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The distribution of mosquitoes in Romania (Diptera: Culicidae). Part I: *Anopheles, Aedes* and *Culex*

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Introduction

The first attempt to map the distribution of Romanian mosquitoes (Zotta *et al.*, 1939, 1940) included the malaria vectors of the *Anopheles maculipennis* complex recorded at that time in 284 localities in the endemic area (Martini & Zotta, 1934, Zotta *et al.*, 1939, 1940). This represented an early concept of "malaria stratification" promoted by Zotta (Nicolescu, 1996) relating the distribution of the different anopheline species and the great "malaria lines" (Zotta, 1938). The distribution of these species, including the most important hydrological basins, were presented on maps without grids (Zotta *et al.*, 1943, 1944, 1945, 1946; Ungureanu, 1947; Duport & Athanasiu, 1949; Radacovici *et al.*, 1958, 1959 a, b, 1961; Lupascu *et al.*, 1958 a, b, c). No distribution maps for the genera *Aedes, Ochlerotatus, Culex, Orthopodomyia, Coquillettidia, Culiseta* and *Uranotaenia* had been prepared until now.

The distribution records of the fifty-five mosquito species recorded in Romania (Nicolescu, 1995) were plotted with a Universal Transverse Mercator (UTM) grid system, and the presence of these species in the different ecological zones in Romania is indicated in this paper. Data from published papers and that held by the Medical Entomology Laboratory of Cantacuzino Institute have been used in their preparation. A 10 square km UTM map and a directory of the localities from Romania with their UTM codes (Lehrer & Lehrer, 1990) were used to plot the sites.

Ecological zones

Four of Illies' (1978) European zoogeographical regions, the Carpathians, the Sarmatian (or Hungarian Pusta), the Pontic Province and the East-European Plain meet in Romania. However, because local factors influence the distribution of mosquito species in these four regions, the country was subdivided into fourteen more or less equal zones representing the different geographical/ecological conditions. These zones are:

1. **Oriental Carpathians,** represented by an ensemble of massifs between the northern border and Buzau Valley in the south, maximum altitude 2000 m and separated by deep and quite large depressions. The moderate continental climate (MCC) is influenced by the western European humid winds; the mean annual temperature (MAT) is 0-4°C, reaching 6°C in the main river valleys; temperature inversions appear in the deep depressions in winter (the Gheorghieni Depression has temperatures as low as -33°C); the mean values of annual rainfall (MAR) are 600-1000 mm. Coniferous and deciduous tree forests cover large areas, and there are pasture, hay and agricultural lands (mainly maize fields) in depressions.

2. **South Carpathians,** include the massifs of 2000-2543 m altitude, situated between Buzău Valley and Timiş-Cerna Gorge to the west, and which are separated by narrow gorges and only by a few larger depressions. The MCC is characterised by humid northwestern winds, MAT of 0-4°C (less than 0°C in the alpine area, but reaching 6°C at lower altitudes), and MAR of 1000-1400 mm (more than 1400 mm in higher areas but only 800-1000 mm at lower altitudes). There is a large zone of alpine pasture surrounded by coniferous and deciduous forests at lower altitudes; there are some agricultural lands (especially maize) in the depressions.

3. **Occidental Carpathians (Apuseni Mountains),** situated between Transylvania County to the east and Bihor and Crişana Counties to the west. This area includes massifs and hills of no more than 1000 m in altitude, separated by large, long depressions. The MCC of this area is influenced by the humid western winds; the MAT are 4-8°C (2-4°C in some very small areas) and the MAR 1000-1400 mm in higher areas and 700-1000 mm at lower altitude. The vegetation contains mixed oak and beech forests, and there are many large areas of hay, pasture and agricultural lands (wheat and maize).

4. **Banat Mountains,** an ensemble of massifs and hills with altitudes up to 1000 m situated between the Danube to the south, the Timiş-Cerna Gorge to the east and the Mureş Valley to the north. The MCC is characterised both by the humid western winds and a quite strong Mediterranean influence; the MAT are 6-8°C, reaching 10°C in some places, and the MAR reach 1000-1400 mm (but only 700-1000 mm in some areas). The vegetation and land-use are quite similar to those in the Apuseni Mountains, but there are endemic and Mediterranean plants and animal species present.

5. **Oriental Subcarpathians** include hills of 500-800 m between the Oriental Carpathians in the west, the Siret Valley to the east and the Buzău Valley to the South. This area has a continental climate (CC) influenced by the East European steppe; the MAT are 6-8°C and the MAR only 500-600 mm. The vegetation is dominated by beech and oak forests with some spruce and there are many agricultural lands (wheat, maize), orchards and vineyards.

