Ecology of the Danube, with particular reference to waterfowl in Lower Austria

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Introduction (Plates IV and V, between pp. 48 and 49)

Research into the biology of a river is much rarer than into that of a lake, not only from an ornithological but also from a limnological point of view. After the Neusiedlersee, the Danube is the most important Austrian water area for waterfowl. The former is exceedingly important as an area for breeding, resting and passage, yet has hardly any waterfowl in winter (Festetics and Leisler 1968); the free flowing river, on the contrary, forms the only possible wintering place for many species. The basis for the following work is the winter counts instigated by the International Wildfowl Research Bureau. Although it has been shown that the Austrian section of the Danube is of international importance for certain species of birds, only a 128 km. stretch in Lower Austria, the transition from the upper course to the middle course, will be dealt with thoroughly. This stretch seemed suitable for ecological comparisons and to serve as a testing area over the years. It is first necessary, however, to sketch the most important biographical characteristics of the total course of the river, using data of the International Research Group for limnological research of the Danube from 1956 onwards (Liepolt 1967; Valkanov, Russev and Naidenow 1968).

PART I. THE DANUBE AS A WHOLE

The Danube is, after the River Volga, the second longest river in Europe and the only one that flows eastwards (WNW.-ESE.). It crosses 22 degrees of longitude, and runs through no less than eight States. Of its 2,858 km., 2,578 km. (80%) are navigable, although sea-going vessels can only sail as far as Budapest (1,639 km.). It has approximately 120 tributaries (of which about 34 are navigable) coming from totally different climatic regions. The river characteristically carves into the right bank after each narrowing, depositing vast mud flats through which the river branches. These are to be found after the breach through the Sauwald into the Eferdinger Basin, after the Linzer breach into the Machland, after the Wachauer Pforte into the Tullnerfeld, after the Wiener Pforte into the Lobau, after the Ungarischen Pforte into the Schüttinseln, after the Ungarischen Mittelgebirge into the Csepel-Insel and after the Eisernen Tor into the Calafat region.

A. Course (Figure 1)

Hardly any other river can be so clearly divided into three stretches of almost equal length. The 900 km. long Upper Danube reaches from the source down to the Porta Hungarica, with an alpine catchment area; the 925 km. long Middle Danube is delimited by its entry into, and exit from, the Karpathenbecken, and by its crossing of the Pannonicum area; finally, the 885 km. long Lower Danube reaches from the Eisernen Tor down to the mouth, thereby touching the Balkans. The Danube is the only European river that is measured backwards from the mouth (km. 2,858 lies at Furtwangen in the Black Forest, for the real source of the Danube is not in Donaueschingen (km. 2,810) as it is generally thought).

The Upper Danube in Germany is a summer cold brook in its mountain region. In this highest section (up to km. 2,750) occurs its steepest gradient, 101 cm./km. In Austria it becomes an alpine mountain stream, considerably narrower and more regulated, with a gradient of 50 to 40 cm./km. The river so far is characterized by a continual movement of coarse boulder detritus. While the flooded plain in the mountain region is narrow even at highwater, it can be 1 to 5 km. wide. The normal widths in this sector are 40 to 95 m. between Ulm and Regensburg (km. 2,379), 224 m. at Passau (km. 2,203) and 300 m. at Pressburg (km. 1,873). The height of the banks is 3 to 4 m. The Danube river has the greatest water capacity in Europe. It pours 203 milliard cu.m. of water into the Black Sea every year. At Passau the average rate of flow is 673 cu.m./sec., at Vienna (km. 1,925) 1,920 cu.m./sec. The river's depth is on average 5 m. at Passau, 3 m. at Vienna, but in general in the Upper Danube it is 8 to 12 m.

The Middle Danube includes a small part of the hill region and about half the flat region. At Gönyü (km. 1,791) there is a striking decrease of the river's

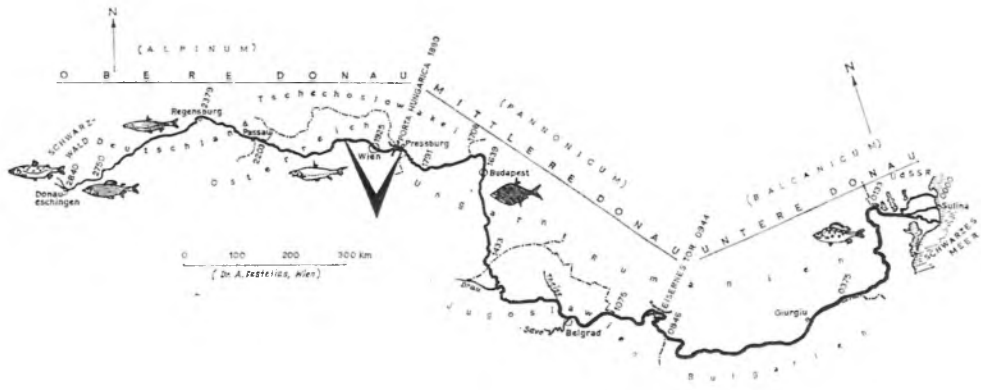

Figure 1. The course of the River Danube. The six fish represent, from source to mouth, the respective regions of Trout, Grayling, Nasling, Barbel, Bream and Pope (see p. 45). The arrowed section indicates the Lower Austrian counting stretch (see p. 50 and Figure 2).

gradient to only 6 cm./km., characteristic for the Pannonicum section. Only at the end of the Middle Danube, in the Katarakten stretch (km. 1,040-0,941) does the gradient increase again to 28 cm./km. From Vienna down to the Eisernen Tor the Danube is already characterized by many sedimentary islands, which are, in part, covered with rich vegetation. In many places the Middle Danube shows the most original landscapes on both sides of the Hungarian border, in the area of the sedimentary islands (from Pressburg to Gönyü) and along the Mohacs island (about km. 1,433), with water meadow belts of 8 to 10 km. wide. To the south of the Hungarian-Yugoslavian border, down to the mouth of the Drave there is a flood area of 35,000 hectares. After the slackening of the strong current, 0.8 to 1.1 m./sec. in the Hungarian lowland, the bottom has more gravel and sand. After crossing the Porta Hungarica the width of the river, when flowing through the Little Hungarian plain, broadens to 300 to 450 m. After narrowing at the Donau-Knie the river takes a north-south course and widens to the south of Budapest in the Great Hungarian plain, where it has an average water-flow of 3,300 cu.m./sec. and a width of 562 m. (km. 1,639). Later in its course it has steep loam, clay or mud banks of 1 to 6 m. In the second (Yugoslavian) part of the Middle Danube the river gets its greatest inflow from the tributaries Drave, Theiss and Save. The width of the river after the Theiss mouth is 600 m. At the Yugoslavian-Rumanian border, which is formed by the Bazias river (km. 1,075), the river is squeezed between cliffs having a sub-Mediterranean flora and fauna. Its narrowest stretch is in the Eisernen Tor (km. 944) with a width of 151 m. and rock gorges up to 240 m. deep. Here the current picks up speed to 5 m./sec. and a maximum depth of 70 m. is reached.

