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THEME 6: Environment (including Climate Change)

Adaptive strategies to Mitigate the Impacts of Climate Change on European Freshwater Ecosystems

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Deliverable 4.14: European map of the spatial extent and environmental state of riverine floodplains and deltaic areas

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PU	Public	X
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Abstract

Floodplains are low-relief Earth surfaces positioned adjacent to freshwaters and subject to flooding (fringing floodplains of lakes and rivers, internal and river deltas). Similarly, riparian zones are transitional semi-terrestrial areas that extend from the edge of permanent water bodies to the edge of uplands and are influenced by.

Floodplains are distributed worldwide and cover about 2 % of the land surface. Floodplains are disturbance-dominated ecosystems tightly linked to fluvial and geomorphic dynamics. As expanding and contracting ecosystems they are among the most complex, dynamic, and diverse ecosystems globally. Because of their unique position at the deepest location in the landscape floodplains integrate and accumulate upstream processes. They offer a remarkably diversity of ecosystem services including flood retention, recharge of ground water, biomass production, nutrient removal, as well as aesthetic and cultural values. Worldwide, floodplains provide about 25 % of all continental ecosystem services, more than any other ecosystem type.

Today, about half of the human population of Europe and of Japan live on (former) floodplains. At the same time, floods are among the most costly natural disasters worldwide. Between 1900 and 2004 about 3 billion people were affected by floods, causing 2.9 million human losses, and making more than 130 million people homeless.

Floodplains are among the most threatened ecosystems. In Europe and North America, more than 90% of the former floodplains are functionally extinct or have been converted into cropland and urban areas. Habitat degradation, species invasion, pollution, and climate change are among the most important pressures threatening floodplain ecosystems and their rich biodiversity. Therefore, conserving the remaining intact floodplains as strategic global resources and restoring degraded floodplains posses highest priority for future ecosystem management. However, floodplains designated for restoration and conservation must be large enough to support its native plant and animal assemblages and to perform key ecosystem functions.

Here we present maps about the spatial distribution and environmental state of European floodplains and deltaic areas.

Deliverable 4.14 European map of the spatial extent and environmental state of riverine floodplains and deltaic areas (FVB-IGB)

Klement Tockner, Vanessa Bremerich, Ilona Jentschke

Introduction

Floodplains are low-relief Earth surfaces positioned adjacent to freshwaters and subject to flooding (fringing floodplains of lakes and rivers, internal and river deltas). Similarly, riparian zones are transitional semiterrestrial areas that extend from the edge of permanent water bodies to the edge of uplands and are influenced by freshwater (Junk et al. 1989, Naiman et al. 2005, Tockner et al. 2002, 2008).

