

The diversity of Croatian vascular flora based on the Checklist and CROFlora database

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The recently completed Checklist of Croatian Vascular Flora for the first time endeavours to quantify the national vascular flora. The vascular flora numbers 5,347 taxa in all (4,275 species and 1,072 subspecies). According to species number per square unit, Croatia takes 3rd place in Europe in floristic richness. The three biggest families are *Compositae* (742), *Fabaceae* (458) and *Poaceae* (448), and the fifteen biggest families contain 77% of all species and subspecies. 447 taxa are considered threatened (8.92%), almost double the number in the last Red list. The 323 endemic taxa were registered in the categories of subendemic, endemic and narrow endemic taxa, and Bykov's index of endemism shows that Croatia has more than the average number of endemic species in a number of European countries. In the best case, for 39% of all the taxa the ecological indices are known. A total of 241 taxonomically or chorologically doubtful taxa have been registered, together with 343 taxa in cultivation, and 120 naturalised taxa. The Checklist contains 7,673 invalid names, mostly synonyms, and the database currently 11,407.

Key words: flora, Check list, database, endemics, Croatia

Introduction

Croatia has a long history of botanical investigation. Although the oldest works date from the 17th century, the leading and definitive works, which more or less cover the area of the state as it is today, were published during the 19th century and at the beginning of the 20th century. Amongst the leading works are *Flora Dalmatica* (VISIANI 1842, 1847, 1852 and supplements from 1872, 1877, 1878), *Flora Croatica, Syllabus* and *Excursion Flora* (SCHLOSSER and VUKOTINOVIĆ 1857 1869, 1876), *Flora Velebitica* (DEGEN 1936–1938, 1938), contributions of D. Hirc (HIRC 1903–1912) and Lj. Rossi (ROSSI 1930), and *Prodromus Florae peninsulae Balcanicae* (HAYEK 1927–1933). Numerous papers and authors, an overview of which is not the subject of this paper, have made abundant contributions to the Croatian flora, but integral approaches have been totally lacking for several decades. Perhaps this is the reason why the vascular flora of Croatia has been presented in some newer botanical and floristic papers very poorly and incompletely (see below).

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In attempt to produce a complete Checklist of Croatian flora after almost 100 years, up-to-date in both nomenclature and taxonomy, work was started on this in 1994 (NIKOLIĆ 1994), and with the two additional volumes has at last been finished (NIKOLIĆ 1997, 2000a). The Checklist led us to quantify and analyse the diversity of Croatian vascular flora and to put it into some relation with the flora of other European countries. As an integral part, the Checklist contains a new Red data list, a list of endemic taxa according to agreed criteria, and the relevant bibliography with about 4000 references.

Material and methods

Geographically, the analysis of vascular flora was limited to within the political borders of the Republic of Croatia (Fig. 1).

Source of Data and Comparisons

Material collected for the purpose of Checklist building (NIKOLIĆ 1994, 1997, 2000 a) during 1998–2000 has been entered into the CROFlora 2.0 database (NIKOLIĆ 1996). Flora analysis and related data has been done by standard queries used on selected groups of taxa

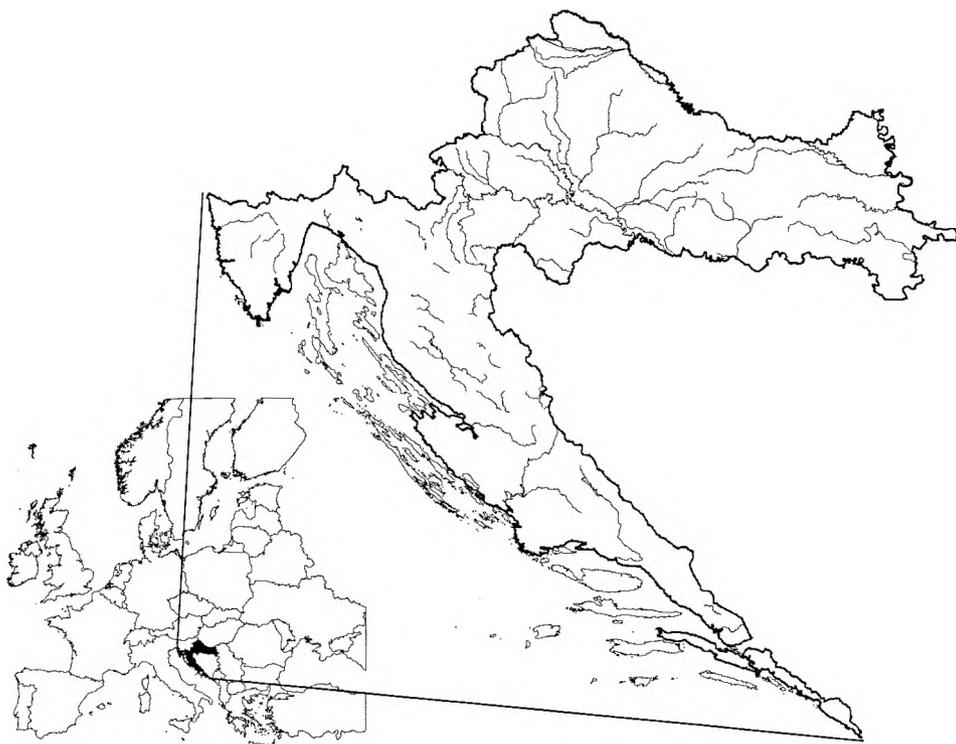


Fig. 1. Geographical scale of analysed vascular flora – position in Europe and borders of Republic of Croatia

and selected groups of attached data. Comparisons of floristic richness with that of neighbouring countries and areas are based on data from NIKLFELD and SCHRATT-EHRENDORFER (1999), MRŠIĆ (1997), Hawksworth and KALIN-ARROYO (1995), GROOMBRIDGE (1992, 1994) and WALTER and GILLETT (1998).

