Enabling
& Transboundary Cooperation
Integrated Water Resources Management
in the extended DRIN RIVER BASIN

Global Water Partnership Mediterranean

UNECE

Ecological Flows in the Drin Basin

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For more information, please contact

Global Water Partnership
Mediterranean

Web: www.gwpmed.org

Headquarters:
12, Kyrristou str., 10556
Athens, Greece
T: +30210-3247490, -3247267
F: +30210-3317127

Ecological Flows in the Drin Basin

Papadaki Christina, Elias Dimitriou

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For more information, please contact:

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1. Background

The hydrologic regime is a key element in determining river processes. All components of a flow regime including floods, medium and low flows are important and influence the river ecosystems (Acreman & Dunbar 2004). River straightening for flood control and/or navigation purposes, water abstractions, water flow regulations (dams, weirs, sluices, and locks), morphological alterations, and the disconnection of flood plains are all hydromorphological pressures (Fehér et al. 2012) that alter the natural flow regime of rivers. Flow alteration can be directly linked to impacts on the physical and chemical attributes and processes of rivers. With so many competing needs for water, there is an urgent need to develop sustainable environmental flow management guidelines to manage the risk associated with alterations to the flow regime (European Commission ─ EC, 2015).

Environmental flow represents the water required to sustain freshwater and estuarine ecosystems, and the human livelihood that depend on these ecosystems (Arthington et al. 2018). River water designated for environmental outcomes, can be either flow remaining in the river protected from abstraction, or actively released water from storages to achieve desired ecosystem outcomes. It is recognized that certain physicochemical and hydromorphological conditions are needed to maintain a healthy ecosystem. A great majority of water supply planners worldwide have already began to address the water needs of river ecosystems proactively by reserving some portion of river flows for ecosystem support (Linnansaari et al. 2013). These restorative and protective actions require development of scientifically credible estimates of environmental flow needs. Priority should be given to better address over-abstraction of water, the second most common pressure on European Union ecological status, and to recognize that water quality and quantity are intimately related within the concept of 'good status' (European Commission ─ EC, 2015).

Environmental flow estimation methods can be grouped into four categories: hydrological, hydraulic rating, habitat simulation, and holistic methods. Details of these methods are presented in the literature (Acreman and Dunbar 2004; Jowett 1997; Tharme 2003). Hydrological methods have been developed for broadscale planning and they use available streamflow data. Historical flow methods use existing and simulated hydrological data from surface water gauging stations. Among the most well-known methods of this category are the flow duration curve analysis and the Montana Method (Tennant 1976). Flow duration curve analysis recommend a fixed proportion of flow derived from a cut-off point on a flow duration curve: i.e. the % exceedance or probability that a certain flow rate is exceeded x% of the time. While the Montana Method (Tennant), developed in the USA, identifies various levels of minimum flows based on specified proportions of the mean flow (Tennant 1976). Hydraulic methods relate channel morphology and cross sections to flow characteristics (rates, velocities, volumes). These flows are intended to retain a certain percentage of habitats, assuming that habitats are controlled by flow. However, some hydraulic habitats are strongly influenced by substrate, water quality and biotic factors. Habitat methods predict the effect of flow on habitat availability from species habitat indexes which relate biological parameters to depth and velocity (Pusey & Arthington 1991, King & Tharme 1994, Bovee 1982). Finally, holistic methodologies examine multiple data inputs together with expert opinion and consideration of socio-economic objectives, leading to recommendations of flow regimes for all components of the riverine ecosystem.

Environmental flow requirements of the extended Drin basin have not been adequately addressed. Currently there is limited understanding of the ecological needs for water and there is virtually no recognition of ecological needs for water in the basin. Over the long term, this is likely to pose risks to ecological health in the extended basin.

2. Introduction

Environmental flow assessment of the extended Drin river basin has been carried out, defined by the degree of deviation of its subbasin from reference flow conditions. Based on the Water Framework Directive 2000/60/EC (WFD) requirements, ecologically appropriate hydrological regimes are necessary to meet a Good Ecological Status (GES) in all waterbodies, which is assessed by reference to aquatic biology. Pristine waterbodies are classified as high ecological status (HES) and must be maintained at this status level. Where any waterbody is moderate, poor or bad, measures must be defined to improve its status to at least good. Waterbodies that have physical modifications, such as dams, weirs and embankments or have been straightened or deepened, can be designated as a heavily modified waterbodies (HMWB) or artificial (Acreman and Ferguson 2010).

Each environmental flow assessment method has certain advantages and limitations. Before selecting among the available methods several factors need to be considered such as the resources available, the practical constraints and data availability. The results from this preliminary analysis will provide the necessary information to all implicants to discuss and decide on relevant to sustainable water resources management issues for the development of a Drin Basin Management Plan in the future. In general holistic methodologies are considered as the most suitable and should be integrated in the future for an effective planning and management of the extended Drin river basin.

3. Study Area

The extended Drin river basin is located in the South Western Balkans. It encompasses the Drin River and its two major tributaries, the Black Drin and the White Drin, as well as the Buna/Bojana River and three lakes: Prespa, Ohrid and Skadar/Shkoder (Fig. 3-1). The extended river basin is shared between Albania, Greece, North Macedonia, Montenegro and Kosovo. Because of the transboundary character of these freshwater bodies, different names have been given to the same places (e.g. Albania: Drin or Drini; North Macedonia: Drim). Hereafter the name Drin river basin (http://drincorda.iwlearn.org/drin-river-basin) will be used in this report. Subbasins are formed by the rivers Black Drin, White Drin, and Buna (Bojana), as well as the lakes Prespa, Ohrid, and Skadar/Shkodër.

Fig. 3-1 Map of the study area

4. Data

Ecological flow assessments were made based on simulated hydrological data (monthly time series for the period of November 2001 to November 2010) from the Panta-Rhei hydrologic model (GIZ 2013). The reference conditions as a 'baseline' were established by adding the water consumptions (urban, agricultural and industrial use) provided by the GEF Project 2018 (Annex A), to the simulated hydrological timeseries (Annex B). The hydrological data have been analyzed for distribution fitting procedures to examine normality using the Kolmogorov-Smirnov test and the Shapiro-Wilk W test (table 1). The data are not following a normal distribution since the p-value is less than the significance level (α=0.05).

Table 1 Normality tests

Subbasins	Kolmogorov-Smirnov p-value	Shapiro-Wilk p-value
White Drini	0,005	0
Black Drini	0	0
Drini	0	0
Skadar/Shkodra	0	0
Ohrid	0,003	0,005
Buna/Bojana	0	0

5. Methodology

In this report different hydrological methods were used to evaluate environmental flows in the extended Drin river basin. Hydrological methodologies are also known as ‘rule of thumb’ methodologies (Tharme 1996). These type of methodologies are all based on historical flow records. The Tennant, Method (Tennant 1976) is the most frequently used method throughout the world. The main features of these methods are described in the followings.

4.1 Flow duration curve method

Flow duration curve methods define the proportion of time that certain flow threshold levels are equaled or exceeded in the particular river or region. These flow threshold levels are required to support biotic integrity. Global Environmental Flow Calculator (GEFC) (available in GEFC), was used for desktop rapid assessment of Environmental Flows (EFs) in the extended Drin River Basin. GEFC uses monthly time series reflecting close to reference flow conditions and a corresponding Flow Duration Curve (FDC) as a cumulative distribution function of flows. Details of the method are described in Smakhtin and Anputhas (2006). Moreover, GEFC estimates Environmental Management Classes (EMCs). The higher the EMC, the more water is needed for ecosystem maintenance and more flow variability needs to be preserved (Smakhtin & Eriyagama, 2008). Placing a river into a certain EMC is often accomplished by expert judgment using a scoring system (DWAF, 1997; Environment Agency, 2001). Six EMCs are used in this method and are presented in Table 2. The Flow Duration Curves, were converted into actual environmental monthly flow time series using a spatial interpolation procedure described in detail by Hughes and Smakhtin (1996).

Table 2 Environmental Management Classes estimated from the GEFC software

EMC	Most likely ecological condition	Management perspective
A (natural)	Natural rivers with minor modification of instream and riparian habitat	Protected rivers and basins; reserves and national parks; No new water projects (dams, diversions) allowed
B (slightly modified)	Slightly modified and/or ecologically important rivers with largely intact biodiversity and habitats despite water resources development and/or basin modifications	Water supply schemes or irrigation development present and/or allowed
C (moderately modified)	The habitats and dynamics of the biota have been disturbed, but basic ecosystem functions are still intact; some sensitive species are lost and/or reduced in extent; alien species present	Multiple disturbances (e.g., dams, diversions, habitat modification, and reduced water quality) associated with the need for socioeconomic development
D (largely modified)	Large changes in natural habitat, biota, and basic ecosystem functions have occurred; species richness is clearly lower than expected; much lowered presence of intolerant species; alien species prevail	Significant and clearly visible disturbances (including dams, diversions, transfers, habitat modification, and water quality degradation) associated with basin and water resources development
E (seriously modified)	Habitat diversity and availability have declined; Species richness is strikingly lower than expected; only tolerant species remain; indigenous species can no longer breed; alien species have invaded the ecosystem	High human population density and extensive water resources exploitation; generally, this status should not be acceptable as a management goal; management interventions are necessary to restore flow pattern and to ''move'' a river to a higher management category
F (Critically modified)	Modifications have reached a critical level; ecosystem has been completely modified with almost total loss of natural habitat and biota; in the worst case, basic ecosystem functions have been destroyed and changes are irreversible	This status is not acceptable from the management perspective; management interventions are necessary to restore flow pattern and river habitats

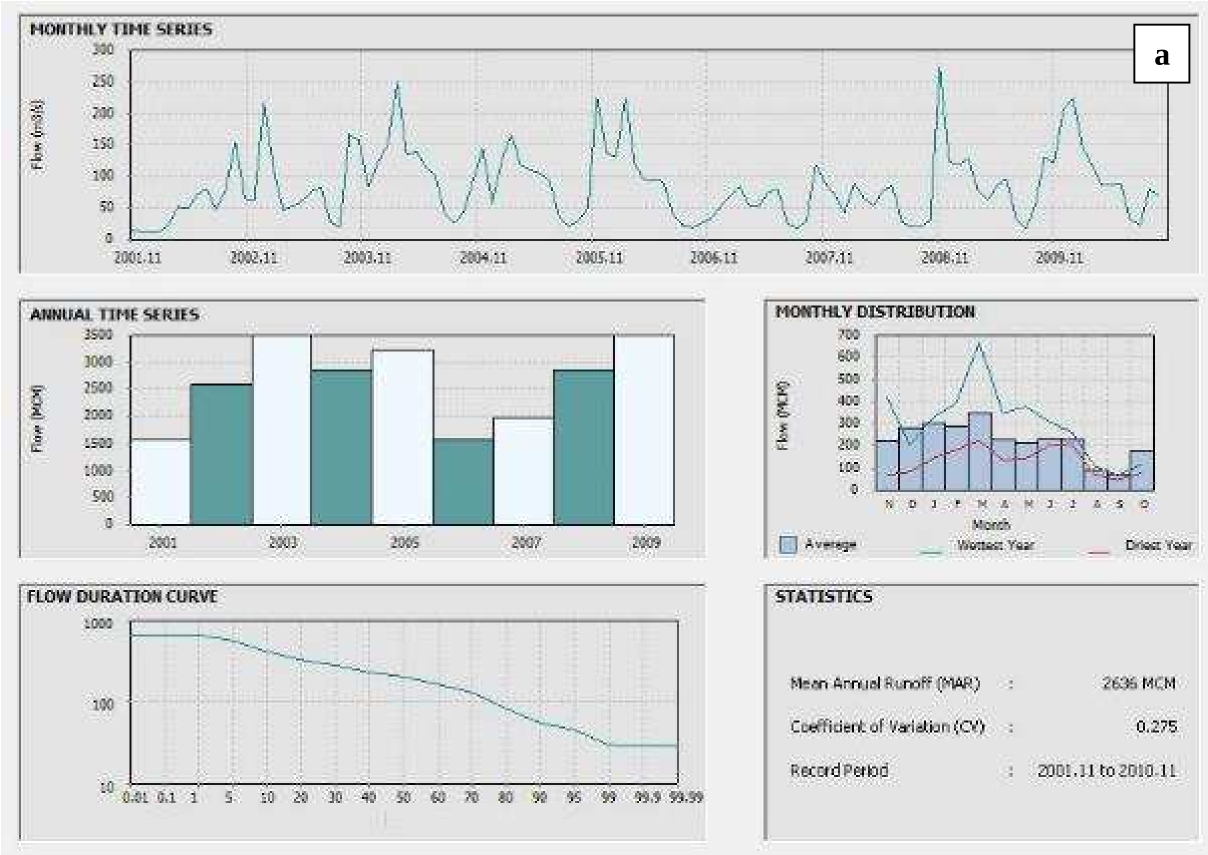
4.2 Tennant method

The Montana, or Tennant, Method (Tennant 1976) has been regularly used throughout the world. This method assumes that some proportion of the average annual flow (mean annual flow - MAF - which is used hereafter) is required to sustain the biological integrity of a river ecosystem. Specifically, 10% of the MAF is considered to be the lowest instantaneous flow to sustain short-term survival of aquatic life, 30% of MAF is considered to provide flows where the biological integrity of the river ecosystem as a whole is sustained, while flows higher than 60% of the MAF provide excellent to outstanding habitat conditions (Arthington and Zalucki 1998). A distinction between high and low flow periods (October-March and April-September), respectively as a modification of the original method due to the different climatic conditions among the earth's hemispheres.

6. Results

The potential environmental flows in the extended Drin river basin were evaluated by the hydrological method (FDC shifting) using GEFC software and the Tennant method. Monthly flow data over 9 years (between 2001 and 2010) were used to develop a FDC and to generate flow requirements corresponding to different levels of river ecosystem values. Among the six EMCs, flow regimes that fall into the category of the D, E and F EMC, fail to meet the WFD requirements for Good Ecological Status (GES) and cannot support healthy ecosystems, so they have been excluded for further analysis.

Actual monthly flow data of six subbasins of the extended Drin river basin together with other hydrological characteristics / time series and FDCs for different EMCs are presented in the following figures (Fig.6-1 to 6-6).



