Review article

TAXONOMIC AND BIOGEOGRAPHICALLY-ECOLOGICAL STUDIES ON THE INSECT FAUNA

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Ćetković A. (2001): *Taxonomic and biogeographically-ecological studies on the insect fauna*. – Genetika, Vol. 34, No. 2-3, 41-52.

The topic of taxonomic and biogeographically-ecological studies is presented in the case of social wasps (Hymenoptera: Vespidae: Vespinae et Polistinae) of the Balkan Peninsula and the neighbouring regions, as an intentionally prepared summary of the author's Ph.D. thesis (ĆETKOVIĆ, 2002). The broader context of this category of studies under local conditions, as well as, topical and spatial frame of the studies, and the summary of the most important results of the analysis, are briefly presented in this paper

Key words: insects, taxonomy, biogeography, ecology

GENERAL AND INTRODUCTORY COMMENTS

Abundance, diversity, specificity and the complex distribution of the living world of the Balkan is a very well-known fact, emphasized in numerous taxonomic, biogeographical and ecological texts - scientific studies and reports, expert's reports, text-books, etc., including the most recent masterpieces related to studies and conservation of Yugoslav biodiversity (RADOVIĆ *et al*., 1985; SAVIĆ *et al*., 1998; STEVANOVIĆ, 1999; and many other authors). The assessments on abundance, specificities, but also on the condition of the (non)studied insect fauna of Serbia and Yugoslavia (both FRY and SFRY) are starting points (so to speak "universal points") of numerous scientific and professional analyses, often followed by

"stereotypic" statements on the significance of the previous fundamental cognition of the fauna as a basis for many other aspects of various biological both, theoretical and practical studies (as a special reflection of a long-term, mainly unsuccessful struggle for a better status of taxonomic and faunally-biogeographical disciplines within the system of biotechnological sciences, but also in a broader practice).

In regard to the fauna of social wasps in our regions, as the subject of the present study, the fact that it encompasses the largest portion of the European fauna (22 of 24 species) is quite illustrative and points out that the Balkan Peninsula is one of the richest faunal territories; no more than one European region - a broader region of the Apennine Peninsula (i.e. Italy) - overnumbers it with 23 wasp species. Generally, members of this group do not belong to more attractive, indicative, i.e. "key" taxa in the actual analyses of the state of endangerment of biodiversity, although nine species appear on red lists of certain central- and northern-European countries (DAY, 1991). Furthermore, particular taxa in our fauna could deserve a certain status endangerment. However, the premise that "overloading legislation with <insect> species that the majority of laymen (and also professionals) cannot easily distinguish, does not present an essential and rational contribution to the strategy of the active conservation" (DAY, 1991) was accepted in one of mentioned studies on diversity in FRY (RADOVIĆ *et al*., 1995). The most efficient control measures against of the majority of insects, as well as, the majority of other groups, are indirect protection measures of their natural habitats, which require certain knowledge on their distribution and ecological characteristics of each species, as well as, appropriate monitoring of changes of the determined "zero" faunal state.

Generally speaking, the aspect, commonly accepted in many scientific and even urgent activities related to protection and conservation of rapidly deteriorated living world all over the planet, that there is often a lack of (or is hardly accessible) basic/reference taxonomic, biogeographical and ecological information without which it is impossible to plan adequately (HAWKSWORTH, 1995; OLIVIERI *et at*., 1995; STORK and SAMWAYS, 1995; WILSON, 2000; and others). In recent times a tendency has been clearly expressed that a creation (and public accessibility) of expansive and actual electronic bases of integrated taxonomic-nomenclatural, faunal and other elementary data, should be defined as an essential content or even a principal aim of ever growing number of international and national projects on inventorying the living world, ensuing from actual, global and regional action programs on protection and conservation of biodiversity (for instance CATIZZONE *et al*., 1998). Thereby, significance of specific-purpose inventorying and formation of reference, geographical and taxonomical data bases on social wasps, as extensive as possible, is also stressed out.

