Bridging the gap between water managers and research communities in a transboundary river: Nutrient transport and monitoring regimes in the Drim/Drini Catchment

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Abstract

The DRIMPOL Project, a joint research project between Albania, Macedonia and Norway, aimed at estimating nutrient losses from different sources in the Drim/Drini River Basin. As the project evolved it was also faced with the challenges of bridging the data and information gap between the scientific community and the managers of this transboundary river. The Drim/Drini is one of thirteen internationally shared catchments in the Balkan region, and is unique in that it, despite of its relatively small size of less than 20000 km^2, is monitored and managed by six institutions in four countries and one UN Protectorate (Albania, Macedonia, Serbia and Montenegro, Greece and Kosovo). The need for harmonised and transparent procedures for monitoring, data assessment and data flow, as well as for transboundary co-operation to achieve integrated management of this catchment, is eminent.

In this region, the problems associated with the management of transboundary waters include insufficient or inadequate monitoring and lack of common approaches; identification and appropriate quantification of pollution sources, deterioration of water quality and over-exploitation of water resources; lack of bilateral and multilateral agreements with subsequent potential tensions; and non-integrated policy for protection of land and water.

This paper presents some of the results of the DRIMPOL Project linked to, inter alia, the load of nitrogen and phosphorus throughout the catchment, results of a project monitoring campaign and soil erosion risk assessment in the catchment. It also raises the questions of data accuracy and reliability, and the consequences of these for the political priorities and decisions taken by managers. One of the products of the DRIMPOL Project is a source apportionment map for nitrogen and phosphorus, with discharge calculations per source and sub-catchments. The use of such maps for management purposes in transboundary catchments may include the establishment of harmonised environmental goals, which again pinpoints the importance of data reliability and transferability. The need for an internationally agreed monitoring network, with transparency and data management across borders, is also be targeted.

Key-words: transboundary, water management, nutrients, source

Introduction

The management of transboundary watercourses is high on the agenda in most international environmental fora, and participation of actors at political, administrative and scientific levels is necessary in order to resolve conflicts, achieve joint management practises and ensure an enhanced knowledge base. The DRIMPOL Project (September 2003 – June 2005), with partners from Norway, the Republic of Albania (hereafter named Albania) and the Former Yugoslavic Republic of Macedonia (hereafter named Macedonia), has studied such a complex transboundary river system, viz. the Drim/Drini. This river is shared between Albania, Macedonia, Serbia and Montenegro (including Kosovo), and Greece, and is under environmental stress from a number of different sources, of which the present study has focused on nutrient loads from the most important sources.

The Drim/Drini Catchment covers an area of 18,518 km² of which about 14,000 km² belongs to the Drim/Drini and the remaining area to the Buna River. For the period 1951-1985, the Drim/Drini River had a mean annual discharge of 680 m³/s, of which 360 m³/s are estimated to come from Drini and 320 m³/s from Buna (Selenica, A. http://medhycos.mpl.ird.fr/en/project/who/pres/alb-pre.htm). The resulting specific discharge is about 35 l/s.km². The largest part of the Drim/Drini River is situated in Albania. It has two main branches, the Black Drini (Drini i Zi), draining areas in south-eastern Albania, Macedonia and Greece, including the large lakes Ohrid and Prespa; and the White Drini (Drini i Bardhë), originating in Kosovo and Serbia, and called Beli Drim by the Serbs. The two branches have a total length of 285 km. The large, very old, natural lakes of Ohrid and Prespa are shared between Macedonia and Albania; and Macedonia, Albania and Greece, respectively. The Buna River drains Lake Shkodra, which is the third of the large lakes in the Drim/Drini system. Lake Shkodra is shared between Albania and Montenegro and has a drainage basin area of 5 490km^2. The DRIMPOL Project concentrated its efforts on the part of Drim/Drini situated in Albania and Macedonia, with particular focus on the upper reaches near the Lakes Ohrid and Prespa.

This catchment (or parts of the catchment) has been subject to many studies and large-scale projects, e.g., the Lake Ohrid Conservation Project and projects related to the Prespa Park projects (e.g. Spirovski et al. 2002; Avramoski and Panovski 2002). However, to the knowledge of the authors, the DRIMPOL Project is the first international project to address the quantification and distribution of nutrient sources in this catchment. During the cause of the DRIMPOL Project it became, however, increasingly clear that there is a significant lack of available, adequate data for estimating discharges and losses from nutrient sources in this catchment. This includes the lack of long-term data series, as well as targeted data for estimating source contributions to the total nutrient load. The national monitoring of lakes and rivers has had severe setbacks due to the political situation in the countries concerned, and there are obvious challenges as to the re-establishment of an appropriate monitoring network. In addition, it must be noted that the availability of existing data for scientific purposes could have been significantly better. Thus, as the project evolved, it was faced with the challenges of bridging the data and information gaps between the scientific community and the managers of this transboundary river. As it turned out, the bringing together of scientists from the two Albania and Macedonia not only improved data exchange *between* the countries, but also improved the dialogue between different institutions *within* the countries. In order to include the management community more actively, the DRIMPOL project, at the end of the project, also organised an end-user workshop in June 2005, aimed at improving the dialogue between scientists and managers from four Balkan countries. This paper therefore presents not only a selection of the DRIMPOL scientific results, but also of some key recommendations on management issues aimed at bridging knowledge and dissemination gaps between scientists and managers. Most of these recommendations were brought forward by the participants attending the DRIMPOL project end-user workshop.

Methodology

Data-sets compiled

Water quality and water discharge data were compiled from several sources, but mainly from the national environmental monitoring programmes performed by the Hydrometeorological Institute in Tirana, Albania, the Hydrometeorological Institute in Skopje, Macedonia, and the Hydrobiological Institute in Ohrid, Macedonia. Sampling frequency ranged from 2 to 8 times a year, and there is a lack of stations with long time series, as illustrated in Table 1. Data for concentrations of ammonium nitrogen (NH_4-N), nitrite and nitrate nitrogen (NO_2-N and NO_3-N), and ortho-phosphate (PO_4-P) were available for the entire DRIMPOL study period. Total nitrogen and total phosphorus values were generally scarce.

In order to increase the data availability for the DRIMPOL Project assessments, additional sampling was done by means of campaign measurements in the Macedonian streams Brajcinska and Kranska, draining into the eastern shores of Lake Prespa (see Table 1). The land use in their catchments is dominated by forest and agricultural land; in the Kranska there also are some settlements. Samples were collected every 2 weeks and analysed for nutrients (total nitrogen, nitrite, nitrate, ammonia, total phosphorus, and orthophosphate), organic and inorganic (minerogenic) suspended sediments, and oxygen levels. Water gauging stations in the Brajcinska stream provided water discharge data from the sampling periods.

Table 1. Duration of time series at the various sampling sites for river water quality in the Drim/Drini drainage basin (Albania and Macedonia).

Macedonia		***Albania***	
Sampling sites	**Duration of time series**	**Sampling sites**	**Duration of time series**
Radika river - Boskov Bridge	1990-2004	Lin	2001
Radika river - Zirovnica village	1990-1996	Pogradec	2001-2003
Drim -Spilje	1990-2004	Drilon	2001-2004
Drim Struga	1990-1996	Cerava	1998-2001
Golema Reka - near Resen	1990-1996	Verdova	2002-2003
Golema Reka - mouth	2000-2002	Tushemisht	2002-2003
Kranska (Hydrobiological Inst.)	2000-2002	Devolli R	2004
Brajcinska (Hydrobiological Inst.)	2000-2002	Vau Dejes Lake	2004
Sateska	1996-2002	River Gomisqe	2004
Koselska	1996-2002	Mjeda Bridge	2004
Velgoska	1998-2002	Buna River	2004
St Naum	1990-1996		

Geographical information systems (GIS) and the TEOTIL2 model

A GIS database was compiled based on data from international sources and data made available by the project partners. The following GIS layers were prepared: Digital elevation model (DEM), sub-catchments, land cover, lake and river and network, hydrological stations, water quality stations, population, and administrative borders (only Albania and Macedonian parts).

In order to establish a reasonable geographical coverage for land-cover, data from different sources and with different resolution were combined. River network was established by digitising from satellite photos for areas not adequately covered by available maps. Sub-catchments were delineated by GIS routines based on the DEM and the river network. Sub-catchment borders were compared with borders for smaller areas made available by the project partners.