The Lower Danube comprises the second half of the plain area, along the Rumanian-Bulgarian border, and the extensive delta area in Rumania. The gradient lessens from 3.9 cm./km. to only a few mm./km. As a steppe river with a normal width of 800 to 1,800 m. it crosses the Wallachei, where during high water it can frequently flood over 5 to 10 km. At the middle stretch between Giurgiu (km. 480) and where it leaves Bulgarian territory (km. 375) its average width is 3,500 m., the average depth 7.5 m. and the speed of the current 1.1 m./sec. Over 100 sedimentary islands, flooded at high water, are a characteristic. Turning to the north the Danube flows through the Balta district, a wide, amphibious belt of subtropical character, an expanse of water 20 km. wide at high water, including all its tributaries. The so-called 'Lacus' Danube lakes are typical of the flood plains of the left bank along almost all the Lower Danube. They include:

(1) independent spring-fed lakes with a total area of about 7,300 hectares and a maximum depth of 3 to 4 m.;

(2) ox-bow lakes and dead river branches with depths of 9 to 10 m.;

(3) river 'limane' which were formed by pleistocene incursions of the sea and

by overflowings of the Danube cut off by sand bars.

In this region there are two high water periods during the early and late spring when up to one million hectares are flooded. A feature of this landscape is its succession of extensive sand dunes, woods, marshes and reed areas and the rows of lakes connected by canals. Finally the delta area in the Dobrudscha forms an equilateral triangle with sides of about 70 km. Here, three main branches enclose a flood plain of 500,000 hectares. Every year, because of the great amount of sedimentation, the middle (Sulina) branch pushes the delta 70 to 80 m. into the brackish Black Sea. Along its extensive lower course, the Danube loses, through evaporation and into the marshes, lagoons and limane, as much water as it receives from the lower tributaries. So its waterflow is just the same as at the Eisernen Tor, 900 km. upstream.

B. Regulating Works

Until the first half of the nineteenth century the Danube was a strongly meandering river with large numbers of side streams, dead river branches, islands, peninsulas and wide flood plains. In the second half of the century, two million of the 2,800,000 hectares of land liable to flood were reclaimed. Because of this regulation the current greatly increased and the water table sank with the rapid deepening of the river. Exchange of nutrients between the dead river arms and the river was also prevented, the most important result from the point of view of biological productivity. The second main alteration is the present building of dams in the river. The first such dam was the Bavarian one at Kachlet (km. 2,230) in 1956. In Germany, eight hydro-electric plants already exist, and a total of 24 have been planned. In Austria there are four in existence and altogether 14 have been planned. A total of 59 will eventually exist along the length of the river.

C. Ecological factors

The river is, in contrast to a lake, an open system, yet limnological terms such as littoral (bank area), benthal (bottom area) and pelagic (free water area) can be used for both (Ruttner 1962). The most important ecological factor, from the point of view of waterfowl, is the water's speed. Turbulence also changes during its course, because of projections of the banks, gravel and sand banks as well as objects in the river bed, which frequently cause whirls and eddies, not to be found in a lake. Turbulence is also the cause of the high oxygen content; an oxygen deficit only occurs in places polluted by Man. Owing to turbulence, approximately the same temperature will be found at any point of a cross-section, though, of course, a continuous rise in temperature is to be noted along the river's length. In contrast to this, equality of temperature in a lake is only possible after complete circulation in autumn and spring. Because of the strong current in the river little ice-formation occurs. It starts first in the slow flowing parts where mud particles act as crystallizing centres. The floes then grow together from beneath into a solid covering. The freezing over of the river takes 20 to 40 days, the thawing 12 to 15 days. The river is frozen for the least time at Melk (km. 2,036) with 14.2 days and the longest at Braila (km. 170) with 38.9 days. Stretches with exceptionally heavy ice formation are the Bavarian Danube, the sector between Aschach and Linz (Upper Austria) and the stretch between Vienna and Budapest. Light transmission is generally good owing to the relative shallowness and the lack of organic matter. However, it is poor, owing to mineral turbidity, in both the upper and lower courses. This has a direct influence on diving waterfowl. The sequence of various geological sedimentary terraces is characteristic of the Danube. The type of bank, a great part of which is man-made stone slopes, quays and groynes, is a crucial ecological factor. Rows of groynes were built to narrow the river and deepen the channel. In the bends of the river the banks are steep on one side and slope gently on the other, with a stagnant water area. On the steep side the bank is eroded by the main stream and eddies occur. Ice floes crowd together here. On the sloping side, sand and gravel is deposited and waterfowl may feed and rest. River barrages not only serve the production of electric current, but are an essential part of the regulation of the river. They improve water management and the navigability of the river and act as natural purification works. The dams increase the surface area and the depth, and reduce the speed of the current. An impoundment is not on a par with a lake from the limnologist's point of view (Reichholf 1966). The river impoundment lacks stratification, its pelagial is devoid of organisms, and there is no great variation in temperature. The relatively high water temperature near the bottom, together

with the high oxygen content cause a rapid conversion of deposited organic matter.

D. Flora and fauna

Current and detritus pressure do not allow the growth of floating or rooted vegetation; the sparse growth is limited to the banks. River plankton can only develop when the average speed of the current is 0 to 1 m./sec. Moreover, only after the spring high water will the formation of a plankton of this type occur, which is characteristically represented by diatoms. The typical forms are *Cyclotella*, *Melosira* and *Stephanodiscus* (Wawrik 1962). With a reduction in the speed of the current and an increase in eutrophication there is an increase in blue-green algae *Cyanophyceae* and green algae *Chlorophyceae*. Like phytoplankton, zooplankton is generally poor in species and number. Rotifers are typical, with *Brachionus* dominant. The strips of forest that grow along the alluvial banks are the most productive of all European woods. Depositing of organic matter occurs mainly in the dead water of old river arms. Decomposition may be incomplete and under extreme conditions can lead to the formation of flat peatland. Silting (inorganic matter, sand and mud) in the area of the slow-flowing branches offers sites for various pioneer vegetation. As there is so little light in these waterside woods, many climbing plants are to be found, such as guelder rose *Viburnum opulus*, hop *Humulus lupulus*, wild vine *Vitis vinifera*, honeysuckle *Lonicera*, *Physalis* and woody nightshade *Solanum dulcamara*. Deposition of organic matter and silting also leads to the formation of water meadows. Low water meadows are formed in the immediate proximity of the river and are flooded for a lengthy period every year, which causes over-fertilization and also prevents the roots from getting any air. Further silting raises the ground and enriches the soil, leading to the development of high water meadow, still within the reach of the flowing ground water, but flooded only occasionally and then for short periods. Willow *Salix* spp. and poplar *Populus* spp. are characteristic of the low water meadow, and ash *Fraxinus excelsior*, elm *Ulnus* spp. and oak *Quercus* spp. of the high water meadow. These water meadow woods are distinguished by their great ecological instability. The second botanical characteristic of the river is the islands in the delta area, built up out of floating plants rooted in a mass of reed rhizomes *Phragmites communis*, about 90 cm. thick, which have become rather peatlike, rising and falling with the water level. This is not strictly a marsh because the plants do not root in the ground.