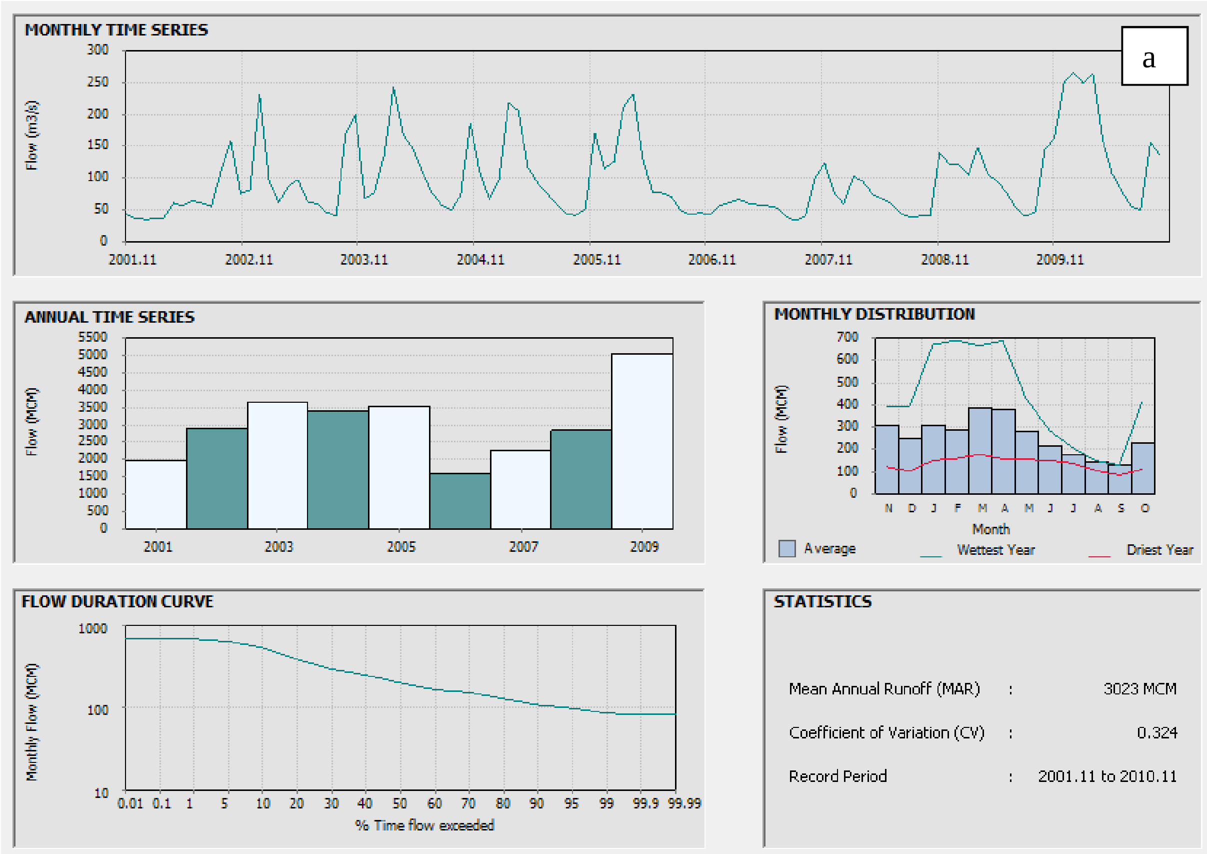
b

DEFAULT ENVIRONMENTAL MANAGEMENT CLASSES

Class	Description	% NATURAL MAR
A: Natural	- Pristine Condition or Minor Modification of In-Stream and Riparian Habitat	80.3
B: Slightly Modifiedl	- Largely Intact Biodiversity and Habitats Despite Water Resources Development and/or Basin Modifications	64.2
C: Moderately Modified	- The Habitats and Dynamics of the Biota have Been Disturbed, but Basic Ecosystem Functions are Still Intact. Some Sensitive Species are Lost and/or Reduced in Extent. Alien Species Present.	51.3
D: Largely Modified	- Large changes in natural habitat, biota and basic ecosystem functions have occurred. A clearly lower than expected species richness. Much lowered presence of intolerant species. Alien species prevail.	41
E: Seriously Modified	- Habitat diversity and availability have declined. A strikingly lower than expected species richness. Only tolerant species remain. Indigenous species can no longer breed. Alien species have invaded the ecosystem	32.4
F: Critically Modified	- Modifications have reached a critical level and ecosystem has been completely modified with almost total loss of natural habitat and biota. In the worst case, the basic ecosystem functions have been destroyed and the changes are irreversible.	25.6

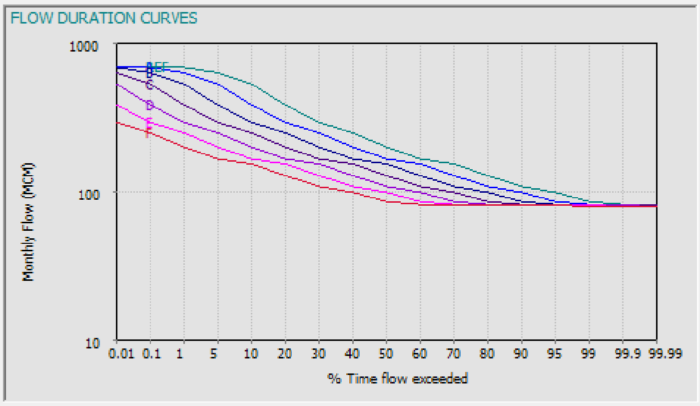
%	REF	A	B	C	D	E	F
0.01	675	675	667	569	415	328	283
0.1	675	667	569	415	328	283	231
1	667	569	415	328	283	231	205
5	569	415	328	283	231	205	165
10	415	328	283	231	205	165	131
20	328	283	231	205	165	131	83.6
30	283	231	205	165	131	83.6	55.4
40	231	205	165	131	83.6	55.4	45.5
50	205	165	131	83.6	55.4	45.5	29.6
60	165	131	83.6	55.4	45.5	29.6	29.0
70	131	83.6	55.4	45.5	29.6	29.0	28.9
80	83.6	55.4	45.5	29.6	29.0	28.9	28.9
90	55.4	45.5	29.6	29.0	28.9	28.9	28.8
95	45.5	29.6	29.0	28.9	28.9	28.8	28.8
99	29.6	29.0	28.9	28.9	28.8	28.8	28.7
99.9	29.0	28.9	28.9	28.8	28.8	28.7	28.6
99.99	28.9	28.9	28.8	28.8	28.7	28.6	28.6

Fig. 6-1 Display of the actual monthly flow data of the White Drin subbasin and other hydrological characteristics / time series (a) and estimation of FDCs for different EMCs by lateral shift (Smakhtin and Anputhas 2006) (b)



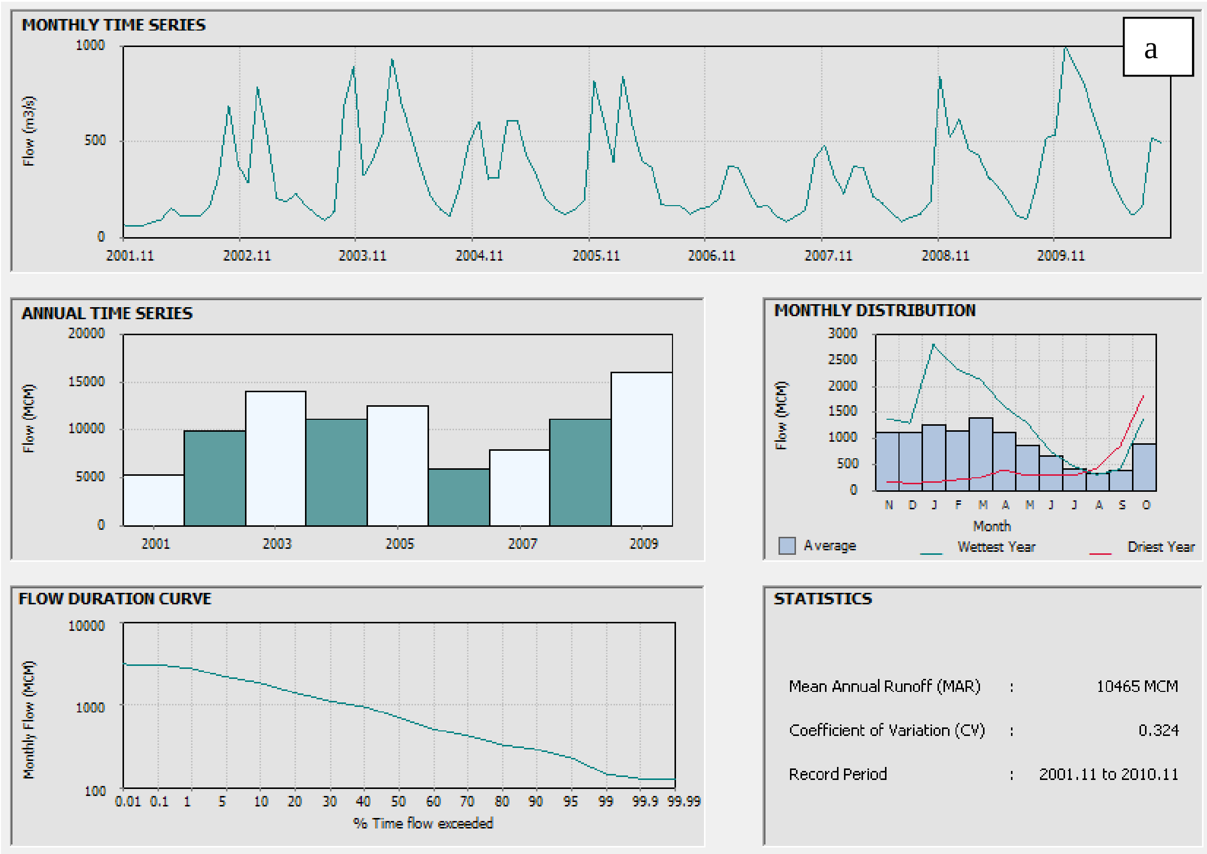
b

DEFAULT ENVIRONMENTAL MANAGEMENT CLASSES		% NATURAL MAR
A: Natural	- Pristine Condition or Minor Modification of In-Stream and Riparian Habitat	82.4
B: Slightly Modifiedl	- Largely Intact Biodiversity and Habitats Despite Water Resources Development and/or Basin Modifications	68.3
C: Moderately Modified	- The Habitats and Dynamics of the Biota have Been Disturbed, but Basic Ecosystem Functions are Still Intact. Some Sensitive Species are Lost and/or Reduced in Extent. Alien Species Present.	57.6
D: Largely Modified	- Large changes in natural habitat, biota and basic ecosystem functions have occurred. A clearly lower than expected species richness. Much lowered presence of intolerant species. Alien species prevail.	49.7
E: Seriously Modified	- Habitat diversity and availability have declined. A strikingly lower than expected species richness. Only tolerant species remain. Indigenous species can no longer breed. Alien species have invaded the ecosystem	44
F: Critically Modified	- Modifications have reached a critical level and ecosystem has been completely modified with almost total loss of natural habitat and biota. In the worst case, the basic ecosystem functions have been destroyed and the changes are irreversible.	39.8



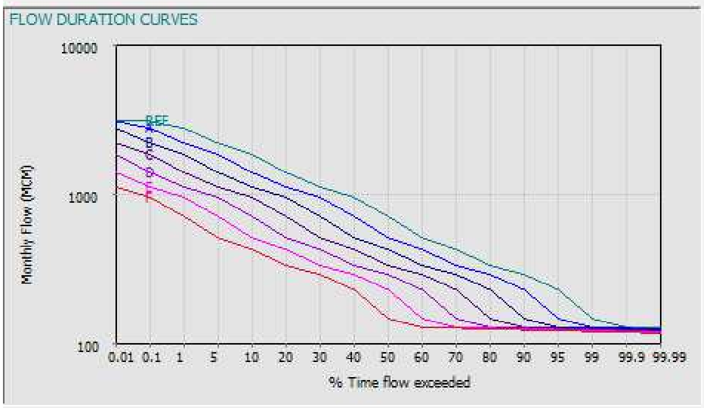
%	REF	A	B	C	D	E	F
0.01	690	690	689	636	534	385	295
0.1	690	689	636	534	385	295	249
1	689	636	534	385	295	249	200
5	636	534	385	295	249	200	167
10	534	385	295	249	200	167	154
20	385	295	249	200	167	154	129
30	295	249	200	167	154	129	109
40	249	200	167	154	129	109	99.3
50	200	167	154	129	109	99.3	86.0
60	167	154	129	109	99.3	86.0	82.2
70	154	129	109	99.3	86.0	82.2	81.8
80	129	109	99.3	86.0	82.2	81.8	81.5
90	109	99.3	86.0	82.2	81.8	81.5	81.1
95	99.3	86.0	82.2	81.8	81.5	81.1	80.7
99	86.0	82.2	81.8	81.5	81.1	80.7	80.4
99.9	82.2	81.8	81.5	81.1	80.7	80.4	80.0
99.99	81.8	81.5	81.1	80.7	80.4	80.0	79.7

Fig. 6-2 Display of the actual monthly flow data of the Black Drin subbasin and other hydrological characteristics / time series (a) and estimation of FDCs for different EMCs by lateral shift (Smakhtin and Anputhas 2006) (b)