Land-cover statistics and population distribution were prepared for each sub-catchment and fed into the Norwegian TEOTIL2 model (Tjomsland and Bratli 1996; Selvik et al. 2004). Point source data were inexistent or unavailable, and all discharges from the population were handled as diffuse sources. Figure 1 shows the land-cover and the monitoring stations in the catchment.

Discharges from the population were estimated on the basis of population distribution maps, which also were used as for estimating discharges from the Ohrid/Struga WWTP[1]. Industrial discharge data were inexistent or unavailable, but it is assumed that very few larger industries were in operation in the catchment.

The TEOTIL2 is a pollution budget model (*op cit*). During the course of the DRIMPOL Project it was also tested in the Kapos catchment in Hungary (Lázár *et al*. 2005). The calculations are based on nutrient discharge data for point sources and a coefficients approach for all diffuse sources. The export coefficients used for unmanaged land (forest, mountain) were nutrient concentrations in the water flow, but for the agriculture areas the coefficients were given as area specific loss coefficients. The nutrient load estimations are shown as annual loads.

[1] This is the only wastewater treatment plant that is in operation in the entire drainage basin. It handles wastewater from the cities of Ohrid and Struga, and is located downstream of Struga, close to Lake Ohrid.

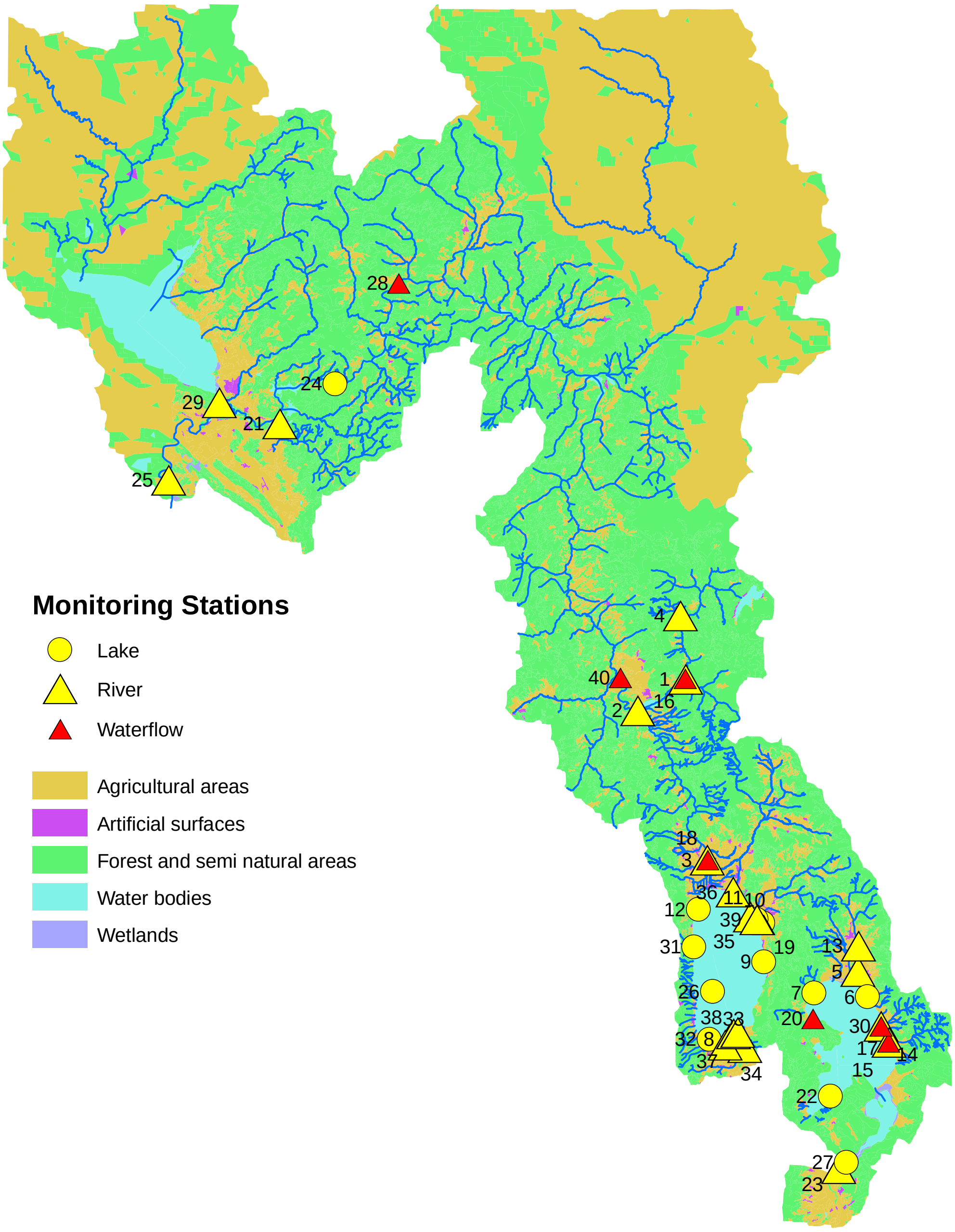

Figure 1: Land-cover and the stations for surface water quality and quantity compiled by the DRIMPOL project. Numbers refer to the stations in Table 2.

In the DRIMPOL project, all included sources are handled as diffuses sources due to lack of actual measured discharges. The TEOTIL2 model summarises all annual loads of phosphorus and nitrogen from the sources in each sub-catchment and accumulates these loads downstream, taking account of transformations such as lake retention that might occur along the discharge route; this in order to obtain the nutrient load for the specific catchment/sub-catchment. Each source is maintained as a separate source in the downstream accumulation and the source apportionment (see also Borgvang and Selvik 2000) can be made for the catchment outlet or at any intermediate location along the river.

Water discharges from different sub-catchments were estimated based on available discharge monitoring data combined with expert judgment when estimating differences in precipitation patterns in different regions not covered by discharge monitoring. In a situation with limited data on nutrient losses from different land cover types, the loss coefficients used will have large uncertainties. Expert judgements were used, together with actual information on coefficients made available from the DRIMPOL partners; this in order to assign a set of coefficients for different land-cover types for different parts of the catchment. Except from adjusting any obvious "out of scope results", no attempt was made to systematically calibrate the model.

Thus, the TEOTIL2 model application can be summarised as follows for the i^{th} sub-basin outlet point for a given year:

$$M_{sum,\, i\, [tons]} = M_{forest,\, i\, [tons]} + M_{lake,\, i\, [tons]} + M_{wetland,\, i\, [tons]} + M_{agriculture,\, i\, [tons]} + M_{artificial,\, i\, [tons]} + M_{sewage,\, i\, [tons]}$$

where

M_{sum}	calculated nutrient load (total)
M_{forest}	diffuse losses from forest/mountains/unmanaged land
M_{lake}	deposition on lakes
$M_{wetland}$	losses from wetlands
$M_{agriculture}$	diffuse losses from agricultural areas
$M_{artificial}$	losses from urban areas (paved surfaces)
M_{sewage}	losses from population (both scattered dwellings and WWTPs)

Assessment of nutrient water quality – status and trends

Assessment based on campaign measurements in two small agricultural streams

The DRIMPOL Project campaign measurements conducted in the two streams Kranska and Brajcinska provided a new set of data collected every two weeks, which is more frequent than in the national monitoring programmes. The two streams run through forested and agricultural areas (see Figure 2). Their hydrology is illustrated by the hydrological station in the Brajcinska, with a catchment area of 61.5 km^2 and an average streamflow in the period 1990-2000 of 0.8 m^3/s. The highest discharges in this period occurred in April and May (average monthly flows of about 2.5); whereas the low flow periods were in the summer from July to September with average monthly flows of about 0.2-0.3 m^3/s.

In the Brajcinska stream, the average values of total nitrogen, total phosphorus and suspended particulate matter amounted to respectively, 0.58; 0.064; and 41 mg/l (see Figure 4). Similar figures for the Kranska Stream were 0.18; 0.115; and 49 mg/l (see Figure 3). The relatively higher levels of average nitrogen in the Brajcinska were mainly caused by one high concentration in October.

