these soils are now restricted to two locations covering an area of 59 ha, or 3 % of the Doiran Plain. Smonitsa soils have clearly defined soil horizons, with the upper part being sandy and the lower being more clayey (Vilarov 1956).

Finally, red terra rossa soils (srvenitsa), totalling 368 ha (19 % of the total area), are present at two locations south of the lake (155 ha and 213 ha, with the latter being near the Greek border). These soils may be divided into three subtypes, all of which are essentially impermeable below about 10 cm. The first consists of eroded, shallow carbonate soils at higher elevations. The second is shallow soils present in low places which, due to wetness, have become "brownised." The third, situated on relatively flat landscapes, is composed of accumulated red soils which have been transported from higher elevations (Vilarov 1956).

2.2. Biotic characteristics

Currently, the biodiversity of the Doiran Valley is composed mainly of Mediterranean elements, although Northern European and Eastern (Aralo-Caspian) steppic elements are also present in smaller proportions. Mediterranean and Northern elements are distributed so that the Mediterranean components occupy the plain and hilly regions along the edge of the valley, as well as within the lake itself, while the Northern constituents are present on the mountain of Belles/Belasitsa. This distribution pattern manifested itself as early as the Pleistocene glaciations, during which time the warmer and colder phases interchanged, but has been particularly evident within the last 10,000 years.

To a large extent, the main reason for climate changes in the Northern Hemisphere during the Tertiary Period was the movement of the continents to the north, which also facilitated the orogeny of the Alps-Carpathian-Himalayan mountain systems in the Miocene and Pliocene Eras. As a result of the gradual but drastic decrease in temperature, the Tertiary tropical elements of European flora and fauna were sentenced to progressive deterioration, especially as they withdrew to the south and were faced with the high mountain barriers mentioned above. Consequently, at the beginning of the Pleistocene Era when harsh climatic conditions became prevalent (even within the Balkan Peninsula), all tropical elements were destroyed. In the resulting depleted South-eastern European

biocenoses, only those few species from the former Tertiary thermophilic elements that were able to migrate to the refugia in the more southern parts survived. As evidence of this huge decline in species numbers, the fossil flora within Miocene Era sediments is represented by 6,000 species whereas, in the sediments of the upper Pleistocene, the number of species had fallen to barely 1,000. Nevertheless, the Pleistocene was not a period of climatic uniformity. It consisted of colder, glacial (Gunz, Mindel, Riss, Wurm) and warmer, interglacial (Gunz/Mindel, Mindel/Riss and Riss/Wurm) phases. Within the Mindel glacial phase (480,000-425,000 years B.P.), a mass migration of the then existing thermophilic floral and faunal species from the Northern, Middle and Eastern European zones, as well as from Siberia, was directed towards the southern portions of the Balkan Peninsula and South-western Asia. At that time, as well as during the subsequent glacial phases – especially the Wurm glacial phase (120,000 – 10,000 years B.P.) – the mean annual temperature was 8-12° C lower than it is today.

During the Wurm glacial phase, the Doiran Basin was inhabited by floral and faunal species that are currently present in Middle and Northern Europe. In the post-glacial phase (10,000 years B.P. to today), with the warming of the Balkans and rising of temperatures, the organisms that were inhabiting the lowlands of the Doiran Basin began to move to higher areas since this warming trend was expressed primarily at lower elevations within the valley and near the lake itself. As a result of the migration of the northern floral and faunal elements to higher mountain areas, the lower portion of the basin became sparsely populated. Consequently, warmer Mediterranean species began to recolonise the area. This also occurred within the lake itself, but to a smaller degree. The Mediterranean flora and fauna of Lake Doiran and its adjacent valley are of Aegean-Mediterranean and Ponto-Mediterranean origin. These elements immigrated northward through the lower reaches of the Axios (Vardar) River, Thessaloniki Plain and, to a lesser degree, through the Strymonas River.

In addition to Mediterranean, Northern and Eastern floral and faunal elements, Lake Doiran and its valley possess their own, specific taxa (i.e., endemic flora and fauna). Such taxa originated partly from residual species deriving from the old relict flora and fauna and partly through the process of speciation and adaptation to the specific local circumstances. In terms of numbers, they are not as abundant as those of Lakes Prespa or Ohrid, which is logical considering the shallow depth of Lake Doiran.

2.2.1. Vegetation - Habitats

The macrophytic vegetation of the lake, including both aquatic and marsh taxa, is not particularly diverse. Micevski (1963) listed a total of 46 species of aquatic and marsh vegetation, of which about 30 comprise the five aquatic and the two marsh communities. The aquatic communities consist of assn. Lemneto-Spirodeletum polyrrhizae W. Koch 1954, sub-assn. salvinietosum natantis W. Koch 1954; assn. Myriophylleto-Nupharetum W. Koch 1926; assn. Potameto-Najadetum Horvatic & Micevski 1958; assn. Potameto-Vallisnerietum Braun-Blanquet 1931, sub-assn. potametosum perfoliati Horvatic & Micevski 1958; and assn. Hydrocharideto-Nymphoidetum peltatae Slavnic 1956. The marsh communities are characterized by assn. Scirpeto-Phragmitetum W. Koch 1926, and assn. Cyperetum longi Micevski 1957. The remaining 16 species are present as accompanying floral elements.