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River floodplains

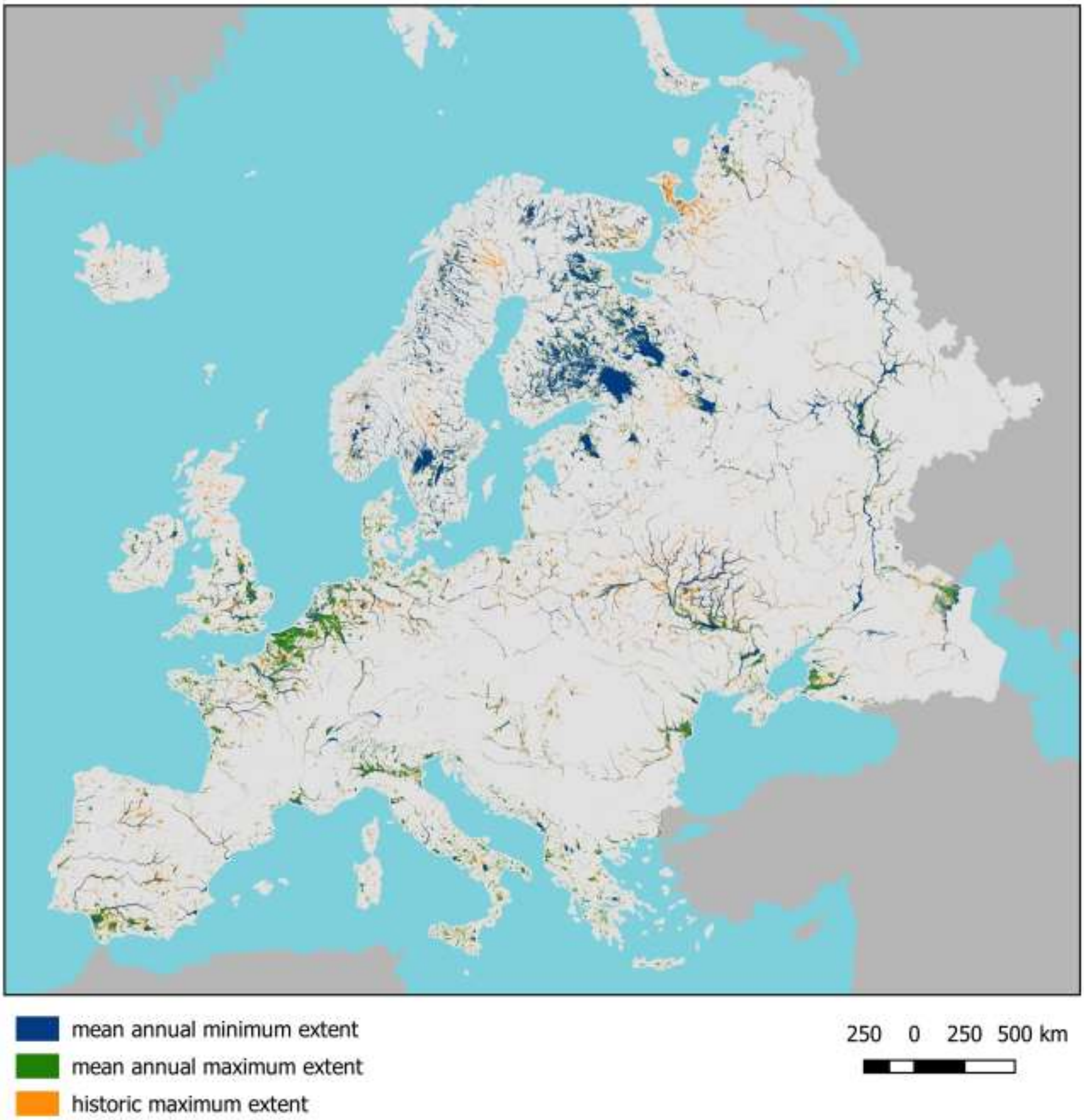

Figure 1: Inundated Areas of continental Europe derived from the Global Inundation Map (GLIN) showing estimates for average annual minimum extent (representing the dry season extent), average annual maximum extent (representing the wet season extent), and long-term maximum inundation at 15 arc-second spatial resolution. Coastal inundated areas in a distance of 5 kilometers from the coastline are not included.

Global Inundation Map (GLIN)

Global estimates of the distribution and area of terrestrial surface waters, including wetlands and floodplains, have greatly improved with the recent development of multi-sensor satellite methodologies combining visible and infrared techniques with active and passive microwave remote sensing. The resulting large-scale surface water estimates, however, still suffer from limitations in either spatial or temporal resolution. Through the process of spatial downscaling, i.e., the conversion of coarse remote sensing data to a finer spatial resolution by means of spatial disaggregation using ancillary data as a guidance, a globally consistent surface water inventory at improved spatial resolution can be produced. Expanding on such pre-existing downscaling efforts, Fluet-Chouinard et al. (submitted) derived a new map of global inundation extent, referred to as the Global Inundation Map (GLIN).

GLIN represents the water extent for the entire land surface except Greenland and Antarctica at 500-m pixel resolution at three temporal states of inundation: mean annual minimum extent (representing the dry season extent), mean annual maximum extent (representing the wet season extent), and a historic maximum extent. For most regions of the world, the inundated areas of the three states are within the range of values expressed by other global assessments, although the historic maximum extent of GLIN represents the largest surface water area of any global map to date.

GLIN is derived by downscaling the dataset of the Global Inundation Extent from Multi-Satellites (GIEMS) project (Prigent et al. 2007; Papa et al. 2010). GIEMS is a novel, recently developed multi-sensor approach capable of measuring surface water area in a globally consistent manner, yielding temporally dynamic surface water area estimates. The measurements of the GIEMS project express surface water extent as the inundated fraction of its 0.25° grid cells at the monthly time-scale. For the generation of GLIN, the available GIEMS time series of 1993-2004 has been used. For the historic maximum inundation extent of GLIN, supplementary data from the Global Lakes and Wetlands Database (GLWD; Lehner and Döll 2004) was used to correct for known limitations of GIEMS.

The general downscaling approach of GIEMS data is inspired by Bwangoy et al. (2010), who used decision trees based on topographic information to generate an inundation probability map over the central Congo Basin. For the generation of GLIN, i.e. to downscale GIEMS globally, a high-resolution (500-m) inundation probability map of the entire world's land surface was produced to determine where inundation should be distributed locally at high spatial resolution. The downscaling technique predicts location of surface water using globally available topographic and hydrographic information. Thirteen topographic variables relevant to inundation dynamics were extracted for the global land mass using the HydroSHEDS database at its 15 arc-second resolution. These variables are based on a combination of four distinct indices: slope; elevation above the nearest river; distance from the nearest river; and river size. A high-resolution inundation probability map was then produced using bagged decision trees based on the topographic predictors and trained on the wetland extent of the GLC2000 global land cover map (Bartholomé and Belward 2005).

Finally, a high-resolution inundation map was generated from the inundation probability map by applying a threshold to reproduce the original GIEMS inundation extents at the higher spatial resolution.

Table 1. Floodplain area and state of 20 large European rivers (Tockner et al. unpublished).