Of the vertebrates, fish can be used as indicators of the ecological regions of a river, namely Brown Trout *Salmo trutta*, Grayling *Thymallus thymallus*, Barbel *Barbus barbus*, Bream *Abramis brama* and Pope *Acerina cernua*. The 'Trout region' is rich in oxygen, with very fast-flowing cold waters and large boulders. The next region downstream, the 'Grayling region', has banks with a fringe of water plants but still a small volume of water. In the 'Barbel area' the brook has grown into a river with warmer water and deposits of sand and pebbles but no mud. The 'Bream area' has leafy vegetation because of a great nitrogen deposit, often poor in oxygen, with sand and silt on the bottom. The 'Pope area' is the most varied one, with a maximum water temperature and volume, a minimum speed and a very muddy bed. The Danube shows a division into three parts, the mountain, hill and plain districts, covering two fish regions each, for in our case an extra region, the 'Nasling region' *Chondrostoma nasus*, can be distinguished in between the 'Grayling' and 'Barbel' regions. The mountain district includes the 'Trout' and 'Grayling' regions. The hill sector covers the 'Nasling' and 'Barbel' regions. The plains sector is also called the 'Carp' region on the Danube, as it is especially characteristic for Carp *Cyprinus carpio*. It includes the 'Bream' and 'Pope' regions.

Shoalfish that occur in the greatest numbers and are therefore important as food for the waterfowl are Bleak *Alburnus alburnus*, Chub *Squalius cephalus*, Zährte *Vimba vimba*, Silver Bream *Blicca björkna* and Roach *Rutilus rutilus*. The Danube takes a midway position between the Western European rivers (like the Rhône or the Rhine) with Trout (*Salmonidae*) and Bullheads (*Cottidae*) and the Eastern European rivers (like the Volga or Don) with Carp (*Cyprinidae*) and Sturgeon species (*Acipenseridae*).

Along the total length of the river the Common Sandpiper *Tringa hypoleucos* and the Little Ringed Plover *Charadrius dubius* are characteristically typical pluvial forms. From Ottensheim in Upper Austria (km. 2,150), where the water meadow belt begins, downstream we find isolated colonies of Grey Heron *Ardea cinerea*, from the Tullnerfeld in

Lower Austria (km. 2,000/1,974) the Cormorant *Phalacrocorax carbo*, the Black Kite *Milvus nigrans* and the River Warbler *Locustella fluviatilis* breed. From Vienna (km. 1,925) down, the Saker Falcon *Falco cherrug* breeds and so did the Thrush Nightingale *Luscinia luscinia* in the last century, and the Rook *Corvus frugilegus* and the White-tailed Eagle *Haliaaetus albicilla* a few decades ago. The last two species still breed regularly on the sedimentary islands of the Czechoslovakian-Hungarian Danube sector (from about km. 1,860 down). Here the first colonies of the Night Heron *Nycticorax nycticorax* are also to be found. In the vicinity of the Hungarian-Yugoslavian border (about km. 1,433) the Black Stork *Ciconia nigra* and the Lesser Spotted Eagle *Aquila pomarina* breed; in the mouth area of the Theiss (about km. 122) the Little Egret *Egretta garzetta*, Squacco Heron *Ardeola ralloides* and the Olivaceous Warbler *Hippolais pallida* breed. The Pygmy Cormorant *Phalacrocorax pygmaeus*, as an indigenous breeding bird, is characteristic of the district of the Lower Save (about km. 1,140). For the Balta and Dobrudscha region (from about km. 180 down) the following birds are typical: the White Pelican *Pelecanus onocrotalus* and the Dalmatian Pelican *Pelecanus crispus*, Mute Swan *Cygnus olor*, Shelduck *Tadorna tadorna*, Ruddy Shelduck *Tadorna ferruginea*, Glossy Ibis *Plegadis falcinellus* and Spoonbill *Platalea leucorodia*, as well as a lagoon fauna of Black-winged Stilt *Himantopus himantopus*, Pratincole *Glareola pratincola*, Gull-billed Tern *Gelochelidon nilotica* and Slender-billed Gull *Larus genei*.

PART II. THE AUSTRIAN DANUBE

The River Danube is of great importance for the waterfowl in Austria, it being the only large water area that is open in winter. The 350.5 km. long Austrian stretch (Pietschmann 1939) from km. 1,872 to km. 2,223, is well delimited by the alpine river Inn and the pannonic March. In this course it shows a total drop of 156 m.

A. Course

Below the mouth of the Inn at Passau, the Danube cuts through the wood-covered slopes of the Bohemian Massif with a deep-lying valley, about 300 m. wide and with many exaggerated meanders. Here, at Jochenstein (km. 2,203), is the first Austrian power station. Then follows the entrance to the Eferdinger Becken, with the second power station, at Aschach (km. 2,163). Thereafter water meadows of 1 to 2 km. wide accompany the main river down to the mouth of the Traun. Next, the Danube flows through a wide valley with spurs of the Bohemian Forest on the left and gravel terraces of the Alpine foreland on the right. The latter widens to the Machland along the long Upper and Lower Austrian border, a vast gravel deposit at the southern edge of the 'Mühlviertels', formerly often covered with moorland pastures. Recently the Wallsee power station (km. 2,093) was put into operation. The Danube leaves Upper Austria through the crystalline rocks of the Strudengaues, a narrow valley with steep rock ridges and, formerly, feared whirlpools, which were cleared away between 1777 and 1791. In general, the Danube follows the precipices of the left bank in an easterly direction from Ybbs to Melk, beginning at the great power station of Ybbs-Persenbeug at km. 2,060, which was temporarily included in our waterfowl counts. From Melk to Krems it flows in a north-easterly direction through a narrow valley in the Wachau, which has a very beautiful landscape. From the Wachauer Pforte (km. 2,001) the Danube, formerly greatly ramified, flows through the Tullnerfeld, on the left bank of which the water meadows and dead branches may have a width of 3 km., and comes, after breaking through the outgoing parts of the Wienerwaldes (Wiener Pforte km. 1,939), into the Weiner Becken, with the plain of the Marchfeldes. With the mouth of the March on the left bank and passing through the Ungarische Pforte (km. 1,880), the river leaves Austria.

For the greater part of the Austrian stretch the Danube has the character of a mountain river/stream, with a maximum water flow in summer (June) and a minimum in winter (October to December). There is an obvious correlation between the melting of the snow in the Alps and the degree to which boulder detritus is carried along. The main maximum in March is caused by the melting of the snow in the relatively low drainage area, from the mountains of the Schwäbischen Alb to the Bayerischen Wald. The melting of the snow in the high drainage area of the Alps, however, causes a sub-maximum in July. The Danube owes its mountain river character especially to the Inn. Before the confluence it is still a lowland stream, then with double the water passage, it becomes

an Alpine river which is cold and turbid. One million tons of debris are transported each year. The river bed is continually moving, which makes it impossible for anything to grow except along the banks in a narrow belt of 3 to 8 m. The current's speed is 2.2 to 2.5 m./sec. Until the beginning of summer the water temperature is about 15°C., rising on a few days in mid-summer with low water level, to about 20°C.; the average is 15° to 18°C. Fourteen days is the yearly average with ice-floes. The average water flow is 1,600 cu.m./sec. Although the Danube is the main sewage drainage for 1,705,000 people from the towns along the river, the quality of the Austrian stretch is relatively good. The width of the river at the Wiener Pforte is 285 m. on average, 1,000 m. at high water. The average depth of the water there is 6 m. The difference between extreme low and high water is 7 to 8 m.