In accordance with the European Community Habitats Directive 92/43/EEC and the *Interpretation Manual for European Habitats* (1999), the following habitats were determined to be present within Lake Doiran and its vicinity:

1. Code 3130 – Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or Isoeto-Nanojuncetea type
2. Code 3150 – Natural eutrophic lakes with Magnopotamion or Hydrocharition - type vegetation
3. Code 6420 – Mediterranean tall humid herb grasslands of the Molinio-Holoschoenion type
4. Code 91F0 – Riparian mixed forest of *Quercus robur, Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia along* the great rivers (Ulmenion minoris)
5. Code 92A0 – *Salix alba* and *Populus alba* galleries.

The habitat type 3150 of Annex I, Dir. 92/43/EEC is abundant and on the coast extensive reed beds of *Phragmites australis*, *Scripus lacustris and Typha angustifolia, T. latifolia, Sparganium neglectum* etc. form a common habitat. Wide zones of 10-15m from dead shells of the fresh water molllusc *Dreissenia polymorpha* are distinctive with scattered vegetation within. Where lake water has dried away that part is transformed into pasture. The tropical/subtropical species *Paspalum distichum* ssp. *paspalodes* grows vigorously, forming large green carpets on the wet soil near the shore.

The recent status of the littoral zone is characterized by a significant reduction in all communities of macrophytic vegetation, which is manifested not only by a

decline in the frequency, but also in the abundance of individual floral species. The most noticeable is the absence of the rich underwater meadows of *Vallisneria spiralis, Ceratophyllum demersum* and other submersed vegetation that used to enhance the littoral zone of the lake (Matevski & Micevski 2001).

A significant element of the vegetation on the Greek side is the Mouries Woods on alluvial deposit which has been designated as "Protected Natural Monument" (Greek Government Gazette 121/79). The woods as well as 200 ha of the lake coast is a proposed SCI (GR1230002) and it is a very important habitat for the fauna of the area. Around the woods the main land uses are crop farming and grazing.

In the wider zone of the Doiran Basin, the following vegetative associations are present: Coccifero-Carpinetum orientalis, Carpinetum orientalis, Quercetum confertae-cerris, Orno-Quercetum petraeae, Fagetum submontanum, Juglando-Platanetum orientalis, Carpinetum orientalis-Quercetum coccifera, Carpinetum orientalis-Philyrietosum mediae, Carpinetum orientalis-Quercetosum confertae and Carpinetum orientalis-Quercetum sessiliflorae.

2.2.2. Flora

The most frequently encountered submersed plants include *Ceratophyllum demersum, Najas marina, N. minor, Potamogeton perfoliatus, Myriophyllum spicatum, Vallisneria spiralis* etc. The species *Najas minor* is limited to the southern margins of the lake, while *Myriophyllum spicatum* is present in almost all communities (most frequently at a depth of 40 cm). *Ceratophyllum demersum* is most abundant at depths of greater than 40 cm, forming large under-water meadows.

Najas marina and *Potamogeton perfoliatus* are equally represented in the lower and deeper parts of the lake, with the only difference being that *N. marina* penetrates only to a depth of 3 m, while *P. perfoliatus* reaches even deeper.

The species *Centaurea rifidula, Verbascum doiranense, Verbascum burgeffii* and *Astragalus thracicus doiranensis* were described from locations that are within or close to the Doiran Basin. In addition, *Marsilea quadrifolia,* a species that is listed in Annex II of the Habitats Directive 92/43/EEC, is also present within this basin.

By 1988, the micro-floral component of Lake Doiran consisted of 257 phytoplanktonic and periphytonic taxa. The lake ecosystem's organic matter is produced primarily by this phytoplankton and serves as a raw material for organic synthesis by other hydrobionts. Thus, phytoplankton is the initial link in the series of food chains within the lake. Lake Doiran also used to host a very rich and diverse periphyton community, considered to be a specific ecological association (Stojanovski 1991; Stojanovski et al. 1996).

The decline in the lake's water level and accompanying changes in ecological parameters have resulted in a reduction in species quality. When competition is reduced due to such circumstances, large numbers of other taxa begin to appear, as was the case in 1996, when the lake took on an intense red color due to the presence of the dinoflagellate, *Ceratium hirundinella*, a form known for its high production of ichthyotoxins. As a result of the accelerated changes within the lake ecosystem, Stojanovski et al. (1996) have reported the increasing presence of the thread-like green algae, *Spyrogira*.

During the latest investigations made by Levkov & Stojanovski (2002), only 139 diatom taxa were detected. Most of these belong to the group of highly tolerant species, which are indicators of eutrophic to hyper-eutrophic water bodies.