Endemism

Analysis of endemism and comparisons with some other countries has been done with the use of the Bykov index of endemism (BYKOV 1983). This index for quantitative comparisons of different areas according to the number of endemic taxa included is defined as linear relationship between percent of endemic taxa (refer to whole taxa number, logarithmic scale) and logarithm of area. The index of endemism I_e is consequently equal to E_f/E_n , where E_f is the real percent of endemic taxa, and E_n is the expected or normal percent of endemic taxa as manifested in the basic graph (HAWKSWORTH and KALIN-ARROYO 1995:173).

Threatened Status

The analysis of threatened taxa is based on the assessment of endangerment of taxa included in Checklists done by particular authors. The category of threat according to IUCN standard from period before 1994 has been used (WALTER and GILLETT 1998).

Comparisons with threatened flora of some adjacent countries are based on the data set from the PHANART database (LINDACHER 1995, by kindness of the author). The origin of data for Austria is NIKLFELD et al. (1986), for Switzerland LANDOLT (1991), for Germany KORNECK and SUKOPP (1988), for Berlin BÖCKER et al. (1991), the province of Baden-Württemberg HARMS et al. (1983), Bavaria SCHÖNFELDER (1987), Italy CONTI et al. (1997), for Bosnia and Herzegovina ŠILIĆ (1996), for Yugoslavia STEVANOVIĆ (1999), Hungary HORVÁTH et al. (1995), for Slovenia WRABER and SKOBERNE (1989) and for the European Union as an integral area ANONYMOUS (1991). For Austria, in the meantime, a new edition has been published (NIKLFELD and SCHRATT-EHRENDORFER 1999), which is not available in digital form, and is therefore not used in these comparisons. For different areas the categories of threat are not given according to the same standard (i.e., do not always follow the IUCN standard), so in this work they are compared in binary fashion, i.e., either threatened or not threatened, irrespective of the level.

Ecological data

The review of the Croatian Checklist with respect to availability of ecological indices has been done by putting in operation adequate database queries. Ecological indices are undertaken partly from PHANART database (LINDACHER 1995), and partly toward ELLENBERG et al. (1991, 1991–1996, i.e. Ellenberg ecological indices). Whole used dataset contains also ecological parameters toward ELLENBERG et al. (1979, 1991), LANDOLT (1977), KOWARIK (1988), SUKOPP et al. (1982), KUNICK (1974), DÜLL et KUTZELNIGG (1986), OBERDORFER (1983), KLAPP et al. (1953) and ROTHMALER (1987 a,b).

Results and Discussion

Magnitude of Croatian vascular flora

The exact magnitude of Croatian vascular flora for the area of the state as it is today has not been known to date. Flora Croatica (SCHLOSSER and VUKOTINOVIĆ 1869) for Croatia without the Istrian peninsula, but including Srijem and Boka Kotorska mention 3495 taxa. ROSSI (1924, 1930) record about 2700 taxa for the coastal area, and DEGEN (1936–1938), for Mt Velebit, Lika, Krbava and Plješivica noted about 3500 taxa. Some estimations of the number of taxa number reach, for example, the number of 4000 (TRINAJSTIĆ 1991 a).

The range of Croatian vascular flora established by the Checklist (NIKOLIĆ 1994, 1997, 2000) is shown briefly in table 1 according to the number of lower and higher taxonomical categories.

Tab. 1. The number of taxa (subclass, order, family, genus, species, subspecies) in the division *Pteridophyta*, subdivision *Cycadophytina* and *Coniferophytina*, and classes *Magnoliopsida* and *Liliopsida* of the Croatian vascular flora

category	name of taxon	subclass	order	fam.	genus	sp. + ssp.	sp.	ssp.
division	<i>Pteridophyta</i>	6	7	17	36	86	76	10
subdivision	<i>Cycadophytina</i>	1	1	1	1	7	3	4
subdivision	<i>Coniferophytina</i>	2	3	5	14	40	31	9
	total of gymnosperms	3	4	6	15	47	34	13
class	<i>Magnoliopsida</i>	6	51	133	803	4277	3356	919
class	<i>Liliopsida</i>	4	11	28	232	937	807	130
	total of angiosperms	10	62	161	1035	5214	4165	1049
	total of seed plants	13	66	167	1050	5261	4199	1062
	total of vascular flora	19	73	184	1086	5347	4275	1072

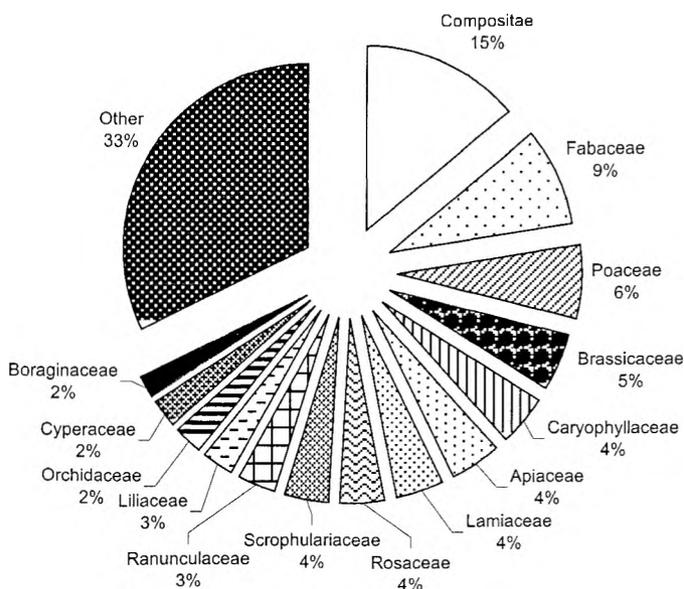
According to these results, the Croatian flora comprises 4275 species and 1072 subspecies (5347 species and subspecies) belonging to 1086 genera and 184 families.