River Basin	total basin area (km^2)	potential floodplain area (km^2)	% floodplain area	Protected Area (km^2)	% protected area	Number of inhabitants	avg. GDP per capita (US $)	total GDP (Mio. US $)
Volga	1392006,7	84779,7	6,1	10385,9	12,3	9452516	6946,8	65660,0
Danube	802032,0	29597,3	3,7	10316,4	34,9	2756028	15669,6	41123,1
Dnieper	512379,4	78558,5	15,3	6710,6	8,5	7021212	3353,3	19928,5
Don	429399,8	19827,0	4,6	2414,0	12,2	2101184	5847,4	10615,9
Northern Dvina	379061,3	11746,3	3,1	1030,1	8,8	204230	6946,9	1418,8
Neva	279586,1	87184,6	31,2	8029,0	9,2	932308	14578,6	19180,4
Ural	253147,3	2793,1	1,1	215,1	7,7	97569	6267,0	615,3
Kura	195720,1	8482,4	4,3	2933,9	34,6	614280	3002,3	1718,1
Vistula	193894,2	11752,3	6,1	5880,4	50,0	1404536	8177,0	11733,9
Rhine	160221,4	11924,5	7,4	7803,3	65,4	9134095	37907,1	335102,5
Elbe	143655,7	10846,4	7,6	6824,5	62,9	2954178	28034,0	101938,4
Oder	118938,5	5444,2	4,6	3151,9	57,9	749754	11648,2	8420,3
Loire	116981,0	10325,0	8,8	4125,3	40,0	2050818	35457,1	72716,0
Duero	97418,7	7621,0	7,8	2534,9	33,3	924498	25389,0	24249,5
Rhone	96619,0	6048,8	6,3	2550,6	42,2	1352508	37045,2	52815,7
Nemunas	95925,1	4199,0	4,4	1259,4	30,0	337841	6347,3	2636,0
Ebro	85611,8	4526,8	5,3	1568,1	34,6	1056919	27847,5	29432,5
Daugava	84607,6	4460,4	5,3	1001,9	22,5	268580	5663,7	1947,2
Seine	75989,5	15137,3	19,9	3518,6	23,2	11147429	35470,1	395260,0
Mezen	74051,7	3235,7	4,4	48,6	1,5	1	6946,9	0,0
Dnister / Nistru	72530,8	2470,0	3,4	362,5	14,7	328132	1759,7	502,0
Po	71327,1	13050,1	18,3	3937,5	30,2	2424179	32021,7	77710,4
Tajo	71202,1	4272,8	6,0	1632,4	38,2	991507	23551,2	26624,1
Guadiana	67062,8	8164,9	12,2	2231,5	27,3	381240	25124,4	10557,2
Narva	58125,6	9330,9	16,1	3227,8	34,6	286036	9342,8	2686,7
Guadalquivir	57052,5	13359,8	23,4	3664,8	27,4	1903271	27847,5	53001,2
Onega	56037,0	3138,4	5,6	458,2	14,6	4401	6946,9	30,6
Garonne	55703,1	904,2	1,6	442,4	48,9	256731	35454,7	9102,7
Evros / Maritsa	53025,7	5267,4	9,9	801,2	15,2	473698	9506,3	4370,7
Kuban	52689,5	5231,7	9,9	1088,8	20,8	495591	6937,5	3442,0
Kemijöki	52512,9	3632,8	6,9	352,3	9,7	30276	34962,0	1168,5
Gota	51464,4	16391,1	31,8	1719,4	10,5	606055	45535,6	26973,6

River Deltas

Deltas are integral features of many catchments, being important depositional landforms where the river mouth flows into an ocean, sea or lake. The geometry, landform, and environment of deltas result from the accumulation of sediments added by the river and the reworking of these sediments by marine forces. Because many European rivers discharge into isolated and inland seas, characterized by low tides and moderate wave powers, they can form extensive deltas. The 35 major European deltas cover a total area of ~90,000 km^2 and are populated in total by 16.9 Million people (12.5 Million on the Rhine delta; Figure 2, Table 2). Human population density ranges between 0.0 and 1760 people. Despite their ecological and socioeconomic importance, European deltas are among the least investigated aquatic ecosystems.

Deltas are highly productive environments and, as a consequence, they have been extensively transformed into cropland and urban areas. Today, the human density in European deltas is often much higher than in the respective upstream catchment (Tables 2), although the opposite pattern can be found such as for the Danube catchment. Deltas formed by the Pechora, the N. Dvina (despite having a large seaport, Archangelsk, with a population of 350,000), and the Volga are among the few remaining relatively pristine deltas. Deltas are biologically diverse ecosystems, thus major efforts are underway to conserve and restore them. Several large deltas are already protected by the Ramsar Convention (e.g., Nestos, Axios, Kuban, Dnieper, Volga, Danube, Rhone). Around 90% of the Danube delta today is officially protected (Ramsar site and Unesco Biosphere heritage). Other large deltas such as those of the Ural, Terek, Seyhan, or Kizilirmak Rivers are not protected.

Modified after Tockner et al. (unpubl data and 2009)

Figure 2: Spatial distribution of the 35 largest and most important European river deltas.

Table 2. Thirty-five large river deltas in Europe (including Turkey and the Caucasus). Average annual temperature (1961-1990). Human population density: People per km^2. Protected: National parks, Ramsar sites, nature reserves, and other nationally protected areas.