B. Regulation

Formerly the Danube spread into three branches before Vienna. The smallest on the right is now the Donau-Kanal, the middle one formed what is now the Kaiser-Wasser and the left, the Floridsdorfer Donau, was the main stream. Most of the work in regulating the Austrian Danube was done between 1850 and 1927. It was exceptionally drastic in the Vienna area, where the stream is now straightened and embanked. Formerly, after breaking through the Wiener Pforte, it spread into many branches between islands with large water meadow woods and meadows. These branches used to be most important spawning places for fish during the spring high water period. Between 1869 and 1874 the Alte Donau and many other branches were cut off. Many of these were filled in and only the deeper places still exist today. From 1885 to 1889, the Hubertus dam was built between Bisamberg and Floridsdorf to prevent the overflow of the high water into the Marchfeld. In the same period dredging took place at shallow places and groynes were built. While these past operations resulted in an increase in the speed of the current, the power stations have just the opposite effect. In the vicinity of the power station the enlargement of the cross-section brings the speed of the current down from about 2.5 m./sec. to 0.4 m./sec. Besides the four existing power stations, all of which were built in the last 15 years, another eleven have been planned along the Austrian stretch. Some of these will affect the following biologically valuable environments: the Grey Heron colony at Ottensheim (km. 2,145), an exceptionally well-structured water meadow environment for several waterfowl species at Grafenwörth (km. 1,985), the Grey Heron colony and deer environment at Petronell (km. 1,890), and the mouth of the March with its pannonic water meadow at Wolfsthal (km. 1,872).

C. Biotope

Five environments can be recognised:

1. The river. The Danube in Austria can be considered a waterway which is poor in food material and oligotrophic. The production of plankton is low and, in addition, can decrease even more as a result of the influence of nitrogen, which causes serious poisoning of the phytoplankton, as for instance in the Linz area. The production of plankton is increased by organic fertilization, as downstream from Vienna. In Vienna itself it may result in algal blooms. The groynes are important bank structures which, have major functions as resting sites for example for Cormorants, and as slack water areas for grebes, diving ducks and mergansers, and as feeding areas.

2. Dead waters that have been cut off from the river. They are important production areas because of the rich growth of underwater plants, floating plants, sedges *Cyperaceae* and reeds, and are thus important resting and feeding sites.

3. Impoundments. The most important ecological factor is the reduced gas exchange of the water with the air. The mud lacks oxygen but this is offset by the river water, rich in oxygen, passing over it. Notwithstanding the depth (10-15 m.) visibility is good because of the sedimentation. The new plant/animal growth in the depths is opposed by a sharp retrogression in that of the bank. Impoundments are characterized by an increase in animals coming to feed, an increase in fish production and a decrease in migratory fish. Frequently a tenfold increase in production will take place; Einsele (1957) counted 100,000 individual animals per cu.m. According to Weber (1961) the biological production at Ybbs-Persenbeug is 124 to 218 gm./cu.m., which corresponds with that of the Lower Danube in Bulgaria. Many plants grow in the calm shallow places of the impoundments.

4. The water meadow woods along the Austrian stretch are usually cut off from the river by a sandy bank with poplars.

Those of the western stretch and the narrow places are chiefly low water meadows (Wendelberger-Zelinka 1952). We only find the high water meadow well developed in the Tullnerfeld and east of Vienna (Marchfeld). The low water meadows, with a growth of willow, offers the bird world a rich supply of food and shelter, but rather little possibility for nesting. However, the intermediate phases and the high water meadows offer nesting, resting and feeding sites because of the pronounced stratification (the undergrowth being intertwined with lianas), the lack of long-lasting floods, the abundance of large and small hollows and especially because of the loose park landscape with 'edge effect' in the vicinity of water. A peculiarity of the Austrian water meadow woods, especially in the pannonic sector, are the so-called 'Heisslands', dry places that occur like islands and show characteristics of a steppe (dry shrubs with hawthorn *Crataegus monogyna*, privet *Ligustrum vulgare*, sea buckthorn *Hippophae rhamnoides*, black poplar *Populus nigra*, the roses *Rosa micrantha* and *canina*, and grasses, like upright brome *Zerna erecta* and the fescue *Festuca pilosa*). They were especially encouraged as the ground sank during the regulation of the Danube. In the last century the use for forestry was small, but as hunting grounds the water meadow woods were greatly valued and often fenced. Only during the last few decades have several fast growing species of tree been planted, which give a considerable yield. This led to a great change because of the introduction and promotion of ash, willow and especially the hybrid black Italian poplar *Populus* × *canadensis*. The short growth cycle and deforestation severely disturb the water meadow wood and encouraged the infiltration of goldenrod *Solidago serotina*.

5. The meadows that have been formed by mowing, have oat-grass *Arrhenatherum elatius* and cock's-foot *Dactylis glomerata*, besides the yellow thistle *Cirsium oleraceum*. The most typical are swamp meadows that are still flooded once a year, while dry meadows were formed after a warmth-loving water meadow wood had been cleared.

D. Fauna

The following forms of invertebrates have importance in biological production and as food for waterfowl. Because of the unstable river bed we find hardly any organisms on the bottom except near and along the banks. These form exceptionally good environments, because the bank growth is very uniform with water mosses, like *Fontinalis*, *Fissidens*, *Hygrohypnum* and *Hygramblystegium*. Here, only current-loving (rheophile) forms can develop, with about ten kinds of flatworms, for example *Planaria torra* and *Dendrocoelum lacteum*. The areas near the banks also form important refuges for young fish. It is precisely these bank areas, which are so important biologically, which are being greatly endangered by waste water and sewage and in places show devastation or accumulation of dirt organisms, as the sewage is sucked out of the pipes into a narrow strip along them. Important animals used as food are the larvae of stoneflies (Plecoptera, 10 species, for example *Perla*) that predominate especially in the Austrian Danube above Vienna, of mayflies (Ephemeroptera, 7 kinds) and of caddis flies (Trichoptera, especially *Hydropsyche*). At the sewage outlets there is an accumulation of the mollusc *Radix peregra* and the zebra mussel *Dreissena polymorpha*, which have only immigrated quite recently and have come as far as Ingolstadt (Germany). In all, 10 mollusc species are to be found. On the stones of the bank we find the leeches *Herpobdella octoculata*, *Haemopis sanguisuga* and the shrimp *Carinogammarus roeselii*, all especially near sewage outlets; in these places the crustacean *Asellus aquaticus* is also very common in the mud. Richer animal life is to be found at the bottom of the reservoirs. Besides the sewage forms, the following are to be found on sand and mud, the crustacean *Gammarus pulex*, blood worms *Tubifex* and pea shells *Sphaerium*. On the rock detritus are the leech *Glossosiphonia*, larvae of the caddisfly *Rhyacophila*, stone-flies and mayflies. Partly in the river, but especially in the tributaries and dead waters there are many molluscs, like *Limnea ovata* and *L. auriculata*, *Vivipara fasciata*, *Valvata*, *Ancylus*, *Neritina danubialis*, *Theodoxus fluviatilis*, *Lithoglyphus naticoides*, and great numbers of *Unio* and *Anodonta*. In the mud, chironomid larvae are to be found in great abundance. The zooplankton is also well developed with masses of *Cyclops strenuus* and *Bosmina longirostris*, of which up to 13,000 per litre can be found in May (Grohs 1943). In the dead waters the phytoplankton also shows a vertical stratification. Of the vertebrates, the fish fauna in particular has changed with the regulation. Before regulation there was a sharp boundary at Vienna where the pontic species never crossed