6. **South Subcarpathians** are 400-800 m hills situated between the Buzău Valley to the east and the Danube Valley to the west. The CC is under the general influence of the East European steppe but there is a Mediterranean influence and some foehn wind effects especially in its western part. The MAT are 6-9°C and the MAR 700-1000 mm. Beech and oak forests, including some Mediterranean species of plants in the west, dominate the vegetation. There are large apple and plums orchards and vineyards.

7. **Subcarpathians of Transylvania** include hills of 500-800 m (the dominant heights being 700-800 m) extending along the western side of the Oriental Carpathians and the northern side of the South Carpathians to the Târnava Mare and Mureş Valleys to the northwest. The MCC is characterised by a MAT of 6-9°C and a MAR of 600-1000 mm. Mixed beech and oak forests are dominant; there are also agricultural lands (wheat, maize and potato).

8. **Western Transylvania** is a territory with hills and tablelands of 400-600 m along the eastern side of the Apuseni Mountains to the Târnava Mare and Mureş Valleys in the southeast. The MCC has some foehn wind influence from the south-west; the MAT are 8-10°C and the MAR 500-700 mm. Essentially, mixed beech and oak forests form the vegetation, but there are very large agricultural lands (wheat and maize fields) and large areas of vineyards and orchards.

9. **Western Plain** of 75-250 m altitude includes Crişana Plain that is crossed by many watercourses along the western side of the Apuseni Mountains and Banat Plain to the south. The MCC is characterised by a MAT of 10-11°C and a MAR of 500-600 mm. There is a steppe and silvo-steppe vegetation, with only few oak forests but with large pastures, agricultural lands (wheat and maize) and vineyards.

10. **North-western Romanian Plain** is the silvo-steppe part of the Romanian Plain with altitudes of 200-400 m, between the Danube to the west, reaching the western limit of the Bărăgan Plain to the east and including the capital city, Bucharest. The CC has a Mediterranean influence in its western part and an East European steppe influence in the rest of the area; the MAT are 9-11°C and the MAR 500-700 mm with a rather irregular distribution in space and time. This silvo-steppe has remnants of the old compact oak forests and includes large agricultural lands (wheat, maize) and many vineyards and orchards.

11. **South-eastern Romanian Plain** is a steppe of 10-100 m altitude including the plains of Oltenia and Muntenia Counties along the Danube and the south of Moldova County to the Covurlui tableland; there are some intermittently flowing streams and, in some parts, areas without watercourses. The CC is influenced by the dominant eastern winds both in winter and summer; the MAT is 11°C or more and the MAR 400-500 mm (sometimes less than 400 mm) with an irregular distribution in space and time. There are large agricultural lands (wheat, maize) usually irrigated and many vineyards; there are also meadows with agricultural lands and some riverine forest along the lower courses of some larger rivers and along the Danube.

12. **Dobrudja** is the territory of 0-400 m altitude between the Danube to the west and north and the Black Sea to the east; there are only few intermittently flowing streams. The CC is influenced by the East European steppe and is quite dry; the moderating influence of the Black Sea appears only on a narrow coastal strip; the MAT are 10-11°C or more and the MAR 400-500 mm on the coast and less than 400 mm inland. This steppe is covered by large irrigated agricultural lands (wheat, maize) and vineyards and by several forests in the north.

13. **The Danube Delta and the lagoon complex**, with an altitude of 0-10 m, is the most humid and lowest land of the country. It includes the territory between the Danube river branches and the area surrounding the Razelm-Sinoe-Zmeica maritime lagoons. The CC is under the same influence as the entire Dobrudja. The MAT are more than 11°C and the MAR 400-500 mm. There are humid lands with meadows, ponds, marshes and meadow riverine forest, and large areas of compact reed beds; there are some agricultural areas in the Delta and outdoor cattle rearing occurs in summer time. The Danube Delta and the maritime lagoons represent a major staging post for migratory birds on their way to and from Africa and northern Europe.

14. **Moldavian Tableland** has an altitude of 150-400 m and is situated between the Siret Valley to the west, the Prut Valley to the east and the lower Valley of Bârlad to the south. The CC of this area is under the influence of the East European steppe winds; the MAT are 8-10°C and the MAR 400-600 mm. The silvo-steppe vegetation is mainly represented by oak and beech forests, and large agricultural lands (wheat, maize) and vineyards.

Zones one to eight are included in Illies' (1978) European zoogeographical Carpathian region, zone nine is a part of the Sarmatian Province, zones ten to thirteen are included in the Pontic Province and zone fourteen is a part of the East-European Plain, each influenced by the characteristics of the European region of which they are part.

Genus *Anopheles*

Seven species of *Anopheles* have been recorded from Romania.