	Area (km^2)	**Average temperature[1] (°C)**	**Precipitation (mm)**	**Population (x1000)**	**Population[2] (People/km^2)**	**Cropland[3] (%)**	**Protected[4] (%)**
Rhine	25347	9.2	764	12456	493	89.7	0.9
Volga	11446	10.3	216	610	53	70.0	24.7
Ural	8586	9.1	177	204	24	13.6	0.0
Pechora	5490	-4.0	450	0	<1	<0.1	26.3
Kuban	5422	11.7	666	345	63	73.9	20.3
Danube	4560	10.7	432	155	34	56.0	89.1
Kura	4175	15.5	298	324	78	57.4	20.6
Terek	4026	11.6	373	187	46	86.3	3.3
Po	2878	12.8	724	342	119	86.9	10.0
Dnieper	2833	8.7	467	226	80	76.2	7.4
N Dvina	2229	0.6	581	262	118	3.4	5.9
Guadalquivir	2213	17.6	581	336	152	69.2	31.9
Seyhan	1903	17.1	726	221	116	86.0	0.0
Vistula	1858	7.7	590	347	187	93.5	0.0
Rhône	1783	13.5	758	114	64	63.7	59.7
Neman	1088	6.7	748	27	24	57.1	18.6
Don	604	10.1	567	327	541	71.9	80.8
Kizilirmak	474	11.1	595	60	126	84.6	0.0
Ebro	331	15.9	518	38	116	49.3	22.3
Nestos	319	12.5	615	17	53	83.3	14.6
Evros	230	13.4	620	11	49	80.1	0.0
Aliakmones	227	12.2	525	15	68	93.1	0.0
Ceyhan	176	17.7	796	21	117	60.7	0.0
Tevere	127	14.0	756	223	1760	42.6	0.0
Acheloos	126	14.5	793	6	48	54.9	0.0
Göksu	96	15.4	554	10	106	72.5	0.0
G. Meander	94	15.9	753	11	118	75.6	0.0
Gediz	72	16.0	684	19	257	63.5	0.0
Alpheios	68	14.8	751	10	146	50.8	0.0
Neretva	61	10.6	1175	2	38	32.7	0.0
Axios	50	13.2	503	4	73	68.3	0.0
Sakarya	43	11.4	703	8	174	40.9	0.0
S. Meander	27	16.0	721	7	256	88.0	0.0
Pinios	22	13.6	522	0	22	81.2	0.0
Umeälven	18	2.6	540	1	44	0.0	0.0

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[1] http://www.ipcc-data.org/obs/get_30yr_means.html

[2] http://gis.ekoi.lt/gis/

[3] http://edcsns17.cr.usgs.gov/glcc/tablambert_euras_eur.html

[4] http://sea.unep-wcmc.org/wdbpa/

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Supplementary Table: Distribution and extent of selected fringing riverine flood plains (including few rain-fed flood plains) in Europe and their pressures/threats/impacts

Drainage system/ geographical area	Area (km^2)[a]	Major flood plains/comment/ reference	Drivers/Pressure/Threats/Impacts	Reference: *Rivers of Europe* 2009
Switzerland	200	A total of 234 flood plains of national importance (Forum Biodiversität Schweiz 2004)	Loss of 95% of its original floodplains, largest remaining 3 km² Water abstraction; gravel mining; fragmentation	p.10, Chapter 1.8. Riverine Floodplains
The Netherlands	498 Catch-ment area: 34.548	Area regularly flooded by rivers (primarily meadows; Yon & Tendron 1981)	**Meuse** (1): Number of large dams(> 15m) (basin): 10; Nonnative fish species: 16 (see also p. 162, Chapter 5.1.6.5.2); Large cities (> 100000): 8 **Water regulation** (weirs, navigation (6,9) dams, large dams (2, 3, 9), structural changes for flood control (3,8,9), reservoirs for drinking water supply (2,3), flow regulation (3), hydroelectricity production (2, 3) and recreation (3), chanels (3) → impact mainly local but can affect biological and ecological processes over long stretches (9) → disturbance of the benthic invertebrates, with the loss of many insects and a decrease in biodiversity (6,9) **Cooling water** for industries and powerplants (2,8) Reception of **thermal discharges** (2) / pollution (9)→ oxygen budget locally and micro-pollutants contaminate the water and sediments in several places (9) **Land use change** (3,9) → suspended load dramatically increased (3) **Intense agriculture** (2) → erosion and diffuse inputs of fertilisers and pesticides to surface and ground waters (organic pollution (2,9) → water quality (2,9) **Water abstraction** and exploitation of groundwater (3,8,9) **Waste water** (domestic, industrial) (4,6,9) → dissolved oxygen, high phytoplankton biomass, organic matter (4) → degrades the benthic community (6,9) **Inputs of nitrogen** (agriculture) and phosphorus (domestic wastewater) (4, 9) → high standing stocks of algae (4) → affect biocenosis of the river and the North Sea, and also water usage (9) Organic micro**pollutants** notably PAHs, various **pesticides** (used herbicides: diuron, isoproturon, atrazine, simazine and their derivatives) (4) → drinking water supplies and quality (4) → affect water and sediment quality, are harmful to the biocenosis and reduce water usage, particularly drinking water supply (9) **Heavy metals** (Cr, Cu, Zn, Pb, Cd) (4) (industrial activity) (4) **Invasive species** (4,6, 9) (esp. macroinvertebrates (9) Hydraulic works (5), eutrophication (5, 9), increased flow variation (5) → loss or decline of	*1* p.153, Chapter 5 Introduction Table 5.1 General Characterisation of the Continental Atlantic Rivers *2* p.154f., Chapter 5.1.1 The Meuse River Basin – Introduction *3* p.155f., Chapter 5.1.2 Historical Perspective *4* p.157ff., Chapter 5.1.5.1 Pollution in the River *5* p.160f., Chapter 5.1.6.2 Aquatic Plants *6* p.161, Chapter 5.1.6.4 Benthic Invertebrates *7* p.162, Chapter 5.1.6.5.3 Endangered fishes *8* p.163, Chapter 5.1.7 Management and Water Use *9* p.164f., Chapter 5.1.11 Conclusion and Perspectives