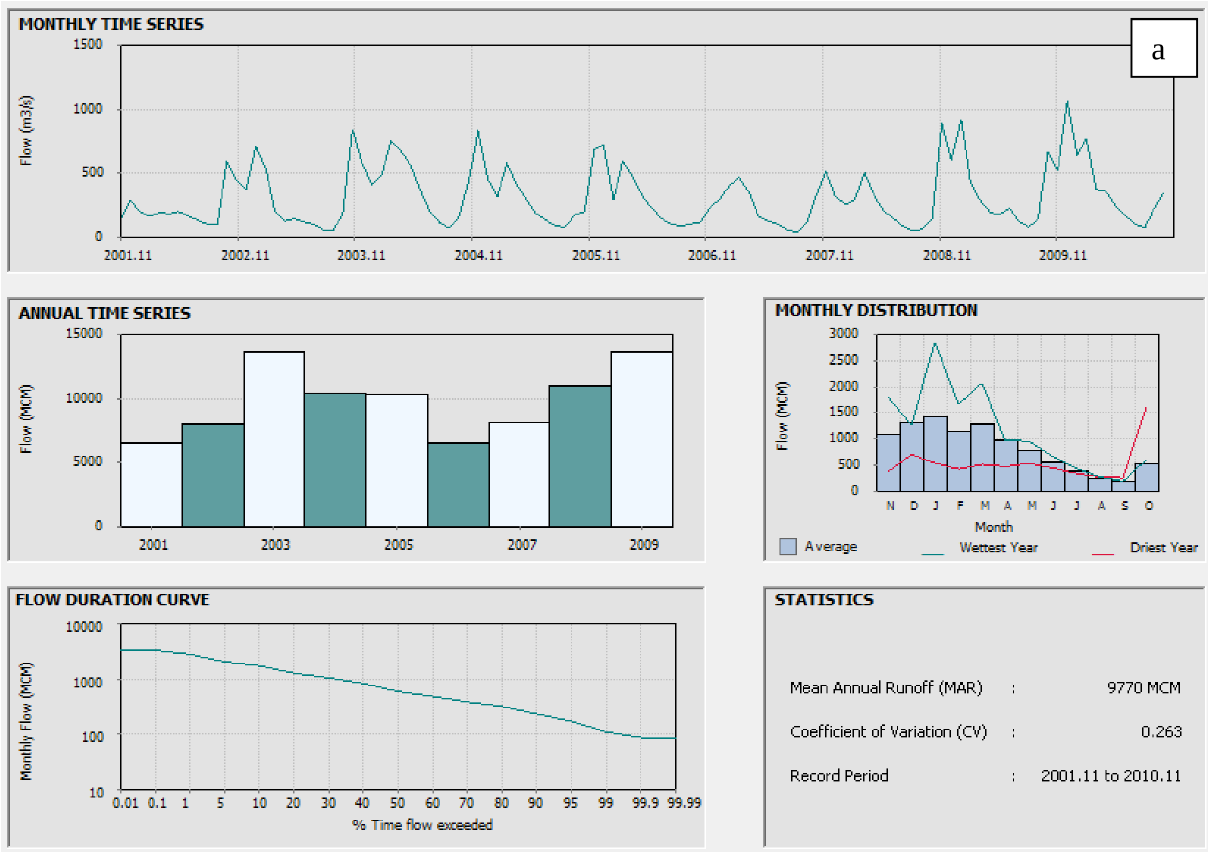
b

DEFAULT ENVIRONMENTAL MANAGEMENT CLASSES		% NATURAL MAR
A: Natural	- Pristine Condition or Minor Modification of In-Stream and Riparian Habitat	79.6
B: Slightly Modifiedl	- Largely Intact Biodiversity and Habitats Despite Water Resources Development and/or Basin Modifications	63.1
C: Moderately Modified	- The Habitats and Dynamics of the Biota have Been Disturbed, but Basic Ecosystem Functions are Still Intact. Some Sensitive Species are Lost and/or Reduced in Extent. Alien Species Present.	49.8
D: Largely Modified	- Large changes in natural habitat, biota and basic ecosystem functions have occurred. A clearly lower than expected species richness. Much lowered presence of intolerant species. Alien species prevail.	39.5
E: Seriously Modified	- Habitat diversity and availability have declined. A strikingly lower than expected species richness. Only tolerant species remain. Indigenous species can no longer breed. Alien species have invaded the ecosystem	31.7
F: Critically Modified	- Modifications have reached a critical level and ecosystem has been completely modified with almost total loss of natural habitat and biota. In the worst case, the basic ecosystem functions have been destroyed and the changes are irreversible.	25.9



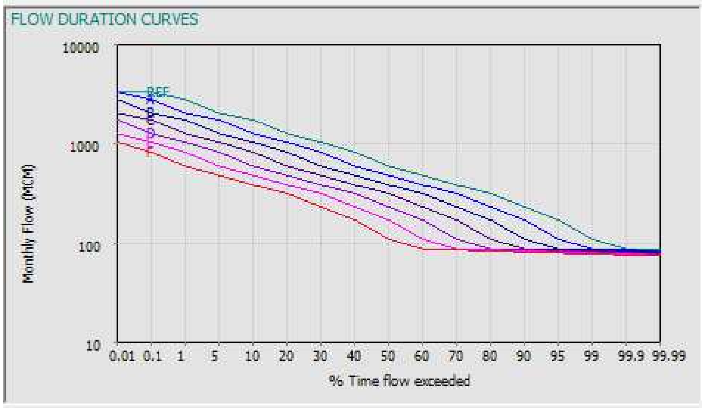
%	REF	A	B	C	D	E	F
0.01	3135	3100	2774	2201	1848	1403	1120
0.1	3100	2774	2201	1848	1403	1120	956
1	2774	2201	1848	1403	1120	956	711
5	2201	1848	1403	1120	956	711	512
10	1848	1403	1120	956	711	512	428
20	1403	1120	956	711	512	428	333
30	1120	956	711	512	428	333	291
40	956	711	512	428	333	291	230
50	711	512	428	333	291	230	147
60	512	428	333	291	230	147	129
70	428	333	291	230	147	129	127
80	333	291	230	147	129	127	126
90	291	230	147	129	127	126	124
95	230	147	129	127	126	124	122
99	147	129	127	126	124	122	121
99.9	129	127	126	124	122	121	119
99.99	127	126	124	122	121	119	118

Fig. 6-3 Display of the actual monthly flow data of the Drin subbasin and other hydrological characteristics / time series (a) and estimation of FDCs for different EMCs by lateral shift (Smakhtin and Anputhas 2006) (b)



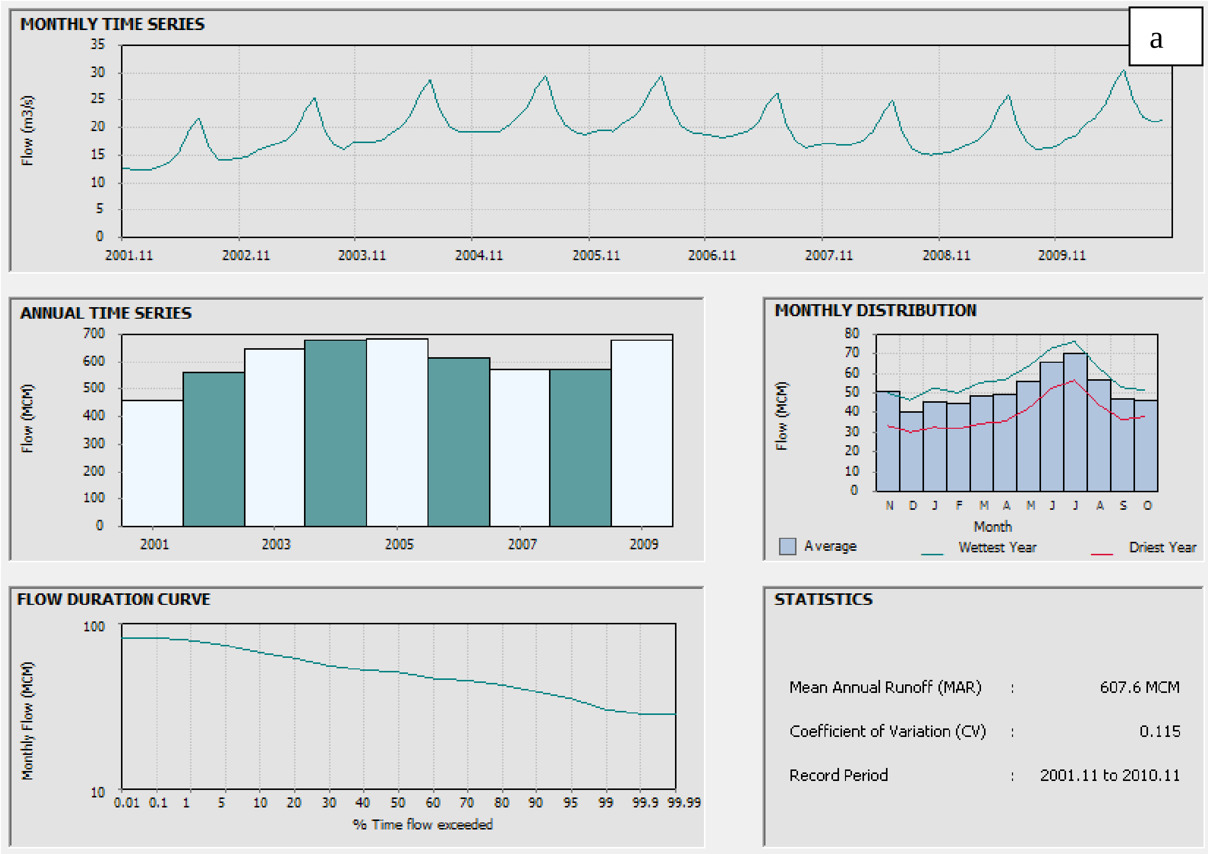
b

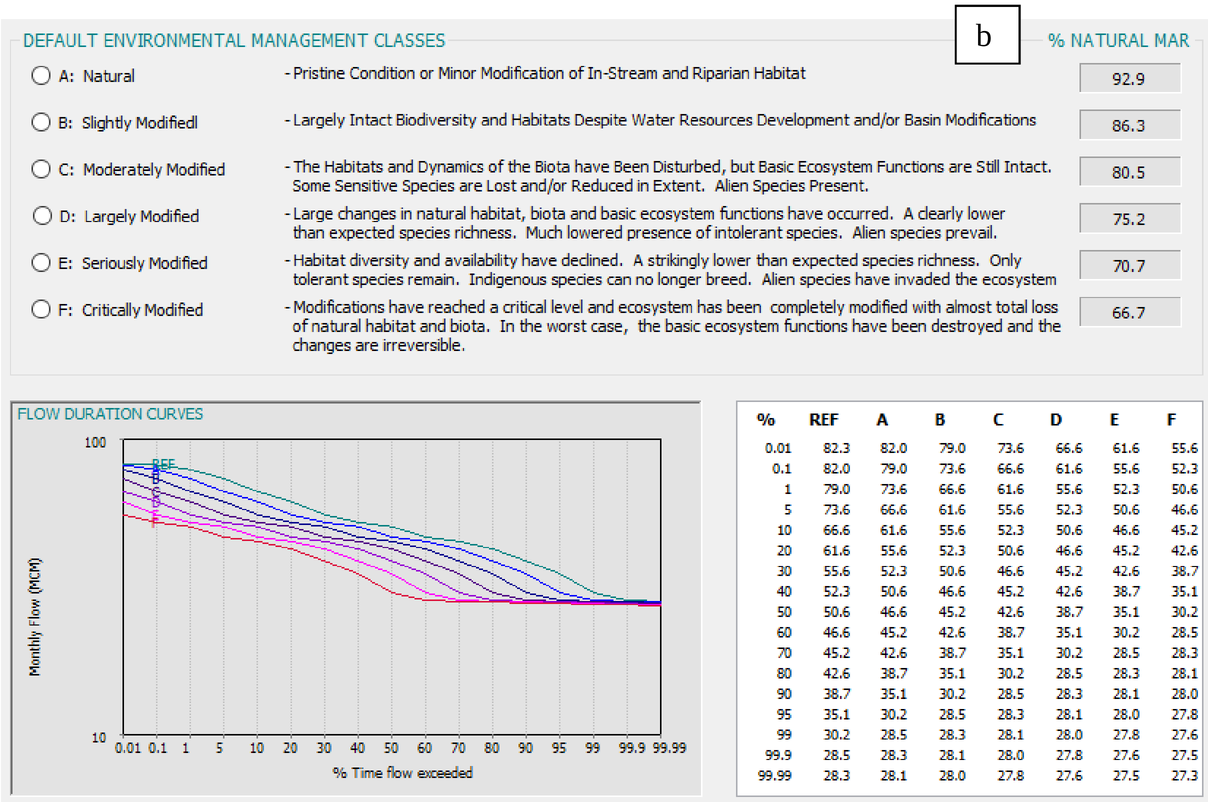
DEFAULT ENVIRONMENTAL MANAGEMENT CLASSES		% NATURAL MAR
A: Natural	- Pristine Condition or Minor Modification of In-Stream and Riparian Habitat	78.1
B: Slightly Modifiedl	- Largely Intact Biodiversity and Habitats Despite Water Resources Development and/or Basin Modifications	60.9
C: Moderately Modified	- The Habitats and Dynamics of the Biota have Been Disturbed, but Basic Ecosystem Functions are Still Intact. Some Sensitive Species are Lost and/or Reduced in Extent. Alien Species Present.	47.3
D: Largely Modified	- Large changes in natural habitat, biota and basic ecosystem functions have occurred. A clearly lower than expected species richness. Much lowered presence of intolerant species. Alien species prevail.	36.9
E: Seriously Modified	- Habitat diversity and availability have declined. A strikingly lower than expected species richness. Only tolerant species remain. Indigenous species can no longer breed. Alien species have invaded the ecosystem	29
F: Critically Modified	- Modifications have reached a critical level and ecosystem has been completely modified with almost total loss of natural habitat and biota. In the worst case, the basic ecosystem functions have been destroyed and the changes are irreversible.	23



%	REF	A	B	C	D	E	F
0.01	3390	3332	2800	2047	1746	1272	1048
0.1	3332	2800	2047	1746	1272	1048	829
1	2800	2047	1746	1272	1048	829	597
5	2047	1746	1272	1048	829	597	485
10	1746	1272	1048	829	597	485	385
20	1272	1048	829	597	485	385	319
30	1048	829	597	485	385	319	233
40	829	597	485	385	319	233	172
50	597	485	385	319	233	172	110
60	485	385	319	233	172	110	87.3
70	385	319	233	172	110	87.3	85.3
80	319	233	172	110	87.3	85.3	83.4
90	233	172	110	87.3	85.3	83.4	81.5
95	172	110	87.3	85.3	83.4	81.5	79.6
99	110	87.3	85.3	83.4	81.5	79.6	77.8
99.9	87.3	85.3	83.4	81.5	79.6	77.8	76.0
99.99	85.3	83.4	81.5	79.6	77.8	76.0	74.2