The four species of the *Anopheles maculipennis* complex recorded in Romania, namely *An. maculipennis, An. messeae, An. sacharovi* and *An. atroparvus,* have been identified in over seven hundred and thirty localities of the malaria endemic area (Martini & Zotta, 1934; Zotta, 1938, 1943; Zotta *et al.*, 1940, 1943, 1944, 1945, 1946; Mezincescu & Cornelson, 1943; Ungureanu, 1940a, 1942a, 1947; Duport & Athanasiu, 1949; Sandulescu & Marotinescu, 1957; Radacovici *et al.*, 1958, 1959a, b, 1961; Ungureanu & Ilies, 1959; Lupascu *et al.*,1958a, b, c; Nicolescu, 1999).

The identification of the species of *Anopheles* was performed on eggs obtained from females collected in animal shelters. *Anopheles maculipennis s.l.* (without further identification) has been additionally recorded in about four hundred and twenty other localities (Thalhammer, 1899; Mezincescu, 1904 cited by Bilbie & Nicolescu, 1986; Leon, 1910; Zotta, 1927, 1932; Giurca *et al.*, 1983; Ciolpan *et al.*, 1990, 1998; Velehorschi *et al.*, 1990; Nicolescu, 1999).

The presence of species of the *An. maculipennis* complex has been recorded in all fourteen ecological zones in Romania: *An. maculipennis* and *An. messeae* in all zones and *An. atroparvus* (Fig. 1) in thirteen zones (1-7 and 9-14). The levels of dominance of these three species in mixed anopheline populations are different. *An. messeae* is dominant in the Danube meadow and the floodplain areas of the lower third of the inland river valleys and in the Danube Delta (an area with anophelism without malaria in Romania). *Anopheles atroparvus* dominates the anopheline fauna along valleys of inland rivers where there is no flooding, and *An. maculipennis* is dominant in the hilly areas along the upper courses of the inland rivers.

Anopheles sacharovi (Fig. 2) is the dominant anopheline species only within the area 15-30 km of the Black Sea coast (zones 12 and 13). Until 1962 this was the most malarial area of the country (Martini & Zotta, 1934; Zotta, 1938, 1943; Zotta *et al.*, 1940, 1943; Duport & Athanasiu, 1949; Sandulescu & Marotinescu, 1957; Lupascu *et al.*, 1958c; Ungureanu & Ilies, 1959). The single record outside this area was in a locality with saline waters in zone 11 (Radacovici *et al.*, 1961).

Anopheles hyrcanus, An. claviger and *An. plumbeus* are not known to have transmitted malaria in Romania. Although only found in quite low densities, *An. claviger* (Fig. 3) has been recorded in eight zones (1, 2, 7, 9-11, 13 and 14) (Thalhammer, 1899; Leon, 1908, 1910; Zotta, 1932, 1938, 1943; Ungureanu, 1940a, 1942a, 1947; Sicart *et al.*, 1961; Motas *et al.*, 1962, Giurca *et al.*, 1983, Ciolpan *et al.*, 1998; Nicolescu, 1999).

Anopheles plumbeus (Fig. 4) develops in tree holes and has been recorded from lowland and upland forests situated in plains or hilly and mountainous areas in zones 2, 4, 5, 7, 10, 11 and 14 (Thalhammer, 1899; Zotta, 1932, 1938, 1943; Ungureanu, 1940 a, 1942 a, 1947; Ciolpan *et al.*, 1990, 1998; Nicolescu, 1999).

Anopheles hyrcanus (Fig. 5) has been recorded in zones 10-14, in the Danube Delta, along the Danube and the Prut rivers, and, very rarely, in the plain (Leon, 1908; 1910; Zotta, 1932, 1938, 1943; Martini & Zotta, 1934; Zotta *et al.*, 1944; Ungureanu & Ilies, 1959; Cristescu *et al.*, 1975). A more restricted distribution in the Danube Delta and the Black Sea littoral only has been observed in the last 30 years (Cristescu *et al.*, 1975; Velehorschi *et al.*, 1990; Nicolescu, 1999).

Genus *Aedes*

The genus *Aedes* is represented in Romania by three, possibly four, species.

Aedes vexans (Fig. 6) has been recorded in thirteen zones (1-2 and 4-14) (Thalhammer, 1899; Zotta, 1932; Martini & Zotta, 1934; Zotta *et al.*, 1944; Ungureanu, 1940a, 1942a; Mardare, 1943; Mezincescu & Cornelson, 1943; Sicart *et al.*, 1961; Motaş *et al.*, 1962; Dancescu, 1980; Giurca, 1982, 1984; Ciolpan *et al.*, 1990, 1998; Velehorschi *et al.*, 1990; Nicolescu, 1999) in abundant populations in some periods and areas in both rural and urban ecosystems, where it could be involved in the transmission of West Nile virus.