Recognition of the extent of dramatic endangerment and establishment of a global concept on biodiversity conservation presents not only a unique paradigm of achievements in biology in the last decade of the 20th centaury, but it is also one of the most important tasks of the organized human society at the beginning of a new millennium. This essentially new, multifactorial approach in rationalizing and implementation of activities on conservation of entire abundance and diversity of

the living world on earth, stipulated, among other things, changes in perception of relative significance of certain traditional, permanently disregarded or even suppressed fields of the basic biology - biosystematics and biogeography (including faunal and floral disciplines, etc.), as well as, reorganizing of focal interests in segments of some other related disciplines, first of all, ecology and evolutionary biology (WILSON, 2001). Parallelly, so called a biodiversity crisis has dramatically emphasized one of consequences of a permanent inferior status of these disciplines - a trend of an extraordinary "extinction" of an appropriate research staff even in many countries and institutions with centuries-old tradition; an insufficient number of competent specialists for fundamental inventorying of biodiversity has been registered as one of the "systemic" problems of practical conservation both, worldwide (MCNEELY *et al*., 1990; QUICKE, 1993; ASF, 2001; etc.) and in our country (VASIĆ and STEVANOVIĆ, 1995).

As far as our country is concerned, in respect to entomology (understood in its common narrow meaning, as a biosystematics, faunal discipline/zoo-/biogeography and ecology of insects), a similar general condition and negative trends have not been perceived as particularly dramatic, due to a very simple reason - disciplines that were not traditionally well founded nor systematically implemented during a longer period of previous history could not have been essentially held back. Assessments on such a condition of appropriate disciplines of our science, reasons, causes and many solutions have been stated and recorded so many times, but with no crucial changes - for instance, a lengthy report on entomology in (former) Yugoslavia presented at the 6th Congress of Yugoslav Biologists is still reasonably actual (NONVEILLER, 1982). It has to be stated that our entomological science has achieved very important and distinguishable results over previous decades and centuries, but in general, these results were not proportional to possibilities (personnel, material, etc.), nor a total "collective" opus by its scope and "qualitative structure" was comparable with many countries of similar fundamental potentials (especially in the domain of major issues and editions such as "national fauna", monographic revisions, etc.).

In spite of indisputable successes and break-troughs in different aspects and segments of the actual practice of biodiversity conservation in Yugoslavia during the last decade (STEVANOVIĆ and VASIĆ, 1995; STEVANOVIĆ, 1999), as well as, despite the impartially difficult and unfavorable general situation during the same period, it still seems that this "decade of biodiversity" (1992-2002) did not result in our entomology in the appropriate positive advances toward essentially new scopes and possibilities of affirmation of the mentioned disciplines. The improvement of the (state and status of) biosystematics and biogeography means research and activities on direct conservation of biodiversity (species, ecosystems, etc.) and also efforts to improve and promote fundamental disciplines themselves with a comprehensible concept of fitting into current international trends, standards and initiatives (including the improvement of specific-purpose inventorying of biodiversity on different bases and levels, and certainly the development of starting assumptions for inventorying - a taxonomic identification system).

Based on the stated, the principal aims of the present study encompassed the following: (I) defying the reference biosystematics frame for the analysis of the social wasp fauna with the reconsideration of the taxonomic and nomenclatural status of disputable taxa; (II) the determination of the faunal composition and verification of the current information on the fauna of the Balkan Peninsula and neighboring regions; (III) electronic inventorying and mapping of the investigated fauna on the basis of the taxonomically and faunally revised status of registered taxa; (IV) (re)definition of the theoretical scope and appropriate methodological elements necessary for biogeographical and ecological analyses of the regional social wasp fauna; (V) the analysis of biogeographical and ecological parameters of distribution of each present species, defying characteristic faunal groups and their biogeographical characterization; (VI) a comparative regional analysis of the social wasp fauna in Yugoslavia and the Balkan Peninsula. Such an approach is the author's attempt to point out the possibility of the functional connection between taxonomic, biogeographical and ecological studies on the entomofauna with the appropriate aspects of a broadly comprehended complex of actual/specific-purpose studies on biodiversity, as well as, his personal contribution to the reaffirmation of so far inadequately verified "naturalistic" disciplines under our conditions.