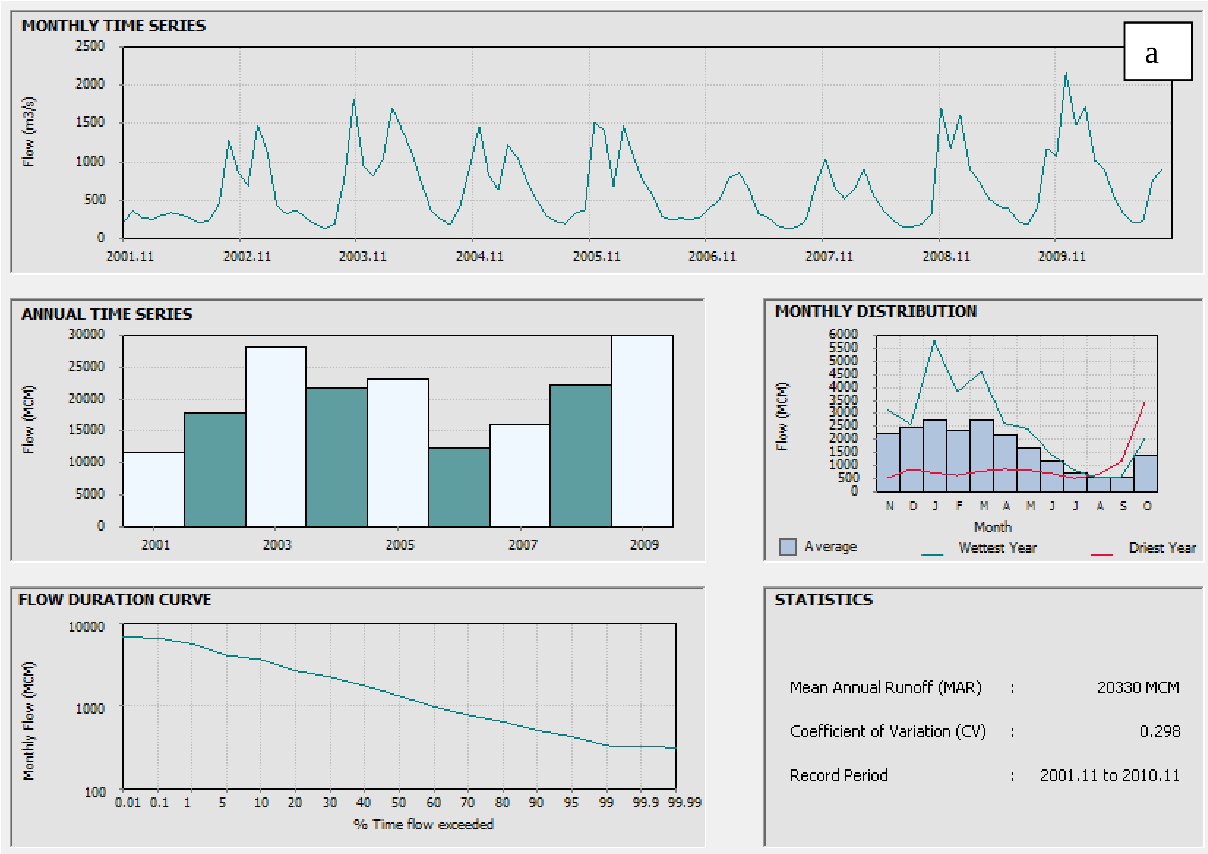
Fig. 6-4 Display of the actual monthly flow data of the Skadar/Shkodra subbasin and other hydrological characteristics / time series (a) and estimation of FDCs for different EMCs by lateral shift (Smakhtin and Anputhas 2006) (b)





%	REF	A	B	C	D	E	F
0.01	82.3	82.0	79.0	73.6	66.6	61.6	55.6
0.1	82.0	79.0	73.6	66.6	61.6	55.6	52.3
1	79.0	73.6	66.6	61.6	55.6	52.3	50.6
5	73.6	66.6	61.6	55.6	52.3	50.6	46.6
10	66.6	61.6	55.6	52.3	50.6	46.6	45.2
20	61.6	55.6	52.3	50.6	46.6	45.2	42.6
30	55.6	52.3	50.6	46.6	45.2	42.6	38.7
40	52.3	50.6	46.6	45.2	42.6	38.7	35.1
50	50.6	46.6	45.2	42.6	38.7	35.1	30.2
60	46.6	45.2	42.6	38.7	35.1	30.2	28.5
70	45.2	42.6	38.7	35.1	30.2	28.5	28.3
80	42.6	38.7	35.1	30.2	28.5	28.3	28.1
90	38.7	35.1	30.2	28.5	28.3	28.1	28.0
95	35.1	30.2	28.5	28.3	28.1	28.0	27.8
99	30.2	28.5	28.3	28.1	28.0	27.8	27.6
99.9	28.5	28.3	28.1	28.0	27.8	27.6	27.5
99.99	28.3	28.1	28.0	27.8	27.6	27.5	27.3

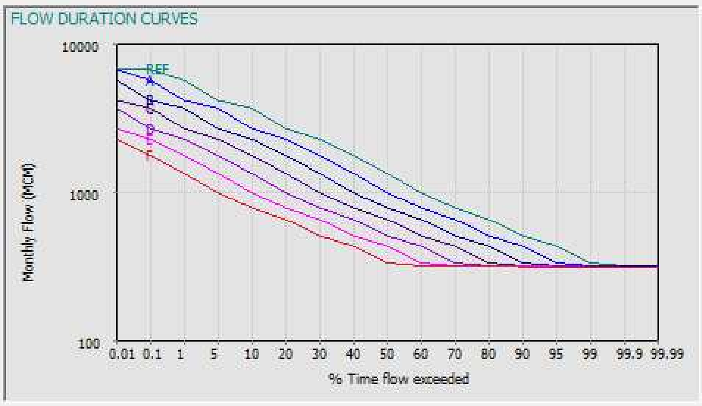
Fig. 6-5 Display of the actual monthly flow data of the Ohrid subbasin and other hydrological characteristics / time series (a) and estimation of FDCs for different EMCs by lateral shift (Smakhtin and Anputhas 2006) (b)



b

DEFAULT ENVIRONMENTAL MANAGEMENT CLASSES

		% NATURAL MAR
A: Natural	- Pristine Condition or Minor Modification of In-Stream and Riparian Habitat	79.1
B: Slightly Modifiedl	- Largely Intact Biodiversity and Habitats Despite Water Resources Development and/or Basin Modifications	62.7
C: Moderately Modified	- The Habitats and Dynamics of the Biota have Been Disturbed, but Basic Ecosystem Functions are Still Intact. Some Sensitive Species are Lost and/or Reduced in Extent. Alien Species Present.	49.7
D: Largely Modified	- Large changes in natural habitat, biota and basic ecosystem functions have occurred. A clearly lower than expected species richness. Much lowered presence of intolerant species. Alien species prevail.	39.9
E: Seriously Modified	- Habitat diversity and availability have declined. A strikingly lower than expected species richness. Only tolerant species remain. Indigenous species can no longer breed. Alien species have invaded the ecosystem	32.7
F: Critically Modified	- Modifications have reached a critical level and ecosystem has been completely modified with almost total loss of natural habitat and biota. In the worst case, the basic ecosystem functions have been destroyed and the changes are irreversible.	27.5



%	REF	A	B	C	D	E	F
0.01	6870	6753	5681	4160	3678	2682	2280
0.1	6753	5681	4160	3678	2682	2280	1768
1	5681	4160	3678	2682	2280	1768	1338
5	4160	3678	2682	2280	1768	1338	992
10	3678	2682	2280	1768	1338	992	785
20	2682	2280	1768	1338	992	785	654
30	2280	1768	1338	992	785	654	510
40	1768	1338	992	785	654	510	433
50	1338	992	785	654	510	433	335
60	992	785	654	510	433	335	320
70	785	654	510	433	335	320	319
80	654	510	433	335	320	319	318
90	510	433	335	320	319	318	316
95	433	335	320	319	318	316	315
99	335	320	319	318	316	315	313
99.9	320	319	318	316	315	313	312
99.99	319	318	316	315	313	312	311

Fig. 6-6 Display of the actual monthly flow data of the Buna/Bojana subbasin and other hydrological characteristics / time series (a) and estimation of FDCs for different EMCs by lateral shift (Smakhtin and Anputhas 2006) (b)

In the next figures (Fig. 6-7 to 6-12) the reference as well as the current flow conditions of the aforementioned subbasins are presented together with the median flow for comparison reasons. There are important water extractions especially for the months April to September regarding White Drini (42.5%), Black Drini (12%), Drini (6%), Skadar/Shkodra (11%) and Ohrid (11.6%) subbasins.

