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HYDROBIOLOGICAL STUDY OF THE ALLONDON RIVER: EVOLUTION SINCE 1975 AND PRESENT CONDITION

BY

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KEYWORDS:

Allondon river, water flow, anthropogenic flow, macroinvertebrates, species' diversity, maximum anthropogenic load.

ABSTRACT

Investigations carried out between 1987 and 1988 (analyses of benthic invertebrates, water physico-chemistry and bacteriology at six major sampling stations) are presented. Compared with previous investigations, they indicate that the river has clearly been degrading over the past few years due namely to a high level of pollution caused by effluents of sewage treatment plants (for instance, the number of species of two benthic invertebrate groups is reduced to less than half of what it was in the early 1980's).

With the quantitative data obtained, the maximum anthropogenic load admissible by the Allondon river is defined.

RÉSUMÉ

Les résultats d'analyses physico-chimiques, biologiques (macroinvertébrés benthiques) et bactériologiques effectuées en six stations principales entre 1987 et 1988 sont présentés ici. Comparés aux résultats d'analyses antérieures, ils montrent clairement que l'Allondon s'est dégradée au cours de ces quelques dernières années, principalement en raison de la pollution résiduelle due aux stations d'épuration. En particulier, le nombre d'espèces dans deux groupes d'invertébrés benthiques a été réduit de moitié par rapport au début des années 1980.

Sur la base de nos données quantitatives, nous avons estimé la charge anthropogène admissible par la rivière.

INTRODUCTION

The Allondon river and its valley constitute a very important part of the Geneva region's landscape, and play a major role in the life of its inhabitants, and its economy. Its role in the conservation of local fauna and flora is of the greatest importance

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(THEURILLAT & ROCH, 1989). That is why since 1977, the valley of the Allondon has been put on the Swiss federal list of landscapes, sites and monuments of national importance.

Despite such measures, the river has clearly been degrading over the past few years due to a high level of pollution caused by the effluents of sewage treatment plants treating the waste waters of a continuously growing population in the French basin.

1. GENERAL CHARACTERISTICS OF THE RIVER AND CHOICE OF SAMPLING STATIONS

The Allondon has its source at an altitude of 649 m (vauclusian source) in the region of Gex (Ain department, France) and flows into the Rhône about 10 km from Geneva at an altitude of 343 m. It extends over a distance of 9 km in France, 5 km in Switzerland and 2 km along the border of the two countries. The total subsidence and length are thus 306 m and 17 km respectively.

The river receives several tributaries among which we shall retain, the Lion, situated shortly before the border, the Allemogne and the Ecra in the border area, and several streams of lesser importance in the Canton of Geneva (see below and fig. 1).

The catchment basin has a total surface area of 148 km^2 of which 17 are in Switzerland.

At the mouth of the river, the mean water flow is of 2,5 m^3/s with peak flows attaining more than 10 m^3/s between the months of November and March, and minimum flows as low as 1 m^3/s from July to September.

The waters of the Allondon are by nature moderately hard since they emerge from calcareous ground. In accordance with the temperate climate of the region, they are generally cool, with temperatures ranging between 2 °C and 20 °C at their most extreme points (DETHIER *et al.*, 1985).

The location of the sampling stations was decided in such a way as to take into account the impact of particular factors along the river's course. From upstream to downstream, these factors are (figure 1):

- the arrival of effluents from the sewage treatment plant (STP) of St. Genis, France, 400 m from the Swiss border;
- the junction with the waters of the Lion, polluted 5000 m upstream by the waste waters of the STP of Prevessin;
- the arrival of good quality water from the Allemogne;
- The lower basin, still reasonably wild and relatively unaffected by direct human intervention.

Thus, six principal sampling stations were established (five on the Allondon and one on the Lion – table 1, fig. 1).

In analysing the data, the results of the sampling station L combined with those obtained from the sampling station A2 give rise to a theoretical station called A2+L which informs of the concentrations and flows after confluence of the two rivers (indirect measurement obtained by the direct measurements at A2 and L).

In addition to the stations presented above, there are eleven sampling stations along the smaller tributaries of the lower basin and two stations along the upper course of the Allondon thanks to which we were able to gather information on the biological state of the catchment basin. These sampling stations were designated as "accessories" since, as opposed to the others, they were only used for the qualitative sampling of benthic macroinvertebrates.

The two sampling stations on the upper course of the Allondon are respectively situated at 7,8 km and 5,5 km up stream from A1 (that is to say respectively 0,8 km and 3,1 km downstream from the source).

The examined tributaries are the Roulavaz, the Missezon, The Eaux Chaudes, the Eaux Froides, the Crêts, the Allemogne, the Prâlies and the "Stream A1" (a small tributary not represented on the map which joins the right bank of the Allondon 50 m upstream from the A1 sampling station); the samplings were mostly made shortly above the mouths of these streams.

2. METHODS AND TECHNIQUES

2.1 PHYSICO-CHEMICAL ANALYSIS

The water was analysed in instant samples collected monthly from July 1987 to August 1988 at the six major sampling stations.

81 samples were analysed by the Hydrobiological Section of the Geneva Cantonal Service of Ecotoxicology using methods derived from those recommended by the Federal Department of the Interior ("Département Fédéral de l'Intérieur"), (DFI, 1982).

The analysis of each sample was undertaken with particular relevance to 4 physical parameters (temperature, pH, conductivity at 25 °C and level of saturation in oxygen) and to 10 chemical parameters: concentration in oxygen (O_2), biological oxygen demand after 5 days at 25 °C (BOD 5 D)., dissolved organic carbon (DOC), mineral phosphorus (mP), total phosphorus (tP), ammonium nitrogen ($NH4^+$- N), nitrite nitrogen (NO_2^- - N), nitrate nitrogen (NO_3^- - N), chloride (Cl^-) and sulphate (SO_4^{2-}).

2.2 BIOLOGY

Monthly samplings of macroinvertebrates were conducted in parallel (simultaneously wherever possible) with the water samplings destined for the physico-chemical analysis.

A Surber net was used for collecting the samples (in order to collect each sample, stones were upturned to dislodge the fauna just upstream from the net, 6 times according to the different facies of the sampling station). Each sample was completed by collecting fauna by hand from the bottom of stones.

The identification of organisms was first taken as far as the taxa necessary to determine the Global Biological Quality Index ("Indice de Qualité Biologique Globale"

- IQBG, VERNEAUX & FAESSEL, 1976), for the most part using the book by TACHET *et al.* (1980). 93 samples were analysed in this way.

For certain groups of organisms (Plecoptera, Ephemeroptera, Trichoptera, Coleoptera, Diptera Simuliidae, Megaloptera Sialidae, Heteroptera, Gasteropoda and Hirudinea) the identification process was systematically followed up as far as the species, and further verified by specialists (see acknowledgements).

The species diversity study was not limited to the six sampling stations mentioned above, but extended to the upstream course as well as to several tributaries (cf. above).

Seasonal quantitative samplings (October, 1987, February 1988, May 1988) were made in addition to the monthly qualitative ones. The organisms were collected at the sampling stations A1, A2, A3, A5 and L using a normalised Surber net (5 net-fulls, one for each 0,2 m^2 surface).