Aedes cinereus (Fig. 7) has been identified on almost half of the Romanian territory, in zones 1, 7, 9-11, 13 and 14 (Ungureanu, 1940 a, 1942 a; Giurca, 1982, 1984; Ciolpan *et al.*, 1990, 1998; Velehorschi *et al.*, 1990; Nicolescu, 1999), equally in upland and lowland forest areas, but the species is not abundant.

Aedes geminus (Fig. 8), identified until now only from Europe, is present in zones 1, 10 and 11 (Ceianu *et al.*, 1995, Nicolescu, 1995, 1999) together with *Ae. cinereus*, but its distribution range in Romania may be wider than currently recorded. It seems that Romania represents the most southern part of Europe where this species is recorded until now.

The presence of *Ae. esoensis rossicus* is uncertain in Romania, where there is a doubtful record from one locality in the north of zone 1 (Mihalyi, 1959, Nicolescu, 1995).

Genus *Culex*

Eight, possibly ten, species of *Culex* have been recorded in Romania.

Culex pipiens, including its autogenous form *molestus*, is ubiquitous (Thalhammer, 1899, 1902; Leon, 1910; Zotta, 1932; Zotta *et al.*, 1944; Ungureanu, 1940a, 1942a, b; Mezincescu & Cornelson, 1943; Ungureanu & Ilies, 1959; Sicart *et al.*, 1961; Motas *et al.*, 1962; Dancescu *et al.*, 1975; Giurca *et al.*, 1983; Giurca, 1984; Ciolpan *et al.*, 1990, 1998; Velehorschi *et al.*, 1990; Nicolescu, 1999). This species is the vector of West Nile virus in rural and urban microfoci in the south of Romania (Nicolescu, 1998). Another representative of this genus, presumably involved in the transmission of West Nile virus in natural ecosystems is *Cx. modestus* (Fig. 9), recorded in seven zones (7, 8 and 10-14) but not in mountainous areas (Leon, 1910; Zotta, 1932; Martini & Zotta, 1934; Zotta *et al.*, 1944; Ungureanu, 1942a, b; Mezincescu & Cornelson, 1943; Ungureanu & Ilies, 1959; Giurca, 1984; Ciolpan *et al.*, 1990, 1998; Velehorschi *et al.*, 1990; Nicolescu, 1999).

Culex territans (Fig. 10) has been recorded in eight non-mountainous zones (5, 7-8, 10-14) in very low densities (Zotta, 1932; Zotta *et al.*, 1944; Ungureanu, 1942 a; Giurca *et al.*, 1983; Giurca, 1984; Ciolpan *et al.*, 1998; Nicolescu, 1999). *Culex theileri* (Fig. 11) has been found only in the plains in zones 10-14 (Zotta, 1932; Ungureanu & Ilies, 1959; Giurca, 1984, Nicolescu, 1999) and *Cx. hortensis* (Fig. 12) in plains, hills and mountainous areas in zones 2, 6, 10, 11 and 14 (Zotta, 1932; Ungureanu, 1942 a; Sicart *et al.*, 1961; Motas *et al.*, 1962; Giurca, 1984). Both species appear to be present as small populations.

Culex torrentium (Fig. 13) (Nicolescu & Velehorschi, 1988) and *Cx. martinii* (Fig. 14) (Nicolescu & Velehorschi, 1988; Ciolpan *et al.*, 1990; Velehorschi *et al.*, 1990; Nicolescu, 1999) have been found in three zones, the first species in zones 2, 10 and 12, and the second in zones 10, 11 and 13. *Culex torrentium* larvae are always found in association with larvae of *Cx. pipiens*.

Culex laticinctus (Fig. 15) was recorded only in the northeastern zone 14 (Zotta, 1932; Ungureanu, 1942a) and two other species, *Cx. mimeticus* and *Cx. impudicus* (Sicart *et al.*, 1961; Motas *et al.*, 1962) remain uncertain records for the Romanian Plain (Nicolescu, 1995).

References

A full listing of the references given in this article will appear in the second part of this paper.

Figures 1-15. The distribution of mosquitoes in the different ecological zones in Romania.

The zones are:

1. Oriental Carpathians, 2. South Carpathians, 3. Occidental Carpathians, 4. Banat Mountains, 5. Oriental Subcarpathians, 6. South Subcarpathians, 7. Subcarpathians of Transylvania, 8. Western Transylvania, 9. Western Plain, 10. North-western Romanian Plain, 11. South-eastern Romanian Plain, 12. Dobrudja, 13. The Danube Delta and the lagoon complex, 14. Moldavian Tableland.

Anopheles maculipennis, *Anopheles messeae* and *Culex pipiens* are present in all zones and hence maps are not provided for these species.