According to the species and subspecies number the biggest family is *Leguminosae* (*Fabaceae*) with 458 taxa (Tab. 2), followed by *Asteraceae* with 448 and *Gramineae* (*Poaceae*) with 341 taxa. The numbers of species and subspecies in the other biggest families of Croatian flora are shown in table 2. If the families *Asteraceae* (Dumort., 1822, nom. cons.) and *Cichoriaceae* (Juss., 1789, nom. cons.) are treated taxonomically as a united family i. e. *Compositae* (Giseke, 1792, nom. cons. et nom. alt.), which is not unusual in the literature, then this family is the biggest in Croatian flora with a total of 742 species and subspecies, which is 15% of all taxa (Fig. 2). The mentioned fifteen biggest families contain as many as 77% of all taxa.

However, this number could not be consider as final for several reasons. Certainly, multiple authority in Checklist development leads to some objective and subjective difficulties. Different authors have used complete freedom in the taxonomic evaluation of particular taxa, which has been especially reflected in doubtful examples. It refers to the choice of authors who (1) negated existence of some taxa during preparation of the Checklist (omitted them from the Checklist), although those taxa have been cited in some publications, (2) treated them as »doubtful smaller species«, as a part of »bigger species« including them

Tab. 2. Biggest families of Croatian vascular flora

no.	family	sp. + ssp.	ssp.	sp.
1	<i>Fabaceae</i>	458	105	353
2	<i>Asteraceae</i>	448	116	332
3	<i>Poaceae</i>	341	29	312
4	<i>Cichoriaceae</i>	294	65	229
5	<i>Brassicaceae</i>	272	73	199
6	<i>Caryophyllaceae</i>	236	85	151
7	<i>Apiaceae</i>	233	61	172
8	<i>Lamiaceae</i>	226	54	172
9	<i>Rosaceae</i>	217	24	193
10	<i>Scrophulariaceae</i>	197	37	160
11	<i>Ranunculaceae</i>	181	50	131
12	<i>Liliaceae</i>	154	24	130
13	<i>Cyperaceae</i>	129	9	120
14	<i>Orchidaceae</i>	129	41	88
15	<i>Boraginaceae</i>	103	28	75

**Fig. 2.** Proportion of fifteen biggest families of Croatian vascular flora (families *Asteraceae* and *Cichoriaceae* together as a *Compositae*) as a percent of total taxa number (species and subspecies)

(marked: incl.) in (as many as 274 taxa, Tab. 8), (3) respected existence of some subspecies, or (4) accepted existence of some species, but as so called »small species in aggregate« (in the Checklist marked as »+«). In the first and second case, such doubtful taxa do not contribute to the magnitude of Croatian vascular flora. By adopting the »splitters« approach, and consequently treating *inclusive* taxa at the level of small but valid species, and treating

about 200 subspecies also as small species, the magnitude of vascular flora could be enlarged to about 4700 species, that is, about 5500 species and subspecies. Such an approach, however, could be justified only if each particular, today doubtful taxon or taxonomic level is followed by taxonomic work meeting high standards. Certainly, such an evaluation of critical taxa and groups will occur sooner or later, the results changing (upwards or downwards) the diversity of Croatian vascular flora.

On the other hand, the findings of already described taxa, are very dynamic in the area of the state, especially in the less known parts. Thus, there have been the first, quite recent, records of *Salvia peloponnesiaca* Boiss. et Heldr. (REGULA-BEVILACQUA 1969), *Sporobolus neglectus* Nash (MARKOVIĆ 1972), *Avellinia michelli* (Savi) Parl. (PAVLETIĆ 1972), *Bidens bipinnata* L. (TRINAJSTIĆ 1975), *Ballota acetabulosa* (L.) Benth (TRINAJSTIĆ 1983), *Panicum dichotomiflorum* Michaux (ILJANIĆ and MARKOVIĆ 1986), *Diplotaxis erucoides* (L.) DC. (PAVLETIĆ 1987), *Guizotia abyssinica* (L. F.) Cass. (TRINAJSTIĆ and PAVLETIĆ 1989), *Ligularia sibirica* (L.) Cass. (ŠEGULJA and KRGA 1990), *Paspalum dilatatum* Poir (ILJANIĆ 1990), *Damasonium polyspermum* Cosson (TRINAJSTIĆ et al. 1995), *Erodium acaule* (L.) Bech. et Thell. (TOPIĆ et al. 1998), *Polypodium interjectum* Shivas and *P. mantoniae* Rothm. et U. Schneid. (HRŠAK 2000) and others. Some species were newly described, for example *Ornithogalum dalmaticum* Speta and *Ornithogalum televrinum* Speta (SPETA 1990). New findings and similar revelations can probably be expected in the future.

The comparison between the number of Croatian species with the number of species known for some European countries is given in table 3 and figure 3. Comparisons of absolute taxa numbers, however, have little sense because of the often large differences in areas compared (HAWKSWORTH and KALIN-ARROYO 1995).