The samples obtained were sorted quantitatively: all the organisms were counted, identified and passed onto blotting paper before estimation of their fresh weight after which they were placed in a drying room at 105 °C for 24 hours in order to determine their dry weight (CHAVANON & BOURNAUD, 1980; DETHIER, 1988).

2.3 MISCELLANEOUS

Information concerning (1) water flow, (2) bacteriology and (3) the functioning of the sewage treatment plant of St. Genis was also obtained from the competent agencies, respectively (1) the Swiss Hydrographic Service, CERN (European Center of Nuclear Research), and Geneva's Department of Public Works ("Départment des travaux publics"), (2) the Hydrobiological Section of the Ecotoxicology Department of Geneva ("Section d'hydrobiologie du Service cantonal d'écotoxicologie") and (3) the management of the St. Genis STP.

Finally, some of the data were obtained from printed sources: DETHIER *et al.*, 1985; PRIMATESTA, 1987; SARTORI *et al.*, 1989; THEURILLAT & ROCH, 1989; MOLANDER, 1990.

3. RESULTS

3.1 WATERFLOW

The evolution of the Allondon's water flow is closely linked to the melting of the snow in the Jura and displays strong annual variations (figure 2). Between 1987 and 1988, the mean annual flow of the Allondon increased by about 340% between the stations A1 and A5 (A1: 0,96 m^3/s; A5: 4,24 m^3/s).

The water flow of the sewage treatment plant (STP) of St. Genis has varied between 0,05 m^3/s and 0,22 m^3/s, thus remaining negligible in relation to the mean water flow of the river between 1987 and 1988 (0,96 m^3/s at A1). Nevertheless, during the lowest water level period, the waste waters of the STP constitute a much larger proportion of the water flow: 38% on the 15th of September 1987, for example.

The Lion and the Allemogne are the two main tributaries of the Allondon. Their water flows, shortly before their mouths in the Allondon, are abundant all year round and almost identical to that of the Allondon itself (mean flow: 0,86 m^3/s, Lion; 1,72 m^3/s, Allemogne). The water contribution of these two tributaries accounts for about 61% of the mean water flow at A5. The small tributaries of the lower basin represent a mere 16% of the water flow at the same sampling station.

The mean daily water flow measured by the Swiss Hydrographic Service during the above mentioned measuring period is at 3,84 m^3/s (sampling station A4), that is to say at a margin of 0,5 % from the mean of our 14 punctual measurements.

3.2 PHYSICAL AND CHEMICAL ANALYSIS

All the results are presented in table 2. In our discussion we will pay special attention to the behaviour of the chemical parameters.

3.2.1 CONCENTRATIONS

Throughout the year, two groups of parameters show variations opposite from one another which are linked to the water flow (figure 2):

– Dissolved oxygen and nitrates increase in concentration during high water periods. Stronger water turbulence, better dilution of atmospheric oxygen and the slowing down of autoepuration phenomena (due in particular to lower temperatures) explain the increase in concentration of dissolved O_2. As for the nitrates, the winter leaching of the soil is responsible for their increase in concentration (1st and 29 th February 1988). The winterly spreading of fertilisers on naked and sometimes frozen soil is possibly responsible, as well.

– On the other hand, the other parameters (NH_4^+- N, NO_2^- - N, SO_4^{2-}, tP, mP, Cl^-, DOC and BOD) have their highest concentrations during the low water periods (the end of Summer and beginning of Autumn; in this study : 15/9 and 26/10/1987) and their minimal concentrations at the beginning of Spring, ie, when the water levels are at their highest (in this study: 28/3 and 12/4/1988).

The low water period is thus a particularly critical one: the water flow and the dissolved oxygen are at their lowest, while the concentrations of various anthropogenic pollution indicating parameters are at their highest: ammonium nitrogen, for example can be greater than 2 mg/l (sampling station A2), which combined with a pH value between 7,4 and 8,5 constitute a serious danger for the aquatic fauna (RODIER, 1975).

The enormous influence that the waste waters of the STP of St. Genis have on the Allondon are brought to light by the evolution of the annual averages from upstream to downstream (table 2). The concentrations of NH_4^+- N, NO_2^- - N, tP and mP increase in the most spectacular manner between the stations A1 and A2. The case of ammonium is the most stunning since the sewage treatment plant of St. Genis does not conduct any nitrification: it's concentration between A1 and A2 is on average multiplied by 135 ! As for the other typically anthropogenic parameters, they are multiplied between 13 and 23 times, which is already a considerable amount. The waters of the Lion contribute to a slight lowering of these figures since the concentrations calculated for A2+L, although still high, are usually inferior to those measured at A2. Further downstream, dilution by the less loaded waters of the Allemogne coupled with the autoepuration phenomena, bring the figures down to a more easily acceptable level, without however entirely regaining the quality observed at A1.

Conductivity and the concentrations of SO_4^{2-}, Cl^-, NO_3^- - N and DOC also increase perceptibly between A1 and A2 but less spectacularly (generally less than a 100% increase in comparison to A1). In this case on the contrary, the waters of the Lion bring forth a slight increase of these parameters (with the exception of DOC, see table 2), as their values calculated for A2+L are usually slightly superior to those measured at A2. The stronger load in nitrate of the Lion can no doubt be explained by a more advanced state of autoepuration (the sewage treatment plant of Prevessin is at 5000 m from the sampling station L whereas the one at St. Genis is only 400 m from A2) and also by the fact that this water course and its tributaries cross a more cultivated catchment basin than the Allondon.

To sum up, the sampling station A1 can be considered a reference point to a state which must resemble the initial one, since according to the water quality classification (based on mean concentration of tP, mP and NH_4^+- N) of the Swiss Federal Department of Environmental Conservation ("Office fédéral pour la protection de l'environnement"- OFPE, 1982), the sampling station A1 can be considered "non-polluted".

However the elevated figures of certain parameters (NO_3^- - N and BOD for example), clearly show that the river already undergoes a certain human influence at this point in its basin.

As we have seen, the waste waters of the STP of St. Genis profoundly disturb the sampling station A2 and the waters of the Lion do not noticeably improve their quality at A2+L.

We must wait for the effects of autoepuration phenomena and dilution by the clean water of the Allemogne 2450 m downstream from A2+L before obtaining a perceptible improvement at A4 for practically all the parameters.

Further downstream, up to A5 (the mouth), autoepuration continues its effects. Dilution of the Allondon by smaller tributaries (Missezon, Roulavaz, etc.) bears little significance.

3.2.2 FLOWS

Similarly to the concentrations, two groups of substances evolve in a somewhat different way from each other throughout the year (figure 2):

– Cl^-, SO_4^{2-}, DOC, O_2 and NO_3^- - N are substances directly linked to the water flow (maximum in Winter and Spring, minimum in Summer). They come from the sewage treatment plants of St. Genis and Prevessin but especially from diffused sources such as leaching (which is stronger when the water flow is high) and as regards O_2, from water turbulence. From upstream to downstream their flow thus increases in the same proportions as the water flow.