Maps are not provided for *Aedes esoensis rossicus*, *Culex mimeticus* and *Culex impudicus* as these are uncertain records.

List of figures:

Figure 1

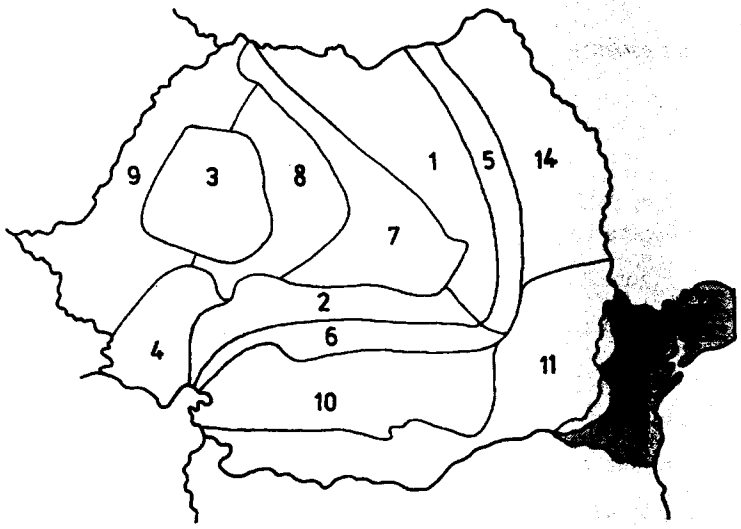


Figure 2

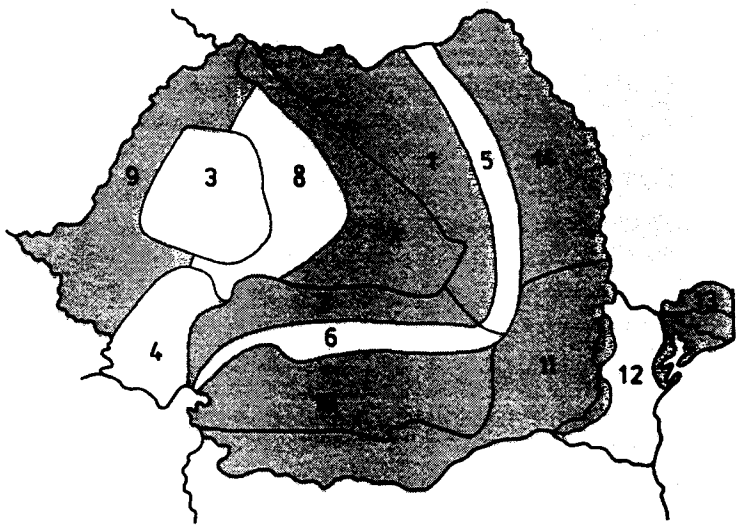


Figure 3