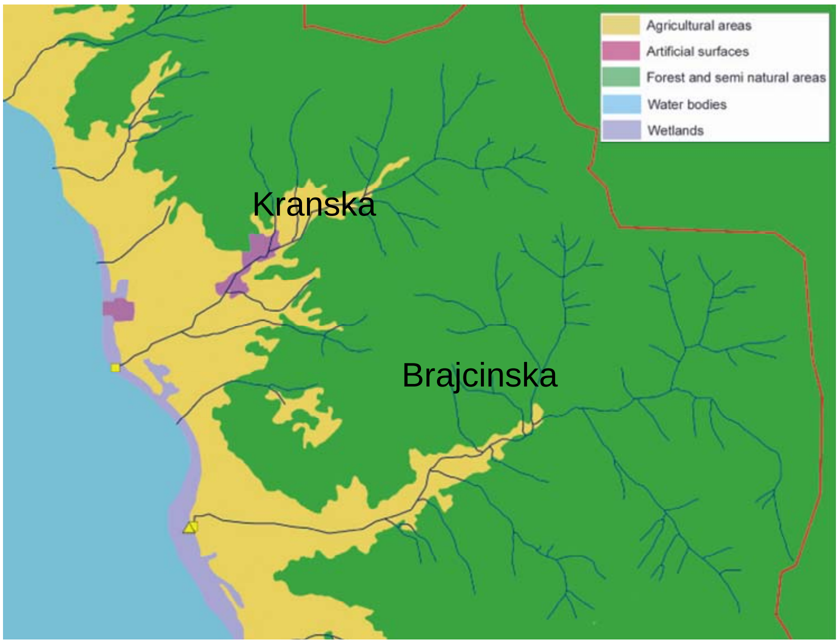

Figure 2: Land-use, water quality and water discharge stations (yellow dots) in the Kranska and Brajcinska streams.

In general, both the nutrient concentrations and the contents of suspended particulate matter in these two rivers are relatively low for rivers draining agricultural areas. If we compare these values with, e.g., those from River Golema (Table 2), with average total nitrogen values of almost 4 mg/l, and average total phosphorus concentrations of 0.26 mg/l, we may conclude that the majority of the nutrient pollution in the upper parts of the Drim/Drini most likely originate from human waste and sewage rather than from agricultural sources. The low nutrient yields from agricultural activities in the upper parts are probably linked to low levels of fertiliser use. The Environmental Information Portal (Earthtrends) reports that in 1999 in Albania the average fertiliser use was 16 kg/ha and in Macedonia 69 kg/ha, as opposed to an average of 77 kg/ha in the rest of Europe (http://earthtrends.wri.org/text/agriculture-food/country-profile-2.html).

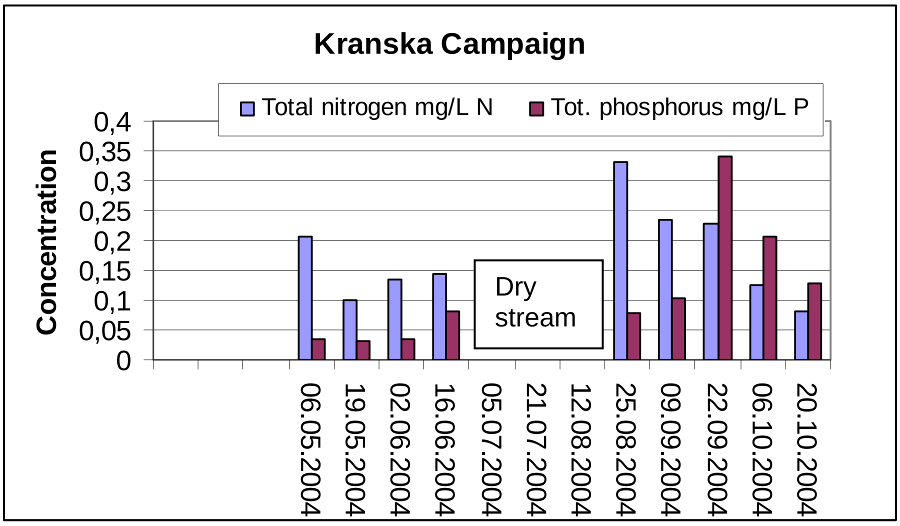

Figure 3: Levels of total nitrogen and total phosphorus in the Kranska stream.

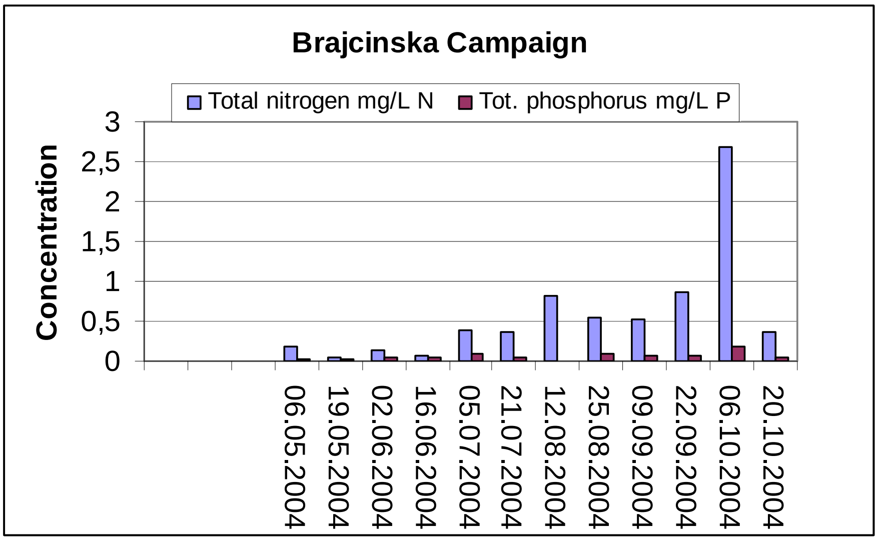

Figure 4: Levels of total nitrogen and total phosphorus in the Brajcinska stream.

There was no correlation between concentrations and water discharge, and the variations in concentrations shown in Figures 3 and 4 did therefore not seem to be connected to water discharge. Most probable, the variations in nutrient levels are not only linked to rain-induced erosion, but also to other activities in the streams, such as sewage from settlements and agricultural activities in the fields. Another element supporting this was that the usual good correlation between the concentrations of suspended particulate matter and total phosphorus was missing in both streams (Figure 5). This may be explained by total phosphorus being transported mainly as dissolved phosphorus in periods with low suspended sediment concentrations. The undertaking of an intercomparison exercise may elucidate this situation.

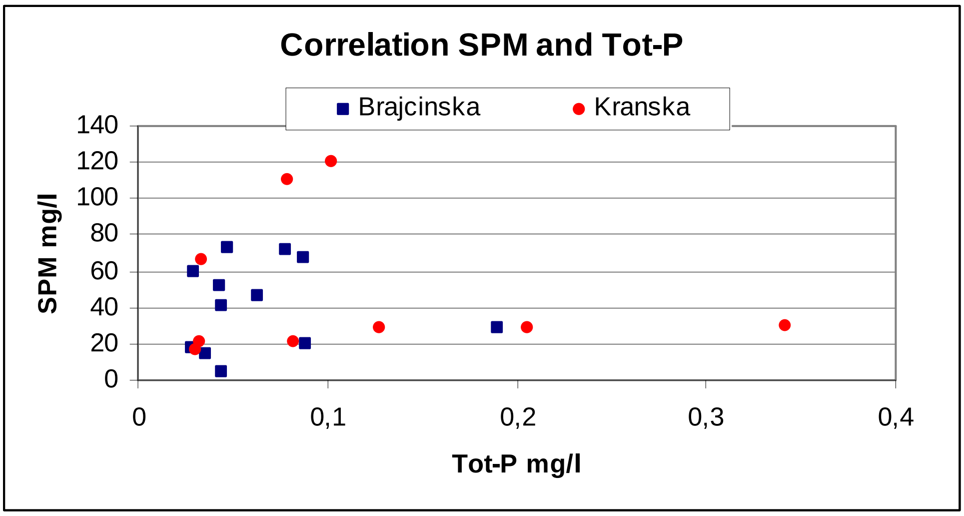

Figure 5: Correlation between suspended particulate matter (SPM) and total phosphorus (Tot-P) concentrations in the two campaign streams.