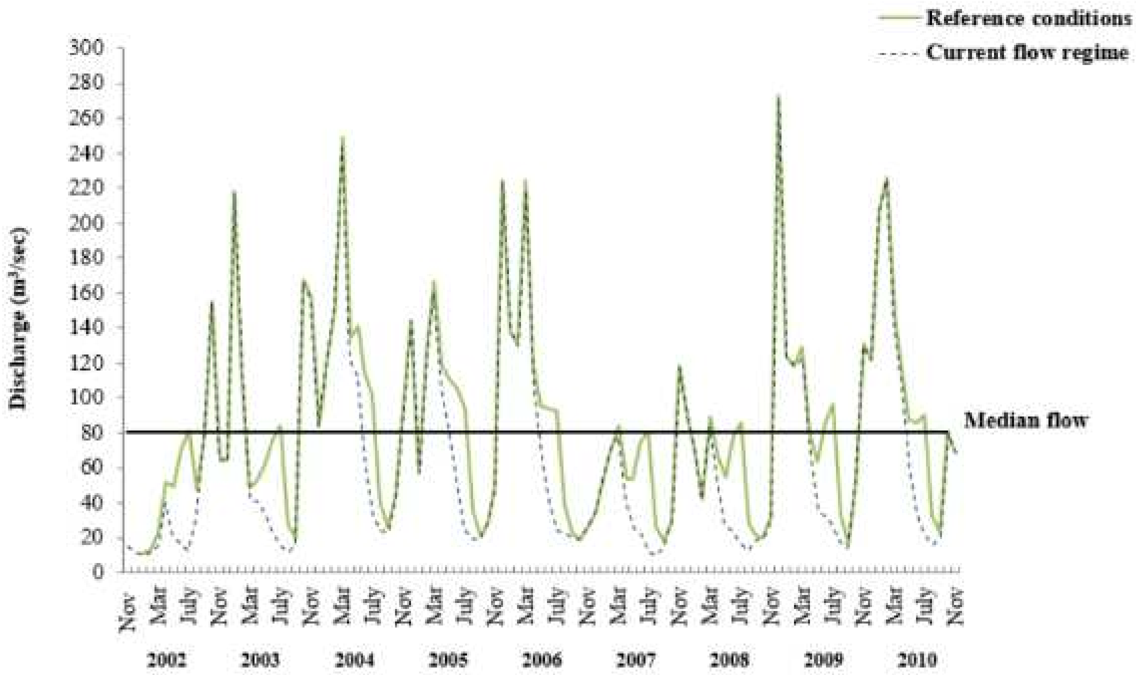


Fig. 6-7 White Drini subbasin

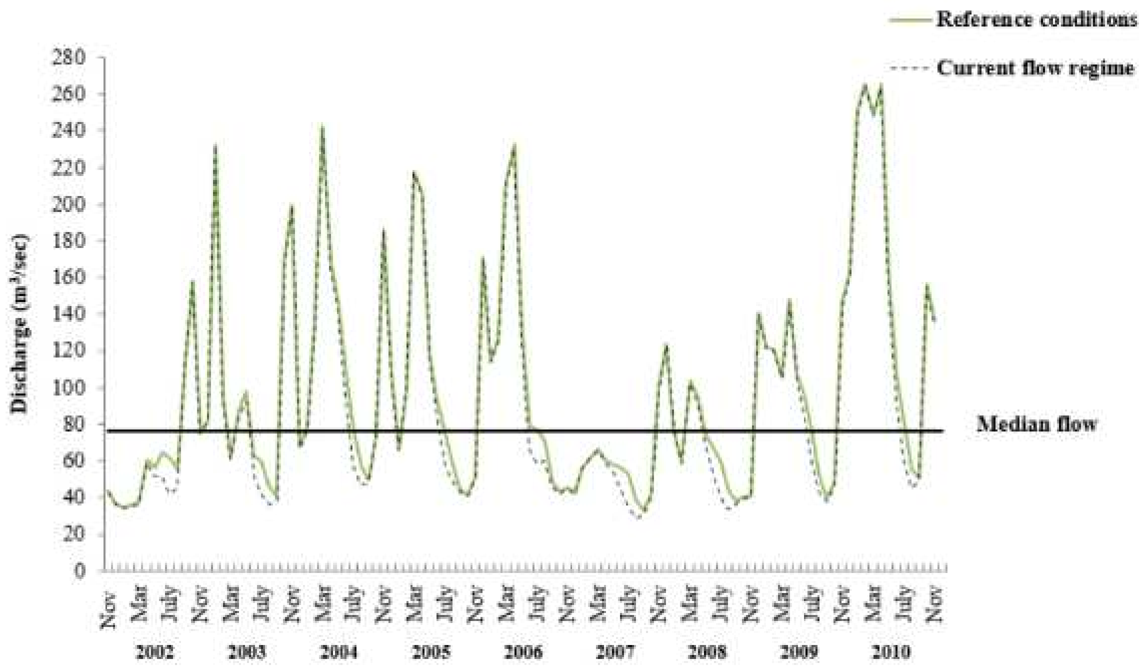


Fig. 6-8 Black Drini subbasin

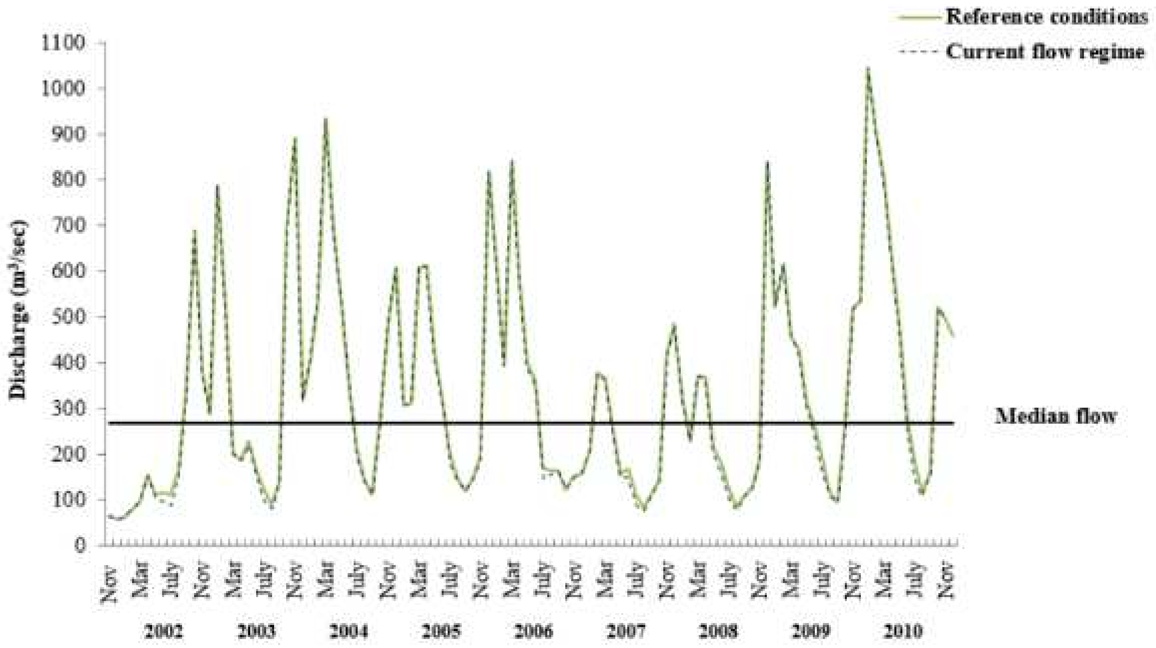


Fig. 6-9 Drini subbasin

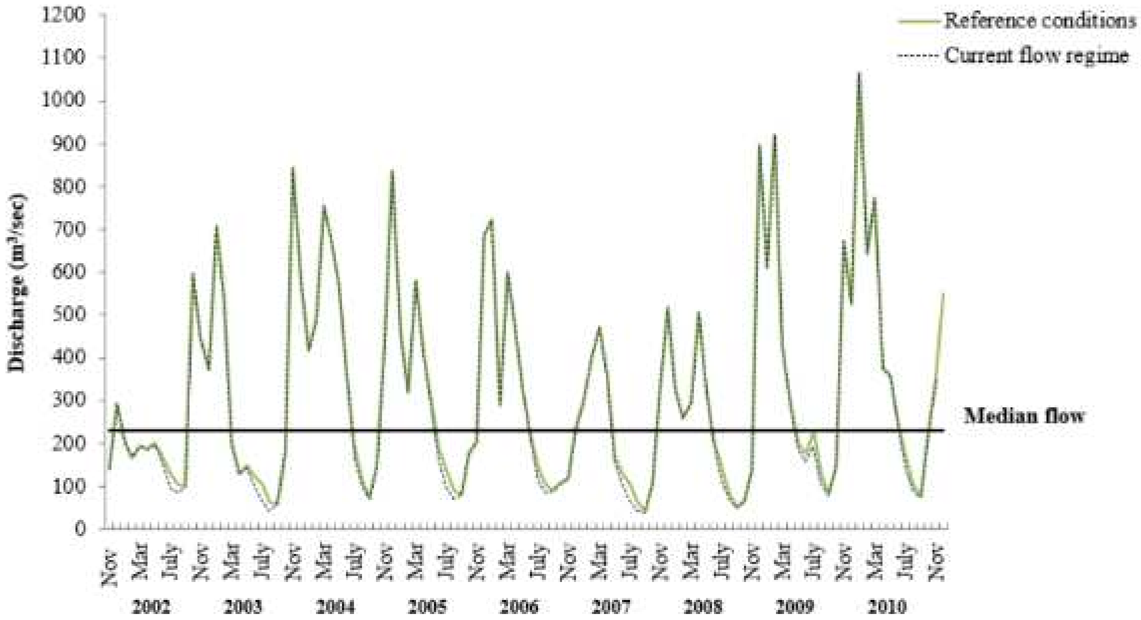


Fig. 6-10 Skadar/Shkodra subbasin

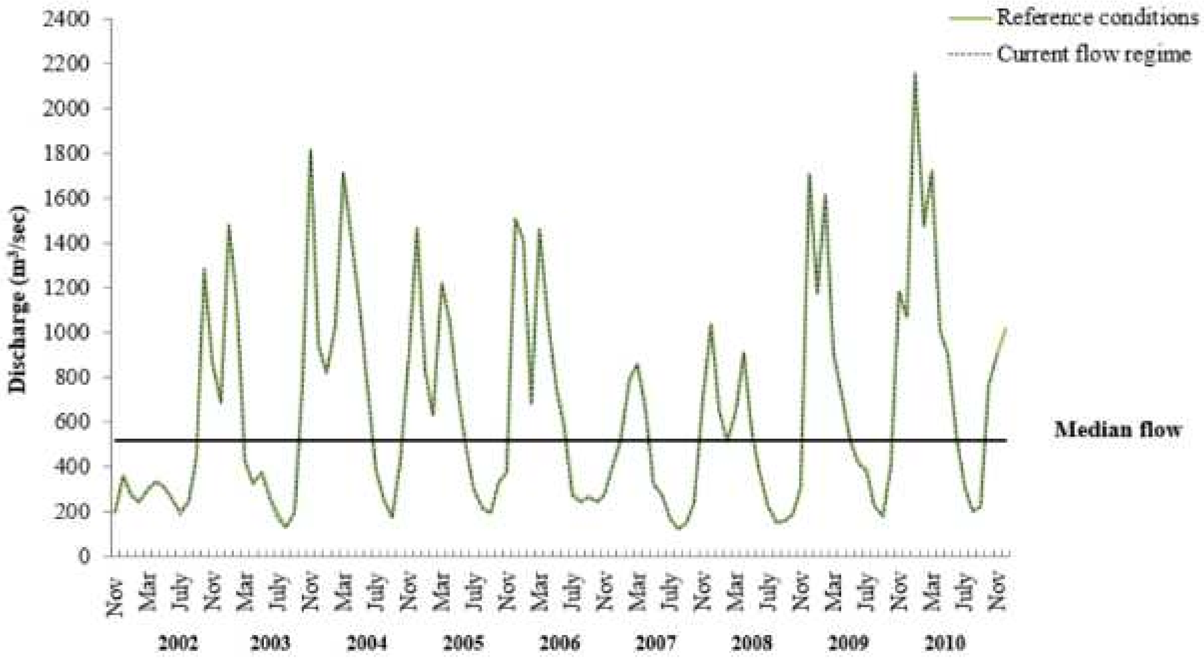


Fig. 6-11 Buna/Bojana subbasin

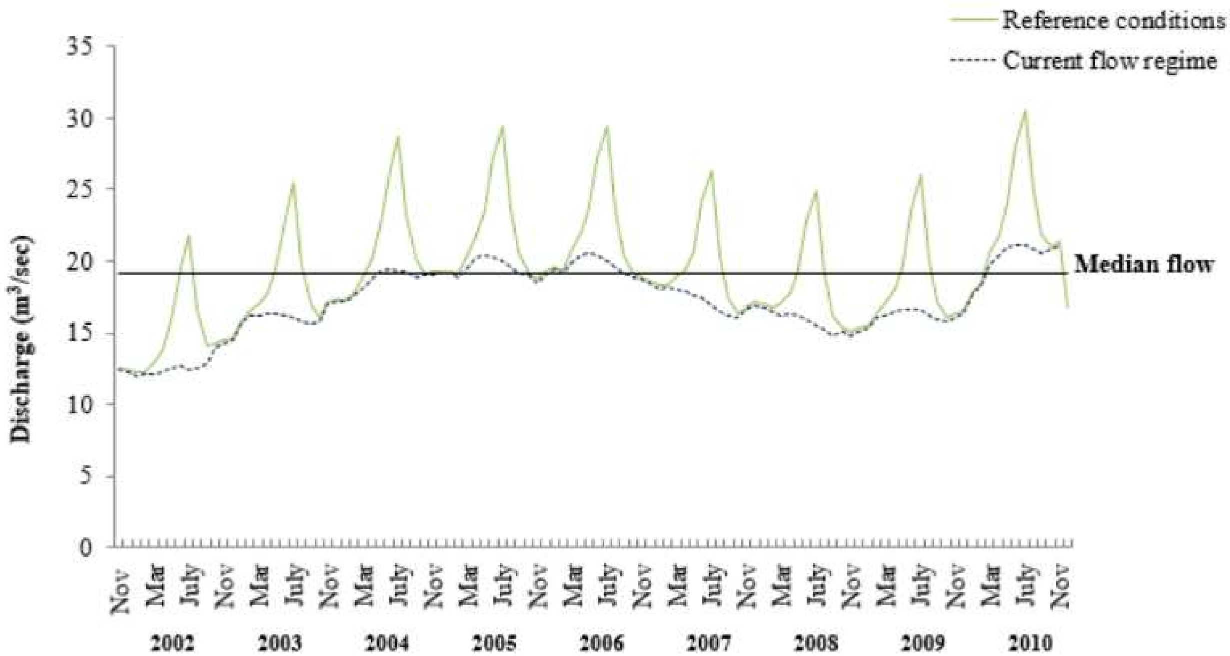


Fig. 6-12 Ohrid subbasin

Estimation of the long-term environmental flows as percent of reference flow conditions for A and C EMCs of the river are presented in the next figures, using the FDC shifting method. The corresponding environmental flow clearly decrease progressively as ecosystem protection decreases. Any water modifications below the C EMC level are critical for the environment. More specifically, White Drini and Black Drini subbasins appeared to be more vulnerable based on the current conditions since more water is needed to fulfill the WFD requirements especially on the summer months.