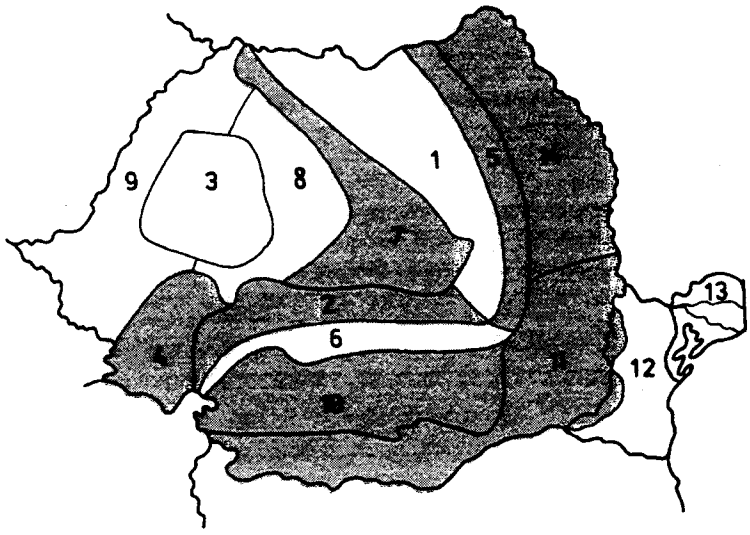


Figure 4

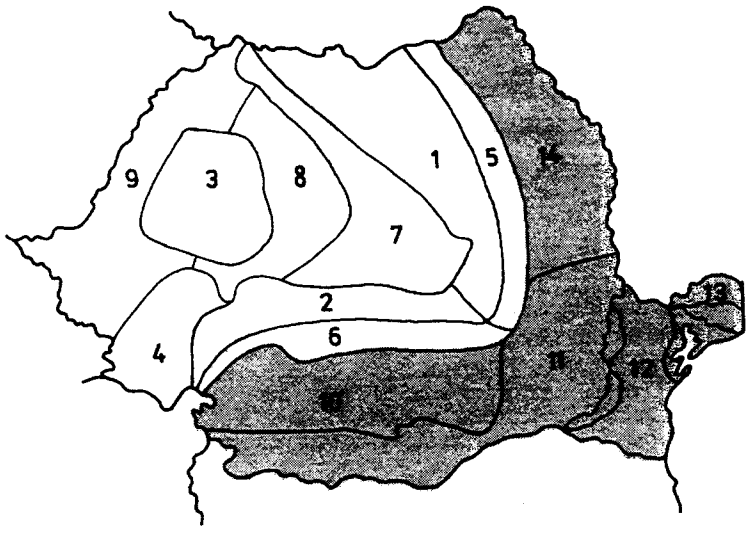


Figure 5

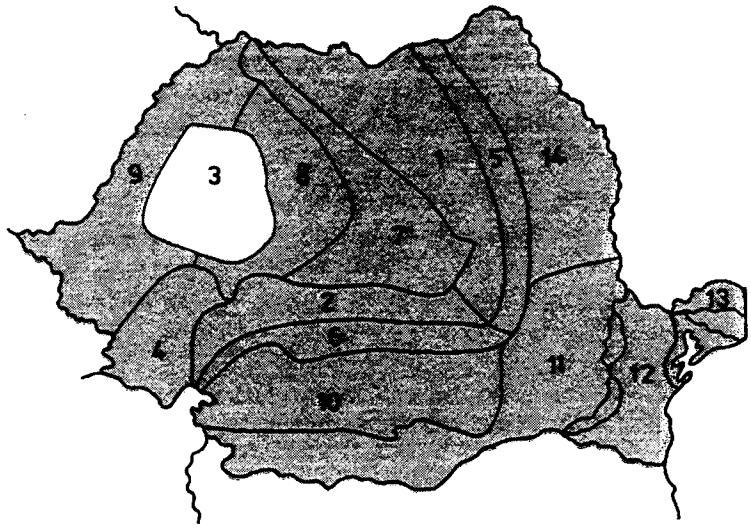
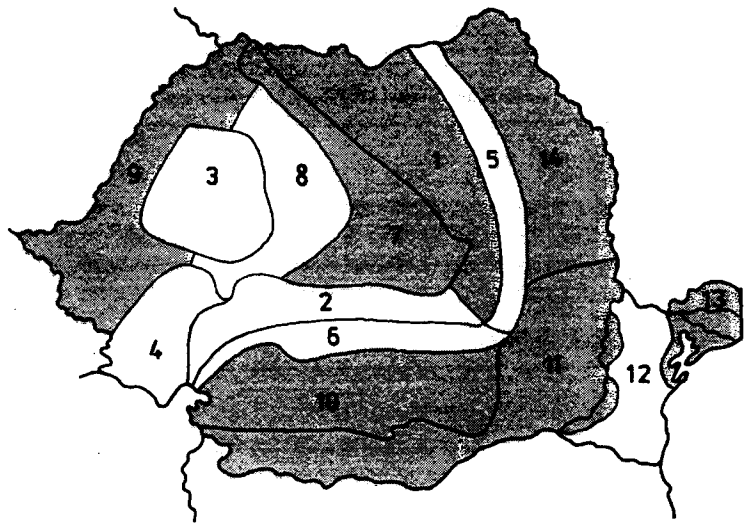


Figure 6



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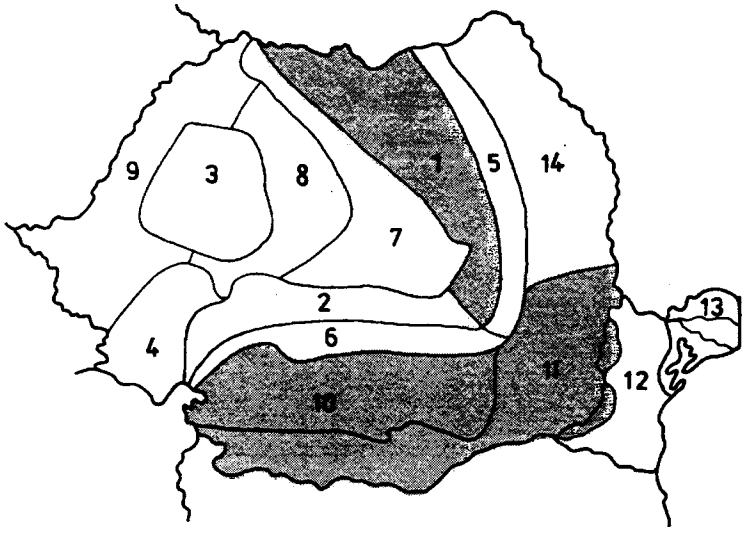