the Upper-Middle Danube border. This was caused by the fact that this reach came as far as the mouth area of the Miozän. Remarkably, this invisible boundary remained until only recently, in that the Danube was inhabited by Trout and Miller's Thumb to the west of Vienna and mostly by Carp and Sturgeon *Acipenser* spp. to the east. A hundred years ago at Vienna there was still a regular catch of Huchen *Hucho hucho* on one side and Sturgeon *Acipenser huso* and Sterlet *Acipenser ruthimus* on the other. Nowadays in fishing, the Pike *Esox lucius* occurs in the greatest numbers in the dead waters. Fish present in large numbers in the Austrian stretch are the sedentary forms like Silver Orfe *Idus idus*, Bream and Chub, besides the migratory forms like the Barbel and the Nasling, and the Bleak, Rudd *Scardinus erythropthalmus* and Roach (Balon 1962). Of the amphibia, the Common and Swamp Frogs *Rana temporaria* and *arvalis* are typical and very numerous in the water meadows. Of the reptiles only the Tesselated Snake *Natrix tesselata* is to be looked upon as an aquatic form. Of the mammals—besides the amphibious small mammals—the Red Deer *Cervus elaphus* is worth mentioning as a characteristic Danube ecotype. Of the birds we will first mention some characteristic ones, though it must be said that no bird species are typical of the Danube. The following species no longer breed along the river: Little Tern *Sterna minuta*, Stone Curlew *Burhinus oedicnemus*, White-tailed Eagle, whose last eyrie (1960) was in the water meadow region of the Lobau, Purple Heron *Ardea purpurea*, Roller *Coracias garrulus* and Bee-Eater *Merops apiaster* (Marschall and Pelzeln 1882). Nowadays, only very few breeding pairs are to be found of Common Tern *Sterna hirundo* in the Upper Austrian Machland, Kingfisher *Alcedo atthis*, Cormorant and Saker Falcon. Finally, mention must be made of *Laro-limicolae* in passage and 12 breeding colonies of Grey Heron totalling about 130 pairs.

E. Web-footed birds

Here, brief statements are made about the breeding populations, which refer to the whole of the Austrian Danube, and winter populations ascertained by means of the 'mid-winter counts' of the last three years. The counts on our experimental stretch, worked thoroughly for five winters, will be dealt with in Part III.

1. Breeding stock along the Austrian Danube

No quantitative research on the breeding ducks of the Danube exists so far, and there are also gaps in our qualitative knowledge. The breeding population is characterized by the great lack of diving ducks; Ferruginous Duck *Aythya nyroca*, which could be found breeding at Vienna until the turn of the century, is not now to be found; there is only a suspicion of breeding on the March. Of the dabbling ducks, Mallard *Anas platyrhynchos* are the commonest. They breed in large numbers at all suitable places from water meadows around Linz, their great adaptability being useful in choosing a nesting place. As a new phenomenon they have noticeably increased on the impoundments, especially those upstream. Teal *Anas crecca* are sporadic breeders in the water meadow forest areas of the Upper Austrian Danube, the meadow bogs area of the Machland, and other places in the Danube valleys (Firbas 1962). They bred in great numbers between Vienna and Hainburg until the nineteen-twenties, then decreased sharply (Abensperg-Traun 1960). Although this species does not exist in the pannonic part of Lower Austria, it has recently been identified as a sporadic breeder along the March. Gadwall *Anas strepera* bred between Vienna and Hainburg until 1920. In the years after, a decrease occurred around Petronell (km. 1,890). Garganey *Anas querquedula* breed sporadically along the Lower Austrian and probably also along the Upper Austrian Danube and in the Machland. Shoveler *Anas clypeata* were rare breeders near Vienna in the first half of the last century; Abensperg-Traun (1960) still called this species a rare breeder at Petronell in 1932. Its status nowadays is unknown. Pintail *Anas acuta* are occasionally suspected of breeding along the Lower Austrian Danube and bred sporadically in the Upper Austrian Machland around 1930. The last three species bred here only as an exception, the decrease of the first three species is an effect of the Danube regulation. Cormorants *Phalacrocorax carbo sinensis* find here, in contrast to the Neusiedlersee area, the desired combination of breeding-trees in quiet woods, and water feeding areas. This species breeds frequently only to the east of the Wachau, in the Tullnerfeld. Occasionally, nesting occurs further west, for example at the Enns-Traun mouth (Upper Austria) in the years 1944-54 (Merwald 1955). Of the

grebes, only Little Grebes *Podiceps ruficollis* are typical breeders of the water meadow. Coots *Fulica atra* breed in the dead waters with reed growth.

2. *Winter conditions on the Austrian Danube*

The stretch of the Danube in Austria forms a remarkable inland concentration area during wintertime for three species. Mallard number about 10,000, the mid-January values being: 1967, 9,122; 1968, 9,641; and 1969, 9,701. Of these, 82% were in Lower Austria. The greater numbers there can be explained by the greater availability of food and the larger areas of suitable living space (gravel banks, dead river branches) to the east of Vienna in the pannonic district. Goldeneye *Bucephala clangula* numbers were 628, 1,239 and 1,326 in the three winters. Of these 99% were in Lower Austria. The Danube flows more slowly through the plains of the Tullnerfeld and the Marchfeld, between banks with a richer structure, both factors that are favourable for the feeding of the Goldeneye. The Goosander *Mergus merganser* concentration is one of the most renowned and easterly on the Continent. Values of 169, 420 and 551 were recorded, 85% in Lower Austria.

PART III. WINTER WATERFOWL POPULATIONS ON A STRETCH OF THE LOWER AUSTRIAN DANUBE

The counting of waterfowl throughout the winter along the Danube round about Vienna (Festetics 1968) was the first large co-operative work of this kind. These 'national' counts were carried out on the days appointed by the International Wildfowl Research Bureau every month during the winter half year since 1963-64 along a 128 km. stretch in Lower Austria. Leisler (1964) gave a provisional report; the detailed analysis of the results of the last five years (1964-65 to 1968-69) has been made by Scherzinger and Böck (in press).