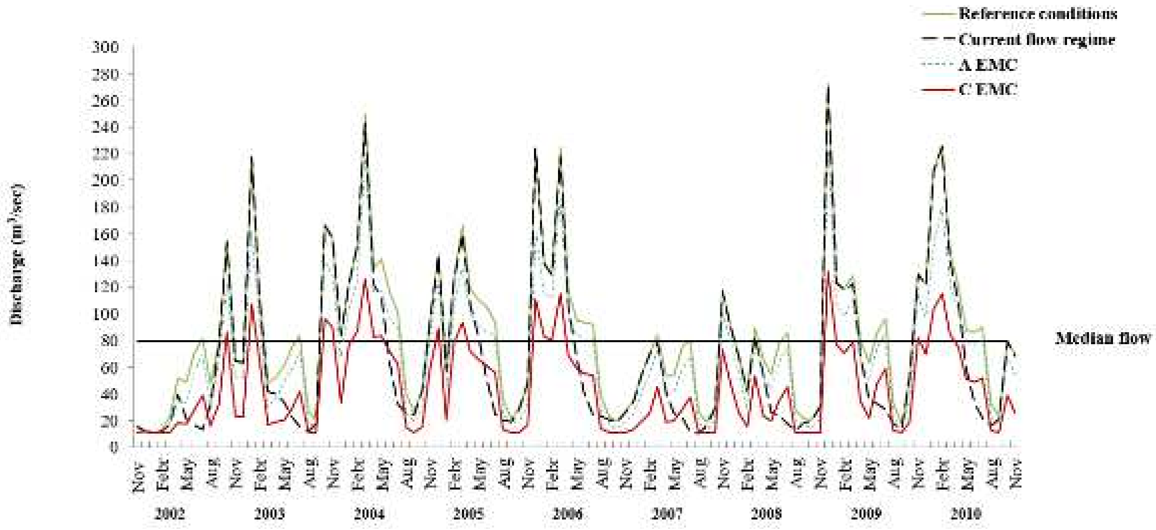


Fig. 6-13 White Drini subbasin with scenarios

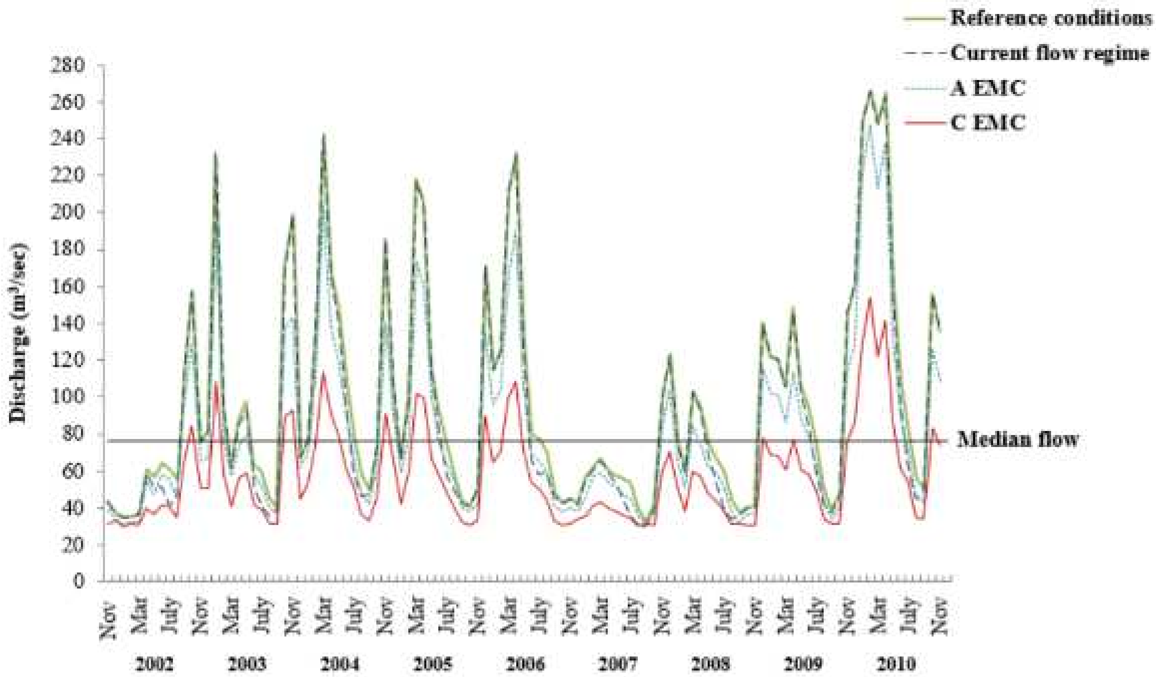


Fig. 6-14 Black Drini subbasin with scenarios

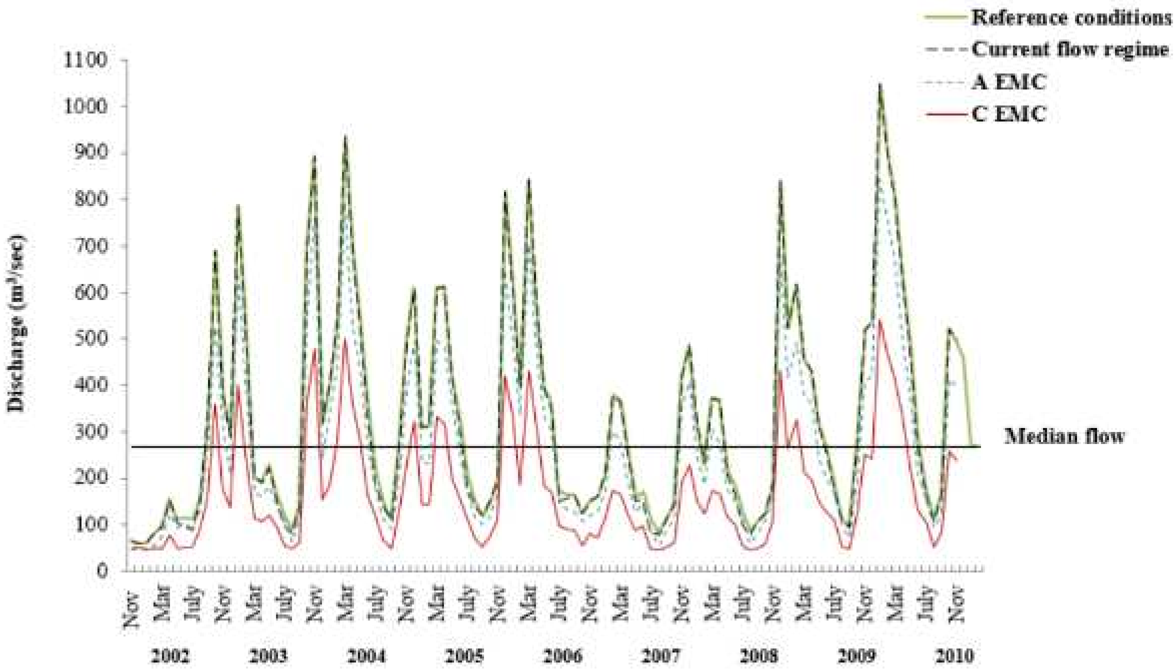


Fig. 6-15 Drini subbasin with scenarios

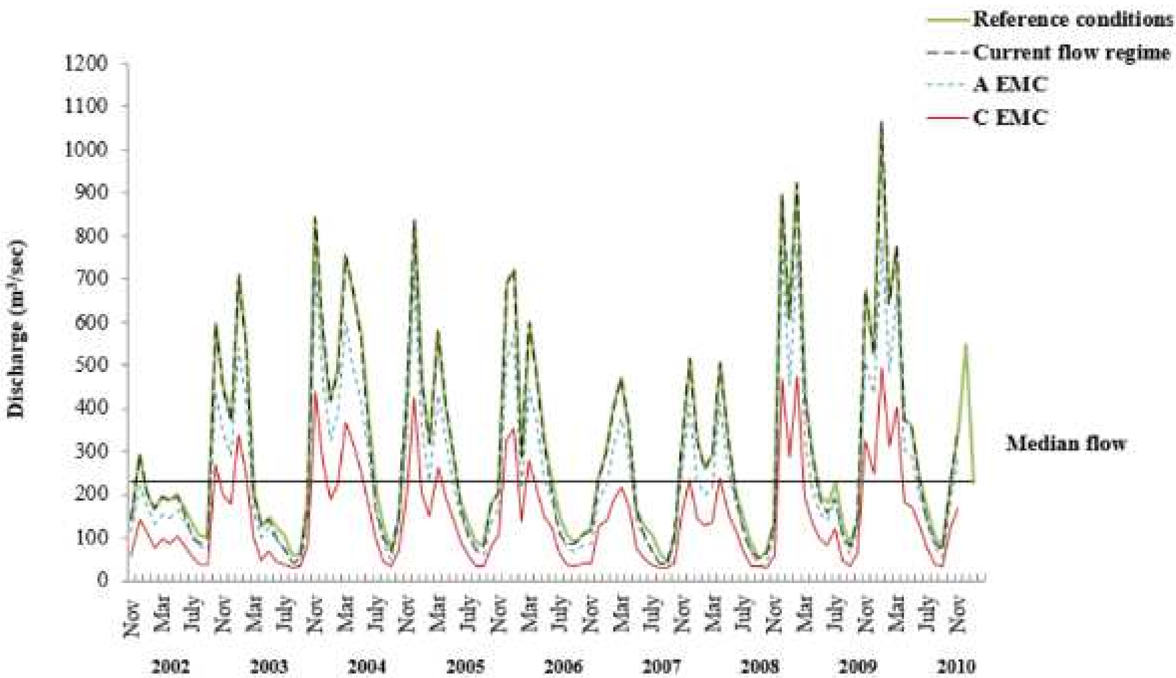


Fig. 6-16 Skadar/Shkodra subbasin with scenarios

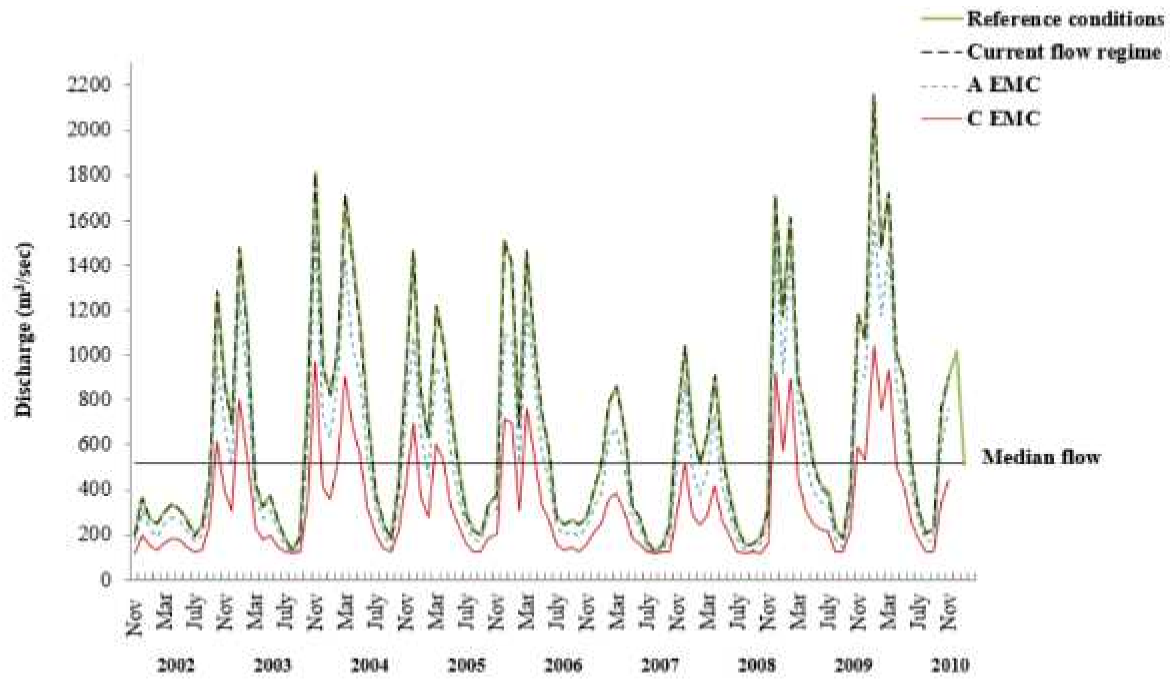


Fig. 6-17 Buna/Bojana subbasin with scenarios

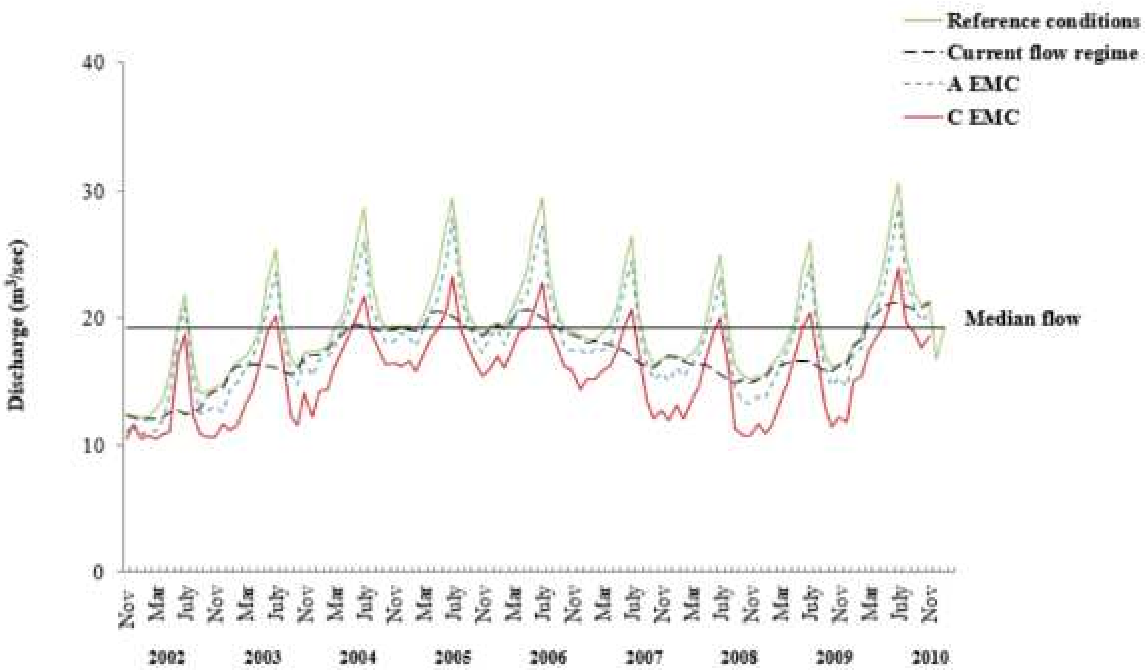


Fig. 6-18 Ohrid subbasin with scenarios

The environmental flow evaluation from the FDC shifting method was compared with the, Tennant method. In the Tennant method, recommended minimum flows (thresholds) are based on percentages of the average annual flow, with different percentages for winter and summer months (Table 3).

Table 3 Tennant Method

Subbasins	Period	October - March	April - September
	Description of flows	**High Flows (m^3/sec)**	**Low Flows (m^3/sec)**
White Drini	Short-term habitat threshold (10% MAF)	10.5	6.8
	Survival habitat threshold (30% MAF)	31.4	20.4
	Excellent to outstanding habitat threshold (60% MAF)	62.9	40.7
Black Drini	Short-term habitat threshold (10% MAF)	11.0	8.5
	Survival habitat threshold (30% MAF)	33.1	25.4
	Excellent to outstanding habitat threshold (60% MAF)	66.2	50.8
Drini	Short-term habitat threshold (10% MAF)	43.5	24.0
	Survival habitat threshold (30% MAF)	130.5	72.0
	Excellent to outstanding habitat threshold (60% MAF)	261.0	144.0
Skadar/Shkodra	Short-term habitat threshold (10% MAF)	42.9	19.9
	Survival habitat (30% MAF)	128.6	59.8
	Excellent to outstanding habitat threshold (60% MAF)	257.2	119.6
Ohrid	Short-term habitat threshold (10% MAF)	1.7	19.9
	Survival habitat threshold (30% MAF)	5.2	59.8
	Excellent to outstanding habitat threshold (60% MAF)	10.4	119.6
Buna/ Bojana	Short-term habitat threshold (10% MAF)	87.7	43.3
	Survival habitat threshold (30% MAF)	263.0	130.0
	Excellent to outstanding habitat threshold (60% MAF)	526.1	260.0

For better comparison, the monthly results of the FDC and the Tennant method for the White Drini subbasin are shown in Fig.6-19 to 6-20. Current flow conditions are already below the survival habitat threshold. Apparently, several times C EMC of the FDC method, meets the lowest threshold (short-term habitat) of the Tennant method regarding the winter months (Fig. 6-19), which is not the case for the summer months (Fig. 6-20).

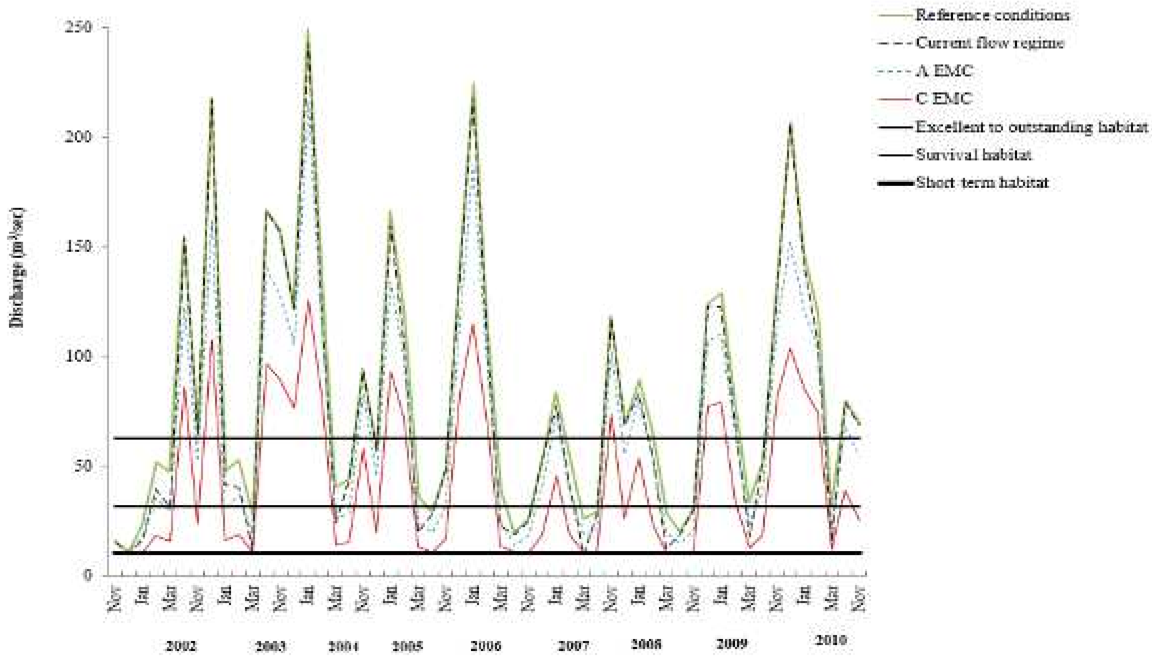


Fig. 6-19 Comparison of the FDC and the Tennant Method for the White Drini subbasin for the months October-March