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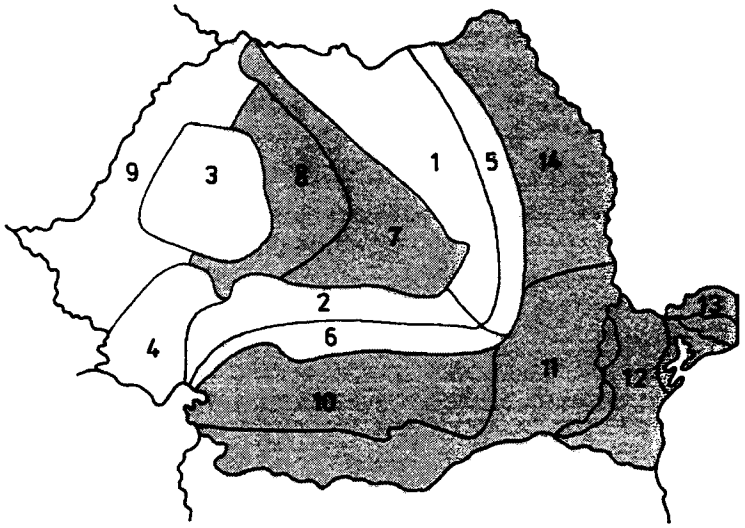


Figure 9

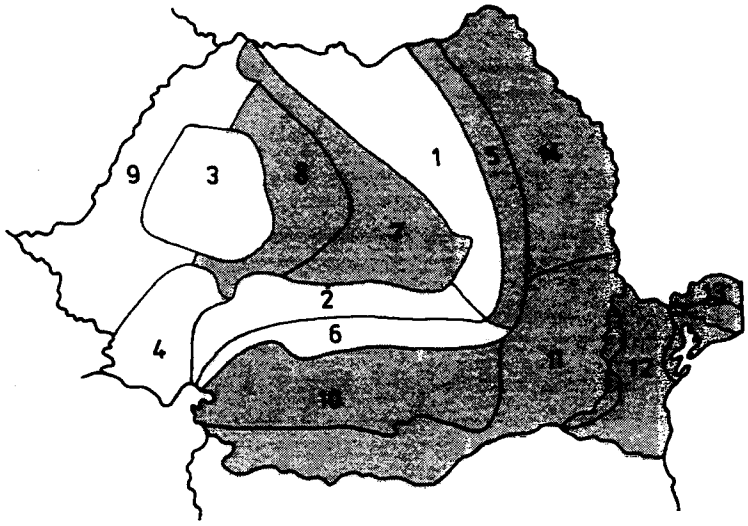


Figure 10

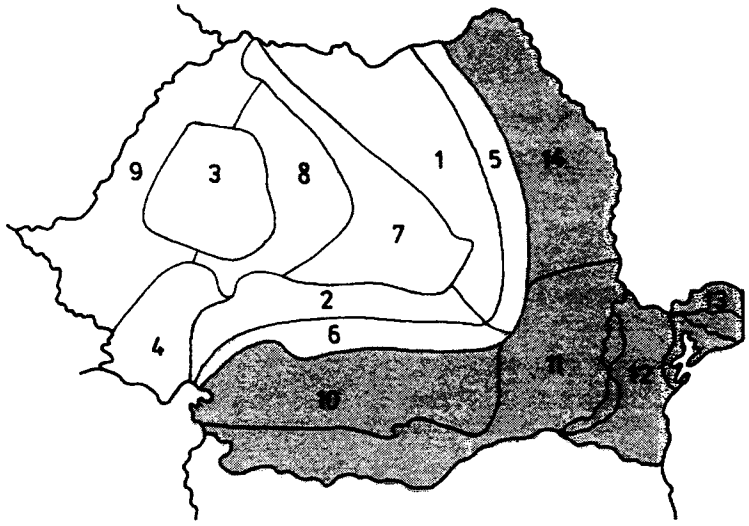
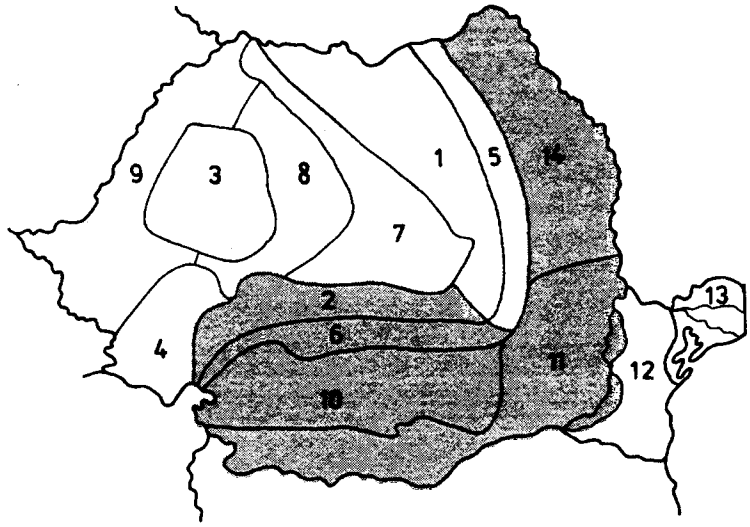