A more realistic approach is the ratio of the species number and the area. On the basis of this comparison, Croatia is in the third position in Europe (0.075), after Slovenia (0.158) and Albania (0.105). Since the number of taxa for Slovenia also includes the taxonomical

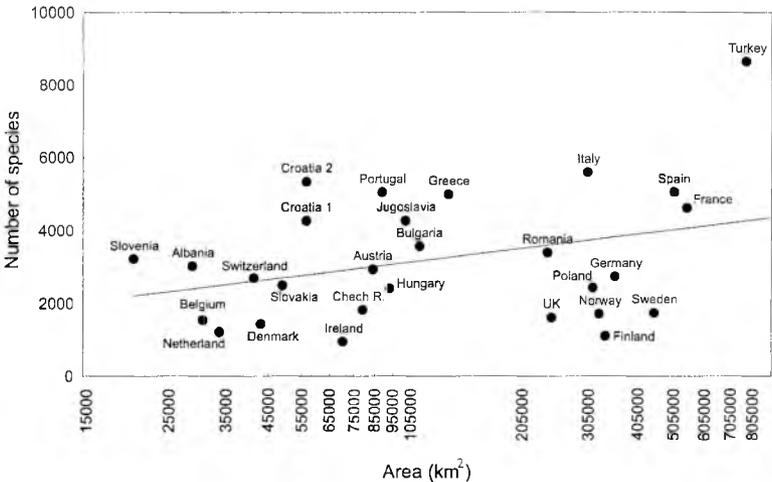


Fig. 3. Dependence of the number of species and the size of area. Areas above regression line show a richness above the average; Croatia¹ – the number of species, Croatia² – the number of species and subspecies

Tab. 3. The comparison of total number of vascular flora species in some European countries according to the order of ratio of species number/state area (km²); ¹ the number of species, ² the number of species and subspecies, ³ not including Madeira (796 km²) and the Azores, ⁴ the number of species supplemented according to NIKLFELD and SCHRATT-EHRENDORFER (1999), ⁶ framed dimension of area of interest (data on the number of species according to WALTER and GILLET 1998, state areas according to OPPITZ 1974)

no.	state/area	no. species	% threatened	area (km ²)	no. species/km ²
1	Slovenia	3216	12,00	20251,00	0,15881
2	Albania	3031	2,60	28748,00	0,10543
3	Croatia ¹	4275	11,01	56538,00	0,07561
4	Croatia ²	5347	8,80	56538,00	0,09457
5	Switzerland ⁴	2696	32,00	41288,00	0,06530
6	Portugal ³	5050	5,30	88500,00	0,05706
7	Slovakia ⁴	2500	41,50	49009,00	0,05101
8	Belgia	1550	0,10	30514,00	0,05080
9	Yugoslavia	4282	5,00	102173,00	0,04191
10	Greece	4992	11,40	131944,00	0,03783
11	Netherlands	1221	0,10	33779,00	0,03615
12	Austria ⁴	2950	40,20	83850,00	0,03518
13	Denmark	1450	0,10	43069,00	0,03367
14	Bulgaria	3572	3,00	110912,00	0,03221
15	Hungary ¹	2411	1,40	93030,00	0,02592
16	Czech R. ⁴	1826	45,00	78851,00	0,02316
17	Italy	5599	5,60	301249,00	0,01859
18	Romania	3400	2,90	237500,00	0,01432
19	Ireland	950	25,30	70280,00	0,01352
20	Turkey	8650	21,70	774810,00	0,01116
21	Spain	5050	19,50	504750,00	0,01000
22	France	4630	0,50	543998,00	0,00851
23	Poland	2450	1,10	311730,00	0,00786
24	Germany ⁴	2742	0,50	355872,00	0,00771
25	UK	1623	1,10	244030,00	0,00665
26	Norway	1715	0,70	324219,00	0,00529
27	Sweden	1750	0,70	449750,00	0,00389
28	Finland	1102	0,50	337032,00	0,00327

category of subspecies, it is justified to use, for the purpose of comparison, the analogous number for Croatia as well. The total order of countries according to richness in vascular flora species does not change. This comparison does, however, bring Croatia (0.094) much closer to Albania (Tab. 3). The list of flora by its documented abundance puts Croatia at the very top of floristic richness amongst the countries in Europe.

The magnitude of Croatian vascular flora and related data in European works

Nevertheless, apart from the continuance of indubitable data about flora, the evaluation of the threat and the magnitude of Croatian flora and endemism, European and some wider approaches are sometimes more than incomplete. Papers published after 1991 and the establishment of Croatia in its present borders do not treat Croatia as a »botanical« entity.

Thus second edition of *Flora Europaea* vol. 1 (TUTIN et al. 1993) still quotes the mark »Yu« as chorological information for all parts of the former »Jugoslavian Republic«. The same things can be found in the World Geographic Scheme for Recording Plant Distribution from 1991 (HOLLIS and BRUMMITT 1991), in *Global Biodiversity, Status of Living Resources* (GROOMBRIDGE 1992), etc. Nevertheless, a few years later »Croatia« did occur as an entity, but with the wrong data. In *Biodiversity – Data Source Book* (GROOMBRIDGE 1994), Croatia had zero threatened taxa (even at that time the Red list contained 226 (ŠUGAR 1994). 10 areas were said to be protected with a total area of 1100 ha (even at that time 18 areas were protected in the category of national park and nature park with a total area of 505,000 ha), there were no herbarium collections (even at that time there are 5 herbariums registered in Index Herbariorum, and today there are 6; HOLMGREN 2000). In last IUCN Red list of threatened plants (WALTER and GILLET 1998) for »Croatia« only 6 threatened species were mentioned, about 0.2 % of the whole flora estimated at only 3000 taxa! The latest edition »The 2000 IUCN Red list of threatened species (both plants and animals)« in the summary statistics table (<http://redlist.cymbiont.ca/tables/table3.html>) carried the information that there are zero threatened plants in Croatia.