A. Methodology

A river is an open system, so a new method was used, distinct from that used in counts on the Rhine (Kramer 1964), Elbe (Dien and Lippert 1965) and the Moldau (Urbanek 1962). There is relatively good going along the Lower Austrian Danube, and river kilometre signs, conspicuously situated on the banks for shipping, enable exact locating. In order to obtain maximum synchronization and comparability, eleven counters covered the river from Krems to Wolfsthal, so that each counter had to walk along 10 to 15 km. of bank. Each observation was registered while in the field, with a note about the location on the river (correct to 100 m.), the time in the case of larger concentrations, the birds' behaviour and the constitution of the banks. In order to avoid double counts, it was noted whether the birds passed the counter flying upstream or downstream. The total of the separate species follows from the sum of all the stationary birds plus those flying in the direction the observer was going, but minus those flying in the opposite direction. The total errors did not exceed 15%. In addition to the counts made from the banks, control trips were made with an assault boat. Restless bird species, like gulls, cormorants and White-tailed Eagles could then be followed at 40 to 60 km./hour, small species which often stay hidden in bays, like grebes and individual ducks, could be located, and finally, in cases of unfavourable light, those parts which are difficult to see from the bank could be examined (with the motor turned off).

B. The counting stretch (Figure 2)

Our experimental stretch forms the last part of the Upper Danube, where the river changes from a mountain stream into a lowland stream while passing through the Vienna Gap, with a decrease in the river's gradient. As a result the river's carrying capacity drops perceptibly and we find here one of those big sedimentations which occur downstream of each such narrowing. This switch is also apparent in the plant and animal distribution, because of which it is advisable to draw the biological border of the Middle Danube, and with it also that of the Pannonicum, further to the west near Vienna instead of coinciding it with the geographical border (Porta Hungarica). This stretch is most varied in landscape, from the impoundments and the steep mountain slopes in the west, via the large industrialized city of Vienna in the middle, to the pannonic lowland in the east.

We divide the counting stretch into three sections: the 62 km. long West section from Krems (km. 2,001) to Klosterneuburg (km. 1,939) which in spite of the effluents of two chemical factories

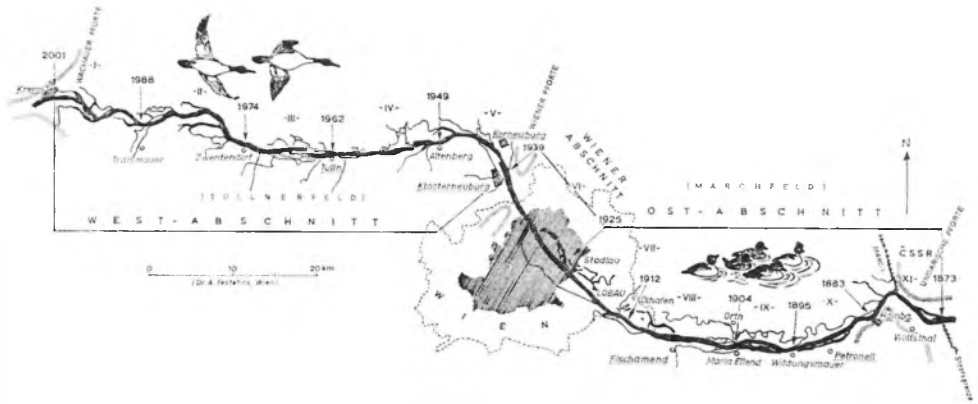

Figure 2. The Lower Austrian Danube counting stretch.

in Krems and Zwentendorf has water of biological quality grade II. Following Liepolt (1967) we can distinguish seven grades from I to IV with intermediate stages. The water deteriorates suddenly over the 14 km.-long Vienna section, between Klosterneuburg and Stadtlau (km. 1,925), as the Danube canal and nine main sewage canals together bring 4,325 cu.m. of waste water per second into the Danube. This leads to such a strong eutrophication and pollution that the Danube takes on the quality grade IV. Almost all sewage pipes empty directly into the Danube without any purification. As a result this sector is the most polluted of the total course of the river. This effect continues at least 20 km. into the 52 km.-long East section from Stadtlau down to the border (km. 1,873), and the lowest oxygen content and the highest phosphate and nitrate values are found at about Haslau (km. 1,901). For more sensitive species of food animals (for example mayfly larvae) a stretch 30 km. downstream from Vienna can be considered as being poisoned. The next stretch down to Wolfsthal generally shows values between II and III. Locally, however, especially along the left bank the situation is made worse by the outlet of the Russ-Bach (quality grade IV) and the March (quality grade III to IV). This pollution is mainly a result of the oil refineries and sugar factories of the Marchfeld. Oil especially enters at high water. Almost every year between October and December there is fish mortality in the March. This difference between the two sections of the river around Vienna is illustrated by the distribution of birds adapted to certain types of food: in the West section are found birds fishing by diving for healthy fish, like the Osprey *Pandion haliaëtus*, Kingfisher and terns. The East section mainly accommodates birds like the White-tailed Eagle, the larger gulls, Rooks and Hooded Crows *Corvus corone cornix*, which find a rich feeding ground in sick and dead fish and in the refuse.

In the Vienna region, the river picks up speed significantly (2.5 m./sec.) in an artificial channel, then follows the old course below Vienna. The high water level is reached in June and reaches its minimum between November and February. The average water flow is 3.8 million litre/sec., the slowest at Vienna 245,000 litre/sec., the fastest 10 million litre/sec. According to Scherzinger and Böck (in press), the rising of the water is slowest in the region of dead rivers and abundant water meadows downstream from Vienna, which helps to stabilise the waterfowl population. When the dead waters and the bays freeze over, only the ice-free current of the river remains for the ducks. At high water the first species to be forced out are those preferring shallow, calm water, like Teal (but also Goosander, Tufted Duck *Aythya fuligula* and Pochard *Aythya ferina*). The most important disturbance factor is the river traffic, the Danube being navigable for an average of 300 days. The prevailing banks are sloping, built up with rough cut stones; only in the town area have they been smoothed by plastering. In the Vienna area, industrial works and storage yards extend along the right bank, while along the left bank is a 450 m. wide flooding area, where a second artificial Danube channel will be built to ensure absolute security. Rough banks are mainly found after the Vienna Gap and especially after confluences. The vegetation of our counting stretch is exceptionally rich in four areas, where vast

and undisturbed water meadows and dead rivers accompany the river. These are at Zwentendorf (km. 1,974), at Stockerau (km. 1,949), at Marie-Ellend (km. 1,904) and at the March mouth (km. 1,879). These water meadows, especially below Vienna, are two to three km. wide along the left bank, while to the right is only a narrow water meadow strip, squeezed between the river and 30 to 40 m. high, steep cliffs.

C. The waterfowl species

As in our work on waterfowl of the Neusiedlersee (Festetics and Leisler 1968) we again will include in this term all species which are 'swimming' species. The 39 species discussed here, which form an ecologically well-characterized group, are representatives of the families Gaviidae (3 species), Podicipidae (5 sp.), Phalacrocoracidae (1 sp.), Anatidae (29 sp.) and Rallidae (1 sp.). In the group of Anatidae are 2 swans, 7 geese, 7 dabbling ducks, 10 diving ducks (in a broad sense) and 3 mergansers. They will be grouped according to their frequency or their ecological importance to the region, and they will be described according to the situation during the counting period between November and March (5 counts).