Assessment based on compiled datasets from the entire Drim/Drini

Table 2 shows the average nutrient concentrations of each of the stations used within the DRIMPOL Project. As illustrated by this table, there are relatively few data series on total nitrogen and total phosphorus in the rivers. The most commonly analysed nitrogen fractions are ammonia-N and nitrite-N, and to a lesser extent nitrate-N, whereas orthophosphate is analysed more often than total phosphorus. Figures 6 and 7 show average concentrations of nitrate and orthophosphate in a number of rivers in the catchment. Typically, the lower parts of the Drini, near the outlet to the Adriatic Sea, have the highest levels of nutrients, but also some of the smaller tributaries to lakes Prespa and Ohrid have relatively high nutrient levels. The main river downstream of Lake Ohrid, and also the tributary Radika, has however, nutrient levels that are low to moderate when compared with rivers in other parts of Europe.

Table 2. Average nutrient concentrations (mg/l) in river stations in the Drim/Drini river basin. Numbers refer to numbers in Figures 7, 12 and 13.

No	Streams	NH_4-N	NO_2-N	NO_3-N	DIN	TOT-N	PO_4-P	TOT-P
	Streams draining into the Prespa lakes:							
14	Kranska Campaign (DRIMPOL)	0,052	0,003	0,122	0,176		0,036	0,115
14	Kranska Hydrobiological Inst.	0,072	0,023	0,277	0,351	0,782		0,080
15	Brajcinska Campaign (DRIMPOL)	0,052	0,003	0,319	0,361		0,026	0,057
15	Brajcinska Hydrobiological Inst.	0,019	0,017	0,172	0,195	0,622		0,064
13	Golema Reka - near city of Resen	0,595	0,160	0,790	1,340		0,004	
5	Golema Reka - mouth	0,217	0,294	0,636	1,056	3,874		0,256
23	Devolli River	0,976	0,029	2,170	3,175		0,067	
	Streams draining into Lake Ohrid							
36	Sateska	0,020	0,007	0,514	0,530	0,708		0,022
35	Koselska	0,056	0,023	0,647	0,364	0,878		0,021
39	Velgoska					4,398		0,257
34	Verdova	1,184	0,361				0,230	
37	Tushemisht	0,261	0,071				0,092	
38	St Naum	0,062	0,004	0,116	0,218		0,000	
32	Pogradec	0,959	0,137				0,228	
8	Drilon	0,035	0,016	1,416	1,467		0,049	
41	Cerava	0,175	0,068	0,860	1,103	1,151	0,116	0,043
31	Lin (sampled in the limnic zone)	0,001	0,020				0,015	
	Other tributaries, downstream Lake Ohrid							
1	Radika river - Boskov Bridge	0,061	0,008	0,170	0,266		0,013	
4	Radika river - Zirovnica village	0,056	0,005	0,140	0,240		0,003	
	Crn Drim/Black Drini							
3	Drim Struga	0,101	0,034	0,187	0,352		0,001	
2	Drim -Spilje	0,092	0,012	0,304	0,427		0,017	
	Lower parts of Drini							
21	River Gomisqe	0,025	0,003	0,630	0,658		0,123	
29	Mjeda Bridge	0,020	0,003	3,290	3,313		0,075	
24	Vau Dejes Lake	0,025	0,002	1,180	1,207		0,038	
25	Buna River	0,025	0,002	3,238	3,266		0,098	

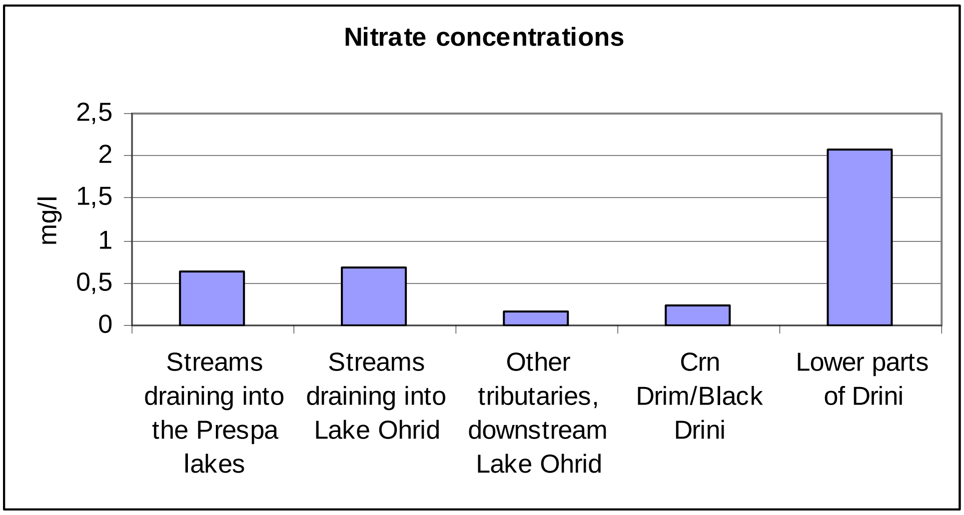

Figure 6: Average concentration values for nitrate (NO_3-N) for parts of the Drim/Drini system. The grouping of stations is shown in Table 2.

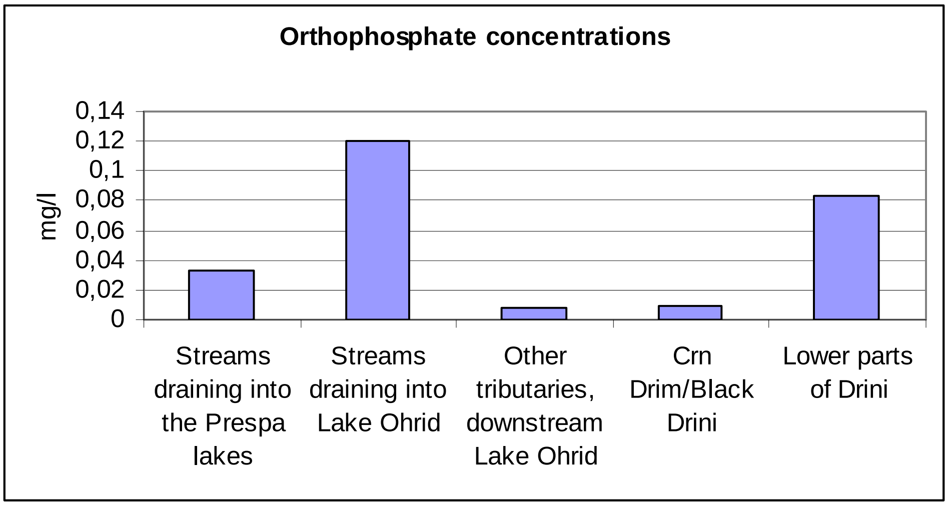

Figure 7: Average concentration values for orthophosphate (PO_4-P) for parts of the Drim/Drini system. The grouping of stations is shown in Table 2.

It should be stressed, however, that the figures shown above are based on a relatively scarce data material, both in terms of sampling frequency and in terms of the length of the data series. The only two series with an appropriate length are the series from Crn Drim at Spilje and Radika River at Boskov Bridge. These data series were used to assess changes over time in nutrient levels.

The statistical properties of water quality data are usually not normally distributed, and they often exhibit a seasonal pattern because they are influenced by water discharge. In this project, a recently modified version of the seasonal Mann–Kendall test (Stålnacke and Grimvall 2001; Libiseller and Grimvall, 2002), referred to as the partial Mann–Kendall (PMK) test, which has been adapted to account for the influence of confounding (i.e. meteorological or hydrological) variables, was used with water discharge as such a variable. It was concluded that the concentrations of nitrogen had not changed to any particular degree during the last 15 years. It should be noted that the nutrient levels in these two stations are among the lowest in the entire Drim/Drini catchment, see Figure 8.