A recent study on the autoecology of the phytoplankton was conducted by the Faculty of Biology (Aristotle University of Thessaloniki) and the Institute of Botany of Copenhagen. According to the total phosphorus content and the total phytoplankton biomass the lake is at the eutrophic state in contrast to previous studies where the lake was characterized as oligotrophic or mesotrophic (Mourkides 1985)**.** Chlorophytes, Diatoms and Cyanophytes comprise most of the 119 taxa that have been recorded in the lake (Temponeras M. et al. 2000). The dinoflagellate *Ceratium monoceras* was a new recording for the lake**.**

Species of cyanobacteria *Aphanizomenon* which are potential toxic cause great concern for the lake water quality. During a 2-month survey (July-August 1999) in 21 lakes in Greece the potentially toxic species *Aphanizomenon flos - aquae* had its highest biomass in Lake Doiran. Toxic cyanobacteria constitute a serious threat to the general state of the lake, public health (water sports, water uses) and fauna through food webs.

Diatom composition responds directly to environmental changes, and five different diatom assemblages may be distinguished during the recent history of the Lake:

1. The period before 1988 was characterized by an extraordinary diatom composition. Diatom and other algal associations were mainly dominated by b-mesosaprobic indicators.

2. The period 1989-1995 began the forced ecological succession of diatom species. The extinction of 109 algal species occurred mainly from the periphyton and rock-encrusting communities. During this period, b-mesosaprobic species were replaced with more tolerant species belonging to the a-p saprobic category.

3. The period 1996-1998 was characterized by complete changes in the diatom composition and abundance of species. The presence of 30 new species was recorded, all of which were unknown for the lake's ecosystem. The newly recorded diatoms belong to a group of species highly tolerant to eutrophication, as well as a high dissolved salt content (halophytic species). During the same period, an increase in the concentration of phosphorus and nitrogen in Lake Doiran was noticed.

4. During the period 1998-2000, an algal bloom dominated by *Microcystys* species occurred over a prolonged period. The planktonic associations were of poor quality, with species that belonged mainly to the Cyanophyta. The decreased water level and the presence of a very large amount of organic sediments resulted in the contamination of all algal communities with species usually inhabiting the mud bottom and in the contamination of the mud bottom itself with the frustules of dead diatoms from other communities. Several species were newly recorded as flora inhabiting Lake Doiran, for example, *Nitzschia closterium* and *N. lorenziana* var. *subtilis*.

5. The main feature of the summer period of 2001 was an overabundance of species of the genus *Nitzschia*, species that are known as being among the most tolerant to eutrophication (hyper-eutrophic indicators) as well as to pollution. All other recorded species during this period had very small populations.

2.2.3. Fauna

The faunal diversity of Lake Doiran and its valley is complex, both taxonomicaly and ecologically.

Representatives of the Phylum Protozoa (protozoans/unicellular organisms) are barely investigated. Popovska-Stankovic (1954, 1990) investigated the free-living protozoans and recorded the presence of two ciliate species, *Tintinnidium fluviatile* and *Tintinopsis lacustris*, within the zooplankton community, the first of which is no longer present within Lake Doiran. In a later investigation, Popovska-Stankovic (1999, 2001) determined the presence of representatives of the genus *Diflugia* (Sarcodina: Testacea). These are amoebas, typical inhabitants of marshes and swamps, which are able to accommodate life in anaerobic conditions for a period of time, an unfavourable indication of the current condition of the lake. The remaining recorded species belong to the genera *Epistylus* and *Vorticella* (Ciliophora: Peritrichia), and are sedentary, ectocommensal forms found on the calanoid copepod *Eudiaptomus gracilis* (Crustacea: Copepoda). This calanoid species has immigrated in the lake within the last 10 years. The only known data concerning parasitic protozoans were presented by Hristovski (1999). He mentioned the following three species: *Myxobolus cyprini, Thelohanellus nikolskii* and *Trichodina sp.*

The Phylum Porifera (sponges) in Lake Doiran is represented by the Family Spongillidae (Incalcaria: Cornacuspongida). With regard to Lake Doiran, Hadzisce (1953) mentioned the presence of three species, including the endemic Doiran sponge *Spongilla carteri dojranensis*.

Within the Phylum Platyelminthes (flatworms), representatives of the Classes Turbellaria (free-living flatworms) and Cestoda (tapeworms) have both been reported from the lake. Krstanovski (1994), while investigating the free-living flatworms of the three large natural lakes, Ohrid, Prespa and Doiran, recorded within Lake Doiran the presence of seven species of the Order Tricladida (triclads) all having a wider distribution. The triclad fauna of the lake is notably sparse, especially when compared to Lake Ohrid, which has a total of 23 recorded species (17 of which are endemics), or to Lake Baikal, where as many as 80 endemic triclad species have been recorded. Hristovski (1999) recorded the presence of two tapeworm species that are parasites of the fishes of Lake Doiran.

Knowledge of the Phylum Rotifera (rotifers) in Lake Doiran is quite satisfactory. Popovska-Stankovic (1954, 1990) identified 52 taxa of rotifers within the plankton community of the lake. Current research (Petkovski & Popovska 1999; Kostovski 2001 and Popovska-Stankovic 2001) shows a drastic reduction in the qualitative composition. Of the 20 taxa recorded, 4 are new for Lake Doiran.