BASIC FACTS ON BALKAN SOCIAL WASPS

The family Vespidae encompasses widely distributed and in our country almost everywhere present "common" wasps/paper wasps (*Vespula* Thompson, subgenus *Paravespula* Blüthen; *Polistes* Latreille) and hornets (*Vespa* Linnaeus), as well as, many other less common, but mutually similar members (*Vespula* s.str., *Dolichovespula* Rohwer), and a great number of genera and species of solitary wasps. Furthermore, the majority of people uses terms "wasp" and/or "paper wasp" exclusively for this group of social insects that is only an insignificant segment of a giant genus of hymenopterous insects (Hymenoptera), mostly presented by solitary forms. Social wasps, similar to other major groups of social insects (ants, bees, termites), belong to the organisms that are relatively well known and present both, in everyday life and collective human experience from the earliest historical times; in spite of this, a number of people, including professional circles (biologists, entomologists, etc.) who have knowledge of elementary facts on both, diversity of the social wasp fauna and series of very interesting specificities in these insects habits, is negligible.

The members of the subfamily Vaspinae are mainly distributed in the Holarctic and Indo-Malay regions. Forty out of 64 already identified species within four genera occur in the Palaearctic and only 13 in Europe. The subfamily Polistinae is almost of the cosmopolitan distribution with approximately 800 validly described species classified into about 30 genera and four tribes; out of this number only the nominotypical subgenus *Polistes* (s.str.) occurs in the greatest part of the Palaearctic - there are 13-15 (9-10 in Europe) species. Based on literature data, social wasps are presented in the European fauna with 22-23 species, grouped into four genera and two families (Vespinae et Polistinae). These four genera, i.e.

12 species of the subfamily Vespinae (*Vespa* - 2 spp., *Vespula* - 4 spp., *Dolichovespula* - 6 spp.) and 9-10 species of the subfamily Polistinae (genus *Polistes*) were detected in the area of investigation.

A systematic status and treatment of the European species of the subfamily Vespinae has been stable for a longer period of time. The biosystematics of the subfamily Polistinae, far from being satisfactory and integral, especially for the region of south and south-eastern Europe, prevents determination of the definite faunal composition; a need to revise the identity and the status of a number of (critical) taxa at the level of the Palaearctic has occurred as a result of such a status.

The degree and character of the European Vespidae fauna studied show expected north-south and west-east downward trends; in less sophisticated analyses of narrow regions, these differences could be leveled, to a certain extent, by extrapolation based on the properties of the fauna of broader territorial zones and registered common trends. However, data obtained in even a greater part of thoroughly observed European regions do not usually provide a perception of a biogeographical and ecological status of neither individual species nor faunal group of social wasps. In addition, several important referent faunal syntheses of the most recent dates (ARCHER 1989; CARPENTER 1996; CARPENTER and KOJIMA 1997) indicate that a great number of species at the level of the world fauna has not been registered adequately over the countries of the encompassed region.

MATERIAL AND THE REGION OF INVESTIGATION

A primary territorial scope of the studies, the Balkan Peninsula, and the southern sector of the Pannonian plane, was set within a frame of a biogeographical segment of the study on the local fauna in accordance with logical topographically-orographical and climatologically-vegetational (and to a certain extent, with territorial and political) entities, as well as, on the basis of distributional checklists of the faunal structure. The need for an adequate encompassment of the distribution and character of variability of a number of disputable taxa (in the genus of *Polistes*) was the reason that biosystematic aspects of the present study were related to a greater part of the Palaearctic.

The basic faunal structure for the biogeographical analysis encompassed over 16,600, i.e. around 1,100, specimens of social wasps form the territory of former Yugoslavia, i.e. other Balkan countries and neighboring regions, respectively. Of this number, 6,000 specimens originated from various collections (predominantly museum ones that were established over more than 100 years ago), while the rest (almost 7,200) was collected personally or obtained from many colleagues and acquaintances (about 4,500) during the 20-year period. The biosystematic segment of the analysis, limited to the genus *Polistes*, with the mentioned material from the referent region, encompassed also the processing of the additional comparative material from the broader region of the western Palaearctic.

An initial base of 3,840, i.e. 520 records, was established by a primary processing of the whole available material based on specimens collected from the territory of former Yugoslavia and other encompassed territories, respectively. Li-

terature data on the fauna were recorded into a special base that included approximately 740, i.e. 940 records from the regions of former Yugoslavia and other territories, respectively, discussed within biogeographical part of the study. A unique derived base with over 1,390 "sub-locations", conjoint (and mapped) in a form of 880 analytical locations was formed by a procedure of cartographic processing, described in detail, and by grouping geographical, faunal and ecological information on determined locations of Vespidae. This base is a territorial foundation of all further analyses.

