than natural average level) will not have any negative effects on fish fauna of the Lake. Here we can say that during spring months eventual increase will have even positive effect on fish, improving effect on fish spawns, especially for carp spawn. Higher level means wider flooded area and more spawning habitats but also it means higher probability for hatching of fertile eggs.

In terms of electricity needs, after high demands for electric power during winter, in spring those demands rapidly decrease. As spring time is very humid (especially April and May) with highest precipitation (including snow melting) and with low demand for electricity we can hypothesize that those months will be used for water loading. This will have, for sure, strongest negative effects during whole year cycle. If we avoid all other season negative effects by balancing of water discharge and loading and leave spring months to have lower water level (due to dams loading) all efforts will be without any effects. As we mentioned before, the key part of the year when we can minimize other negative effects of Moraca dam installation is spring time.

By **indirect** effects we intend those that do not impact directly on fish populations (like decreasing of water level). Those impacts will affect some other components of Skadar lake ecosystem and through them it will affect fish fauna. Indirect impact of dam building is related to changes that could occur in Skadar Lake ecosystem physiology. Namely, Moraca river is highly erosive river that feeds Skadar Lake with nutrients (phosphorus and nitrogenous soils). Considering that Moraca river brings majority of nutrients (that are of crucial importance for whole Lake productivity) we can expect that some significant part of them will be deposited in newly formed artificial Lakes (slow moving lake water will allow nutrient precipitation on lake bottom). Skadar lake will receive significantly smaller amount of nutrients causing changes to Lake physiology and decreasing of bio-production. This decreasing of bio-production will reflect on all living components but regarding fish fauna bleak will be most negatively affected. As bleak larva lives in free water and they feed on zooplankton they will be faced with decreasing of food. Bio-production of lake on first level is related to plankton algae which are main productive component of Lake ecosystem. Zooplankton, as animal component, most directly depends on phytoplankton (algae) while for algae nutrients are one of the most restrictive needs. As for processes of photosynthesis algae have unlimited source of water, sunlight and carbon dioxide, the nutrients are their limiting factor that moderate intensity and mass of their growing. Decreasing of bio-production will reflect on bleak larva food items and on bleak as species. It will decrease bio-mass of bleak population. Other fish species will also be affected by this impact but bleak will be faced with most direct impact due to their life cycle and their high bio-mass. All other components of Skadar lake ecosystem (except vascular plants around the periphery of the Lake) will feel the effects of food items decrease due to decreasing of Lake productivity.

The precise nature of the decrease is hard to predict because there is no established system for such estimation. First we don't know the quantity of nutrients entering the Lake every year and we can't predict how much of this will be deposited in artificial lake. Without this it is impossible to predict decreasing of Skadar lake production. Some rough estimation should be that this decrease couldn't be more than 10 %. We can estimate than Skadar lake bio-production will, on annual level, drop by at least 5 %. For bleak population will be the same as for the whole Lake ecosystem. We can expect that this species number will decrease by 5% also. This impact will be even stronger if dams load majority of water during spring months (April, May, June) because by this period all plants (algae and vascular plants) have strong need for nutrients. This comes through rapid increasing of photosynthesis and bio-mass production. In spring time water level of Moraca river is at its maximum flow (Graph 6.12.) and river is full of dirt and plant remnants that fertilise Skadar lake. Loading of water will cause precipitation of that material (and nutrients) in artificial lakes and by this, Lake will receive less than usual in most important part of the year. Such scenario could even double this negative impact.

7. Impact of planned dams on fish-related economy

As we mentioned before, majority of fish-related economy (fishery, fish product, tourism, restaurants) concerns Skadar lake. Moraca river has a minor, almost insignificant contribution to whole fishery of Skadar Lake system. Until the 1990s this river was famous for its trout species (brown and marble trout), plenty of chub, nase and eel. During the past two decades, however, the population of almost all fish species has rapidly decreased due to intensive overfishing. Even in those years Moraca wasn't a significant part of fresh water fishery, but was mostly frequented by recreational anglers, mainly oriented to trout. The catch in those days, as it is now, was completely unknown. Eventual construction of dams on Morača river will, as stated in the in previous chapter, divide river in two separate parts. Upper part that will not have any direct environmental impact (in terms of water flow changing) but it will become almost independent in terms of fish migrations. The lower part will have changed water flow fluctuation (different than natural) and fish will need approximately 10 years to adapt to new environmental conditions. Regarding the middle part where all dams are planned, river will be completely changed into artificial lakes ecosystem. By this we can hypothesize that amount of fish could be greater than today (due to cyprinid fish in artificial lakes) but attractive fish species (in terms of tourist offer and sport or fly fishing) that are trout will drop in number unless there are some population reconstructing activities. While Morača river is not important for fisheries it is highly prominent in terms of biodiversity (spawning ground for trout species and several cyprinids), natural value and with high potential for developing different types of tourism. Construction of dams will destroy those potentials, especially in middle and upper part. In upper part of river flow we will have intact mountain river that is attractive for all kinds of sport fishery especially for trout fly fishing, but due to barriers to river flow this part will need strong conservation measures. Those measures are mostly based on an increase in spawn efficiency and an increase in population numbers. In the lower part the same conservation measures should be applied in order to minimize loss (due to river flow interruption) of upper course spawning ground. By those measures Morača river will somehow preserve its tourist potential as an angler destination. A fish-related economy based on Morača river could become significant part of whole Skadar lake system fishery.