The Phylum Nematoda (nematodes) is poorly investigated. Hristovski (1999) recorded two parasitic species (*Philometria ovata* and *Cammalanus lacustris*), whose hosts are the Doiran roach, *Rutilus rutilus*, and the perch, *Perca fluviatilis*, respectively.

The Phylum Mollusca (mollusks) in Lake Doiran is comprised of species from both Class Gastropoda (snails) and Class Bivalvia (bivalve mollusks). The aquatic gastropods consist of 21 species, including the Doiran endemic snail, *Graecanatolica macedonica* (Roding 1966; Sapkarev 1975; Stankovic 1985, 1991, 2001 and Griffiths et al. 2002). According to Stankovic (1951), Roding (1966), Angelov (1971), Sapkarev (1991) and Griffiths et al. (2002), the Class Bivalvia is represented by five species, the most outstanding of which is *Dreissena polymorpha*, whose dead shells are present in large masses along the current shoreline zone of the lake.

Of the Phylum Annelida (segmented worms) in Lake Doiran, representatives of the Classes Oligochaeta (oligochaetes) and Hirudinea (leeches) have been studied primarily. Also studied are the Branchiobdelidae (branchiobdelids), which, according to some authors, is only a single family of the Class Oligochaeta, while others regard it as a separate taxonomic group. On this occasion, the group will be presented separately from the oligochaetes. Georgevitch (1955) studied the Branchiobdelidae occurring as ectobionts of the Balkan river crayfish, *Astacus astacus balcanicus*, and identified 15 species, 14 of which were new to the science and also Doiran endemics. According to Petkovski et al. (2003), only four branchiobdelid species have been accepted as Doiran endemics (see Section 2.2.3.1.1.). The drastic reduction in the populations of river crayfishes within the lake has had a negative effect on the survival of the four Doiran endemic branchiobdelids. According to Hrabe (1958), Sapkarev (1975a, 1975b, 1980, et al. 1991) and Griffiths et al. (2002), the Class Oligochaeta within the lake is represented by 22 species, including the Doiran endemic species, *Isochaeta dojranensis*. The Class Hirudinea (leeches) in Lake Doiran is represented by 10 species (Sapkarev et al. 1991; Sapkarev 1999).

The Phylum Arthropoda (arthropods) is the most numerous taxonomic group within the Animal Kingdom; therefore, both in the lake itself as well as its valley, this phylum is represented by highest number of species.

The Subphylum Crustacea (crustaceans) is widely represented in the waters of the lake. The Class Branchiopoda (branchiopods) is represented by the Order Cladocera (water fleas), with a total number of 25 species, mostly planktonic forms (Popovska-Stankovic 1954, 1990, 2001; Petkovski 1998; Petkovski et al. 1999, 2001; and Griffiths et al. 2002). Recent investigations (Petkovski et al. 1999, 2001) have determined that only nine of the original 25 are still present within the lake, restricted to the pelagic complex of the zooplankton.

Until the 1990s, the Class Copepoda (copepods) within the lake was represented by all three orders of freshwater copepods (Calanoida, Cyclopoida and Harpacticoida), with a total of 17 species, among them the endemic Doiran cyclopoid, *Microcyclops varicans dojranensis* (Petkovski 1954, 1983, 1991, 1999; Popovska-Stankovic 1954, 1990, 2001; Petkovski et al. 1999, 2001; and Griffiths et al. 2002). The current qualitative status of the copepods of the lake (Petkovski et al. 2001, 2003) indicates they are now restricted to eight species.

The Class Ostracoda (ostracods) is quite well investigated in Lake Doiran. According to Klie (1941) and T. Petkovski (1958, 1959, 1960, 1969, 1991, 1998, 1999, 2001, 2003), the total number of ostracods in Lake Doiran is eight species, four of which are Doiran endemics. The current status of the ostracods of the lake is not threatened, including the endemic species.

The Class Branchiura (fish lice) is a small taxonomic group of ectoparasites on freshwater fishes, mostly on the carp, *Cyprinus carpio*, and its relatives. According to Petkovski (1999, 2001), Popovska-Stankovic (2001) and Griffiths et al. (2002), the fish louse, *Argulus foliaceus*, has been recorded as an ectoparasite of the Doiran carp, but it is also capable of swimming independently; therefore, it has also been recorded within the zooplankton community.