Newer reviews based on *Atlas Florae Europaea* according to published materials, which cover 20% of European flora (2370 species, 465892 chorological data, 12 vol.) are more realistic. On analytical maps and according to several criteria, the Croatian area, especially the Dinaric part, is at the top of European floristic richness (DELBAERE 1998:14, Fig. 1). Although authors mention that the data for south Europe are incomplete, the numbers will actually rise in the near future in parallel with the inventory making activities.

The main reasons for the incomplete appearance of the richness of Croatian flora in European and world literature is the insufficiency of adequate works about the Croatian area. Even with those existing, the language obstacle inhibits further publicity, while some works are distributed locally only (for example the Red data book of 1994.).

Endemic taxa

The concept of endemism must be concerned as a relative one, and the biological meaning depends on a range of elements (HAWKSWORTH and KALIN-ARROYO 1995). In practice endemic taxa are traditionally classified according to four, not strictly defined, criteria: (1) according to incidence in a geographically/topographically defined area, mostly a site of some smallish size, (2) according to incidence, i.e. being bound to a specific habitat type, (3) according to some biogeographically defined area and (4) according to some political boundary. Besides this, the classification of endemes is often by origin: (1) autochthonous endemic taxa (those evolved originally in some area of limited size) and (2) allochthonous taxa (those evolved somewhere else or on a bigger area, but surviving in a small part of the former distribution area) (BROWN and GIBSON 1983). Often enough there is a distinction of endemic taxa according to oldness, into (1) palaeoendemic taxa (taxa occurring relatively long ago, before the glacial, tertiary, conservative, relict) and (2) neoendemic taxa (relatively newer evolved taxa, of quaternary origin, postglacial, progressive; sometimes additionally split into shizo-, patro- and apo-endemic). According to the oldness supplementary categories there appears (3) the archiendemic, or palaeoendemic taxa with exceptional oldness (living fossils). Obviously, calling into play any of mentioned categories often requires from an author a subjective valuation, which could lead to different treatments of endemic categories for particular taxa (COX and MOORE 2000).

In reviews of endemic taxa in Croatian vascular flora almost all the mentioned criteria have been used, together or in different combinations (BORZAN et al. 1992, TRINAJSTIĆ 1991 a,b, ŠILIĆ 1984, LOVRIĆ 1983 and others). Together with authors' different opinions concerning taxonomic treatment, especially in the difficult groups, the number of endemic taxa in Croatian flora is beginning to be variable.

The treatment of endemics in the Checklist is based on two elements (standards). The first one is taxonomical, which means, that the endemic status is connected only to taxa treated taxonomically or nomenclaturally as is done in the Checklist. The second is connected with criteria for the facilitation of endemism evaluation for some taxon for the authors who worked out the Checklist (NIKOLIĆ 1994: 6–7). Those criteria relate geographically to the political boundary of the Republic of Croatia on the one hand and the taxa range with respect to them on the other. In category (a) there are endemic or narrow endemic taxa restricted in distribution to 20 MTB fields (stenoendemic taxa according BORZAN et al. 1992 and ŠILIĆ 1984, or strict endemic taxa according to ŠILIĆ 1984). In category (b) there are endemic taxa distributed inside the state borders with sometimes a smallish number of locations in neighbouring countries (more endemic, less subendemic taxa), and in category (c) there are all taxa with not such a strict distribution, the so called subendemic taxa, i.e. taxa with the centre of their distribution in some of the neighbouring countries, but with the part of their ranges in Croatia (also halfendemic, wide endemic, subendemic taxa but in wider sense than »b«). This segregation has no pretension to be an objective biogeographical division. The main purpose is to facilitate the assignation of endemic status to some taxa according to the political boundary of Croatia. Each category is illustrated by a concrete example of the distribution according to a particular map in Atlas Florae Europaea (JALAS and SUOMINEN 1989).

Based on such elements, a list of endemic taxa has been generated from the Checklist and analysed according to presence in the higher taxonomic levels (Tab. 4). Endemic status has established for 323 taxa (species and subspecies). This makes 6.04% of the total number of species and subspecies.

Certainly, this basic list must be biogeographically judged from the point of view of the origin and oldness of the respective taxa versus clearly defined criteria. Also, for the purpose of national and international communication it seems advantageous to use the categories of (1) stenoendemics (narrow endemics, taxa with small scattered ranges inside the Croatian borders limited to 10 (–20) basic mapping fields of the MTB grid, NIKOLIĆ 1998),

Tab. 4. The number of endemic taxa in Croatian flora represented by larger taxonomical groups

category	name of taxon	no. of endemic sp./ssp.
division	<i>Pteridophyta</i>	2
subdivision	<i>Cycadophytina</i>	0
subdivision	<i>Coniferophytina</i>	1
	total of Gymnosperms	1
class	<i>Magnoliopsida</i>	291
class	<i>Liliopsida</i>	29
	total of Angiosperms	320
	total of seed plants	321
	total of vascular flora	323

(2) endemics (range bigger than »1« but entirely inside the state borders, at the most on 557 basic mapping fields of the MTB grid of the land area of the state) and (3) subendemics (wider endemics, taxa distributed also in one or several directly neighbouring countries, with the center of distribution either in Croatia or outside it (also drawing upon criteria »b« and »c« according to NIKOLIĆ 1994). Such a division would be somewhat in accord with ŠILIC (1989) (1 – local or exclusive endemics, 2 – stenoendemics or strict endemics and 3 – subendemics).