As fresh water fishery and fish-related economy is most relevant to Skadar lake basin (almost 100%) negative impact that dams on Morača river could cause will be reflected in economy of Skadar lake region. In previous chapter, where we developed different scenarios for all seasons, we give some estimation how much in fish biomass (in percentage) could be lost as consequence of negative impacts. For different seasons those negative impacts are different as well as for different species that are most important by fishery. As we stressed, bleak will suffer indirect impact caused of ecosystem productivity decrease and in worst scenario bleak population will decrease by 10%. For carp population spring and early summer (July) are crucial and most vulnerable part of the year. If the carp population is affected in spring this could generate a 30% decrease in carp population in Lake. Without entering into a detailed analysis we can make a generalization that 30% of fish in terms of resources will be lost. For fishery and fish-related economy all this will cause a 30% decrease in main resource (fish from Skadar lake, carp and bleak). This will result in 30% less fisherman. If all fisherman stay on job they each will lose 30% of income (from 6435 € fisherman income will drop to 4504 €). This further means that 30% of income made by tourism will be missing also. In order to estimate how much the economy will lose we have first to estimate the total value of fish-based economy.

In previous parts we give an estimation that at least 300 families directly depend on fishing and if we assume that for each family there is at least one fisherman this gives total income by fishing. This means that fisherman earn (all together, 300 x 6435€) 1,930,500.00 €. Families that indirectly depend on fish stock mainly own or work in restaurants (fish from Skadar lake is main on menu), work in "Rijeka Crnojevica" cannery, work in concessions in Lake "oka" or deal with fish processing (smoked carp and bleak). We estimate that there are 300 such families and we can conclude that those families have at least the same income (all together) as families that directly depend on fish stock, approximately 2,000,000.00 annual income. Another component of this economy are the concessionaires that use Skadar lake "oka" for their fishery area. Although there are no official data about their annual income we have data about how much they pay to Skadar Lake National Park for their areas and licenses. In 2006 they paid almost 30,000.00 € for their license and we can estimate that their business is at least five times bigger than their initial investments for licenses and fishing area exclusivity. This brings us to amount of 150 000,00 € for this economy item. Furthermore, the Skadar Lake National Park generates incomes from selling of fishing licenses (recreational, economic and industrial) and in 2006 they collected 85,890.00 €. We can conclude that by this time their fishing licenses income has grown to 100,000.00 €. All this gives us an amount of approximately 4,250,000.00 € as the value of this economy. The data are given in table 12.

Table 12. The total economy based on fish from Skadar lake as a main resource

Items	Ammount [€]
Fishermen incomes, direct dependence	~ 2 000 000,00
Indirect dependence (workers in restaurants, fish processing, workers in cannery, workers at concessions)	~ 2 000 000,00
Concessionaires	150 000,00
Skadar Lake National Park income by licences	100 000,00
Total	**4 250 000,00**

Potential decrease of incomes based on fish resource is proportionate to decrease of fish resource. We mentioned before in previous part that decreasing of resource on which some economy is based will cause proportionate decrease in whole related economy. In our case, this means that a 30% decrease of fish resource will induce whole economy decrease for same percentage (30 %). In terms of incomes this further means that fish-based economy will lose ~ 1 416 666,00 €.

At first sight this could look that we have chosen the worst combination of scenarios but this is not the case. The maximum decrease of carp population in combination of worst scenarios is 40% while for bleak we estimate that is up to 10%. If we consider the proportion of carp in total fisherman income we can see that this fish contribute with 60%. For restaurant this percentage is even bigger. We decided to adopt the 30% decrease as for whole fish stock without entering in deeper analysis. In terms of families that directly or indirectly depend on fish stock it is obvious that, if dams reduce water level in Skadar lake during spring time, some of them will be forced to find another source of income, others will faced with a drop in their incomes while third (shareholders in concessionaries and in cannery, restaurant owners) could be faced with loss of their investments. Speaking in numbers this means that 200 families will be faced with some kind of economic problems or simply, fish for them will not represent economic resource any more. In conclusion, if dams dramatically decrease Lake water level during spring time, this will cause loss of 1 416 666,00 € in related economy and 200 families will lose their major income. Moreover, this further means that price of fish will significantly increase (by 30%) and this could result in this economy becoming unsustainable. Higher price of fish will caused more expense for consumers and if they are not willing to, or cannot, pay that will have even more dramatic and negative effects than we describe above.