			aquatic vegetation (5) Decrease of fish biodiversity (7) and of aquatic biota / plants (9) **Global warming** (9) → temperature of the river (9) → unknown consequences for aquatic organisms.	
Danube NP Austria	93	The last remaining semi-natural floodplain along the Upper Danube (Tockner *et al*. 2000)		
Taglia-mento, Italy	150	The last morphologically intact river corridor in the Alps (Tockner *et al*. 2003)	(1) Catchment area (km²): 2580; Number of large dams (> 15m): 5; Non-Native fish species: 6 **Land use change**, partly agriculture (Tockner et al. 2003) (3). High water quality (low nutrient and organic matter concentrations) (4) Low concentrations of phosphorus and ammonium (4) Local **waste water pollution** (e.g. Forni di Sotto) (4) **agricultural inputs** (4) Future plans: retention basins (5), new industrial areas (5), new highway (5)	*1* p.472, Chapter 12 Introduction Table 12.1 General characterization of the Italian Rivers 2 p.473, Chapter 12.3.1 Landforms and Geology 3 p.478, Chapter 12.4.1 Geomorphology 4 p.484, Chapter 12.4.3 Biogeochemistry 5 p.491, Chapter 12.6.2 Conservation and Restoration
Lonjsko polje (Sava River), Croatia	507 Catch-ment area: 95 793	One of largest and best preserved floodplains in Europe (Spanjol *et al*. 1999) (1)	(1) Number of large dams (>15m): 18; Nonnative fish species: 5; Large cities (>100000): 5 **Water infrastructure** (dams (3), hydroelectric power plants (3), overflow concrete gravity dam and other facilities (3), reservoir (3), flood protection dikes (5) → significantly changed sediment transportation and the groundwater regime (Zinke 1999; Klaver et al. 2007) (3). **Nutrients**: TOC increased (2) **Industrial pollution** (leather, paper, oil and food industries) and pollution from **agriculture** cause major transboundary challenges for some city water supplies (e.g. Zagreb and Belgrade) (5) **Heavy pollution** (until 1990s: metallurgical, chemical, leather, textile, food, cellulose, paper industries (Jovi_ci_c et al. 1989) (4), agricultural activities (agrochemicals, pesticides and pollution from pig and poultry farms) (4) **Organic pollution** (N, P): high (ICPDR 2005) (4), higher concentrations of Al, As, Cd, Cu, Fe, Mn, Ni and Zn **Waste / polluted water** from cities (Bosnir et al. 2003) (4) and **urban sewage** (5)→ polluted water from tributaries in the Zagreb region (Brilly et al. 2000). **Thermal pollution** (conventional powerplants, nuclear powerplant) (4) habitat degradation, organic pollution (4) → alterations in biodiversity (4) Five non-native / **invasive species** (4) Increasing anthropogenic activities (urbanisation, industrial development and agricultural monoculture) → increased impact by organic, inorganic and hazardous pollutants (5) → Insufficient water supply in dry season (5)	*1* p.62, Chapter 3.1 Table 3.1 General characterization of the Danube River Basin *2* p.72, Chapter 3.6.2 Water Quality *3* p.82, Chapter 3.8 Human Impacts, Conservation and Management *4* p.95f., Chapter 3.9.6 Sava River *5* p.96., Chapter 3.9.6.4 Human Impacts and Management
Kopacki rit,	177	Semi-natural flood	14 non-native/ **invasive species**	p.92, Chapter 3.9.4 Drava