BIOSYSTEMATIC ANALYSIS - METHODOLOGICAL APPROACH, RESULTS AND DISCUSSION

The biosystematic analysis of the genus *Polistes*, encompassing two parallel procedures, was performed in a form of a thorough taxonomical revision: (a) the establishment of the mode of separation and discrimination of species and (b) the revision of the status of a great number of previously established taxa, i.e. the critical revalorization of published keys for identification and differential diagnoses. The revision mainly remains within the scope of "traditional" procedures in taxonomy (MAYR, 1969) with a practical application of a number of common principles of the population and biological approach.

A great uniformity in the fundamental pattern of body coloration was registered in the Palaearctic species of the genus *Polistes*, hence variability of essential colouristic properties was expressed in a similar way, and i.e. it resulted in a comparable phenomenon of relatively similar phonotypical forms in a number of species. Furthermore, variations of colouristic properties showed a particular geographical regularities that pointed out to a lesser or greater congruence with basic macro-zonal and orographical gradients of eco-climatic conditions. Considering possibly complex history of a development of widely distributed Palaearctic species of the recent regions, a registered differentiation of phenotypical (colouristic) forms in social wasp's points out to a complicated genetic background of observed properties of geographical intraspecific variabilities.

A key moment in redefining the approach of the use of colouristic properties means a complete consideration of actually present variabilities of essential properties, i.e. those for which it is determined that they are suitable for taxa diagnosing. At the same time, the analysis of specific variabilities was not an aim, but a methodological tool; hence the applied procedure was not established in accordance with routine standards of numerically statistical processing and verification. In the analytical procedure, an array and a type of variations of all discriminatory properties are determined in detail. This includes registering of all distinguishable variants/phases of a variation spectrum and (if necessary) individually for each narrower geographical region.

Based on the overall analysis of the complete taxonomic-nomenclatural literature relevant to a taxonomic separation of Palaearctic species, three categories, i.e. topical groups of problems were defined:

(I) In the case of the parasitic group of *Polistes* species (group *semenowi*) there are significant doubts in relation to a valid nomenclature, i.e. to a nominal identity of the eldest of three indisputably different taxa. Considering the spatial distribution of indisputable findings of all three parasitic species, it seems possible that *P. semenowi* Morawitz has been completely incorrectly taxonomically interpreted from the very beginning, which can have considerable repercussions on the nomenclature of this specific group, established a long time ago. With certain insignificant reserves, the species *P. semenowi* has been excluded from the group of confirmed members of the Balkan Peninsula fauna.

(II) The group of four non-parasitic (unrelated) species of the European fauna (*associus, biglumis, dominulus* and *nimpha*) is sufficiently clearly and resolutely defined on the basis of morphological properties of males, but in some regions problems related to the distinction of a portion of the female sympatric population occur. The detailed analysis of these problems of taxonomic (and to a certain extent nomenclatural) nature related to the whole range (summarized) of distribution of these four species has provided almost a complete discrimination of members of the European fauna (of all castes), while the status of a number of problematic quotations of faunal members of this group in the Asian regions has been significantly redefined.

(III) The rest of the European species (of the group *gallicus*) present a group of extremely closely related taxa in which difficulties in the identification are expressed in both sexes, while the distinguishing of taxa (including a number of species not listed yet) has not be successfully solved in any of available variants of identification keys for any of geographical areas. An extensive analysis of the material from the Balkan area, Panonnian plane, Mediterranean area and partly from broader areas of the Palaearctic is the initial stage in elucidation of complex biosystematics of these taxa. A presence of at least four taxa of the group *gallicus* with a status of a species has been confirmed for both, Europe and the Mediterranean area, in relation to two that had been usually accepted in recent taxonomic sources. Three species have valid names, while the fourth one is obviously a non-described taxon, i.e. a species new for science. It means that the European fauna is richer in the total number of species and encompasses 11 species. Also, at least one other species is detected on the basis of the material originating from south-west Asia.