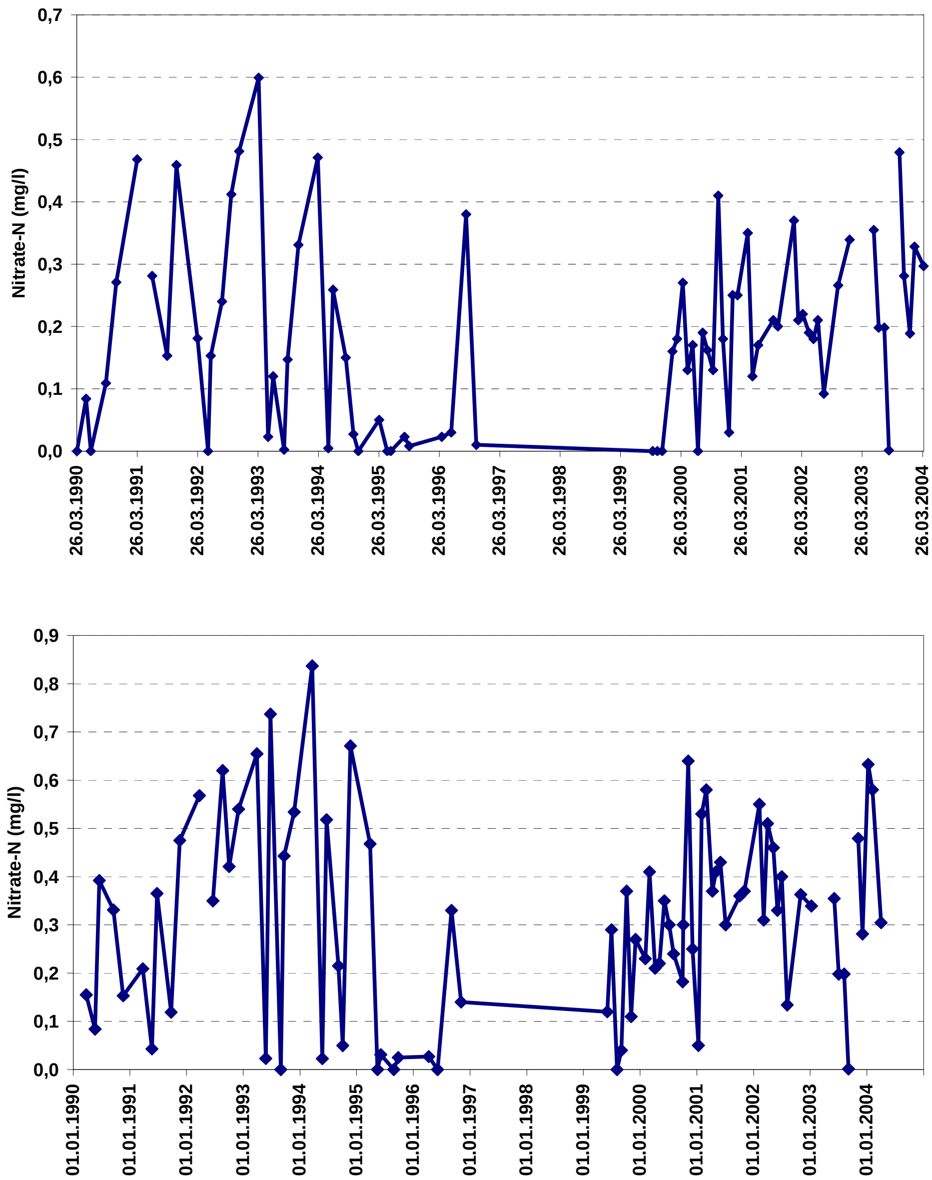

Figure 8. Time series of nitrate-N concentrations at the Boskov Bridge on the Radika River (upper panel) and at Crn Drim at Spilje on the Macedonian/Albanian border (lower panel).

It is not possible to assess, based on the available data, if this result is valid also for the other sites. The situation with an insufficient number of monitoring sites with long-term data confirms a strong need for a long-term transboundary monitoring programme in the Drim/Drini catchment. This becomes particularly important when future large-scale mitigation measures are planned and implemented in the Drim/Drini drainage area.

In addition to the long time series, an increased sampling frequency is necessary. This is especially important for rivers, since riverine water quality usually is affected by seasonality and discharge. Both factors need to be compensated for in order to distinguish the specific natural processes from the anthropogenic processes that affect water quality over time. In case of infrequent sampling or too short time periods it is inappropriate to develop trends, since these in reality may be caused by random natural fluctuations.

The loads of Nitrogen and Phosphorus from various sources in the catchment

The quantification of diffuse nitrogen and phosphorus losses can be carried out by different methods, including

- Direct calculations from data from field measurements / monitoring programmes
- Theoretical estimates through modelling
- Use of indicators, such as classification of loss potential by risk assessments

Operational programmes for watershed- and water resources management would normally require a combination of all three methods. In the DRIMPOL Project, all three methods were approached, but due to lack of appropriate available data and the limited time frame of the project, most efforts were deployed within the modelling part.

Load estimated from direct measurements

The two longest datasets in the Drim/Drini DRIMPOL Database, i.e. from the Crn Drim at Spilje and the Radika at Boskov Bridge, were used to calculate average loads. For the Crn Drim at Spilje, average concentrations of orthophosphate and nitrate-N in the years 1990-2004 were multiplied with average annual water flow data for the period 1990-1996. This provide an annual transport of orthophosphate of about 35 kg/year, or 80 grams/ha and year, and an average nitrate transport of 630 kg of nitrate per year, or 1.5 kg/ha and year.

Similarly, for Radika at Boskov Bridge, the annual transport of orthophosphate was calculated to 27 kg/year, or 360 grams/ha and year; and the nitrate-N transport to 353 kg/year or 4.7 kg/ha and year. The calculations are based on average concentration data from the period of 1990-2004 and average streamflow data for the period 1990-2000.

As shown in Figure 8 however, these two stations are located in areas of low river water nutrient concentrations. Furthermore, such estimates should be treated with great care. Estimations of sediments and sediment associated loads have been shown to vary considerable with frequency of sampling and the interpolation methods used (e.g. Borgvang et al. 2006b).

Source related loads based on modelling

The second modelling approach, modelling was undertaken with the Norwegian TEOTIL2 Model (Selvik et al. 2004). The model is source orientated, which implies that the loads are calculated based on the expected contributions from various point and non-point sources. The entire catchment was divided into 57 sub-catchments, and the total load can be given both for individual and accumulated areas. The results of the modelling for the 57 individual sub-catchments are shown in the phosphorus and nitrogen load maps in Figures 12 and 13

Figures 9 and 10 show the accumulated modelled values of nitrogen and phosphorus for the entire river at the outlet to the Adriatic Sea, distributed for six sources. These sources comprise natural deposition and loads from forests, lakes and wetlands, as well as anthropogenic sources segregated into agricultural activities; urban areas and settlements (“artificial”); and sewage (based on population densities).