Group A: birds to be found regularly and in large numbers (over 100), see Table I.

1. Mallard *Anas platyrhynchos.*

This has a maximum of 7,000 to 15,000. It is the dominant species of our stretch and accounts for about 92% of the total waterfowl population in November, 94% in December when it reaches its maximum, 85% in January, reducing to about 75% in March. The aggregate counts of the Mallard counted in the five winter periods 1964-65 to 1968-69 (5 counts each time) and the maximum in each winter are shown in Table I. In addition, the Ybbs-Persenbeug reservoir to the west of our counting stretch holds a flock of 4,000 per winter, and the dead waters of the Danube at Vienna an average of 4-5,000. The maximum figures for the latter region are 1,300 to 1,500 between December and March. It is clear that this species reaches its peak in the height of winter (December to January), which justifies the timing of the international mid-winter counts. This also holds for Goldeneye, Goosander and Tufted Duck (see below). The fluctuations of Mallard along the Danube below Vienna are exactly opposite to those in the Seewinkel 20 km. away (Festetics and Leisler 1968). Early in November the number of Mallard along the Danube is still quite insignificant; while by the end of the month it rises considerably. Around mid-December (after the frost period has usually set in in Seewinkel, where the small shallow lakes freeze solid) as many as 5,500 birds can be counted at a point below Vienna. In mild winters this concentration at the mouth of the Fischa amounts to 2,500 to 2,800. The decline of the winter population usually begins by the end of January, only exceptionally does this species reach a maximum in February. The month of March is marked by a rapid decrease.

The total counts for the five winters can be divided among the three sections of our count stretch already mentioned, the West, Vienna and East sections, though these are, of course, not of an equal length. The percentages distribution is shown in Table II. The stretch between the Schwechat and Fischa mouths accommodates 28% of the total Mallard population. Here we find the ideal combination for this adaptable omnivorous species of large rubble flats as resting sites with a water rich in food. Above Vienna, only three constant large concentrations exist, all distinguished by a similar favourable combination of resting site and feeding site, below Krems, above

Table I. Aggregate and maximum counts of waterfowl wintering regularly and in large numbers (Group A) on a stretch of the Lower Danube, 1964-65 to 1968-69. The aggregate total is the sum of five counts each winter.

	1964-65		*1965-66*		*1966-67*		*1967-68*		*1968-69*	
	Agg.	*Max.*	*Agg.*	*Max.*	*Agg.*	*Max.*	*Agg.*	*Max.*	*Agg.*	*Max.*
Mallard	20558	7484	18028	11502	13216	8509	24959	11137	27769	13359
Goldeneye	3065	1191	1773	984	1035	593	2973	1204	2741	1328
Goosander	459	268	495	324	282	157	661	339	973	425
Tufted Duck	512	197	217	147	88	82	483	331		
Pochard	207	110	143	131	96	71	376	120		
Teal	258	81	227	136	250	106	260	88		

Traismauer and below Klosterneuburg. Interesting changes in resting sites of the Mallard at the time of an average water height (November) and at the time of the ice-drift (January) were shown by Scherzinger and Böck (in press). The shallow waters and reservoirs frequented by 52% of the Mallard freeze and then the ducks are forced to rest on sand and rubble banks (rising from 28% to 66%), the movement generally being favoured by the simultaneous dropping of the water level, making extra rubble flats available. Ice floes and ice along the edges are also used as resting sites, while the stone slopes hold constant numbers (11% in November and 13% in January).

Table II. Distribution of the commoner waterfowl species in the three counting sections of the Lower Danube, shown by percentages of total aggregate counts for the winters 1964-65 to 1968-69.

	West Section (above Vienna)	*Vienna Section*	*East Section (below Vienna)*
Length of section (km.)	62	14	52
Mallard	45	2	53
Goldeneye	63	2	35
Goosander	72	1	27
Tufted Duck	12	83	5
Pochard	34	46	20
Teal	97	1	2
Little Grebe	69	3	28

Mallard have a very specific type of feeding behaviour on flowing water, the 'conveyor belt'. They let themselves be carried along by the current, searching for food from the surface and then fly upstream again, only to let themselves be carried down again. Often up-ending occurs, especially near the banks and in shallow waters and impoundments, and they also feed by swimming with their heads under water, wading, or from loose floating ice-floes. The sewage drainage of the city greatly benefits the Mallard, especially because the refuse (particularly kitchen refuse) floats on the surface. An important food source may be the floating seeds of sedges *Cyperaceae* and pondweeds *Potamogetonaceae*. The Mallard also feed extensively on mollusca, especially *Dreissena polymorpha*.

Mallard have established themselves in the Vienna town region in the past ten years, showing clear signs of self-domestication. The birds will breed in the smallest parks and are fed all through the year. Especially in the winter, densely crowded flocks of several hundreds are found on the dead river branches of the town region. Of these ducks a minority are full-winged domestic ducks with the appearance of an eastern Asiatic race. They have longer bodies, the brown breast colouring continues irregularly along their sides, and the plumage is very variable. During the winter they will tolerate people within a metre or two.

2. Goldeneye *Bucephala clangula.*

One thousand to 2,000 birds reaching in the middle of winter a share of 13 to 15% (March) of the waterfowl population of the Lower Austrian Danube (Table I). A striking immigration begins in the last third of October, only exceptionally is the peak reached in December, and the population falls off very gradually in March. Mild winters are marked by a strikingly low population. The distribution pattern (Table II) is probably due to the insect larvae, on which the birds prefer to feed, being sensitive to pollution. Another factor could be the greater number of groynes on the West section. This species rests only in the shallow waters and impoundments and usually feeds in the vicinity of the banks. Stomach analysis of four specimens from the Danube showed the main food to be larvae of crustacea, such as Gammaridae, and stone-flies. The latter could come from the littoral zone, the former mainly from the bottom.

3. Cormorant *Phalacrocorax carbo.*

The third most numerous species, 500 to 700 occurring along the Danube between November and March. The totals of the five counts for winter 1964-65 were 873; 1965-66, 332; and 1966-67, 176. By the end of December the last big flocks of the species are seen. Much larger numbers may be seen during migration, outside the main counting period, for instance 946 birds in March 1965. Around this time they occur regularly in the relatively clean section, rich in groynes and dead river arms, between the water pollution zone of Vienna and the no less polluted mouth of the March. Here, at Sections X and XI, there are two roosting sites on old, high poplars on the left side, one along the Austrian bank with about 250 birds, and one along the Czechoslovakian bank with 400 to 600. As resting sites, however, the stone groynes and rubble banks are preferred. As purely

fish-eating birds they hunt mainly for bigger Cyprinidae, especially 20 to 40 cm. long Rudd, with a day's ration of up to 1 kg. per bird. These migrants, like the Austrian breeding population, are usually classed under the continental race *P. c. sinensis.*

4. Goosander *Mergus merganser.*

Total counts of 300 to 600 (Table I). The mid-winter percentage of the total number of waterfowl of the Danube reaches 5%, in the middle of March. The species appears in the middle of November, reaches a maximum in January, decreases slightly in February, and reaches a migration peak in March. Those present from the middle of March to the beginning of April considerably outnumber the maximum winter population. Their numbers are, however, difficult to determine, as the main flock withdraws into the calmer and now ice-free dead river arms. This species reflects very precisely the weather and the water level, with low numbers in mild winters and at high water. The preponderance of Goosanders west of Vienna (Table II) results from the water there being unpolluted, the quantity of live fish being much greater, and the presence of many groynes. For resting sites this species makes few demands, using shallow water and reservoirs, rubble and sand banks, and occasionally ice. The main food is 10 to 20 cm. long Cyprinidae; Keve (1969) also found Sturgeon *Acipenser* sp. up to a length of 35 cm. as being taken in the adjoining Hungarian section of the Middle Danube.