– For NH_4^+- N, NO_2^- - N, tP and mP the source is essentially punctual: the sewage treatment plant at St. Genis and to a lesser degree, the Lion. More than the water flow, the variation in the loads introduced by these two sources determines the temporal evolution of the flow of NH_4^+- N, NO_2^- - N, tP and mP. Their flow reaches a maximum at A2+L and not at A5 as was the case with the previous groups of substances.

In order to clarify the importance of the anthropogenic contribution to the measured flow of each substance, we have, for each sampling station, attempted to separate it from the natural contribution. Two hypotheses were made:

1. The concentration in substances of natural origin remains relatively constant throughout the last 10 km of the Allondon (A1 --> A5). Thus, since the flow of a substance is the product of its concentration by the water flow, the flows of substances of natural origin increase in direct proportion to the water flow downstream from A1.

Several facts favour this hypothesis:

- The relative shortness of the length considered (A1 --> A5 = 10 km) and consequently the weak importance of the bottom input ("self-contribution") on the changing of natural concentrations from A1 to A5.
- The uniformity of the geological characteristics of the basin downstream from A1 and consequently the weak influence of lateral inputs on the natural concentrations (natural chemical characteristics of tributaries identical to that of the Allondon).
- VESPINI *et al.* (1987) research work on the natural evolution of the chemical characteristics of an unpolluted river comparable to the Allondon.

2. The anthropogenic chemical flow at A1 sampling station is negligible (see 3.2.1). We therefore believe that the chemical flows measured at A1 are equal to the natural ones.

From what precedes, and despite the simplifying aspect of our hypotheses, we established a two-equation system (see below) of which the two variables correspond on the one hand to the natural chemical flow (1) and on the other, to the anthropogenic chemical flow.

$$AF\ (Ai) = MF\ (Ai) - NF\ (Ai)$$
$$NF\ (Ai) = WF\ (Ai) \cdot AC\ (A1)$$

AF = anthropogenic flow; NF = natural flow; MF = measured flow;
A1, Ai = sampling stations; WF = water flow; AC = mean concentration

The examination of the results shows that (figure 3):

(1) Since it is calculated from a reference, or norm of concentration it is a normalised flow.

– It is with the arrival of the water of the Lion (A2+L) that for any one of the parameters, the anthropogenic flow is at it's highest in the Allondon.

– Between A2+L and A3, as the phenomenon of dilution is practically absent (very little lateral contribution), one observes a resorption of the anthropogenic chemical flows due essentially to autoepuration phenomena, the effects of which are manifest in all of the biodegradable chemical types.

– Downstream from A3 and up to the mouth, a diminution of the anthropogenic flow of ammonium, nitrite and COD is observed. On the other hand the anthropogenic flow of tP and mP stabilises or even slightly increased. This situation is not due to an interruption of autoepuration phenomena but to the existence of contributions downstream from A3 which dissimulate its effects (agriculture, camping site located near sampling station A4, . . .).

– The essentially human origin of ammonium and nitrite is particularly obvious: their natural flow is so weak that even after important reductions of the anthropogenic flow, the fraction which is of human origin remains extremely high in relation to the total flow of these substances. The effect is such that the river never recovers its "natural state" of upstream from the STP as it is impossible for it to rid itself of the totality of human contributions.

3.2.3 EVOLUTION OF ANNUAL MEAN CONCENTRATIONS OF SIGNIFICANT PARAMETERS (O_2, Cl^-, P and NH_4^+- N) SINCE 1975 AT SAMPLING STATION A3

Chemical measurements were regularly made by the Hydrobiological Section of the Ecotoxicology Department of Geneva ("Section d'hydrobiologie du Service cantonal d'écotoxicologie") at sampling station A3. However, regular measurements of the water flow were made only at sampling station A5 (Swiss Hydrographic Service).

Figure 4 shows that:

1. According to the water quality classification of the Swiss Federal Department of Environmental Conservation ("Office fédéral pour la conservation de l'environnement" - OFPE, 1982) (based on mean concentration of tP, mP and NH_4^+), the sampling station A3 is clearly ("nettement") polluted and very often heavily ("fortement") polluted (4 years out of 15 for tP, 7 for mP and 11 for NH_4^+- N).

2. It is surprising to find out that in 1987-88 the annual mean concentrations of NH_4^+- N, tP and mP are among the lowest recorded since 1975. This can be explained if one considers in parallel the mean annual water flow (upper histogram): 1987-88 is a year in which the mean water flow was high (superior to 4 m^3/s). Again we can see, but this time over a period of 15 years, that high concentrations of Cl^-, P and NH_4^+- N correspond to a low water flow. By contrast, oxygen is more abundant during years of high water flow.

3. The improvement that took place between 1985 and 1987-88 is no doubt not due to a reduction of discharge but rather to several consecutive years of high water

flow. As we shall see in the following chapter, such an improvement is not at all valid as regards the biological quality and the biota diversity: the benthic macrofauna of the Allondon has not ceased to degrade itself since 1981 (DETHIER *et al.*, 1985).

In addition to this, if we consider the evolution of certain chemical parameters since 1968 we are forced to notice a sensitive increase of their concentrations: NO_3^-- N goes from 1,46 mg/l (1968-72 mean) to 3,2 (1987-88) and to 4,28 (1990). For the same periods, NO_2^-- N goes from 0,014 mg/l to 0,041, and then in a spectacular manner to 0,28. For these two chemical types, let us underline the fact that though the most recent (1990) mean concentrations are the highest ever recorded, the mean water flow of 1990, though weak, is however not the lowest ever recorded (without taking into account the very high water flow of February (> 12 m^3/s at A5)), the water flow is, however, among the lowest recorded since 1975.

3.3 BIOLOGY

3.3.1 BENTHIC MACROINVERTEBRATES: GLOBAL BIOLOGICAL QUALITY INDEX (IQBG)

The Global Biological Quality Index ("Indice de Qualité Biologique Globale" - IQBG, VERNEAUX & FAESSEL, 1976) which seems to be the best method of accounting for the different types of possible situation and habitat (DETHIER *et al.*, 1985) was used. It is useful and applicable to rivers of small and medium importance (MAUCET *et al.*, 1984). It characterizes the biological quality of a river from the population of benthic macroinvertebrates.

Throughout the year the IQBG evolves in a parallel manner to certain physico-chemical results: in Summer and in Autumn, the concentration of polluting matter increases due to the low water flow, and the degradation of the biological state is accentuated; by contrast, in Winter and in Spring the more abundant water flow leads to a decrease of the concentration in polluting substances and thus to an improvement of the biological state. The percentage increase in the mean index figures for the favorable period (Winter-Spring), relative to the mean index figures for the non-favorable period (Summer-Autumn) clearly demonstrate this seasonal behaviour: + 66% (A1 sampling site), + 98% (A2), + 42% (A3) and + 49% (L).

As for spatial evolution (figure 4), one also observes that the biological analysis goes in the same direction as the physico-chemical analysis in a striking manner: sampling station A1 still presents a good annual average IQBG (14,1), immediatly after, at sampling station A2 the annual average is at its lowest (9,0). Thanks to phenomena of autoepuration and dilution by the slightly less polluted waters of the Lion (mean IQBG: 13,3), an amelioration is recorded at A3. The situation nevertheless remains rather poor (mean IQBG: 11,2). The averages observed at A4 and A5 are much better (15,8 and 16,2). Let us however take note of the fact that contrary to the other stations, the means calculated for A4 and A5 are based only on the results from samples obtained during the first half of 1988. It is for this reason that they are so high, since the averages for 1988 are higher for all the samplings stations than those which also take into account the results obtained in 1987 (figure 4, stations A1, A2, A3 and L).