What is the level of endemism of Croatian flora in comparison with that of other areas? The index of endemism according to BYKOV (1983) for value $le = 1$ represents the expected (normal) level of endemic species for a given area (for example Austria, Guinea, Libya, USA). Values $le < 1$ represents a number of endemics lower than the average (i.e. expected, Denmark, Ireland, Niger), while the le values > 1 represent more than the average number of endemics (for instance in extreme cases, like New Caledonia, New Zealand, $le > 80$) (Fig. 4).

Bykov's coefficient le for Croatia is, according to this, $le = 6,04/\sim 2 \approx 3 > 1$, which characterises the endemics of Croatian vascular flora as approximately three times the average.

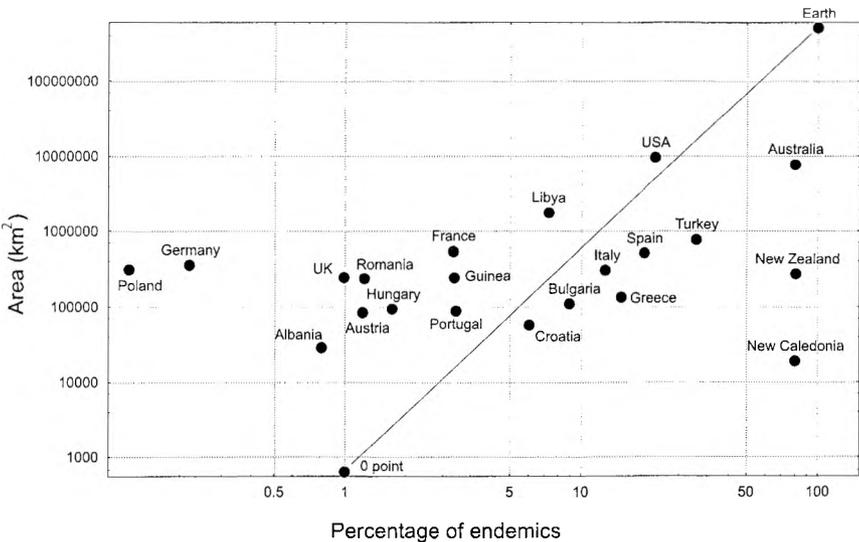


Fig. 4. Bykov's nomogram for determining the average endemism on the sample of European countries and some non-European areas

Threatened flora

First evaluations of the endangerment of Croatian flora were connected with the Red Book of 1994 (ŠUGAR 1994). This work, as is known, marked a total of 226 endangered taxa. IUCN categories were applied for the evaluation of endangerment (i.e. before-1994). Since the work on the list started in 1994, the same categories were applied, although at the same time new categories were designed (IUCN 1994, WALTER and GILLET 1998).

According to the Checklist, in Croatia 477 taxa are threatened, which makes 8.92 % of all taxa. The numbers of threatened taxa following IUCN categories are given in table 5, and comparison with ŠUGAR (1994) in figure 5.

Tab. 5. The number of threatened taxa (species and subspecies together) according to IUCN categories in larger taxonomical groups of Croatia vascular flora (Ex? – probably extinct, Ex – extinct, E – endangered, V – vulnerable, R – rare, I – indefinite, K – insufficiently known, o – earlier endangered, nt – not endangered, Z – protected by the Act of Nature Protection in the Republic of Croatia)

level	taxa	Ex?	Ex	E	V	R	I	K	o	nt	total	Z	% from total no. of taxa
division	<i>Pteridophyta</i>	0	1	4	2	7	0	0	0	0	14	0	16.27
subdivision	<i>Cycadophytina</i>	0	0	0	2	1	0	0	0	0	3	0	42.85
subdivision	<i>Caniferophytina</i>	0	0	0	1	0	0	0	0	0	1	2	2.50
	total of Gymnosperms	0	0	0	3	1	0	0	0	0	4	2	8.51
class	<i>Magnoliopsida</i>	3	1	30	24	123	7	5	0	6	199	29	4.65
class	<i>Liliopsida</i>	1	0	53	57	84	4	61	0	0	260	13	27.74
	total of Angiosperms	4	1	83	81	207	11	66	0	6	459	42	8.80
	total of seed plants	4	1	83	84	208	11	66	0	6	463	44	8.80
	total of vascular flora	4	2	87	86	215	11	66	0	6	477	44	8.92
	% from total no. of taxa	0.04	0.07	1.63	1.61	4.02	0.21	1.23	0.00	0.11	8.92	0.82	

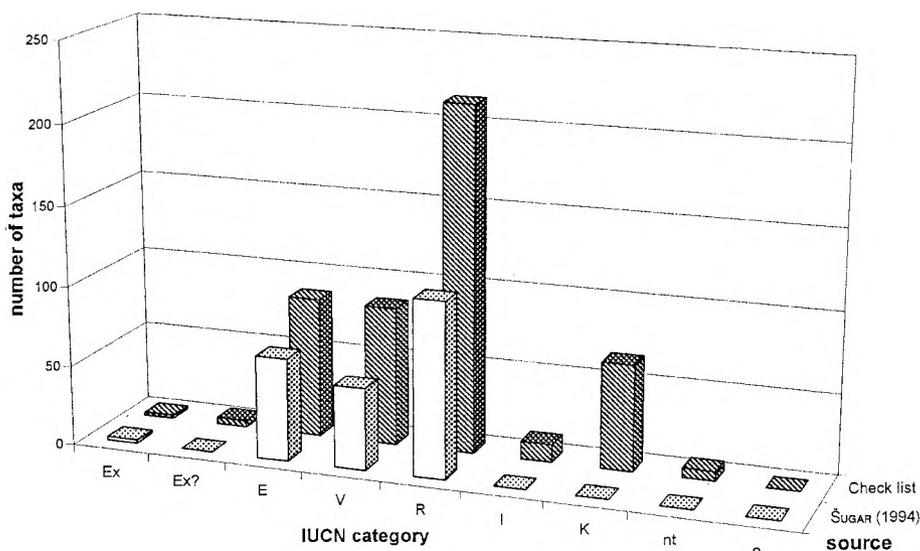


Fig. 5. Comparative display of the amount of threatened species in the »old« Red Databook (ŠUGAR 1994) and the new list published in Checklist of Croatian Vascular Flora (NIKOLIĆ 1994, 1997, 2000 a) (Ex? – probably extinct, Ex – extinct, E – endangered, V – vulnerable, R – rare, I – indefinite, K – insufficiently known, o – earlier endangered, nt – not endangered)