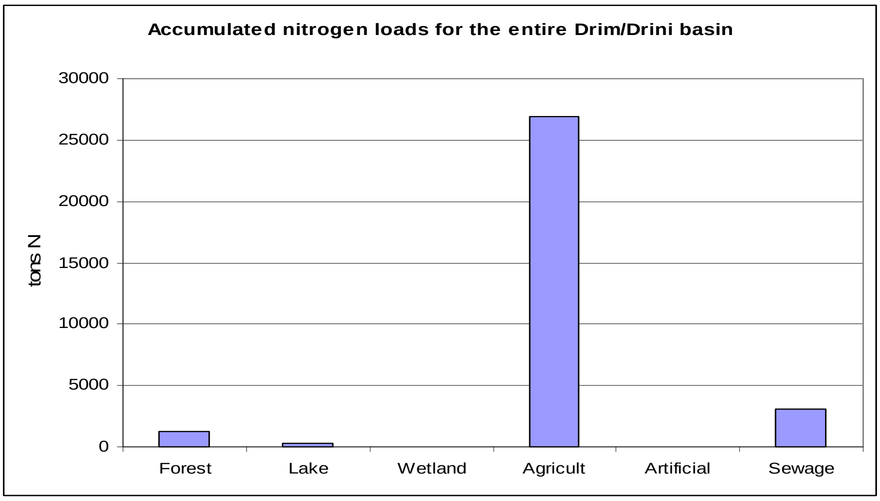

Figure 9: Total load of nitrogen in the entire Drim/Drini

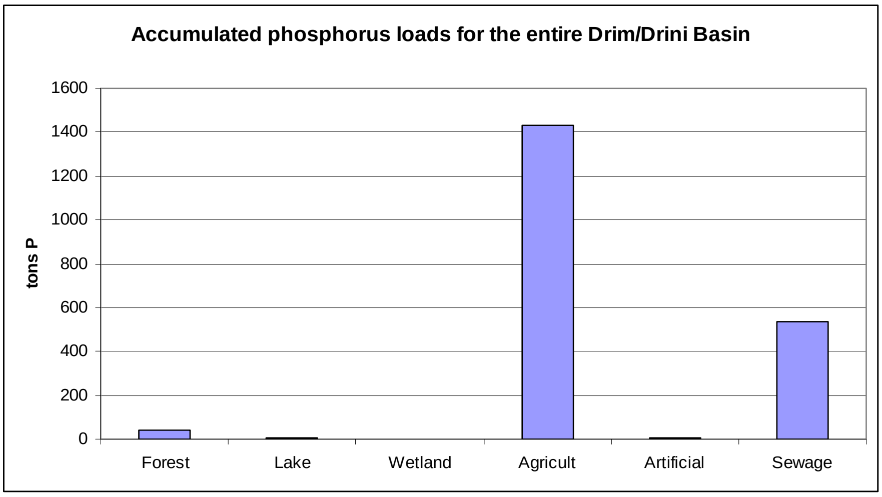

Figure 10: Total load of phosphorus in the entire Drim/Drini

The result of the modelling provided a total nitrogen load for the entire catchment of 31,580 tonnes, of which more than 30,000 tonnes, or about 95%, derived from anthropogenic sources. This total load corresponds to an area-specific load of about 17 kg/ha. As a comparison, the corresponding figure for the Danube basin is only 7.5 kg/ha (Screiber *et al*. 2003), and in 2004 the largest river in Norway, River Glomma, transported about 3 kg/ha of total nitrogen (Borgvang *et al*. 2006a).

The total phosphorus load for the Drim/Drini amounted to about 2020 tonnes, of which 1970 tonnes, or 98 %, derived from anthropogenic sources. This corresponds to an area-specific load of 1.1 kg/ha. This is somewhat higher than the corresponding figure for the Danube basin (0.7 kg/ha; Schreiber *et al.* 2003) and significantly higher than the corresponding figure for River Glomma in Norway (0.07 kg/ha; Borgvang *et al.* 2006a).

Whereas agriculture is the main source of nitrogen and phosphorus in the river system as a whole, the source distribution varies from site to site. Examples of site-specific loads of phosphorus are shown in Figure 11. Whereas in the lower parts of the drainage system, in the Buna river, most of the phosphorus load derives from agriculture, sewage is more important in the Golema River, draining the city of Resen, as well as in the campaign streams of Kranska and Brajcinska, in spite of the fact that these two streams are draining agricultural areas.

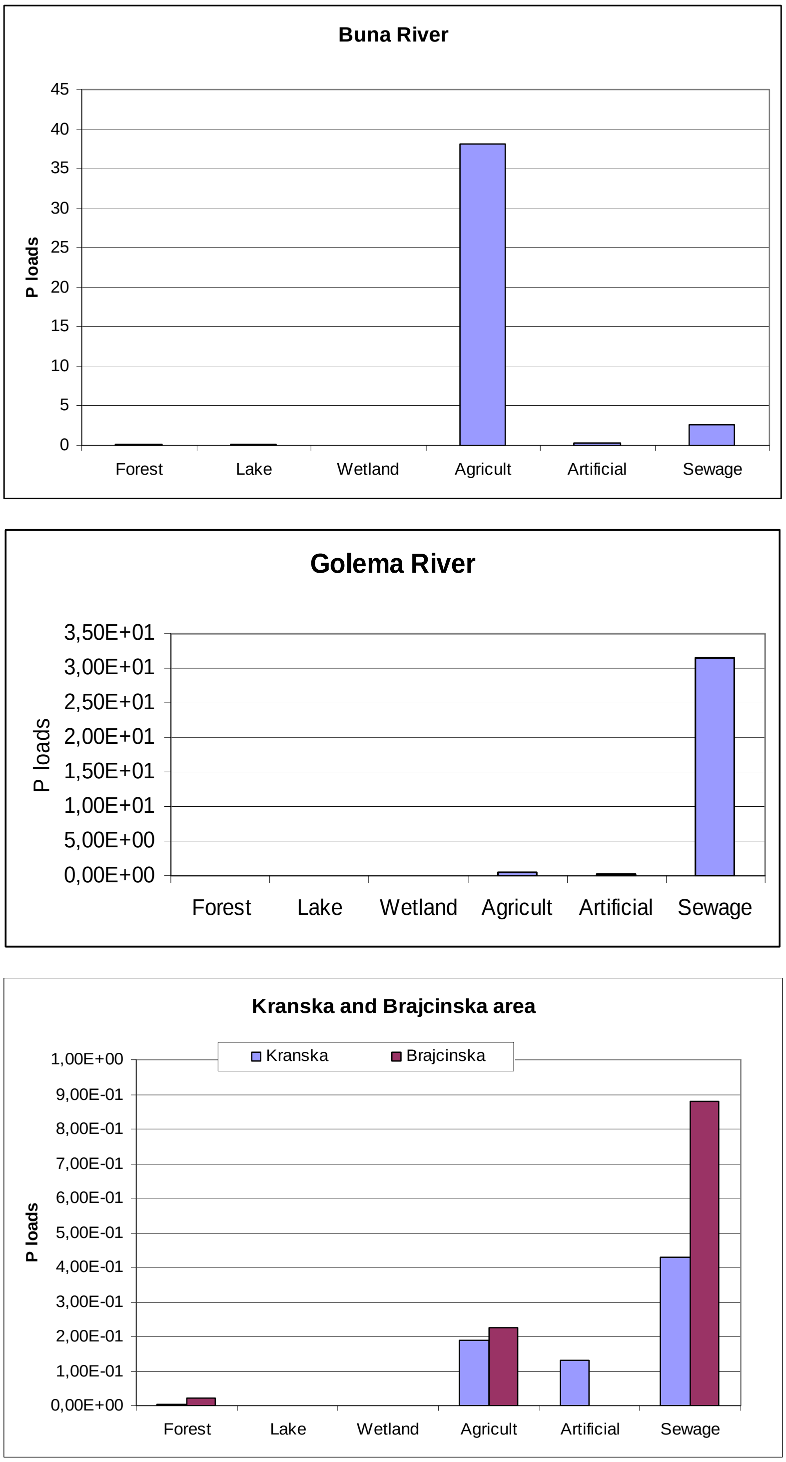

Figure 11: Variations in the importance of sources for phosphorus loads at different sites in the Drim/Drini river system. From top to bottom: The Buna River and its tributaries, close to the Adriatic Sea; Golema River draining into Lake Prespa; and the two campaign streams Kranska and Brajcinska, also draining into Lake Prespa. All loads are given in tonnes.