Let us be reminded of the extreme instability of the indexes throughout the year: the weakest annual range registred so far was of 8 index units (A3); the strongest was of 13 (A1). Such a situation was already observed by DETHIER *et al.* (1985) and demonstrates a state of chronic imbalance.

Generally speaking, in 1987-88, the index figures observed at sampling stations A3, A4 and A5 are lower than those obtained 5 years earlier by DETHIER *et al.* (1985) at the same sampling stations.

Biological surveillance in 1989 and 1990 (21/4) and 31/8 1988: 8/3 and 6/9 1990), demonstrates an even stronger state of degradation: mean IQBG at A3 and A5 are respectively 9,25 and 11,25 (11,2 and 13,7 in 1987-88); for the first time the Global Biological Quality Index at A5 goes below 10 in Summer samples.

3.3.2 BENTHIC MACROINVERTEBRATES: SPECIES' DIVERSITY

Within the groups having been the object of specific identification (cf. supra), the number of species observed between 1981 and 1986 were compared to the number observed during the course of this research. This comparision cannot be made in an extremely rigorous manner since in 1987-88 sampling was carried out much more intensively (13 or 14 depending on the sampling stations) than between 1981 and 1986 (2 to 6 depending on the station), especially in the Lion and upstream from the sewage treatment plant of St. Genis.

The columns representing the sampling stations (table 3) were grouped in three series:

– The first gathers the results obtained in the Allondon during the study made in 1981 and 1982 (DETHIER *et al.*, 1985) as well as that obtained from samples taken in 1986.

– The second presents the results of this study.

– The third groups the species found in the tributaries of the Allondon without making any temporal distinction since in this case no important differences were registred between the "old" samplings (1981-82: DETHIER *et al.*, 1985; 1986) and the "new" (1987-88: our sampling work).

From the examination of table 3, two observations are made:

1. There is an important decrease of the pollution-sensitive groups at the sampling stations A3, A4 and A5 (amongst the Plecoptera and the Ephemeroptera the drop is spectacular: the number of species is reduced by more than half). The campaigns having been more numerous than in the past and the sampling techniques having remained the same, it can reasonably be infered that the species that were not found in 1987-88 in the downstream portion of the Allondon have dissappeared from this part of the river or at least that they have become exceedingly rare.

More extensive research on Ephemeroptera has largely confirmed this phenomenon: between the lists of species found before 1985 (SARTORI & DETHIER, 1985) and those found during the course of this study, the Allondon and the Lion have lost 8 Ephemeroptera species (that is to say, 30% of the fauna) and 6 other species are in regression. Within the Geneva portion of the Allondon strictly speaking, no less than 12 species seem to have disappeared. Thus even if one takes into account the few "new" species recently found (SARTORI *et al.*, 1989), the decrease is none the less spectacular.

It is not only the "rare" species which have vanished but also some species which were quite abundant in 1981-86: *Ecdyonurus helveticus, Habrophlebia lauta* and *Habroleptoïdes confusa* were not found during the 1987-88 period within the Geneva canton portion of the river (A3, A4 and A5) although they had been numerous there previously (DE SOUSA, 1990 and SARTORI & DETHIER, 1985).

2. "Reservoirs" of fauna nevertheless subsist. These are the portion of the Allondon upstream from St. Genis (A1) and the tributaries (principally the Allemogne, the Eaux Froides, the Eaux Chaudes and the Roulavaz). In these areas of the basin diverse fauna can still be found as shown in table 3.

Furthermore, important modifications of the fauna since 1981 have never been observed (this is particularly clear in the case of the Eaux Chaudes which have been visited practically every year).

One could thus hope that drift phenomena would cause regular recolonization of the Allondon. One must not however have such illusions, as a recent study has effectively demonstrated that the possibility of recolonization by fauna deriving from tributaries in a better state (the Allemogne in particular) is rather limited both spatially and temporally (MOLANDER, 1990). Furthermore, it takes very little to seriously and durably damage the quality of these small streams.

Finally, as we have already stressed concerning certain chemical parameters the biological quality and the diversity of species, even as far upstream as A1 do not quite correspond to what they ought to be in a river of this type.

3.3.3 BENTHIC MACROINVERTEBRATES: QUANTITATIVE ASPECTS

At the sampling stations A1, A2, A3, A5 and L, three quantitative sampling campaigns were made: October 1987, February 1988 and May 1988, which is totally insufficient for evaluating the seasonal evolution of the biomass. We shall therefore stick to bringing out the principal differences between the various sampled stations.

At A1 the smallest biomass was recorded: less than 1 gram of dry weight per m^2. At A2, A3 and L it was more than tripled (approximately 3 g dry weight/m^2) and detritivorous organisms dominate the community by 80%: Oligochaeta and Chironomids at A2 and A3, *Gammarus* at L. At A5 the biomass diminishes greatly (about 1 g dry weight/m^2) in favour of a slight re-equilibration (reduction of detritivours).

Once more one can see the importance of the impact that the waste waters of the sewage treatment plant of St. Genis (and less directly those of the STP of Prevessin) have on the Allondon, the result being a manifest decrease in the diversity of the benthic communities, as well as a sometimes spectacular increase of the biomass. This double phenomena has been revealed innumerable times: in the Rhône (REVACLIER & DETHIER, 1986; DETHIER, 1988) and in the Allondon course (DETHIER *et al.*, 1985). The other rivers of the region suffer to different degrees, sometimes to the point where autoepuration phenomena becomes almost impossible (in the Aire for example: LACHAVANNE *et al.*, 1979; SERVICE D'HYDROBIOLOGIE, 1981 and 1985; NUSSBAUM, 1985).

3.3.4 BACTERIOLOGY

The bacteriological analysis conducted simultaneously with the water samplings destined for the physico-chemical analysis, once again confirms the influence of the effluents of the sewage treatment plant of St. Genis: a very strong rise in the concentration of heterotrophic bacteria germs in the water followed by a progressive decrease all along the river right up to its mouth is observed. This amelioration is however only relative: the analysis concerning coliforms shows that even at the mouth, the Allondon is practically never fit for bathing (79% of the samples exceeded the Swiss norms: 100 coliforms/ml).

4. SUMMARY AND CONCLUSIONS

CHEMICAL PARAMETERS

The chemical parameters studied quite clearly belong to two groups, whose contents vary slightly according to whether the flow or the concentration is taken into consideration.

Parameters strongly linked to the water flow

The concentrations, and more strikingly the flows, increase in direct proportion to the water flow over a period of time (high concentrations and flows during periods of high water flow, low when the water flow is low) as well as with the sites along the river, from upstream to downstream. Dissolved oxygen and nitrates are the most representative of this group. The flows of Cl^-, SO_4^{2-} and DOC vary in the same way. Their concentrations are sensitively more influenced by the waste water of the sewage treatment plant of St. Genis or by the seasonal spreadings (Cl^-).