Croatia		plain at the intersection of the Danube and the Drava (Spanjol *et al*. 1999)	Groundwater well-fields for **public water supply** and **hydro-technical melioration** systems Human activities → changes in the hydrological regime of the river. **Water infrastructure** (regulation, dams, hydropower generation (hydropeaking) → water level changes and impacts the aquatic fauna. → decrease in fish biodiversity in Austrian part (ICPDR 2005)	River
Upper Rhine	70[d]	Originally, flood plains covered 1000 km^2 (Carbiener & Schnitzler 1990)	**Upper Rhine:** (1): Catchment area (km^2): 62 967 including the catchments of Neckar and Main; Non-Native fish species: 17; Large cities (> 100000): 15 **Agriculture** and relatively small-scale manufacturing, including mining and metallurgy in mountainous areas (until up to the early 19th century) → mostly local impacts (2) Coal, Chemical and iron industry (later (6)), population increased → increasingly affected by domestic and industrial sewage (2) **Pesticides** (dyes, solvents, raw, intermediate chemicals) disaster (1986 near Basel) → killed organisms, prompted drinking water of Rhine (2) **Water infrastructures** (meander cuts, regulations (3), flood defense systems (3,7), dams, flow regulation (7), → shortening and narrowing the river (3) Large-scale **hydroelectrical power production**: Rhine stem: 24 run-of-river powerplants, within the entire Rhine basin: >2000 hydroelectrical powerplants 10 nuclear powerplants (cooling water) (6) **Nutrient pollution** (4) (*see also: p. 222, Table 6.4.* →macrozoobenthos decrease (5) **Organic micropollutants** (4) **Polar organic pollutants** adsorb onto suspended solids and sediments → high concentrations in sediments of impounded reaches (4) Concentrations of lead, cadmium, chromium, copper mercury and zinc, primarily originating from human activities, increase downstream (LUA NWR 2002). (4) **Non-native species** immigrated through (the connection of Dnieper and Bug with the Rhine) and Main–Danube–Canal (Bij de Vaate et al. 2002; BUWAL 2005; Leuven et al. 2009; Tittizer et al. 1994) (5). *See also Chapter 6.6.6. for invasive fish species*.	*1* p.202, Chapter 6.1 Introduction Table 6.1 General Characterisation of the Rhine River Basin 2 p. 203 3 p.211, Chapter 6.5.1 Geomorphology of the main corridor 4 p.221ff, Chapter 6.5.3 Biogeochemistry *5* p.227ff, Chapter 6.6.5 Benthic Invertebrates 6 p.234, Chapter 6.7.1. Economic Aspects 7 see for details p.235, Chapter 6.7.2 Flood defense
French Rhône (fringing flood plain)	70 Catchment area: 90 538	Mostly functionally extinct flood plains. Former extent 830 km^2 (Bravard 1987) (1)	(1) Number of large dams (> 15m): 6; **Non-Native fish species**: 16; 1 Large city (> 100000) **Water infrastructure**: Dam construction, hydropower, dikes, flood control (see Table 7.2 p. 253, also Chapter 7.6 p. 274ff) **Nutrient transport** (see Table 7.3 p. 258) **Organic pollution** (see Chapter 7.4.5 p. 259) **Heavy metals pollution** (see Chapter 7.4.6 p. 260) **Pesticides** (see Chapter 7.4.7 p. 260) Effects of **climate change**, of invasive species spread and of more recent rehabilitation measures → temporal variability in zoobenthic communities (2)	1 p.250, Chapter 7.1 Introduction Table 7.1 General characterization of the Rhône River Basin 2 p.265, Chapter 7.5.4 Aquatic invertebrates 3 p.270, Chapter 7.5.12 Table 7.6

			Non-native species (see also chapter 7.5.5, p. 265) (3) Non-native fish species: in Upper French Rhône: 15, in Lower French Rhône: 14 (3) **Fish biodiversity** (see chapter 7.5.8 Fish and 7.5.11 + 12)	
Rhône delta, Carmargue	750	Former delta of 1 644 km^2 (Bravard 1987)	Rhône delta: **Non-native fish species**: 11	p.270, Chapter 7.5.12 Table 7.6 Total number of fish species
Guadiana river, Spain	450 Catch-ment area: 67.048	Floodplain marshes in the Donana National and Nature Parks (Benayas *et al*. 1999)	(1) Number of large dams (> 15m): 87; **Nonnative fish species**: 13 High human impacts → flow regime, water chemistry, riparian vegetation biodiversity (2) **Water infrastructure**; Regime modifications; reservoirs (highly regulated river) Spain: 86 reservoirs >1 Mm^3 (CH Guadiana 2002). In Portugal, 13 dams (4) Former wetlands: 250 km^2, today: 70km^2, drained for agricultural lands (4) **Land use change** (agriculture) (3) **Pollution** (high ammonia levels): agriculture (organic and inorganic contaminents), wastewater treatment plants, direct inputs of **wastewater** (cities) (3). → periodic blooms of Cyanobacteria or Azolla (3) **Water abstraction** (4); water extraction (Forn_es et al. 2000) (4) → groundwater depletion (Alvarez Cobelas 2006) (4)	*1* p.114, Chapter 4.1 Introduction Table 4.1 General Characterisation of the Iberian Rivers *2* p.116, Chapter 4.2 The Guadiana *3* p. 118f *4* p.120, Chapter 4.2.6 Management and Conservation
Danube main stem (including Delta)	17 400	Mostly disconnected, therefore functionally extinct	**Water regulation**: former 26 000 km^2 floodplain area → morphological dynamics are missing (Klimo & Hager 2001). (1) **Water modification:** Loss of flood plain: (3,7, 9) (Schneider 2002) (5): - Upper Danube: 95%, Middle/Central: 75%, Lower: 72%, Delta: 30%, in total: 65% → strong eutrophication in the Danube deltalakes after 1980 and a drastic decrease in biodiversity (Vdineanu et al. 2001). (9). Sum of Upper, Middle, Lower and Delta data: (2) - Number of large **dams** (> 15m): 217+143+227+0 = 587 (2) → great impact on sturgeon populations (see (8)) **- Non-native fish species**: 13, 12, 7, 4; Large cities (> 100.000): 7+23+18+0 = 48 (2) **Pollution** (N; P): industrial wastewater, groundwater, agriculture; WWTPs, land erosion (Kroiss et al. 2005) (4) **Water regulation / Infrastructure**: hydropower, navigation, dykes (flood protection) are the main pressures today (WWF 2002; ICPDR 2007a). Danube (mainstem): 69 dams, 30% of its total length is impounded. (9). **Non-native species** (Tittizer et al. 2000; Literáthy et al. 2002; Slobodn_ık et al. 2005; Csányi & Paunovi_c 2006; Liska et al. 2008). Caused by opening Rhine–Main–Danube Canal in 1992 (‘Southern Invasive Corridor’ (Galil et al. 2007)) (6) (see also (8) for invasive fish species) ~ 40% of all documented species along the Danube are non-native (Liska et al. 2008) (6)	*1* p.10, Chapter 1.8. Riverine Floodplains *2* p.62, Chapter 3.1 Table 3.1 General characterization of the Danube River Basin *3*p.66, Chapter 3.4 Geomorphology *4* p.72, Chapter 3.6.2 Water Quality *5* p.73, Chapter 3.7.1 Riparian Vegetation 6 p.75, Chapter 3.7.4 Macroinvertebrates *7* p.76, Chapter 3.7.5 Fish Table 3.4 Flood Plain loss in the Danube River Basin *8* p.76f, Chapter 3.7.5 Fish *9* p.81ff., Chapter 3.8 Human Impacts, Conservation and Management