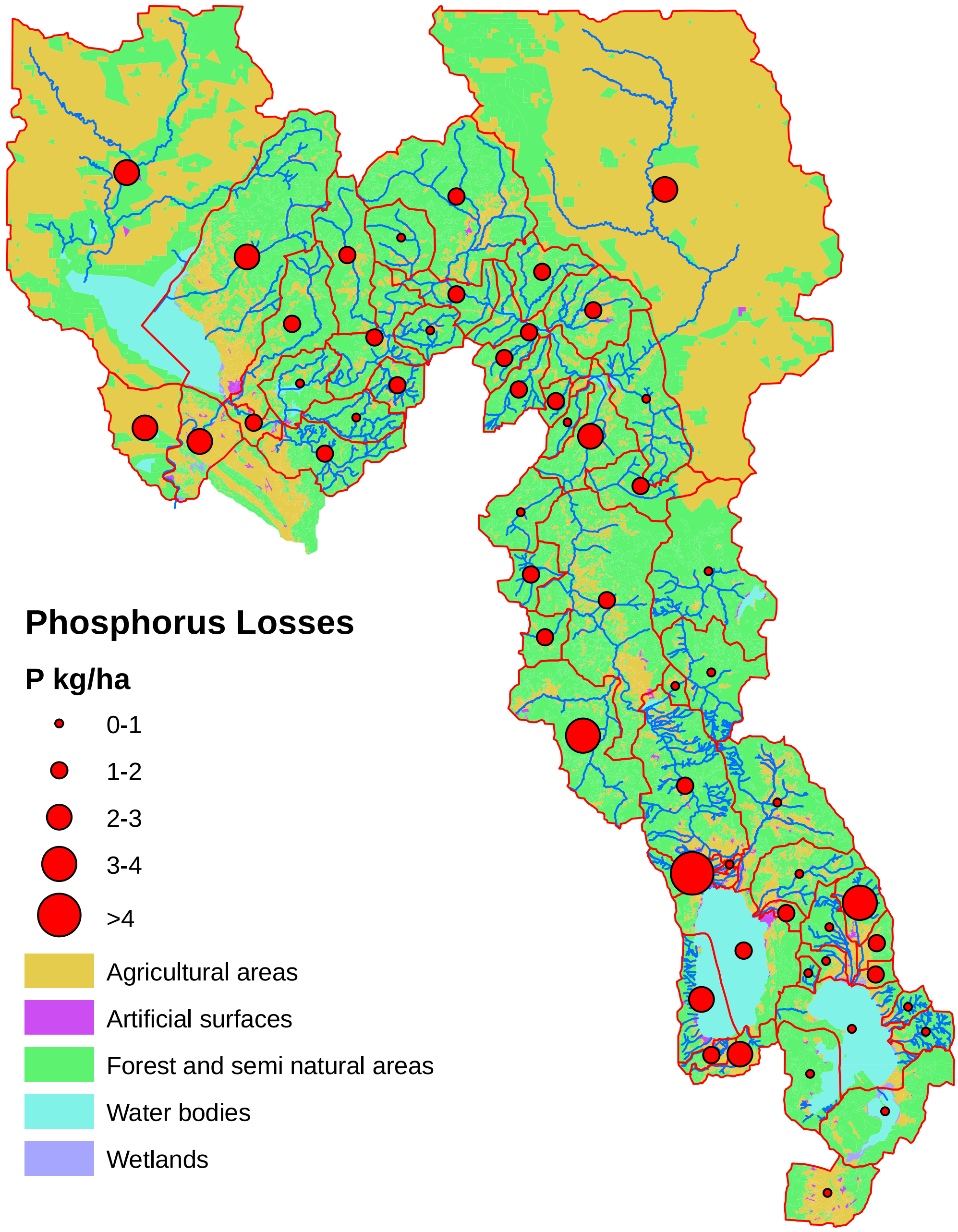

Figure 12: Map of P losses in the Drim/Drini Catchment area.

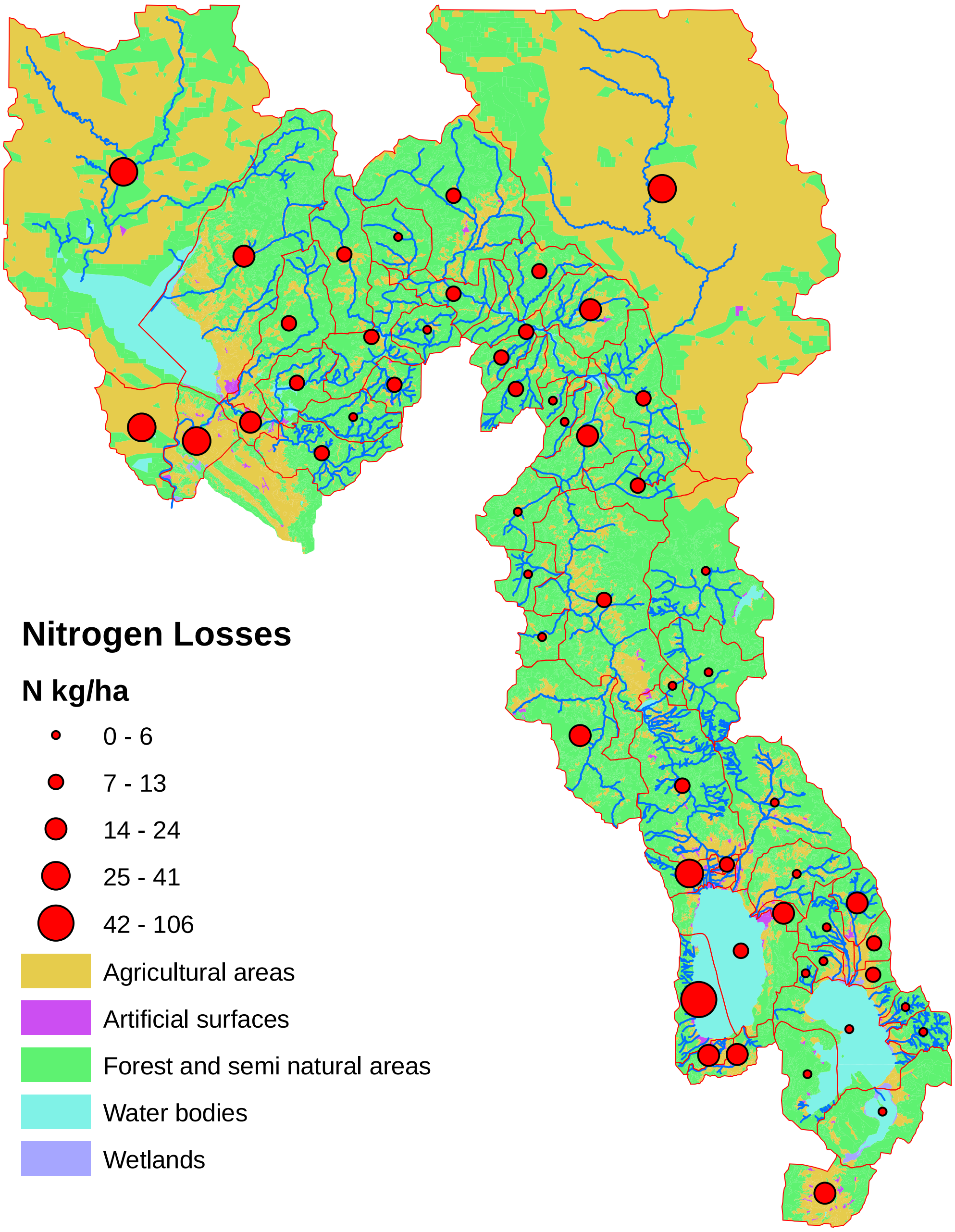

Figure 13: Map of nitrogen losses in the Drim/Drini Catchment area.

Loads calculated through indicators; Soil erosion risk assessment

Soil erosion processes is believed to contribute significantly to the degradation of the soil and water quality in the drainage basin of the Drim/Drini river basin, but the erosion processes and the resulting sediment and nutrient deliveries typically exhibit a considerable spatial variability. Thus, in the context of water resource management it is extremely important to be able to identify "hot spot areas" and to distinguish areas with low erosion risks from areas with high erosion risks.

Risk map presentations might include themes such as the spatial distribution of nutrient balances (N and P), different index systems for both N and P where known risk factors are combined, and the spatial variability in soil erosion risk. The DRIMPOL project has developed a first approach to include the erosion risk assessments into an overall context of an integrated water resource management in the Macedonian parts of the Ohrid and Prespa drainage basins (Figure 14). The catchment area is classified according to its natural erosion risk, and distributed into 5 classes, from low erosion risk (light green in figure), to high risks (red and orange colours). The risk assessment is based on the Universal Soil Loss Equation (USLE), which represents the key tool world-wide to quantify erosion risks in a standardised way (Wishmeier and Smith 1978). The quantification of erosion risk takes account of the site specific soil physical properties, the slope (i.e. the steepness of the land), the typical slope lengths, specific erosion control measures, the protective effects (on the soil surface) of the vegetation cover, and, lastly, the rainfall intensity. These factors are the major governing factors determining the level of soil erosion.