Parameters strongly linked to punctual sources

In the case of ammonium, nitrite, mineral phosphorus and total phosphorus, flows and concentrations are strongly influenced by the loads introduced in the river by man. These parameters clearly reveal the enormous influence that the sewage treatment plant of St. Genis and to a lesser degree, the one of Prevessin, have on the Allondon. Maximal concentrations are all observed at A2 (downstream from the STP of St. Genis), whereas the highest flows are found, not at A5 (the mouth of the Allondon) as is the case for dissolved oxygen for example, but at A2+L (influence of the loaded waters of the Lion).

Autoepuration phenomena act upon diverse substances (NH_4^+, DOC, ...) and one can generally see a certain improvement in the chemical quality of the water at A5 that is, with the concentrations approaching those at A1 (upstream form STP's effluents), without however completely returning to the "normal" state (P for example remains four times more abundant at A5 than at A1). Furthermore, it is important to point out that although the water quality classification of the Swiss Federal Department of Environmental Conservation ("Office fédéral pour la conservation de l'environnement" – OFPE, 1982) (based on mean concentration of tP, mP and NH_4^+), allows one to consider A1 as non-polluted, the quantity of BOD and nitrates found at that station is rather high.

Finally, certain parameters can at certain times, rise to critical levels for the aquatic fauna. This is particularly the case for dissolved oxygen and ammonium which during low water periods verge on bareable limits, particulary for pollution-sensitive macro-invertebrates and Salmonidae.

MACROINVERTEBRATES

The impact that the effluents of the sewage treatment plant of St. Genis have on the benthic macrofauna is stricking. Between A1 and A2, the Global Biological Quality Index ("Indice de Qualité Biologique Globale" – IQBG, VERNEAUX & FAESSEL, 1976) annual means drop from 14 to 9. All the pollution sensitive species disappear at A2 and A3 to reappear only at A4 and more often only at A5.

The abundance of nutrients causes a considerable increase of the biomass at A3 and L, which is essentially due to detritivorous organisms. Shortly before the mouth of the river (A5), the situation gets better: IQBG and diversity increase whereas the biomass diminishes, without however reaching the quality observed at A1. It is important once more to underline the fact that the state of the sampling station A1 is not as good as it could be: the average IQBG is rather deceiving (14) and the range of its fluctuations indicates a certain imbalance. The richness in pollution-sensitive species at this station is relatively modest, whereas by contrast, the abundance of photosynthetic organisms shows that there is a non negligeable quantity of nutrients.

We also observed the disappearance of several species after the early 1980's, particularly in the lower belt of the Allondon (amongst the Plecoptera and Ephemeroptera groups, the number of species is reduced to less than half of what it was).

Finally, though certain tributaries still present significant richness in fauna (Allemogne, Eaux Froides, ...) and may constitute "reservoirs", it seems unlikely that the present state of the Allondon favours any recolonisation by drifting.

All our measurements and observations lead to the same conclusion: the last 10 km of the Allondon are seriously polluted, its state is getting worse and worse, and this situation must be attributed to the St. Genis sewage treatment plant. During low water flow periods when dilution is insufficient, precise analyses are not even necessary: sight and smell suffice to convince the hiker of the bad state of the river !

Less obvious but no doubt more irreversible, are the effects that the river in its present state of eutrophication has on the whole valley. The heavily charged water which is infiltrated by high water flows and the water shelf through the ground surrounding the river provokes the disappearance of soils poor in nutrients together with their characteristic and rare vegetation.

Finally, the effluents of sewage treatment plants are not the only threats which weigh on the ecosystem. The lower valley, a "protected" site of national importance suffers from a real indigestion of undisciplined and unscrupulous picnickers.

The state in which we found the river during the course of this study compared with what was observed in the preceeding years is not too catastrophic thanks to the fact that in 1987-88, the water flow was generally high. However it must be considered a limit beyond which one cannot go without putting the Allondon into a state of pollution way beyond its autoepuration capacities.

We have seen that the water flow of the Allondon is extremely variable and that its minimal annual mean is 50% of what was observed during the course of this study. Consequently, for the mean concentrations to remain within the same limits as those that we measured during a year of minimal water flow it would be necessary to define the maximum anthropogenic load admissible by the Allondon as equal to 50% of the one quantified during the 1987-88 period (cf. 3.2.2), which was a year of high mean water flow.

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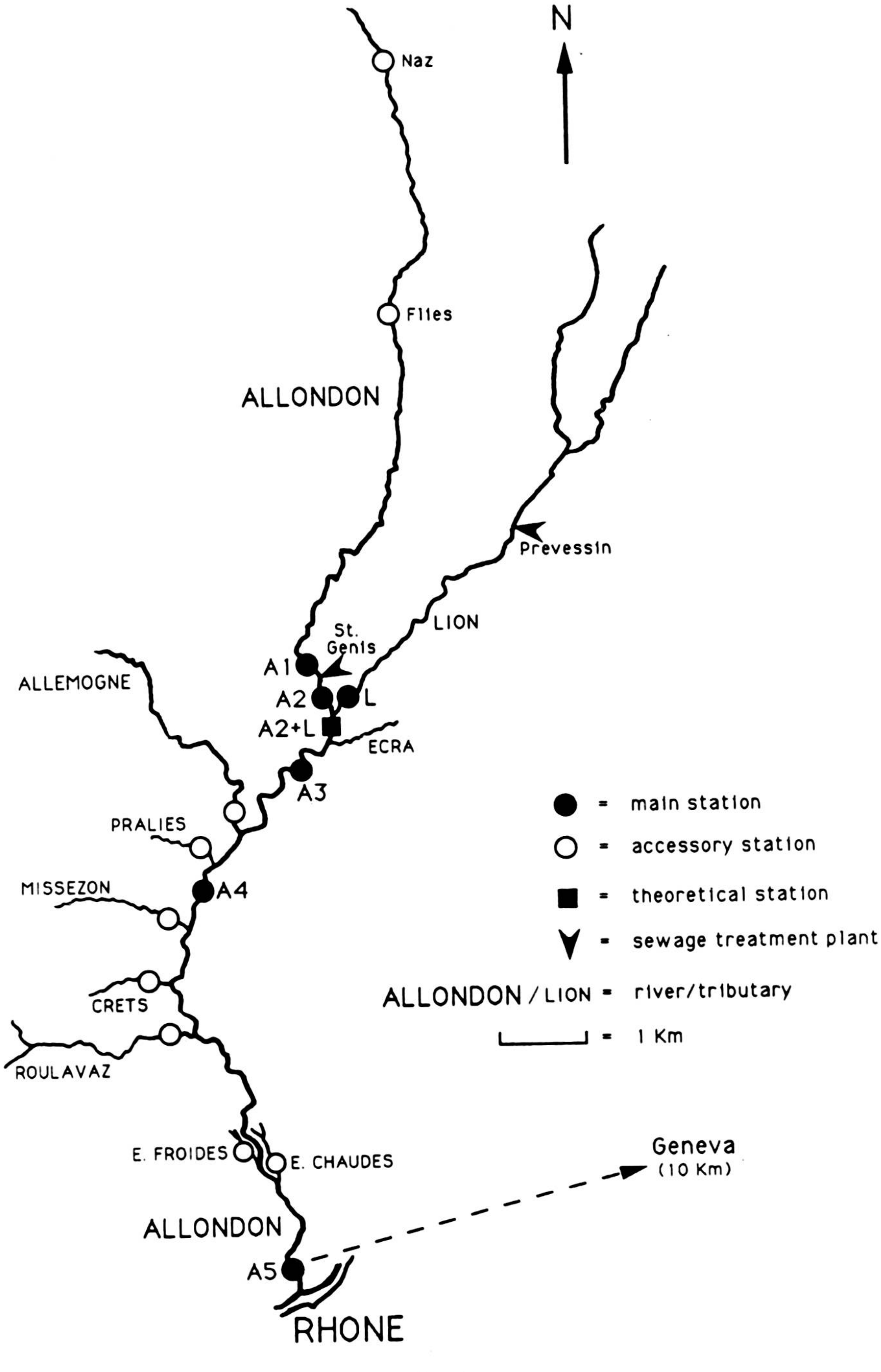