The Class Malacostraca (higher crustaceans) is represented in the lake by the Orders Amphipoda (scuds), Isopoda (sow-bugs) and Decapoda (freshwater crayfishes), with a total of eight species (Karaman 1974; Sket 1967; Karaman 1976; Sapkarev 1975a, 1975b, 1980; Petkovski 1991, 1999; and Petkovski et al. 2001). The fauna of the higher crustaceans within the lake is not rich in species, but their abundance used to be strongly expressed in the aquatic ecosystem. The recent status

of the representatives of this group is marked by a strong reduction in the populations of certain species. The Order Amphipoda (scuds) is represented by three species, of which *Orchestia cavicama* and *Gammarus roeselii triacanthus* were very abundant in the littoral zone of the lake at depths up to 3 m. In recent investigations, their presence was recorded only sporadically (Petkovski et al. 1999, 2001; and Griffiths et al. 2002). The third amphipod species – the Doiran endemic subspecies, *Niphargus pancici dojranensis* – is not directly linked to the lake waters themselves. It is found in the spring area of the stream Deribash above Star Doiran. The Order Isopoda (sow-bugs) is represented by two subspecies, of which the subspecies, *Asellus aquaticus balcanicus*, is still relatively well represented within the lake waters. The second isopod subspecies, *Stenasellus skopljensis meridionalis*, inhabits the streams that flow into the lake. Of the Order Decapoda (freshwater crayfishes), three species have been recorded in the lake. *Atyaephyra desmaresti stankoi,* which was abundant throughout the submersed vegetation of the littoral zone of the lake (reaching an abundance of up to 100 individuals/m^2 during the period prior to 1989), can now be found only sporadically. The situation with the other two species is similar. The river crayfish *(Astacus astacus balcanicus)* and the Doiran crab *(Potamon ibericum)* used to be abundant in the inshore zone and in the streams that flow into the lake.

The Subphylum Tracheata (tracheates) is most numerous within the arthropods. While Class Myriapoda (myriapods) will not be discussed in this report, the orders of the Class Insecta (insects) whose representatives, throughout some portion of their life cycles, are directly connected with the lake ecosystem or, if not directly connected, perform some important role in the composition of the faunal diversity of the Doiran Basin, will be presented.

The Order Odonata (dragonflies) is well investigated within the lake. Karaman (1981), in her study on the dragonflies of Lake Doiran, recorded 39 species. Peters & Hackethal (1986) have extended the list with three new species, leaving the current number of recorded species at 42. This is 80% of the total dragonfly fauna of the FYROM, which consists of 52 species. The dragonfly species *Lindenia tetraphylla* is included within Annexes II and IV of the Habitats Directive 92/43/EEC.

The Order Plecoptera (stoneflies) is completely investigated within the FYROM, thus also in the Doiran Basin. For the Doiran Valley, Ikonomov (1983, 1986) identified six species in the streams that flow into Lake Doiran. The species *Rhabdiopteryx doiranensis* is a Doiran endemic present only in the stream that flows

into Lake Doiran in the vicinity of Acikot. The species *Brachyptera macedonica,* described from the same area and also found in the rivers, Stara Reka (in the Doiran Valley) and Gradiska Reka (on the mountain, Gradeska Planina), is a national endemic. The subspecies *Capnioneura balcanica macedonica,* another national endemic, is also described from the same stream near Acikot and is also found in the rivers Stara Reka and Gradiska Reka.

According to Gunther (1980), the Order Psocoptera (barklice and booklice) in the Doiran Basin is comprised of 16 recognized species, which constitutes 33% of the barklice fauna of the FYROM. The unique national endemic species of this taxonomic group, *Liposcelis macedonicus*, is actually a Lake Doiran endemic, originally described from the vicinity of Achikot.

The Order Lepidoptera (moths and butterflies) is one of the best-studied groups of insects within the FYROM, with a huge species richness. Within the Doiran Basin, Thurner (1964) recorded 103 species from the Family Noctuidae (noctuid moths), including the national endemic, *Cosmia rhodopsis*, and two subtropical species, *Scotia spinifera* and *Mythimna vitellina*. Daniel (1964), in his study of the Families Bombycidae (silk moths) and Sphingidae (hawk moths) of the Doiran Basin, recognised 56 species, including the four Doiran endemic taxa: *Zygaena purpuralis doiranica, Zygaena carniolica paeonica, Zygaena ramburi europensis* and *Cosmotriche potatoria*. The Family Geometridae (geometer moths) in the Doiran Basin is represented by 89 species (Pinker 1968). The Tribus Microlepidoptera (small moths) is most numerous in the Doiran Basin, consisting of 192 species (Klimesch 1968), including the Doiran endemic species, *Cnephasia klimeschi*. Finally, Thurner (1964) and Schaider & Jaksic (1989), investigating the butterflies of the Families Hesperiidae, Papilionidae, Pieridae, Lycaenidae and Nymphalidae in the Doiran Basin, recognised 86 species, which is 43% of the diurnal butterfly fauna of the FYROM. The total number of recorded species (526) from the Order Lepidoptera shows an enormous diversity within a relatively restricted area. The diurnal butterfly species *Lycaena dispar* is included in Annexes II and IV of the Habitats Directive 92/43/EEC.

The Order Diptera (two-winged flies) in Lake Doiran consists primarily of representatives of the Family Chironomidae (non-biting midges). According to Angelovski & Sapkarev (1983), 51 chironomid species have been recorded in the lake, which is 55% of

the total chironomid fauna of the FYROM. The chironomid fauna plays an important role in the benthos community of Lake Doiran.