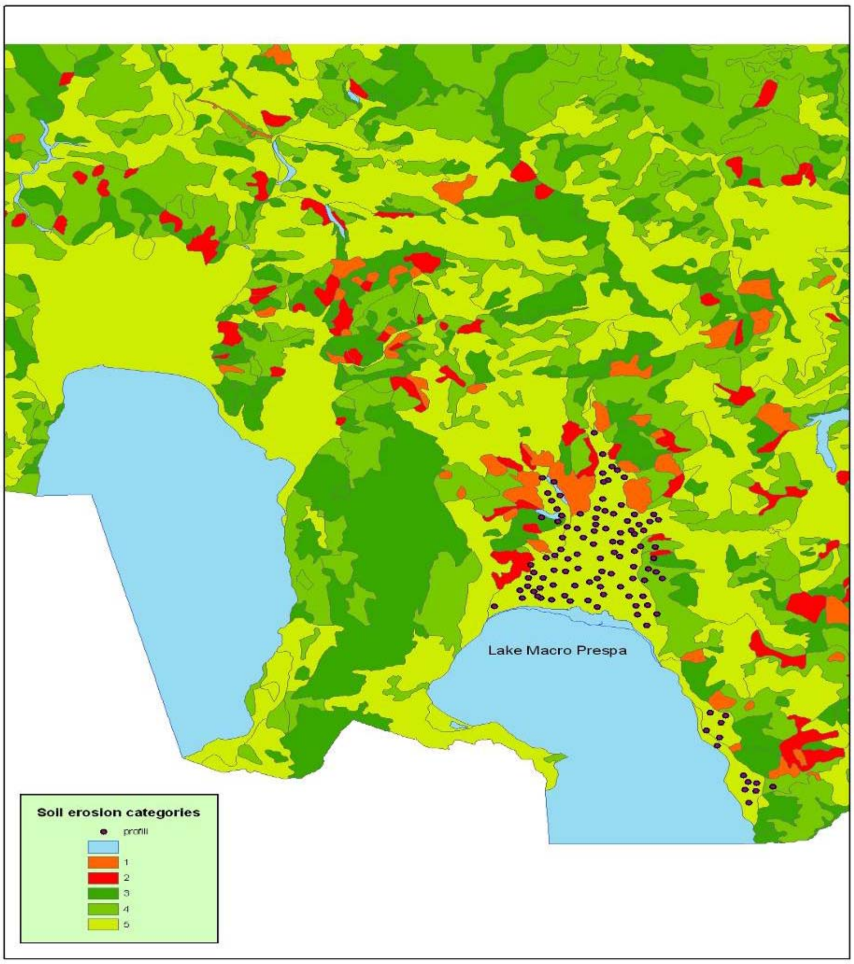

Figure 14*: Draft erosion risk map of the Macedonian part of the catchment area of the Prespa and Ohrid lakes. The colours represent different erosion coefficient categories, where orange represents areas most prone to erosion and shades of green areas with low to medium erosion risks. (Soil profiles analysed are also shown, but this part of the project is not reported in this paper).*

Thus, the pre-requisite for doing the erosion risk classification is the access to topographical data and relevant soil data. The generation of such data would usually require substantial efforts in terms of field surveys and soil mapping, combined with appropriate GIS presentation tools, but with the access to modern techniques based on remote sensing also more "indirect" approaches have become feasible. At this stage, therefore, the most interesting aspect of the classification in Figure 14 is the visualisation of the spatial variability in erosion risks and not the quantitative boundaries of each class in e.g. tonnes/ha. The latter would require substantial inputs of empirical data from local field measurements. Such field campaign measurements are, thus, another of the DRIMPOL project's recommendations in terms of priorities for future monitoring policies in the area.

Research and management needs – bridging the gaps

The main objective of the DRIMPOL Project was to quantify nutrient sources throughout the catchment area of the Drim/Drini. This was initially approached through three methods, i.e., based on direct measurements; modelling; and mapping of risks by using GIS. The DRIMPOL Project has demonstrated all three methods, but due to lack of appropriate and long-term datasets the results should be subject for further refinement in the years to come, when new data are collected through the strengthening of the water quality and quantity monitoring in the countries (e.g., WMO 2001; Milevski et al. 2004). As such, the approach used by the DRIMPOL project is useful inasmuch as it pinpoints the need for targeted data and sets the scene for design of appropriate monitoring networks.

The load estimates of about 31.000 tonnes of nitrogen and about 2000 tonnes of phosphorus at the outlet of the Drini in the Adriatic Sea should, thus, be adjusted as new information is obtained. It is data such as these that should be used to establish environmental goals for the catchment. Setting environmental goals is one of the requirements of the EC Water Framework Directive, the purpose of which is to restore the river system to a "good ecological status". Environmental goals may be very useful tools for decision makers; an example is the goal set by the Ministers of Environment of the Baltic countries in 1988, declaring that by 1995 the nutrient loads to the Baltic Sea should be reduced by 50% from the levels that prevailed in 1987 (HELCOM, 1993). Similar reduction goals were also set at an even earlier stage by North-East Atlantic countries within the Oslo-Paris Convention Framework, now OSPAR (PARCOM 1988).

Monitoring should not only be used to assess the status of a water body's ecology, but also to assess whether this status has changed over time due to human impacts, and to which extent various abatement measures is improving the situation. For this, long term data series are of vital importance, but since these are scarce in the area, it is even more important to set up monitoring campaigns to assess the relative importance of different nutrient sources. Campaign measurements such as the one performed in the Kranska and Brajcinska streams should be done in other areas with more intensive agriculture. Furthermore, the use of risk maps should be further developed, as these are excellent tools to pinpoint risk areas and visualise for managers in an efficient way where target abatement practices should be set in. This would benefit the further risk and vulnerability characterisation of the drainage basin as a whole, which is imperative for the development of a river basin management plan for the entire drainage basin of the Drim/Drini.

In terms of parameters, it is a problem that many of the past monitoring data only comprise fractions of nutrients, and not total phosphorus or total nitrogen. Fractions such as orthophosphate may be present in very low concentrations, and when these are close to the detection limits of the analysis methods used, the reliability of the results decrease. It also becomes impossible to compare values when different stations use different nutrient fractions. It is therefore highly recommended that total phosphorus and total nitrogen are prioritised in all stations. It should also be considered to reduce the number of analyses per sample and rather increase the number of samples. This may give more information without increasing the budget radically.

The DRIMPOL Project has shown that agriculture is of a relative low importance as a nutrient source in the sub-catchments to lakes Prespa and Ohrid, but that this changes further downstream in the catchment, and at the outlet agriculture is the main nutrient source. The most probable reason for the low nutrient losses in the upper parts will be low levels of fertiliser use. This, however, is most likely changing in the years to come; agriculture is the main source of nutrients throughout Europe, and it is very likely that this will also be the situation due to increased development of agricultural practices in these regions (Borgvang and Selvik 2000). At the upper reaches of the catchment, the DRIMPOL results have demonstrated the importance of controlling a major point source, i.e. sewage. Only one wastewater treatment plant is in operation in the entire drainage basin; located downstream of Struga City close to Lake Ohrid. Increasing the number of wastewater treatment plants in the upper parts of the catchment should therefore be a prime priority in order to reduce nutrient loads to the river system.

The DRIMPOL Project, thus, started out as a research project between three research institutes, but during the project period it became increasingly clear that there is a need to bridge the gap between researchers and managers in terms of data and information transfer. Furthermore, the experiences and scientific results gained during both this project and other past and on-going projects in the region should be useful not only to researchers, but also to the managers of this transboundary catchment area. For this reason, the DRIMPOL Project organised an end-user workshop in Ohrid in June 2005, where scientists from both the DRIMPOL project and other past and on-going scientific projects presented their results, and managers informed about monitoring networks and water resources management policies. The main purpose of the workshop was to provide a meeting arena for managers and researchers, where open discussions on needs for knowledge and data were held. Participants from Albania, Macedonia, Serbia and Montenegro, and Norway were present, and a list of key issues was made from the discussions (cf. www.drimpol.net). A main conclusion was that there is a lack of continuous monitoring programmes in most countries and of harmonised programmes across borders, including choice of parameters and timing of sampling. It is a challenge to avoid that appropriate project related monitoring activities are disrupted when the projects come to an end. Based on this, the main recommendation was to upgrade the monitoring networks by increasing the long-term commitments and co-operation across borders.

In summary, thus, the main DRIMPOL management recommendations comprise:

- Abatement measures for nutrient reductions in the upper parts of the catchment should target the problem of untreated sewage; more sewage treatment plants should be built
- For the Drim/Drini as a whole, agriculture is the main nutrient source, and measures to reduce losses of nutrients from agricultural areas should be implemented, especially since it is likely that the agriculture also in the upper reaches will gradually develop into more intensive cropping.
- The results of the DRIMPOL Project may be used as a basis for setting environmental goals, but these will need to be adjusted according to new information gained; this, again, will require a close co-operation between managers and scientists.
- When upgrading the monitoring networks, long-term commitments, frequency of sampling, harmonised choice of parameters, and, not least, co-operation across borders should be prioritised.

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