FIG. 1

Location of the sampling stations on the river Allondon bassin (see text in section 1 for detailed explanations).

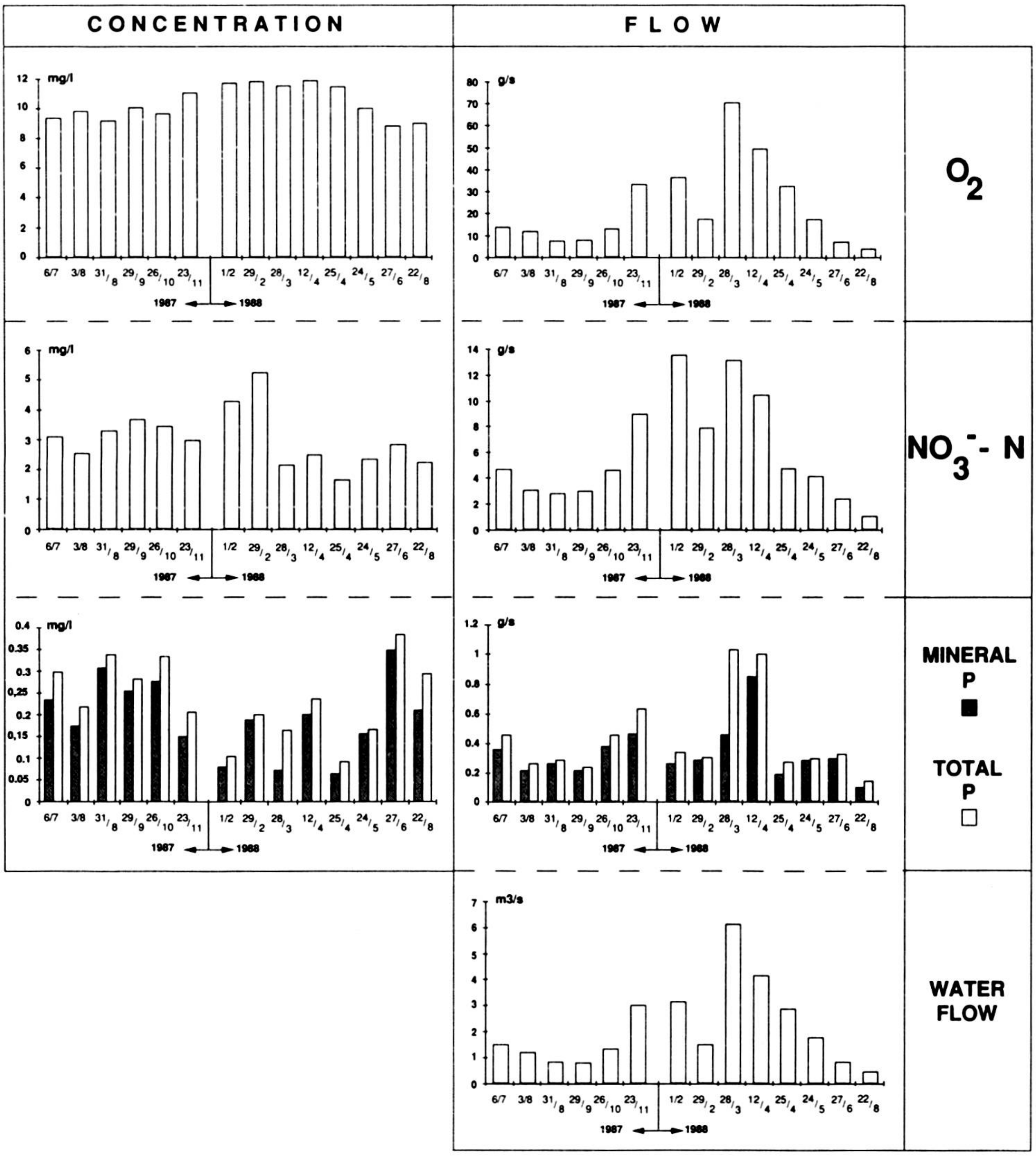

FIG. 2.

Evolution of the water flow, concentrations and flow of significant parameters (O_2, NO_3^- - N, P) at sampling station A3 (see text in section 3.1, 3.2.1 and 3.2.2 for detailed explanations).