			High nutrient concentration and loss of 400 000 ha of wetlands along the Lower Danube	
Danube delta	5 800 Catch-ment area: 4.560 km^2	Danube Delta Biosphere Reserve, *c.* 50% of this area belongs to the 'Danube Delta' (RIZA 2000) (1)	**Delta Danube** (1): Nonnative fish species: 4 **Modifications (2), canalizations (4)**: 1000 km^2 were poldered in the Romanian part (Schiemer et al. 2004) (3) for agriculture (2), forestry (2) fish/ aqua culture (2,3) → altered sediment regime, embanked floodplains and increased pollution → decreased connectivity between the river and its wetlands. (5) Higher **concentrations** of dissolved nutrients and iron, cadmium and lead (4) → eutrophication of the Delta lakes (1950s–1990s) → reduced biodiversity (Vdineanu et al. 2001). (4) **Invasive species** (4)	*1* p.62, Chapter 3.1 Table 3.1 General characterization of the Danube River Basin *2* p.67, Chapter 3.4 Geomorphology *3* p.76, Chapter 3.7.5 Fish *4* p.103f., Chapter 3.9.11 Danube Delta *5* p.104f., Chapter 3.9.11.4 Human Impacts and Management
Danube islands, Bulgaria	107	75 islands in the main stem (Bulgarian Ministry of Agriculture and Forests, unpublished report 2001)	high conservation value (1)	*1* p.73f., Chapter 3.7.2 Vegetated Islands
Dnieper river delta, Ukraine	*c.*500	Hydrologic impact by unpredictable flood releases from upstream dams, pollution (Timchenko *et al*. 2000)	Catchment area (km^2): 512 293; Number of large dams (> 15m): 6; Non-native fish species: 13; Large cities (>100000): 18 (2) Warming effect: after 1930: local warming effect from the massive reservoir network on the Dnieper and concomitant industrial development (3) **Land use change**, industrialization (coal, manufacturing) (4) Sewage **discharge** and accidental spills of toxic contaminants (9, 5) → influence of reservoirs on river hydrology: reduction of maximal runoff and increase in the mean low water discharge (5) **Water infrastructure** (reservoirs (6, 7, 9), dams (7, 9), hydropower (8)) → altered conditions for phytoplankton development, increased biomass (blue–greens, diatoms and green algae) (6) Alteration of fish population / biodiversity caused by abrupt decreases in current velocity and increases in water depth, absence of submerged shallow grasslands, and poor water quality (7)	*1* Table 13.1 General characterization of the Western Steppic rivers, p. 500 *3* p.504, Chapter 13.3.2 Climate *4* p.504, Chapter 13.3.3 Land Use Patterns *5* p.508, Chapter 13.4.2 Hydrology and Temperature *6 Rivers of Europe* 2009, p.515, Chapter 13.5.1 Phytoplankton, Zooplankton and Zoobenthos *7 Rivers of Europe* 2009, p.516, Chapter 13.5.2 Fish Fauna, Amphibians and Mammals *8 Rivers of Europe* 2009, p.519, Chapter 13.6.1 Economic Importance *9* p.521, Chapter 13.7 Conclusions and Perspectives
Elbe river, Germany	840	Original extent: 6 170 km^2 (Helms *et al.* 2002)	**Land use change** (agriculture, waste water, treatment plants) (1) → **nutrient inputs** (P, N) (1) **Invasive species** (2) **hydro-morphological alterations**, hydropower, nutrients, dam, dikes (4) **heavy metals** and **organic contaminants** (3)	*1* p. 536, Chapter 14.3.3.3 Biogeochemistry *2* p. 539, Chapter 14.3.4.2 Fish Communities *3* p. 541, Chapter 14.3.5.2 Conservation and Restoration *4* Chapter 14.3.5.3 Perspective for further impacts
Volga delta	18 000	Largest European	(Lower Volga) (1): Number of large dams (> 15 m): 2; **Non-native** fish species:	*1*p. 27, Chapter 2 (Table 2.1: General characterization of the Volga River Basin)