The Order Coleoptera (beetles) is poorly investigated within Lake Doiran. Gueorgiev (1960), in his study on the aquatic beetles (Hydracanthares) of the Families Dytiscidae (predaceous diving beetles), Gyrinidae (whirligig beetles), Haliplidae and Hygrobiidae (screech beetles) of Yugoslavia, gave special attention to the FYROM. For Lake Doiran, he recorded five species from two locations on the lake.

The Phylum Chordata within the Doiran Basin fauna is represented by the Subphylum Vertebrata. Because of their high level of complexity of composition, richness and diversity of features, the vertebrates embrace the most significant group of the Animal Kingdom.

The taxonomic status of the fish fauna (Superclass Pisces) in Lake Doiran has not yet been defined in full, although this matter has been treated by many authors (Karaman 1924, 1928, 1955; Apostolski et al. 1956; Dimovski & Grupce 1975, 1977; Grupce & Dimovski 1973, 1982, 1984; Naumovski 1991, 1995; Economidis 1991 and Economidis & Nalbant 1996). A recent overview for the northern Mediterranean region gives insight to the fish fauna of the area (Crivelli 1996).

There are great discrepancies among the above mentioned authors with regard to the taxonomic status of certain species, which imposes the need for a general review by applying new, modern methods of taxonomic analysis (Georgiev 1998). We will present the list of fishes in Lake Doiran on the basis of data compiled from the above authors, as well as from the official list of species presented within the European Red List of Vertebrates. This compilation includes the following species: roach - *Rutilus rutilus* Linnaeus, 1758; carp - *Cyprinus carpio* Linnaeus 1758; Vardar chub - *Leucaspius delineatus* Heckel 1843; rudd - *Scardinius erythrophtalmus* Linnaeus 1758; tench – *Tinca tinca* Linnaeus 1758; bleak - *Alburnus alburnus makedonicus* Karaman , 1924; bitterling – *Rhodeus sericeus amarus* Bloch 1782; Macedonian roach – *Pachychilon makedonicus* Steindachner 1892; gudgeon - *Gobio gobio balanicus* Dimovski & Grupce 1977; Balkan barbel – *Barbus peloponnesius* Valencienes 1842; goldfish – *Carassius auratus gibelio* Bloch 1782; Vardar spined loach - *Cobitis vardarensis* Karaman 1928; catfish - *Silurus glanis* Linnaeus 1758; eel - *Anguilla anguilla* Linnaeus 1758; perch - *Perca fluviatilis* Linnaeus 1758; river blenny - *Salaria fluviatilis* Asso, 1801; and Doiran loach *Sabanejewia aurata doiranica* Economidis & Nalbant 1996. Three of the above fish species are included in Annex II of Dir.

92/43/EEC (under the species names *Barbus plebejus*, *Sabanjewia aurata* and *Cobitis taenia), Pachychilon macedonicus* and *Gobio gobio balcanicus* are in the Hellenic Red Data Book and *Salaria fluviatilis* is included in Annex III on the Bern Convention.

Within the ecosystem of Lake Doiran, the Class Amphibia (amphibians) consists of ten species (Sidorovska et al. 2001; Dzukic et al. 2001; Sidorovska et al. 2003 and Sidorovska et al. unpubl. data). The species *Rana balcanica* and *Triturus karelinii*, as well as the subspecies *Pelobates syriacus balcanicus, Bombina variegata scabra* and *Triturus vulgaris graecus*, are Balkan endemics. *Triturus vulgaris graecus* manifests itself as a neotenic population only in the Doiran Basin, while the Greek marsh frog, *Rana balcanica*, has its most abundant population within the lake. The Balkan spadefoot toad, *Pelobates syriacus balcanicus,* was described from a specimen collected from the shore of Lake Doiran. It should be noted that *Tristurus karelinii* and *Pelobates syriacus* (both at the species level) are included in Annex II of Dir. 92/43/EEC and Annex II on the Bern Convention accordingly.

There are 23 reptiles species in the Doiran Basin (Petkovski et al. 1999, 2000/2001, 2001). Four species are directly related to the water biotope of the lake while, in the wider area of the Doiran Valley, there are 19 other species, among which Mediterranean faunal elements dominate. The subspecies *Emys orbicularis hellenica*, *Cyrtodactylus kotschyi skopjensis*, *Ablepharus kitaibelii stepaneki* and *Podarcis erhardii riveti* are Balkan endemics. The sand boa, *Eryx jaculus turcicus*, was first recorded on the Balkan Peninsula at a location within the Doiran Basin. This species is the only European representative of the large family of boas. Also, there are *Emys orbicularis* which includes in Annex II of Dir. 92/43/EEC, *Lacerta viridis* and *Podarcis taurica* Annex II on the Bern Convention and Presidential Degree 67/81.

There are 87 bird species in the Doiran Basin (Dangel 1973; Dimovski and Matvejev 1955; Matvejev and Vasic 1973; Micevski 1991; and Sere and Ivanovski, pers. comm.). There are about 36 bird species abundant in the area all included in Annex II and III of the Bern Convention. Fifteen of these species are also included in the Birds Directive 79/409/EEC. *Phalacrocorax pygmeus* and *Pelecanus crispus* are globally threatened species and their presence renders the site as an Important Bird Area for both countries. The most abundant waterbird species are the coot (*Fulica atra*) and the pochard (*Aythia farina*).