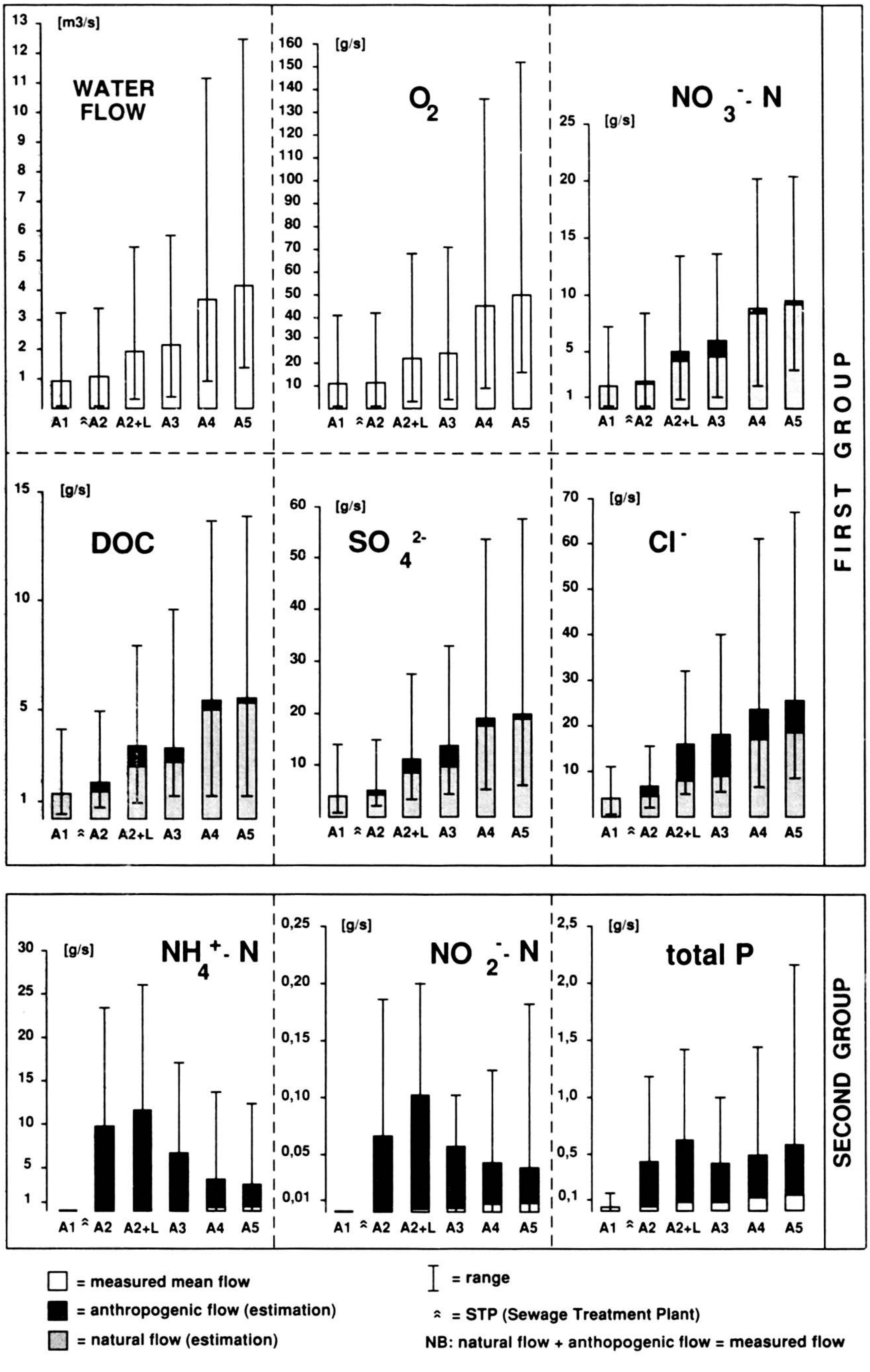

FIG. 3.

Mean flows at each sampling station (see text in section 3.2.2 for detailed explanations).

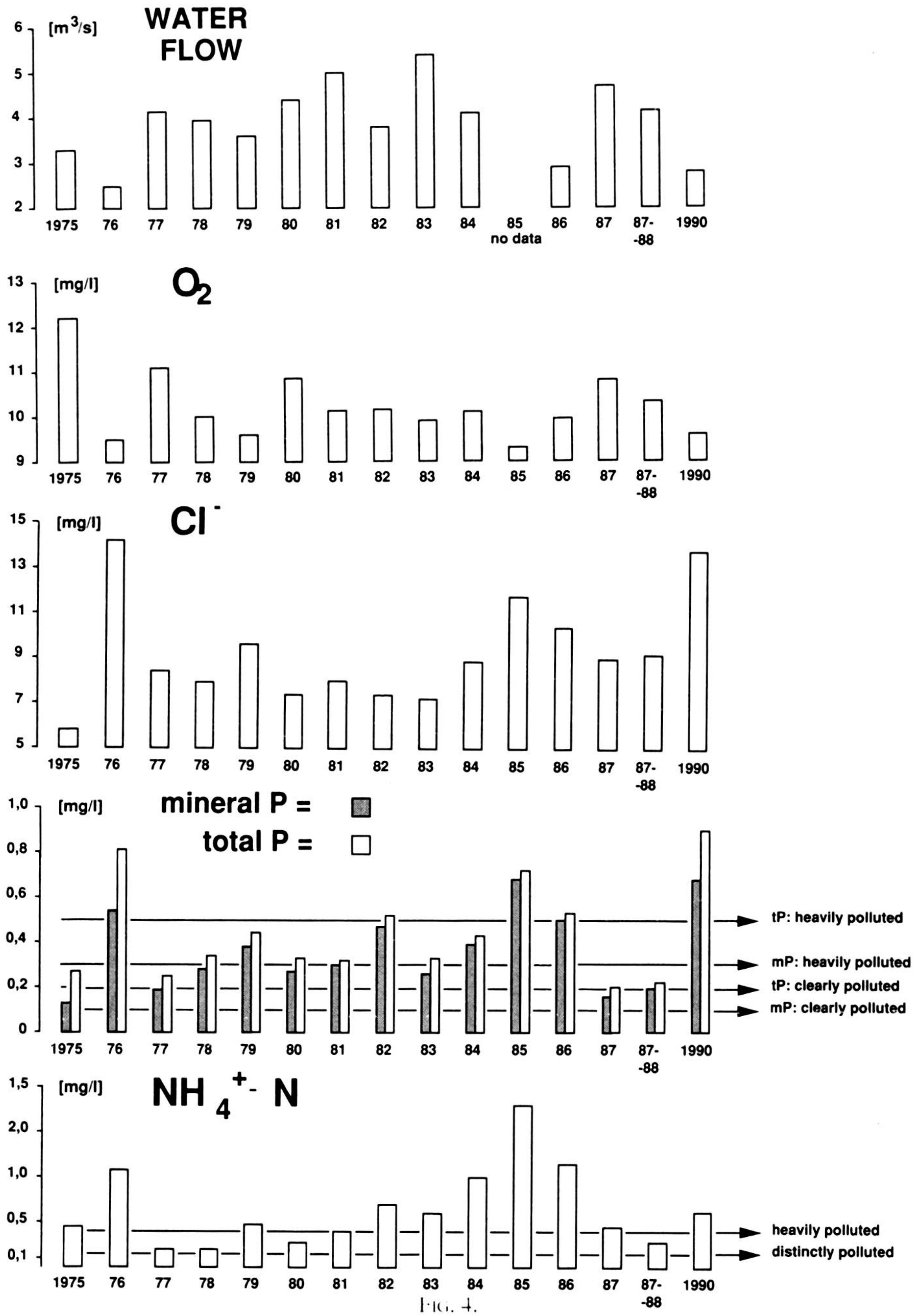

FIG. 4.

Evolution since 1975 of the average water flow at the Allondon's mouth and of the mean concentrations of significant parameters (O_2, Cl^-, P, NH_4^+ - N) at sampling station A3. Water quality classification (based on mean concentration of total P, mineral P and NH_4^+ - N) according to the Swiss Federal Department of Environment Conservation ("Office fédéral pour la protection de l'environnement" - OFPE, 1982). See text in section 3.2.3 for detailed explanations.