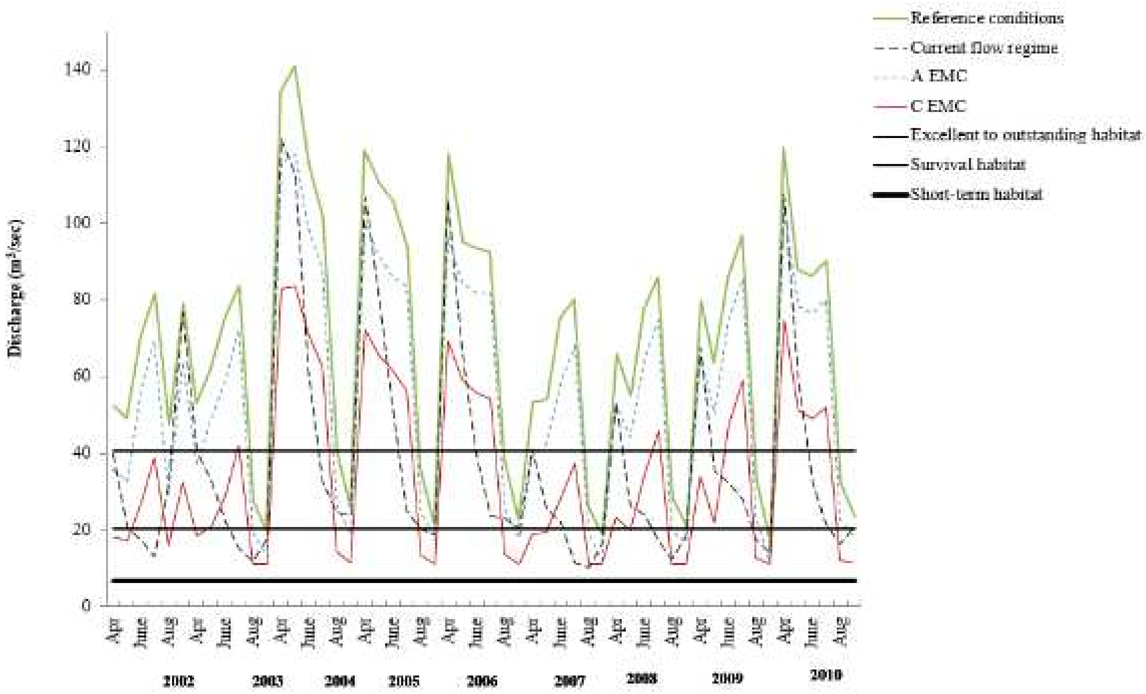


Fig. 6-20 Comparison of the FDC and the Tennant Method for the White Drini subbasin for the months April-September

Comparative results of the two aforementioned environmental flows estimation methods from the Black Drini subbasin indicated that C EMC meets the survival habitat threshold of the Tennant method for the winter months (Fig. 6-21). While for the summer months all scenarios (A to C EMCs) are above it (Fig. 6-22).

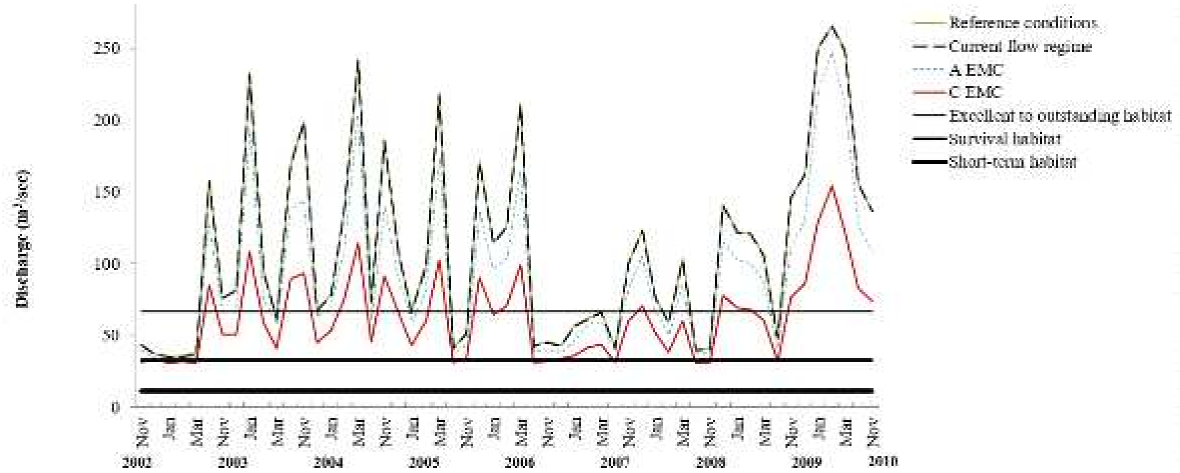


Fig. 6-21 Comparison of the FDC and the Tennant Method for the Black Drini subbasin for the months October-March

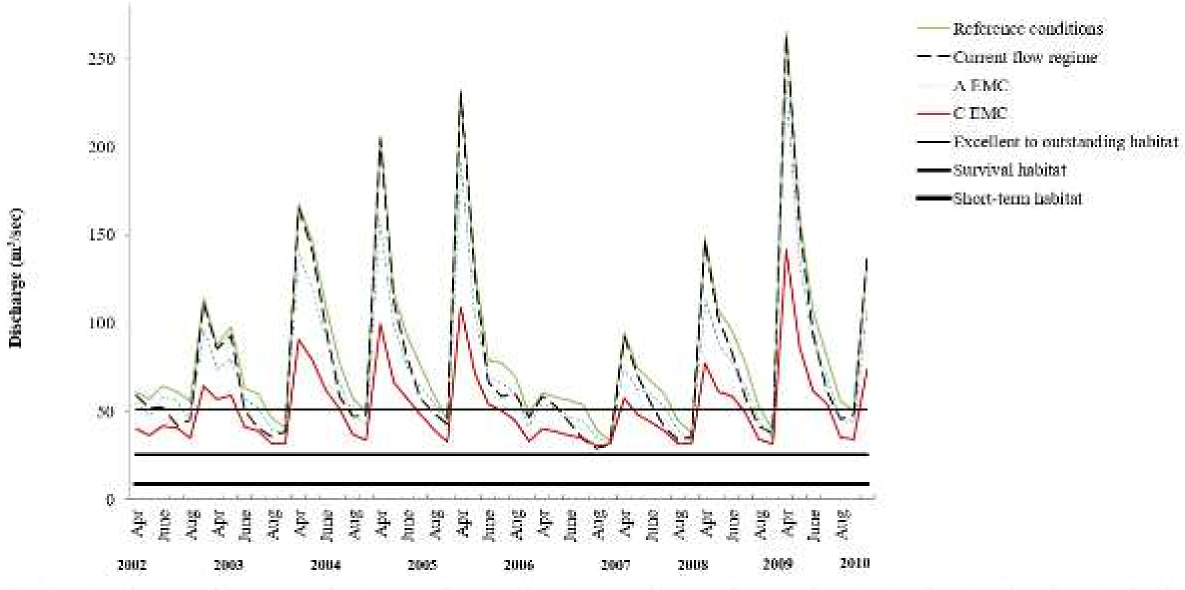


Fig. 6-22 Comparison of the FDC and the Tennant Method for the Black Drini subbasin for the months April-September

Comparative results of the two aforementioned environmental flows estimation methods from the Drini subbasin indicated that C EMC meets the short-term habitat threshold of the Tennant method for the winter months (Fig. 6-23). While for the summer months all scenarios (A to C EMCs) are above it (Fig. 6-24).

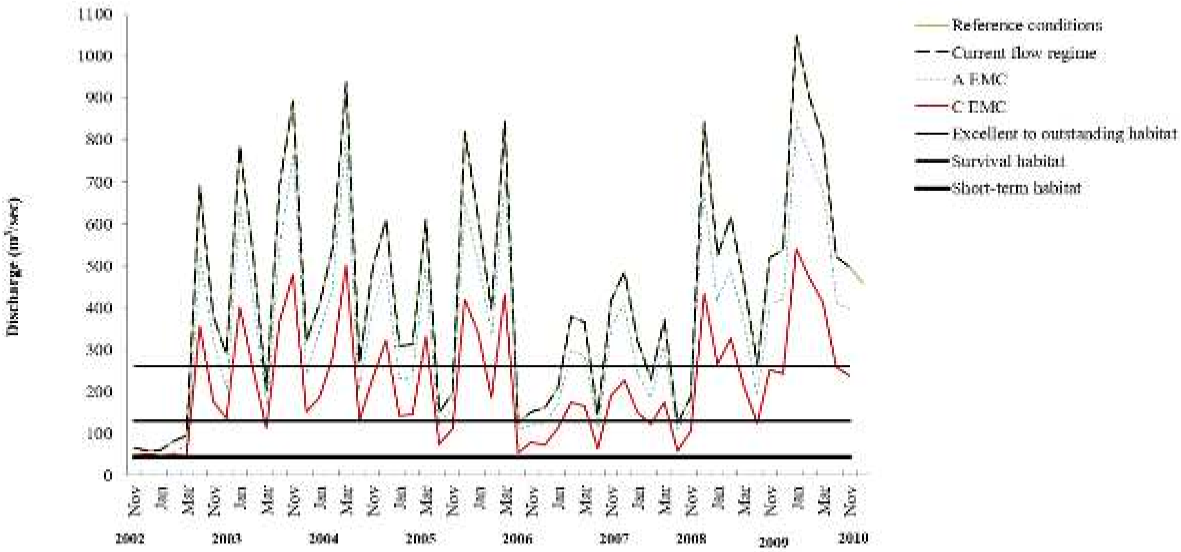


Fig. 6-23 Comparison of the FDC and the Tennant Method for the Drini subbasin for the months October-March

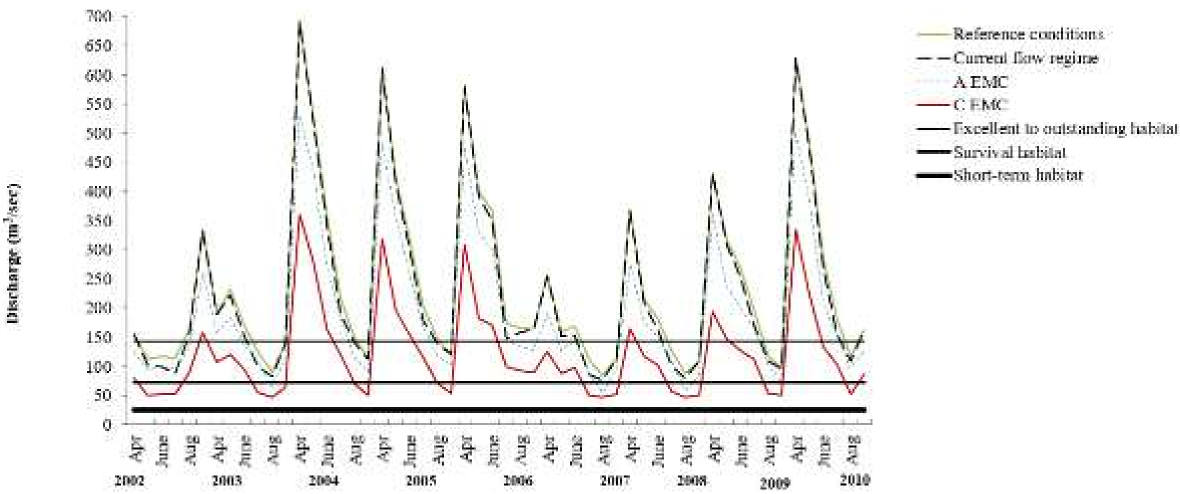


Fig. 6-24 Comparison of the FDC and the Tennant Method for the Drini subbasin for the months April-September

Comparative results of the two aforementioned environmental flows estimation methods from the Skadar/Shkodra subbasin indicated that C EMC meets the short-term habitat threshold of the Tennant method for the winter months (Fig. 6-25). While for the summer months all scenarios (A to C EMCs) are above it (Fig. 6-26).

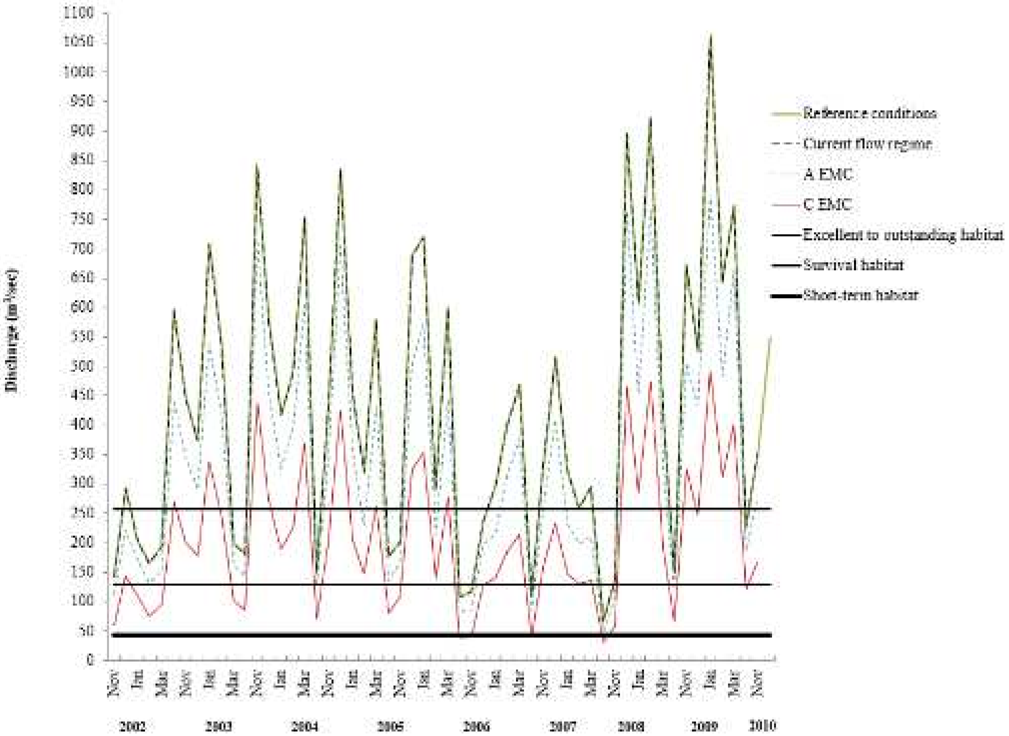


Fig. 6-25 Comparison of the FDC and the Tennant Method for the Skadar/Shkodra subbasin for the months October-March