As a practical result of the applied analytic and synthetic approach, a redefined version of the identification key for the species of the studied geographical area has been formulated; the key is inevitably relied on significantly broader descriptions and consideration of variability of adequate characters. Furthermore, this revision has provided redefinition of the *Polistes* taxa catalogue for the Palaearctic, which at the present contains 18 specific taxa, as well as, a number of synonymising and other nomenclatural corrections.

BIOGEOGRAPHICALLY-ECOLOGICAL ANALYSIS -METHODOLOGICAL APPROACH, RESULTS AND DISCUSSION

The aspect (after HENGEVELD, 1990) that differences between biogeographical and ecological approaches to studying of an essentially unique phenomenon - survival of living beings within the natural environment resulted from mutual differences within a spatial and time scale of "magnification" and convergency of analytical observations, has been accepted as the most common conceptual and methodological frame of the biogeographical analysis. Such an approach provides the complementary coalescence of ecological and biogeographical aspects of the faunal analysis. In accordance with the operational comprehension of all biogeographical and ecological phenomena, as complexly structured and dynamic entities, the analysis is conceived on the basis of distinguishing three levels of a hierarchical structure of the observed object (species and its range of distribution, the faunal element and the unity of fauna).

Considering general characteristics of the faunal spatial configuration of social wasps (as members of a category of non-specific - broadly distributed and significantly vagiel insects) "aerographic concept" has been adopted as the most appropriate methodological approach; the verification (as well as the application) of the available variants of the "geographically-horological" and "eco-geographical" approaches (all terms according to UDVARDY, 1969) was only limitedly possible on the basis of the given fauna. Elements and facts related to the most important zoo/biogeographical zonation of the regions of SFRY and the Balkan were, to a various extent, used as a reference frame for a comparative analysis, i.e. for defining the principal spatial and ecological gradients of the observed region. The analysis of results was performed in three stages: a) individual analyzing of properties of each species; b) the biogeographical classification and the comparative analysis of ecologically-horological groups of species; c) the regional analysis of the integral fauna of social wasps.

Some criteria and elements of the analytical procedure were for the first time applied in the present study; first of all, methodological aspects of ecological and especially biogeographical evaluation of predominantly faunal data in the analysis of the ranges of distribution of individual species and selected faunal groups were considered at length. A quantitative approach in evaluation of faunal data was established for the analysis of different biogeographical properties of each species. Relying on a previously defined structure of territorial determinants, a unit finding, as an "average" and/or "the most objective" parameter of frequency of a species encounter, was established as a principal unit of biogeographical quantification. Since different categories of findings were not equally reliable parameters of the real presence of the species, a qualitative categorization, i.e. evaluation of various types of data, applied in the analysis of the altitudinal distribution of species and their preference for habitats and biomes was performed.

For the first time, all species of social wasps were explicitly and documentary registered, at the level of the integral fauna of the investigated region and over the formal territorial (sub) faunae of all actual countries of this region with a

critical valorization of a number of disputable literature findings and with a correction of inaccuracies of various types. As a result of the taxonomic revision of the genus *Polistes*, the faunal composition of the Balkan Peninsula, with a previous determination of 12 species of the subfamily Vespinae, was improved and also the list of ten species of the subfamily Polistinae was reinterpreted. The ranges of distribution of the majority of the European species are overreached in the studied region, and a wide scope of geographical variations (of a number of species) is present, which probably provided the integral consideration of taxonomic and biogeographical separation of studied fauna of the genus *Polistes*.

The initial biogeographical analysis encompassed the detailed determination of elementary biogeographical and ecological characteristics of all registered species, horizontal and vertical distribution, preference for basic macro-types of ecosystems, phenological properties of an annual cycle, as well as, other determinations of their status within the local and the regional fauna.

According to the "standard" typology of ranges of distribution, the social wasp's faun of the Balkan and neighboring regions encompasses the following five elements: five Holarctic species, eight widely distributed (mainly) Palaearctic species, eight primarily west Palaearctic species and one Palaetropical-subtropical species. Based on detailed comparative analysis of properties of their integral ranges of distribution in relation to altitudinal and distribution of places of their discovering in the Balkan it can be observed that this group of relatively modest scaling ratios encompasses rather heterogeneous group of faunal elements. In terms of such facts and the adopted quantitative approach it was possible to establish even insignificant differences among certain groups/pairs of biogeographically very similar species, as well as, to define a particular faunal and ecological gradient: from polystenovalent, over intermediary and (sub)eryvalent to oligostenovalent species. Based on such a defined sequence a hierarchical grouping of members of the regional fauna was done in the form of classification of "operative faunal types":