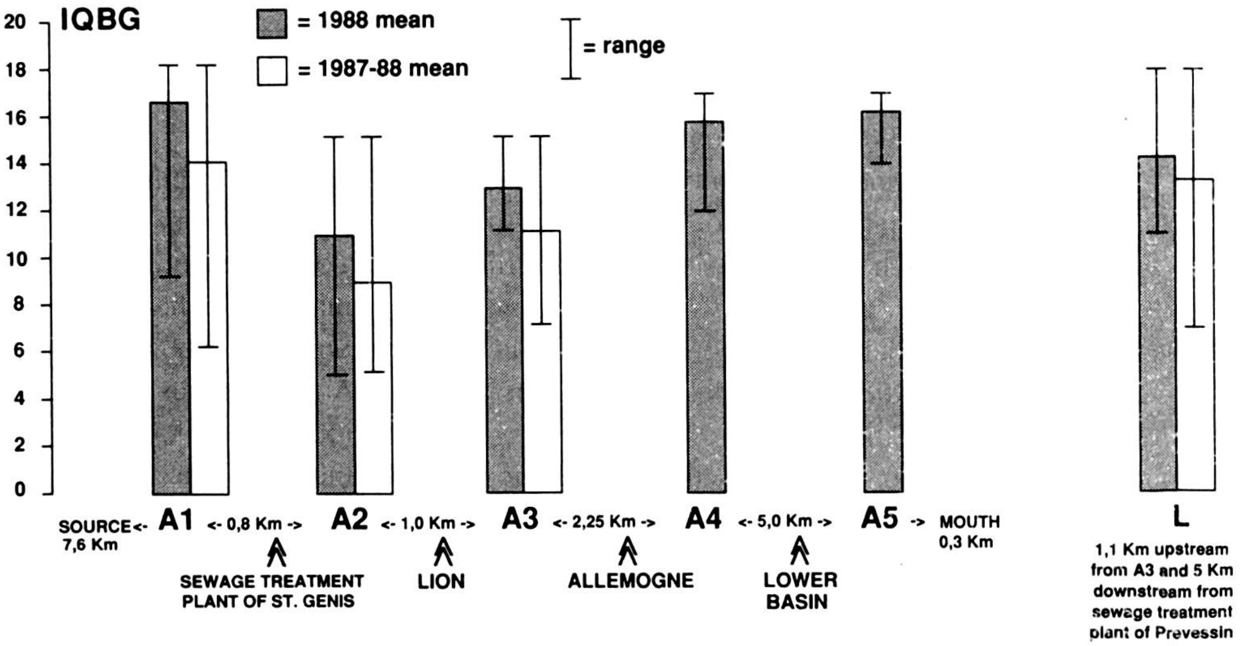

FIG. 5.

Biological global quality index ("Indice de Qualité Biologique Globale" – IQBG, VERNEAUX & FAESSEL, 1976) at each sampling station (see text in section 3.3.1 for detailed expanations).

SAMPLING STATIONS	COORDINATES	DISTANCE FROM THE ALLONDON'S MOUTH [Km]	ALTITUDE [Km]
A1	490,100/121,887	9,35	430
A2	490,100/121,287	8,55	424
A3	490,031/120,700	7,55	416
A4	489,075/119,838	5,30	397
A5	488,638/115,125	0,30	349
L	490,300/121,375	8,65	425

TABLE 1.

Coordinates, distances from the Allondon's mouth and altitudes of the sampling stations (see text in section 1 for detailed explanations).

PARAMETERS		A1 min.	A1 X	A1 MAX.	A2 min.	A2 X	A2 MAX.	L min.	L X	L MAX.	A2+L min.	A2+L X	A2+L MAX.	A3 min.	A3 X	A3 MAX.	A4 min.	A4 X	A4 MAX.	A5 min.	A5 X	A5 MAX.
Water flow	m3/s	0.13	0.96	3.38	0.17	1.05	3.57	0.21	0.88	2.24	0.46	1.91	5.81	0.82	2.12	6.14	0.92	3.84	11.6	1.03	4.24	12.9
Temperature	C	4	8.8	14	4.5	9.4	15	4.5	9.1	13.5	*	*	*	4.8	9.3	14	5.5	9.3	13.5	5.6	9.8	15.5
pH	- -	7.83	8	8.32	7.74	7.9	8.43	7.84	8	8.47	*	*	*	7.55	7.9	8.19	7.92	8.1	8.32	8.05	8.1	8.33
Conductivity at 25 C	S/cm	368	440	508	389	516	594	475	538	599	*	*	*	305	486	536	380	457	502	340	454	494
Dissolved oxygen	mg/l	9.8	11.5	13.1	7.67	10.4	13.6	9.73	11.1	12.6	9.08	10.8	13.1	8.86	10.4	11.9	10.2	11.2	12.3	10.2	11.3	12.9
Percent of saturation	%	100	106	124	83.9	98	112	96.5	103	114	*	*	*	89	98	110	101	105	112	102	107	125
DBO 5j.	mg/l	0.92	>4.8	>11.73	0.98	>7.7	>11.27	1.91	>5.9	>11.6	*	*	*	1.35	>4.8	>9.38	0.87	2.6	6.19	0.73	1.8	4.11
DOC	mg/l	1.16	1.57	1.92	1.73	2.9	3.05	1.2	2.3	8	1.6	2.53	8.78	1.39	1.9	3.53	1.24	1.64	2.07	1.17	1.58	2.05
NH4 - N	mg/l	0	0.02	0.04	0.1	2.02	5.31	0.05	0.22	0.66	0.1	1	2.73	0.01	0.31	2.23	0	0.11	0.45	0	0.06	0.36
NO3 - N	mg/l	0	0	0.01	0.02	0.09	0.21	0.01	0.04	0.08	0.02	0.06	0.1	0	0.04	0.15	0	0.02	0.07	0	0.01	0.03
NO2 - N	mg/l	1.2	2.1	4.6	0.75	2.1	5.05	1.9	3.2	5.25	1.65	2.71	5.14	1.65	3	5.25	1.1	2.29	4.2	1.15	2.3	4.3
Mineral phosphorus	mg/l	0.01	0.03	0.05	0.05	0.32	0.7	0.06	0.19	0.44	0.05	0.25	0.48	0.07	0.19	0.34	0.04	0.13	0.33	0.04	0.12	0.225
Total phosphorus	mg/l	0.02	0.04	0.08	0.22	0.57	0.9	0.11	0.27	0.48	0.17	0.42	1.47	0.11	0.23	0.39	0.06	0.16	0.35	0.06	0.16	0.29
SO4	mg/l	5.8	9.12	14.9	6.5	11.6	20.2	10.4	13.5	17.1	8.17	12.6	18	8.6	13.5	17.7	6.8	10.1	12.4	7.1	9.99	13.8
Cl	mg/l	2.7	4.6	6.8	4	8.4	14	9.6	11	12.8	5.58	10.5	13.6	6.6	9.2	11.2	4	6.47	7.6	4.6	6.39	8

* = no data

TABLE 2.

Physico-chemical measurements (X = mean; MAX./min. = maximum/minimum measured).

MACROINVERTEBRATE GROUPS	A1 1981-88	A3 + A4 + A5 1981-86	A3 + A4 + A5 1987-88	TRIBUTARIES 1981-88
PLECOPTERA	11	10	5	11
EPHEMEROPTERA	12	19	9	19
TRICHOPTERA	12	9 (1)	11	18
COLEOPTERA	12	10	8	12
DIPTERA SIMULIIDAE	3	8	2	9
MEGALOPTERA SIALIDAE	1	1	0	2
HETEROPTERA	0	2	3	7
GASTEROPODA	3	3	3	4
HIRUDINEA	2	4	5	4
TOTAL	56	66	46	86

(1) In some old samples the organisms could not be determined as far as the species

NB: A3, A4 et A5 = sampling stations affected by the sewage treatment plant of St. Genis

TABLE 3.

Evolution of the number of species of macroinvertebrates in the Allondon (see text in section 3.3.2 for detailed explanations).