8. Conclusion

The study made by Knežević predicts the consequences of variation in an important ecological requirement of fish, the spawning habitat. It is widely known that the most vulnerable part of the year for all fish species is the spawning period. In Skadar lake, predominantly inhabited by Cyprinids, this occurs in spring when natural floods occur. Of the two most important fishery species, carp and bleak, the carp uses a special and temporary habitat for spawning, created by spring flood events, so that the carp migrates from the deeper water habitats in the lake into the shallow flooded areas that are overgrown by macrophytic vegetation. In these temporary habitats they gather in massive groups, spawn and leave fertilized eggs in the submerged vegetation. After spawning they return to the lake while their larva stay in pools, channels and small lakes to grow. Kneževic calculated that if water is loaded in dam reservoirs during spring months (April, May and June) this will cause a decrease in the water level of Skadar lake in April of approximately 63cm, meaning that the lake's surface will decrease by 12.6km^2. The lost surface corresponds to the spawning ground for carp. The data for May and June are similar: in May the water level will decrease by 64cm causing a decrease in lake surface of 12.8km^2 , while in June the water level will decrease by 65cm which will result in a decrease of the lake surface of 15.8 km^2. If this happens the fertilized eggs or the carp's larva would perish.

It is estimated that 20% of spawning ground will be destroyed resulting in 20% fewer juveniles in the next carp generation. This is a significant loss which, if it occurred every year, would result in a decrease, in 3 -10 years, of almost 20% of the total carp biomass of Skadar Lake. The bleak population on the other side is not expected to face the same direct impacts because of a different life cycle. The bleak, in fact, spawns in open waters and their larva are pelagic hence it will not suffer littoral habitat loss.

It is important to mention an indirect impact of dam building. This is related to the expected changes in the physiology of Skadar Lake's ecosystem. Morača river is a highly erosive river that feeds Skadar Lake with nutrients (phosphorus and nitrogenous soils). Considering that Morača river brings the majority of the lake's nutrients (crucially important for the unusually high productivity of the lake) we can expect that some significant part of them will be stored in the new artificial reservoirs without ever reaching the lake. In other words Skadar lake will receive a significantly smaller amount of nutrients which would change the lake's physiology and lower its bio-production. This loss will impact on all living components but in particular on the bleak as its larva live in free water and feed on zooplankton (bio-production). The bio-production is related to the plankton algae which are the main productive component of the lake ecosystem. Zooplankton, as an animal component, most directly depends on phytoplankton (algae) while for algae nutrients are one of the most restrictive needs. The decrease of bio-production will affect the bleak larva and consequently the bleak population. The exact extent of this decrease is hard to estimate. We do not know the amount of nutrients that can be expected to be deposited in the reservoirs and this makes it very difficult to accurately predict the decrease in Skadar lake production. A rough conservative estimate predicts a 10% decrease in the bleak population of Skadar lake.

As the dams on Morača river will be installed in the medium course we can expect a strong negative impact on the trout population living there. Brown trout, the most abundant trout species, will face population fragmentation. In the upper part of the river (downstream of the dams) brown trout individuals will be isolated and the genetic diversity survival will rely on isolated individuals. Upstream and downstream migrations occurring every year will be restricted to the upper and lower areas separately. The brown trout from the lower stretch will lose spawning ground which is located in the upper part of the drainage which will be unreachable due to the dams. We can hence expect a decrease in their number which can increase again only if they adapt and find new suitable spawning habitats. The middle course where the dams will be placed will be directly destroyed and will become an artificial lake ecosystem. Brown trout will be likely to inhabit those lakes but in drastically smaller numbers and they will be forced to adapt to the new reservoir habitats which may not be suitable. We can expect that they will face big constraints in spawning because no fast-flowing water with gravel bottom will be present (the habitat required for their spawning).

The marble trout will be also negatively affected because the medium course of Morača river, where this species is more abundant, will be completely changed. We can expect that the number of marble trout individuals will dramatically decrease and this is of particular concern as the species is already at a critically low number compared to 25 years ago. As the middle course of Morača river is the main spawning ground for marble trout in Morača river, their number will suffer due to small spawning efficiency.

The brown trout could potentially survive in two separate populations (upstream and downstream of the dams) while marble trout will remain only in the lower course (from Skadar lake till the first dam on Zlatica).

9. Literature

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