The number of threatened taxa in the Checklist, as compared with the Red book (ŠUGAR 1994), has grown to 251 (4.61%). The category of probably extinct includes four new taxa (?Ex), endangered 23 (E), vulnerable 35 (V), rare 106 (R), indefinite 11 (I), insufficiently known 66 taxa (Fig. 5).

The causes of status changes and obvious differences probably have different sources. One of the sources is definitely a growing anthropogenic pressure on habitats together with a real increase in the number of threatened taxa. The second one is probably defective work in the first Red book. But also probably even the new Red list originating from the Checklist is not realistic. The reason is that the pre-1994 IUCN categories, with their general definitions, have left enough spaces for subjective estimations. On the other hand, the oldness of the available data, our knowledge about natural conditions, the lack of any atlas of distribution, the estimation of population size, the level of habitat endangerment, projections of events in the near future, etc. are either deficient or insufficient, which makes the evaluation of the endangerment of some taxa very general.

The comparison of the treatment of Croatian vascular flora with the treatment of flora in neighbouring countries and areas is given in table 6.

According to new data the number of endangered taxa has risen also in the neighbouring areas. In Austria 1187 taxa are considered as threatened (40.2 %), in Switzerland 773 (32 %), in Germany 906 (33 %), in Bavaria 809 (36.6%), in the Czech Republic 822 (45%), in Slovakia 1037 (41.5%), in Hungary 610 (25.3%) taxa, etc. (NIKLFELD and SCHRATT-EHRENDORFER 1999).

Tab. 6. The number of taxa in Croatian vascular flora and the percentage of total number of taxa with endangered status in some neighbouring middle European areas and countries (sp.+ssp. – species and subspecies together, ssp. – subspecies alone, sp. – species alone, % sp. + ssp. – percent of species and subspecies)

district/state	source	sp. + ssp.	ssp.	sp.	% sp. + ssp. of Croatian flora
Austria	NIKLFELD et al. (1986)	538	8	530	10.06
Baden-Württemberg	HARMS et al. (1983)	604	17	587	11.29
Bayern	SCHÖNFELDER (1987)	660	24	636	12.34
Berlin	BÖCKER et al. (1991)	382	4	378	7.14
Bosnia and Herzegovina	ŠILIC (1996)	454	42	412	8.49
Brandenburg	LINDACHER (1995)	490	9	481	9.16
EU	ANONYMUS (1991)	73	0	73	1.36
Germany	KORNECK and SUKOPP (1988)	480	9	471	8.97
Hungary	HORVÁTH et al. (1995)	389	34	355	7.27
Italy	CONTI et al. (1997)	159	10	149	2.97
Mittelfranken	LINDACHER (1995)	1487	31	1456	27.80
Oberfranken	LINDACHER (1995)	1511	108	1403	28.25
Slovenia	WRABER and SKOBERNE (1989)	379	22	357	7.08
Switzerland	LANDOLT (1991)	513	7	506	9.59
Thüringen	LINDACHER (1995)	408	2	406	7.63
Unterfranken	LINDACHER (1995)	503	5	498	9.40
World list	WALTER and GILLET (1998)	70	1	69	1.31
Yugoslavia (Serbia)	STEVANOVIĆ (1999)	79 (77)	9 (9)	70 (70)	1.47 (1.44)

The data in table 6 demonstrate that 10–30% of Croatian flora are already threatened in neighbouring countries. At the same time, in Croatia, only 8.92% of flora is threatened. Also, according to the new data, neighbouring countries have 2–4 times more threatened taxa. These facts show that the conservation of Croatian flora, with all the inadequacies in status ascription, is better than in our north and north-west neighbours. This does not diminish the need for constant updating of the Red list and the assessment of threat levels. Since the karst area generally demonstrates the most conserved part of national territory, it is in the focus of interest also as the reservoir of flora that in other regions has already suffered more or less from anthropogenic influence.

Ecological indices

Between the multitude of ecological, biotic and abiotic variables, plant species achieve their biomass and occupy their ranges. Depending on the potentiality of each particular ecological variable, i.e. the existence of optimal conditions or some irregularity in them, the species differ. Endeavours to describe the relationship of a taxon to some respective ecological variable, result in ecological indices building. Many of developed ecological indices have been derived for a particular area and are not suitable to be used uncritically in some other. Many species have developed geographically-ecological forms that are not morphologically distinguishable, but which do have different indicator values. Nevertheless, for widely distributed taxa, particularly cosmopolitan taxa, homogeneity of ecological values is great, and changes mostly refer to edges of the range. For some indices, i.e. continentality, life forms, relation to soil acidity, etc., the indicator values have a wider applicability, and the variability in relation to plants is small. The applicability of such taxa as indicators is greater

A review of the availability of ecological indices (developed by various authors and for various areas) for Croatian vascular flora is given in table 7. The table includes even those indices which are unable to be used uncritically outside the area for which they were developed. It can be seen that the data in the best case encompass about 39% of the taxa.