There are 53 mammals in the Doiran basin, according to Petrov 1992; Krystufek et al. 1992; Petkovski and Krystufek 1998; Krystufek and Petkovski 1999; and Petkovski et al., 2001, or 64% of the total mammal fauna of the FYROM. Of these, only a few species are directly related to the water biotope of Lake Doiran. The most common mammal is the weasel (*Mustela nivalis*), which is included in Annex III of the Bern Convention and the Presidential Degree 67/81.

Vertebrate species of special concern (i.e., those species listed within the European Red List of Vertebrates, Annexes II and IV of the Habitats Directive 92/43/EEC, Council Directive 79/409/EEC and Appendix II of the Bern Convention) are presented separately as a table in Annex III of this report.

2.2.3.1. Endemic taxa within Lake Doiran and vicinity

Lake Doiran and its surrounding valley are characterised by a substantial number of fauna unique to the aquatic ecosystem and surrounding uplands, that is, endemic species. The extinction of these taxa would mean their irreversible disappearance from the planet Earth.

2.2.3.1.1. Endemic taxa of Lake Doiran

1. *Spongilla carteri dojranensis* Hadzisce, 1953
2. *Graecanatolica macedonica* Radoman & Stankovic, 1978
3. *Branchiobdella capito* Georgevitch, 1955
4. *Cambarincola dojranensis* Georgevitch, 1955
5. *Pterodrilus prion* Georgevitch, 1955
6. *Xironodrilus crassus* Georgevitch, 1955
7. *Isochaeta dojranensis* Hrabe, 1958
8. *Microcyclops varicans dojranensis* Petkovski, 1954
9. *Physocypria inversa* Klie, 1941
10. *Candona paionica* Petkovski, 1958
11. *Candona angulata meridionalis* Petkovski, 1958

12. *Limnocytere inopinata* Baird,1843 amended Petkovski, 1959

13. *Niphargus pancici dojranensis* Karaman, 1960

14. *Rhabdiopteryx doiranensis* Ikonomov, 1983

15. *Sabanejewia aurata doiranica* Economidis & Nalbant, 1996

According to this list, it is clear that Lake Doiran hosts a number of endemic taxa and that the Doiran endemics are mainly of low taxonomic category.

Hadzisce (1953) originally described the new subspecies of freshwater sponge, *Spongilla carteri dojranensis*. Although the nominative species is more widely distributed, to date, the subspecies *dojranensis* has not been recorded in any other freshwater biotope. This sponge is closely linked to the shallow littoral zone, which has experienced drastic changes over the last two decades. It still exists in the lake, however, adapting itself to the altered circumstances of the lake's ecosystem.

Radoman & Stankovic (1978) described a new gastropod species, *Graecanatolica macedonica,* from the lake. Stankovic (1987) recorded an abundance of 25,000 individuals/m² at certain locations within the littoral zone. According to the latest research (Petkovski et al. 1999; 2001), however, only 11 individuals/m² were recorded, which indicates the population of this species has been greatly reduced.

Although Georgevitch (1955) described 14 new branchiobdelid species occurring as ectobionts of the Balkan river crayfish (*Astacus astacus balcanicus*), Petkovski et al. (2003) accepted only four of these as Doiran endemics (*Branchiobdella capito, Cambarincola dojranensis*, *Pterodrilus prion* and *Xironodrilus crassus*). The other ten species are considered to be synonyms.

Hrabe (1958), investigating the oligochaetes of Lakes Doiran and Scutari, described a new species under the name, *Isochaeta dojranensis*, which is still accepted as a Doiran endemic. While investigating the oligochaetes of Lake Doiran, Sapkarev (1975a, 1975b, 1980, 1991) pointed out that the abundance and the frequency of this endemic species has been continuously decreasing. In the 1970s, the abundance was 88 individuals/m² in the littoral zone and 44/m² in the benthic zone; by the 1980s, the number had decreased to 44 individuals/m² in the littoral and 22/m² in the sublittoral zone. Recent investigations (Petkovski et al. 1999, 2001, and Griffiths et al. 2002) encountered only 11 individuals/m².

Petkovski (1954), in his study on the cyclopoid fauna of Yugoslavia (Crustacea: Copepoda), described the subspecies *Microcyclops varicans dojranensis* from the

muddy waters by the shoreline of Lake Doiran. So far, this taxon has not been found at any other location; therefore, it is accepted as a Doiran endemic.

Klie (1941), in his study on the freshwater ostracods of South-eastern Europe, described a new species from Lake Doiran, *Physocypria inversa*, which is considered to be a Doiran endemic. T. Petkovski (1958) described two new ostacods from the benthic zone of Lake Doiran, *Candona paionica* and *Candona angulata meridionalis*, which are also accepted as Doiran endemic taxa.