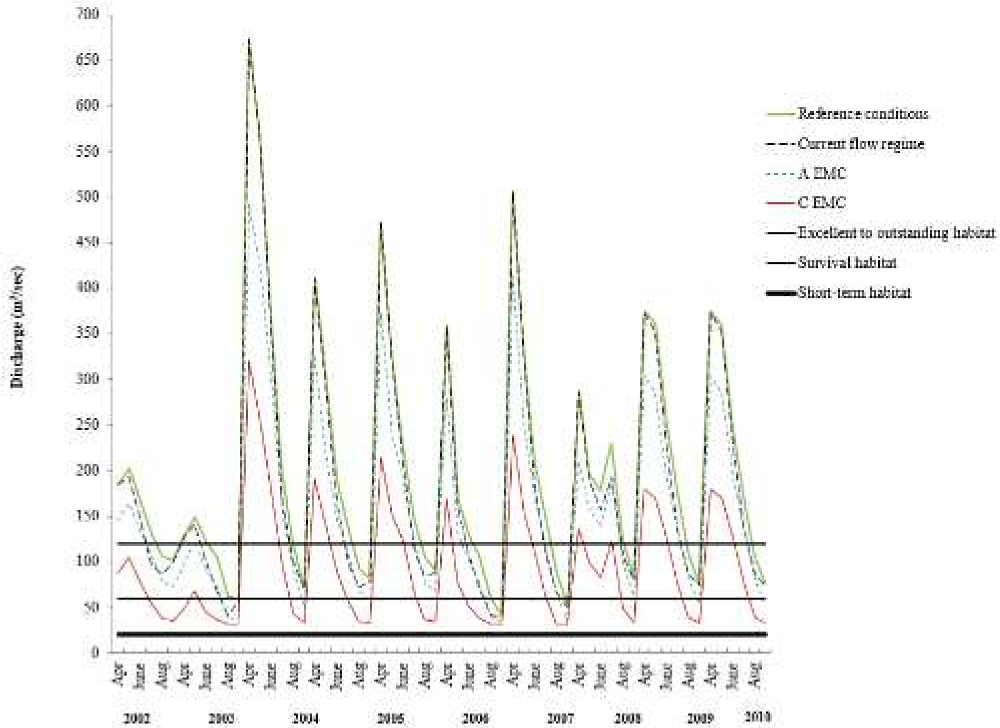


Fig. 6-26 Comparison of the FDC and the Tennant Method for the Skadar/Shkodra subbasin for the months April-September

5 Discussion

Estimating environmental flow information allows environmental impacts to be identified and traded off against anthropogenic water uses. Implementation of environmental flows is a key measure for restoring and managing river ecosystems. Nevertheless, biologically acceptable instream flows are affected by a number of factors and choices regarding the level of protection required, the historic and current conditions (e.g., distribution and abundance of a fish species), and tradeoffs between competing water uses. Determination of the hydrological potential of a river requires an assessment of how existing and future land and water uses, storage systems (natural and constructed), and other anthropogenic activities, affect the rivers.

In this report two environmental flow assessment methods, the Tennant method (1976) and the FDC shifting method using GEFC software, were compared using nine year of hydrological simulated data on a monthly basis from the extended Drin river basin. The estimation from the FDC shifting method is consistently more optimistic than the lowest threshold of the Tennant's method. Tennant's method main limitation is the requirement for similar morphological characteristics among the rivers from which the method has been initially developed and the rivers that may be applied. Moreover, transferability of the method should be made with special caution. Field observation of the stream at the various base flow levels is recommended for verification. Also, as the method is based on the average flow it does not account for daily, seasonal or yearly flow variations (Arthington and Zalucki 1998). Variability of the river flow is very important since numerous ecological processes are dependent on these variations over time. For instance, high flows support a healthy stream as they rejuvenate the channel, affecting its shape, create habitats and clear wood debris. The FDC shifting method enables rapid estimation of EFRs for different environmental classes if relevant hydrological data (i.e., monthly flow rates) are available. Both methods are very simplistic and do not incorporate any biological component following the WFD requirements. The Tennant methodology indicated minimum Ecological Flows, during the dry period of the year, that fluctuate from approx. 7 m^3/s in White Drin to 260 m^3/s in Buna/Bojana. During the wet period of the year the same methodology indicated Ecological Flows that range from 11 m^3/s in White Drin to 526 m^3/s in Buna/Bojana (Table 3). The GEFC tool indicated ecological flow regimes that follow the natural hydrologic variations and fluctuate, during the dry period in White Drin, from 10 m^3/s to 80 m^3/s (moderate modifications) and during the wet period, from 10 m^3/s to 100 m^3/s (moderate modifications in White Drin, Table 6). If the water managers in the Drin sub basins would like to apply ecological flows based on only the present data then an acceptable compromise could be to follow the scenario C flow regime suggested by the GEFC tool as presented in Figure 6.

Combinations of desk study methods (e.g. hydrological) and in-situ methods have been previously recommended to increase the credibility of the desk study methods (Papadaki et al., 2017). Nevertheless, in cases where ecological information is insufficient, hydrological indices can be used to provide an adequate estimation of environmental water requirements in rivers (Karimi 2012).

In the future the identification of appropriate indicator species or groups, which are selected with respect to their sensitivity to hydraulic and morphologic attributes of the riverine environment is recommended as part of habitat simulation methods and holistic approaches for scientifically sound environmental flow assessments.

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7 ANNEX A

Subbasin						Water Consumptions (m^3/sec)							
Prespa	0.37	0.10	0.10	0.10	0.10	0.83	1.49	2.96	6.00	7.58	2.92	1.30	23.82
Ohrid	0.25	0.22	0.22	0.22	0.22	0.83	1.45	3.11	6.86	9.40	3.96	1.30	28.03
Black Drin	0.64	0.56	0.56	0.56	0.56	0.91	1.99	4.77	12.41	19.01	10.45	2.03	54.44
White Drin	0.72	0.72	0.72	0.72	0.72	6.39	12.30	28.34	53.50	68.74	15.96	2.46	191.30
Drin	0.39	0.38	0.38	0.38	0.38	0.46	1.20	8.65	17.49	25.72	7.79	0.78	63.98
Skadar / Shkoder	0.93	0.93	0.93	0.93	0.93	0.93	0.93	8.23	20.81	36.86	19.93	2.33	94.66
Buna/Bojana	0.06	0.06	0.06	0.06	0.06	0.06	0.14	4.88	8.74	12.29	2.15	0.14	28.71
Total	3.36	2.96	2.96	2.96	2.96	10.41	19.49	60.94	125.81	179.61	63.15	10.34	484.95

8 ANNEX B

Simulated hydrological data from Panta-Rhei hydrologic model (GIZ 2013)

Months	Average of					
	Lake Ohrid Outflow	Black Drin	White Drin	Drin	Lake Shkoder/ Skadar outflow	Buna/ Bojana Outlet
2001 Total	**12.3**	**39.8**	**13.5**	**62.7**	**218.0**	**281.6**
11	12.3	43.2	15.2	65.9	141.3	199.3
12	12.2	36.5	11.7	59.7	292.2	361.2
2002 Total	**12.9**	**65.3**	**43.5**	**211.4**	**232.9**	**455.3**
1	12.0	34.8	10.3	61.6	202.4	273.3
2	12.1	35.2	11.9	80.9	165.6	247.8
3	12.1	36.5	16.5	95.0	193.6	298.2
4	12.3	59.0	39.9	154.1	184.7	336.9
5	12.6	51.9	20.9	103.0	194.1	308.8
6	12.7	52.0	17.1	99.4	149.0	256.8
7	12.5	42.1	12.9	88.1	97.8	189.4
8	12.6	45.2	31.5	154.6	86.3	244.6
9	12.8	111.8	76.6	333.2	100.1	450.1
10	13.9	157.4	154.1	689.7	595.9	1283.5
11	14.2	75.3	64.9	379.8	444.7	869.8
12	14.5	81.2	63.4	288.9	372.3	687.1
2003 Total	**16.2**	**97.4**	**76.4**	**357.8**	**296.4**	**665.0**
1	15.6	231.8	217.0	787.4	708.0	1478.2
2	16.2	94.2	113.3	528.6	534.9	1131.5

3	16.2	61.4	41.7	204.1	198.4	428.7
4	16.3	85.4	40.5	188.9	127.7	322.7
5	16.3	92.8	33.2	222.2	141.2	369.5
6	16.1	50.9	22.2	151.2	101.9	261.6
7	16.0	40.9	15.1	99.4	68.2	175.8
8	15.7	36.0	11.6	82.3	41.8	128.2
9	15.6	38.8	17.4	138.5	56.7	194.3
10	15.7	169.2	166.3	692.9	180.2	778.0
11	17.0	198.8	156.6	892.2	842.5	1812.4
12	17.1	67.2	83.4	320.7	576.3	942.4
2004 Total	**18.7**	**114.6**	**97.8**	**438.0**	**416.0**	**868.1**
1	17.2	77.5	121.8	408.5	416.7	819.4
2	17.5	135.7	150.8	543.7	488.1	1034.8
3	18.2	241.4	242.9	935.9	753.2	1710.7
4	18.7	165.3	121.9	690.5	672.8	1419.0
5	19.3	142.1	112.7	525.5	561.4	1122.0
6	19.5	96.4	61.9	340.1	352.1	722.7
7	19.3	58.5	32.7	190.4	163.2	370.4
8	19.2	47.0	24.5	140.3	99.5	251.5
9	18.9	47.8	23.6	112.3	69.8	180.0
10	19.0	73.0	43.7	268.2	150.3	415.5
11	19.1	185.5	93.5	493.4	430.7	909.4
12	19.1	107.8	143.8	609.6	834.6	1464.4
2005 Total	**19.5**	**99.2**	**78.8**	**348.0**	**295.6**	**658.4**
1	19.1	66.1	57.1	308.5	455.0	832.4
2	18.9	98.1	124.8	312.3	318.7	632.4
3	19.4	217.2	159.8	610.0	578.9	1218.0

4	20.3	204.3	106.7	611.4	411.0	1048.2
5	20.5	112.6	82.2	416.3	292.6	737.7
6	20.3	80.6	52.2	306.7	166.9	490.7
7	20.1	57.3	24.9	178.4	100.1	290.4
8	19.6	48.9	20.0	140.5	71.8	217.4
9	19.2	42.9	18.9	119.9	79.6	197.8
10	18.9	40.9	28.4	149.0	176.3	331.4
11	18.5	50.7	48.3	196.3	201.5	375.7
12	19.1	170.5	223.4	817.8	687.1	1510.0
2006 Total	**19.6**	**97.1**	**70.0**	**340.0**	**279.8**	**639.5**
1	19.4	114.1	137.7	613.7	720.6	1413.7
2	19.1	125.3	129.9	396.2	288.3	681.9
3	19.9	210.4	218.1	842.7	599.4	1463.0
4	20.5	230.6	105.9	579.6	471.0	1080.1
5	20.6	126.5	66.8	392.0	319.2	747.1
6	20.4	66.6	40.0	350.1	206.7	573.3
7	20.0	58.4	23.7	148.8	111.8	273.8
8	19.6	59.9	23.0	157.9	85.0	242.8
9	19.1	46.5	20.4	164.3	87.6	266.3
10	18.9	42.3	18.6	124.1	106.9	244.3
11	18.7	45.0	25.5	151.3	118.0	278.8
12	18.4	42.1	33.9	160.7	235.9	401.4
2007 Total	**17.2**	**58.0**	**46.7**	**234.9**	**240.7**	**485.4**
1	18.1	55.8	53.1	208.4	296.4	517.9
2	18.1	61.1	69.8	378.7	403.6	790.4
3	18.0	65.8	77.8	364.5	468.5	859.7
4	18.0	58.7	41.1	254.8	358.8	659.4

5	17.6	53.3	25.5	151.2	160.5	324.4
6	17.4	44.0	21.9	152.5	107.9	269.6
7	17.0	34.5	11.5	86.6	69.2	162.8
8	16.5	28.9	10.0	76.9	42.2	122.4
9	16.1	31.0	16.2	112.7	39.2	149.0
10	16.1	40.8	29.0	143.7	108.6	242.5
11	16.5	99.9	117.7	418.0	330.2	712.9
12	16.9	122.8	89.6	485.3	515.0	1038.5
2008 Total	**15.7**	**65.6**	**56.0**	**259.4**	**268.6**	**533.8**
1	16.8	75.6	68.7	320.7	323.2	657.8
2	16.5	58.8	41.7	230.0	258.0	514.4
3	16.3	102.6	83.2	371.6	294.1	645.4
4	16.3	92.6	53.6	367.5	504.9	908.2
5	16.3	70.1	26.4	206.7	321.6	557.9
6	15.9	54.8	24.1	165.1	188.4	365.5
7	15.5	41.0	17.2	101.3	111.4	223.3
8	15.2	33.9	12.4	79.5	67.1	151.8
9	14.9	35.9	18.5	108.2	50.2	159.5
10	15.1	39.9	19.5	124.6	65.3	190.4
11	14.9	40.6	30.5	188.2	137.2	308.5
12	15.1	140.0	272.1	840.9	894.9	1709.2
2009 Total	**16.2**	**97.4**	**71.6**	**355.2**	**355.7**	**727.2**
1	15.3	121.5	123.3	523.6	607.2	1172.8
2	16.1	120.4	117.9	617.5	921.3	1614.6
3	16.2	105.1	122.7	456.5	428.4	911.3
4	16.5	146.4	67.7	429.5	287.2	730.5
5	16.6	102.0	35.3	308.1	188.1	514.4

6	16.6	83.5	32.4	250.6	157.0	412.3
7	16.6	58.1	28.0	171.8	193.6	379.8
8	16.2	41.9	17.6	109.5	107.8	226.8
9	15.9	37.6	14.0	96.1	79.8	181.4
10	15.7	47.5	52.4	265.1	148.0	405.0
11	16.1	145.7	129.9	518.5	672.4	1182.7
12	16.3	161.7	121.4	537.4	524.8	1068.0
2010 Total	**20.2**	**157.9**	**90.0**	**504.7**	**395.1**	**927.2**
1	17.7	249.9	206.3	1047.1	1062.9	2158.2
2	18.3	265.3	225.0	900.0	642.5	1476.0
3	19.8	247.8	140.4	800.2	773.2	1721.3
4	20.4	263.3	107.4	627.9	373.5	1013.2
5	20.9	155.4	59.5	478.6	352.5	897.8
6	21.2	94.7	32.7	267.1	230.2	526.8
7	21.2	61.3	21.6	156.3	136.5	306.8
8	20.9	45.3	16.2	108.8	86.8	203.1
9	20.6	48.3	20.9	162.3	74.2	225.7
10	20.8	155.5	79.3	522.1	226.1	763.7
11	21.1	136.1	68.6	497.0	350.0	909.8
Grand Total	**17.2**	**92.5**	**68.7**	**330.6**	**305.7**	**650.3**