A. Termophilic faunal elements

A1. Palaearctic-subtropical elements: *Vespa orientalis* Linnaeus

A2. broad-sense Mediterranean species

A2a. Mediterranean-sub Mediterranean species: *Polistes* sp.n.1, *Polistes gallicus* (Linnaeus)

A2b. Mediterranean-pond Pannonian species: *Polistes foederatus* Kohl, *Polistes bischoffi* Weyrauch, *Polistes associus* Kohl.

A3. Lowland-subalpine species: *Vespa crabro* Lennaeus, *Vespula germanica* (Fabricius), *Polistes dominulus* (Christ), *Polistes nimpha* (Christ)

B. Faunal elements of intermediary character: *Dolichovespula media* (Retzius), *Dolichovespul saxonica* (Fabricius)

C. Species of a broad altitudinal scope: *Vespula vulgaris* (Linnaeus), *Vespula rufa* (Linnaeus), *Dolichovespula sylvestris* (Scopoli)

D. Alpine elements of fauna

D1. Montane-sub-boreal species of the southern origin: *Polistes biglumis* (Linneaus)

D2. Sub-boreal-montane species: *Dolichovespula omissa* (Bischoff)

D3. Broad-sense boreal-montane species: *Dolichovespula norwegica* (Fabricius), *D. adulterina* (Buysson), *Vespula austriaca* (Panzer)

E. Species of insufficiently clarified biogeographical status: *Polistes sulcifer* Zimmermann, *Polistes atrimandibularis* Zimmermann.

Regional aspects of biogeographical differentiation of the social wasp's fauna are presented concisely in the form of preliminary evaluations limited, in this segment, only to the area of SFRY (considering availability of the verified faunal structure). The fauna of certain regions and broader areas within this region is characterized on the basis of less significantly obvious differential properties: local absence of a smaller or a greater number of species; relative quantitative presence of species and faunal elements; regional properties of altitudinal distribution of fauna; etc. According to local ad regional properties of the altitudinal distribution of species a provisory scheme of diffusely-zonal altitudinal differentiation at the level of the regional fauna was suggested. The character of zoning of each mountain is conditioned by the total range of the altitude, as well as, by its geographical position, while orographical modifications of broader regularities occur locally.

Based on the overall analysis of the material it is possible to establish some common regularities in the relative quantitative distribution and significance of the species within the faunal spectrum of this region, as well as, to esteem the "use-value" of certain numerical parameters of taxa presence intensities. According to the quantitative distribution expressed over different parameters, three provisory quantitative "classes" - groups - "more prevalent ", "medium prevalent" and "less prevalent" species can be observed. The segment of "more prevalent" species consists almost exclusively of members of biogeographical categories *A3* and *C* (combined). The class of medium abundant/prevalent species is relatively the most coherent over the composition and a relative order of specific quantitativeness, as well as, over the distribution of members of different biogeographical categories; this class always encompasses both species of the "intermediary" category *B*, then two species of the category *A2*, as well as, both eusocial species within the group of frigorific montane elements; these specific pairs almost always occur in the same mutual sequence. The class of the "less prevalent" species encompasses virtually all social parasites, then, one member of the Palaetropical fauna, as well as, two Mediterranean-pond Pannonian species.

Received October 1st, 2002.
Accepted December 16th, 2002.

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TAKSONOMSKA I BIOGEOGRAFSKO-EKOLOŠKA ISTRAŽIVANJA FAUNE INSEKATA

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Problematika taksonomskih i biogeografsko-ekoloških istraživanja prezentirana je na primeru faune socijalnih osa (Hymenoptera: Vespidae: Vespinae et Polistinae) Balkanskog poluostrva i susednih regiona, kao namenski pripremljen ižvod iz doktorske disertacije autora (ĆETKOVIĆ, 2002). Ukratko je prikazan širi kontekst ove kategorije istraživanja u našim uslovima, problemski i prostorni okvir istraživanja, kao i rezime najvažnijih rezultata analize.Ovde unesi prevod izvoda

Primljeno 1. X 2002.
Odobreno 16. XII 2002.