		delta (Czaya 1981)	17; Number of large cities (> 100 000): 8; Delta: 11 446 km^2 (2, 3). **Water infrastructure**/ transformations (12): 12 reservoirs in the catchment, 9 of these in Volga (2), flow regulation hrough reservoirs (4) → velocity decrease (5); changes in thermal regime (6) → changes in water circulation → affects energy flow and massexchange (12) → flooding of productive lands, collapse of banks due to fluctuations in water level, and losses in the fishery (12) → Changes in hydrological regimes → alterations in species community / abundance **Land use change** (7) High **nutrient loads** (agriculture: P, N) → growth of phytoplankton (7) **Invasive species**: diatoms, cyanobacteria, planktonic species, fishes, plants (8, 9, 10, 11) → Alterations in biodiversity, disappearance of native species (11, 12)	*2* p. 28, Chapter 2.5.1 Geomorphic Development of the Main Corridor *3* p. 31, Chapter 2.5.1.3 The Lower Volga *4*p. 31, Chapter 2.5.2.1 Water Flow *5* p. 32, Chapter 2.5.2.2 Current 6 p. 32, Chapter 2.5.2.3 Water Temperature 7 p. 34, Chapter 2.5.3.6 Nutrients *8* p. 40, Chapter 2.6.3.2 Algae *9* p. 40., Chapter 2.6.3.3 Zooplankton *10* p. 40f., Chapter 2.6.3.4 Zoobenthos 11 p. 41., Chapter 2.6.3.5 Fish 12 p. 43., Chapter 2.8 Conclusions and Perspectives
Tisza, Ukraine Romania, Slovakia, Hungary, Serbia	1 800	Remaining area represents only 4.7% of former flood plains (Haraszthy 2001)	(2) Catchment area (km^2): 156.087; Number of large dams (> 15m): 45; **Nonnative** fish **species**: 12; Large cities (> 100000): 13 **Water infrastructure** (dams, hydroelectric power plants, reservoir (4) regulation, draining marshland, short river course (by 30–40% (7)) (1), floodplain reduction of 96% (7), irrigation channels (7), 37 hydropower stations (7) → significantly changed sediment transportation and the ground-water regime (Zinke 1999; Klaver et al. 2007) (4). Intense **regulation** and **exploitation** → groundwater table along the Tisza has decreased, salinisation has increased, and soil-incrustination in the western area is prevalent (7) low water levels in summer (7) Higher **nutrient load** TOC (organic carbon load) (3) **Land Use Change** (Agriculture, forestry) (5) → runoff, soil erosion and diffuse nutrient inputs (7) → floods, landslides and droughts (particularly in Hungary and Serbia) are more common today (ICPDR 2008) (7) **Global Warming** → flood events (6) **Waste water pollution** (cities, runoff from stockyards and animal wastes) (6) → organic load and microbial contamination (6), industries (mining, metal processing, oil pipeline): heavy metals i.e., copper, iron, manganese, zinc, lead, cadmium and other toxic substances such as cyanide from → contamination of surface and ground waters (6)	*1* p. 5, Chapter 1.5. Early and recent human impacts *2*, p.62, Chapter 3.1 Table 3.1 General characterization of the Danube River Basin *3*, p.72, Chapter 3.6.2 Water Quality *4* p.82, Chapter 3.8 Human Impacts, Conservation and Management *5* p.92, Chapter 3.9.5 Tisza River *6* p.93ff. *7* p. 94f. Chapter 3.9.5.4 Human Impacts and Management
Poland	820	Originally, floodplain forests covered 27 800 km^2 (Sienkiewicz *et al*. 2001)		
European	9 000	Approximate estimation (Shatalov 2001)		

part of Russia				

: The reported areas differ substantially between reference sources: Upper Nile Swamps (Sudd): > 30,000 km^2 (Mitsch & Gosselink 2000), 50,000 km^2 (Grombridge 1992), > 90,000 km^2 (Howard-Williams & Thompson 1985). Central Niger Delta: 30,000 km^2 (Howard-Williams & Thompson 1985), 320,000 km^2 (Mitsch & Gosselink 2000). Middle Congo depression: 70,000 km^2 (Howard-Williams & Thompson 1985), 200,000 km^2 (Mitsch & Gosselink 2000). Several major 'floodplains' listed are composed of different wetland types including swamps, wet grasslands or shallow lakes (e.g., Kagera valley, Central Congo basin, Sudd, Orinoco delta).

[d]: plantations cover 50% of the remaining floodplains

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