Figure 11



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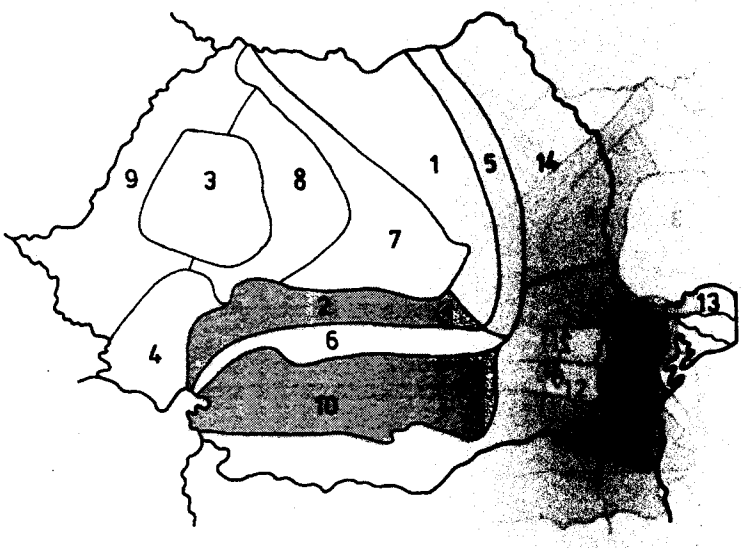

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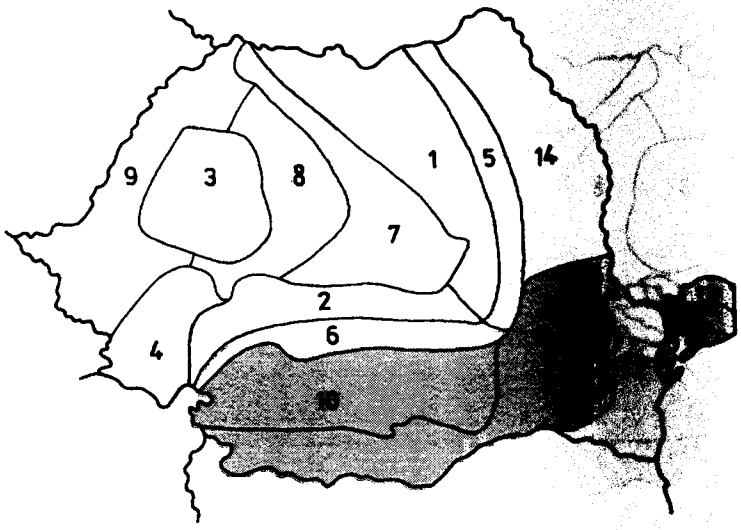

Figure 14

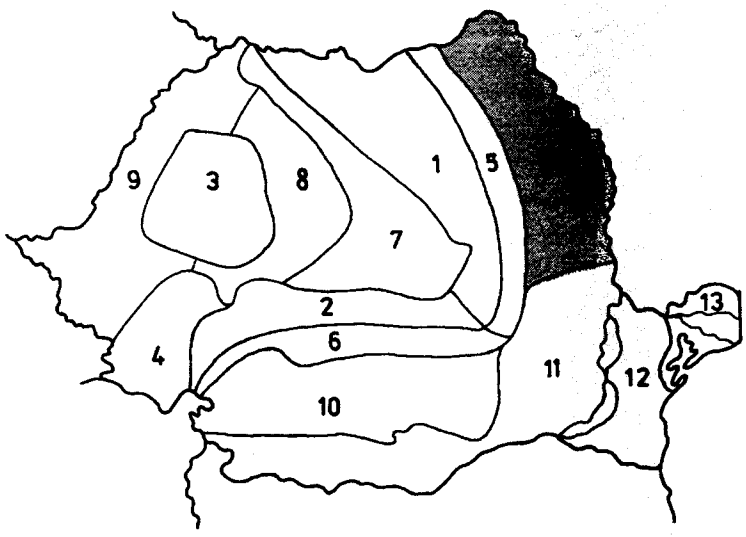

Figure 15