The ostracod species, *Limnocytere inopinata* Baird, 1843, with its parthenogenetic populations, is widely distributed within the Holarctic Zoogeographic Region. Fossil males of this species have been found at a number of locations in Europe and have been incorrectly described as new species. T. Petkovski (1959) was the first to describe the relict bisexual population of this species from Lake Doiran. To date, there have been no further records from other locations. Therefore, the bisexual population of this species is classified as a relict endemic taxon restricted only to Lake Doiran.

Karaman (1960), in his paper on the representatives of the genus, *Niphargus* (Crustacea: Copepoda), described the subspecies, *Niphargus pancici dojranensis* which is restricted to the springs of the stream Deribash above Star Doiran. In 1974, he confirmed that this subspecies is a Doiran endemic taxon.

From a stream that flows into Lake Doiran in the vicinity of Achikot, Ikonomov (1983) described a new stonefly species, *Rhabdiopteryx doiranensis*. The same author (1986), in his study on the stonefly fauna of FYROM, confirmed the status of this species as a Doiran endemic.

Economidis and Nalbant (1996) described a new fish species, *Sabanejewia doiranica*, which is restricted to Lake Doiran.

2.2.3.1.2. Endemic taxa of the Doiran Valley

1. *Liposcelis macedonicus* Gunther, 1980
2. *Zygaena purpuralis doiranica* Daniel, 1964
3. *Zygaena carniolica paeonica* Burgeff, 1914
4. *Zygaena ramburi europensis* Daniel, 1964

5. *Cosmotriche potatoria* Mace, 1920
6. *Cnephasia klimeschi* Razowski, 1958

These endemic taxa, which are not directly connected with the Lake Doiran ecosystem, are present primarily within the Doiran Valley. Further details concerning these species are presented in Section 2.2.3.

2.2.3.2. The zooplankton of Lake Doiran

Prior to the 1990s, 94 zooplankton taxa from the faunal groups Protozoa (2), Rotifera (52), Cladocera (24), Copepoda (14), and one each from Mollusca and Insecta had been identified in the littoral and pelagic zones of the lake (Doflein 1921; Popovska-Stankovic 1954, 1958, 1990; Karvounaris 1973; and Petkovski 1998, 1999, 2001). From the ecological aspect, zooplankton is a very important constituent of the trophic pyramid of the lake. This is especially relevant considering that it is also one of three main components in the diet of the economically important fish species of the lake: *Alburnus alburnus*, *Cyprinus carpio*, *Rutilus rutilus* and *Perca fluviatilis* (Popovska-Stankovic 1968, 1971, 1977).

Throughout the period leading up to the 1990s (Popovska-Stankovic 1990), the zooplankton density in the littoral zone during the spring maximum ranged from 240,000 to 800,000 individuals/m^3 of water, while in the autumn, the maximum value ranged from 80,000 to 100,000 individuals/m^3. The spring maximum in the pelagic zone of the lake ranged between 340,000 and 380,000 individuals/m^3, whereas in the autumn, between 360,000 and 420,000 individuals/m^3 were observed.

According to Petkovski et al. (1999, 2001), by the late 1990s, the zooplankton density within the littoral zone during the spring maximum had fallen to a range of 14,000 to 17,000 individuals/m^3, while the autumn maximum was between 9,000 and 12,000 individuals/m^3. The spring maximum in the pelagic zone was from 46,000 to 52,000 individuals/m^3; in the autumn, between 54,000 and 57,000 individuals/m^3 were encountered.

A quick comparison reveals that, quantitatively, zooplankton in the pelagic zone has decreased to roughly 1/7 its former abundance, while in the littoral zone, current numbers are 1/10 to 1/20 of their former values.

2.2.3.3. The benthos of Lake Doiran

Lake-bottom fauna variations take place over the course of time and thus are useful biological indicators of freshwater ecosystem succession. Within Lake Doiran, the fauna has undergone dramatic shifts. Such changes include drastic reductions in the abundance of oligochaetes, from 2,000 to 202 individuals/m^2 (Sapkarev 1975a, 1975b, 1980, 1991; Petkovski et al. 1999; Griffiths et al. 2002), and of Chironomidae larvae, from 2,000 to 200 individuals/m^2. The populations of nematodes, on the other hand, have maintained a relatively constant level.

The only group that has benefited from the changing status of the lake is the Ostracoda, with an average increase from 100 individuals/m^2 to 900 individuals/m^2. This is partially due to the detrivorous nature of a large number of ostracod taxa. Considering that, in the past, ostracods were only a minor component of the zoobenthos community, this change is very important. In the deeper parts of the lake, the larva of *Chaoborus crystallinus* (Insecta: Chaoboridae) used to dominate the benthos community (Sapkarev 1975a, 1975b). In the early 1960s, the yearly average abundance of this species was about 10,000 individuals/m^2, whereas by 1989, it had decreased to 1,420 individuals/m^2 (Sapkarev et al. 1991). According to recent research during the period 1997-1999 (Petkovski et al. 1999, Griffiths et al. 2002), the average larval density for the entire community of the Order Nematocere was 427 individuals/m^2.