Analysis of Croatian flora on the groundwork of the available data is possible with respect to each of mentioned indices, in spite of all the weakness connected to the usage of particular ones. The complex and demanding task of building ecological indices for all taxa of Croatian flora have enormous practical and scientific potential, and this task is a test that is waiting for some enterprising botanist.

Related data connected with the Checklist

Beside the valid taxa names, the Checklist contains a total of 7673 additional names sorted out in 9 categories (Tab. 8). A total of 7211 are synonyms. To date the number of synonyms in related database is 11234 and still growing.

The question mark »?« in the Checklist means »doubtful taxa«. Doubtful taxa are those taxa which have controversial distribution in Croatia and controversial taxonomic status. The total number of such cases in the Checklist is 241 (Tab. 9). Taxa of this kind clearly stand out as research priorities.

There are 343 taxa registered in cultivation. This number pertains to those plants that are cultivated and bred in bigger acreages and to a considerable extent follow the criteria in

Tab. 7. Availability of ecological indices for Croatian vascular flora (species and subspecies)

ecological index	orig. abr.	author/source	no. taxa	% from total taxa no.
light	L	ELLENBERG et al. (1991)	1744	32.63
temperature	T	ELLENBERG et al. (1991)	1482	27.73
continentality	K	ELLENBERG et al. (1991)	1733	32.42
moisture	F	ELLENBERG et al. (1991)	1684	31.51
moisture dynamics	FX	ELLENBERG et al. (1991)	355	6.64
acidity	R	ELLENBERG et al. (1991)	1480	27.69
nitrogen	N	ELLENBERG et al. (1991)	1628	30.46
salinity	S	ELLENBERG et al. (1991)	1680	31.43
heavy metal resistance	SMR	ELLENBERG et al. (1991)	5	0.09
leaves cover	BA	ELLENBERG et al. (1991)	1762	32.97
phytocenose	SOZIO	ELLENBERG et al. (1991)	1736	32.48
strategy		ELLENBERG et al. (1991)	1349	25.24
life form	LF	ELLENBERG (1979), OBERDORFER (1983)	2071	38.75
anatomy	AB	ELLENBERG et al. (1991)	1459	27.30
moisture	FX_L	LANDOLT (1977)	1929	36.09
acidity	R_L	LANDOLT (1977)	1932	36.15
nutritional value	N_L	LANDOLT (1977)	1932	36.15
humus	H	LANDOLT (1977)	1933	36.16
light	L_L	LANDOLT (1977)	1933	36.16
temperature	T_L	LANDOLT (1977)	1932	36.15
continentality	K_L	LANDOLT (1977)	1929	36.09
soil texture	D	LANDOLT (1977)	1942	36.33
water	F_L	LANDOLT (1977)	591	11.06
haemeroby	HMR	KOWARIK (1988)	1035	19.36
newcomer	EZ	SUKOPP et al. (1982)	1110	20.77
socio-ecological group	SOG	KUNICK (1974)	737	13.79
grazing	FW	KLAPP et al. (1953)	565	10.57
flowering	BZ	ROTHMALER (1987 a,b)	1927	36.05
areal	AREAL	OBERDORFER (1983)	1600	29.93
pollination type	BT	DÜLL and KUTZELNIGG (1986)	589	11.02
distribution	VT	DÜLL and KUTZELNIGG (1986)	684	12.80

Tab. 8. Numbers of invalid names in the Checklist according to types

no.	type	number
1	inclusive	274
2	bazonim	12
3	exclusive	4
4	nomen ambiguum	7
5	nomen illegitimum	72
6	nomen nudum	0
7	pro-parte sinonim	72
8	synonym	7211
9	indefinitely	21
	total	7673

Tab. 9. Total number of doubtful taxa (?), cultivated taxa (cult.) and naturalised taxa (nat.) in main groups

category	name of taxa	?	cult.	nat.
division	Pteridophyta	1	0	0
subdivision	<i>Cycadophytina</i>	0	0	0
subdivision	<i>Coniferophytina</i>	2	18	0
	total gymnosperms	2	18	0
class	Magnoliopsida	177	287	102
class	Liliopsida	61	38	18
	total angiosperms	238	325	120
	total seed plants	240	343	120
	total vascular flora	241	343	120

NIKOLIĆ (1994). As those criteria are not so rigid, the other approaches are also available, so the appearance of new taxa is possible.

The Checklist also quotes 120 naturalised taxa, those which have successfully »escaped« from cultivation, and grows securely in habitats not right beside the place of their cultivation. This category also include taxa introduced by seeds.

Conclusion

The Checklist and related data analysis using CROFlora database shows Croatia to be an area with an exceptionally rich and well preserved flora with a high degree of endemism. These facts, documented for the first time, make work on flora processing an especially responsible and important task even outside the national context. Providing the taxonomic and nomenclatural basis and standard, the Checklist will constitute the grounds for any future practical and theoretical work in various botanical disciplines and in other regions, and finally presents the backbone for a new analytical Flora of Croatia. However, taxonomy and nomenclature is not revised completely in the Checklist. We expect that next revisions and editions, as well as periodical *Notulae ad Indicem Florae Croaticae* (i.e. NIKOLIĆ 1996 b, 2000 b) will contain further amendments. Separately, the necessity for the application of the new IUCN categories to taxa of the Redlist should be emphasized, also work on the evaluation and solving of taxonomical and chorological problems of 241 doubtful and other difficult taxa and groups, development and completion of the ecological index system, and distribution mapping.

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