5. Tufted Duck *Aythya fuligula.*

This species numbers about 100 to 200 birds (Table I). The fast flowing water is unsuitable as a feeding site for these diving ducks. The values in Table I refer to the river to which the birds also moved from the Vienna dead river arms. Individuals stay to the end of April. Migration is hardly noticeable. Table II shows a striking phenomenon, namely that the lion's share of this species concentrates on the 14 km. long Vienna section. This can be explained by its commensalism with Man. In the Vienna town region the dead river branches, totally separated and stagnant waters, have been converted into sporting areas and swimming pools. Here the Tufted Duck are abundantly fed by the people. In this case they profit by their adaptability (Busch 1964) and their talent for safeguarding bits of food from the sponging Black-headed Gulls *Larus ridibundus* (Scherner 1967). Because of underground springs, parts of the water areas generally remain unfrozen. Flocks of them move to the river and seek their food there mainly below sewage inlets. It is clearly an omnivorous feeder, with a slight domination of molluscs in its food.

6. Pochard *Aythya ferina.*

This is represented by about 100 birds (Table I). The maximum values fluctuate from December to February. By the middle of November as many as 150 birds can be counted at the Old Danube and the record for this region was 310, at the beginning of February. The population decreases in March when a clear but weak migration can be noticed. The Pochard shows a somewhat similar division pattern to the Tufted Duck (Table II).

7. Teal *Anas crecca.*

About as numerous as Pochard (Table I). The constant size of the small winter population is striking. A site on sector I (between Krems and Traismauer) accounts for more than half (53%) of the total population, thus explaining the distribution shown in Table II. Here dead river branches lie in a district rich in water meadows on the right hand bank. The West section is more suitable for this species which avoids human settlements (Bezzel 1963), because of the numerous river mouths and the absence of towns or villages. The principal food is especially the floating plant seeds in the dead river branches, next to the animal food from the silted bottoms. As resting sites this species prefers stagnant water and it is exceptionally sensitive to high water and the ice break-up.

Group B: birds to be found regularly but in smaller numbers (less than 100)

1. Coot *Fulica atra.*

The maximum is 70 birds. They are difficult to record, as most stay on the dead river branches except when these freeze. The aggregate for 1964-65, 125; 1965-66, 8; and 1966-67, 58. The winter population in Vienna on the Old Danube, where the birds are fed by the people, appears when the frost sets in an early winter (on 13.11.66 there were 1,603 birds in Vienna) and remains unchanged until the middle of February. Along the river proper a few small flocks will occur only in severe winters. The food in the river is floating plant seeds, especially near the groynes and banks, submerged vegetation in the dead river arms and, according to Keve (1969), in the Hungarian Danube stretch

also molluscs and fish spawn. They prefer firm ground as sleeping sites, often in the company of Black-headed Gulls. Our winter populations are extremely small in comparison with those of the Voralpenseen. A not insignificant migration occurs over our area (Keve 1969).

2. Little Grebe *Podiceps ruficollis.*

Winter numbers are very variable. In the winter 1964-65 the aggregate was 93; in 1965-66, 60; and in 1966-67, 18. The maximum count was 55 in March 1965. The preponderance above Vienna (Table II) can be explained by the many river mouths and groynes. Sector II (Traismauer-Zwentendorf) holds nearly a third of the total. Within the East section, sector VIII (Ölhafen-Maria Ellend) has 18% of the total. As resting sites the shallow waters, reservoirs, groynes and river mouths are mainly used.

3. Red-breasted Merganser *Mergus serrator.*

In the winter 1964-65 an aggregate of 16; in 1965-66, 49; and in 1966-67, 51. The maximum count was 35 in February 1967. From that it follows that larger numbers of the species in the area (about 50) are only migrants. The first observations date from the middle of October, the migration and general maximum follows in mid-November. A clear decrease follows in December, in January and February there are only a few. The spring migration takes place in March and often extends into the middle of May. This species occurs regularly along the river, though there seems to be a preference for stretches with many groynes. Individual winter visitors show surprising constancy in the sites they occupy on the water.

4. Smew *Mergus albellus.*

In the winter 1964-65, an aggregate of 88; 1965-66, 20; and 1966-67, 17. Peak counts were 35 in January and February 1965. The very first appear as early as the middle of November. The numbers increase slowly and reach a maximum in February, departure occurring in March. The relative depth of the river (shipping channel) determines its distribution.

5. Great Crested Grebe *Podiceps cristatus.*

In the winter 1964-65 an aggregate of 14; 1965-66, 8; and 1966-67, 28. Maximum: 23 in January 1967. Migration in November and beginning of December. They are mainly found in areas with groynes, river bends and river mouths.

6. Red-throated Diver *Gavia stellata.*

In 1964-65 a maximum of 5 birds in November; 1965-66, 7 in November; 1966-67, 2 in November.

7. Black-throated Diver *Gavia arctica.*

The maximum numbers, always in November, were in 1964-65, 6; 1965-66, 4; and 1966-67, 2. The migration begins by the end of October and continues until the middle of December, reaching its maximum by the middle of November. Under certain circumstances, 10 to 15 birds have been counted. According to Keve (1969) they will eat, on the Danube, fish and molluscs. They prefer to search for their food close to the banks.

8. Velvet Scoter *Melanitta fusca.*

The species is a winter visitor in varying numbers. In mild winters they are only represented by a very few individuals, as in the winter 1965-66, aggregate 24. Yet the maximum of this species lies in December with about 20 to 25 specimens, and as an exception, 46. This species is found on the stretches with groynes, not in their slack water but in the rapids below.

9. Mute Swan *Cygnus olor.*

In the Vienna town region semi-tame birds are kept, and for the winter they are taken from the parks to the Old Danube which rarely freezes and where the birds are fed. Individuals or smaller groups are also found on both sides of Vienna, where they up-end near the banks in the shallow water regions. The maximum count is 46 birds in the middle of February 1965.

10. Wigeon *Anas penelope.*

It is found regularly with an aggregate of 5 to 35 and a maximum of 10 (November to January). It is a scarce wintering bird, but may be more numerous during migration, from the second half of August to the middle of November and from the beginning of March to the end of May.

11. Gadwall *Anas strepera.*

It is to be found in this area with a maximum of less than 20 birds. The aggregate for the winter 1964-65 is 16; 1965-66, only 1 bird in November; 1966-67, 9; and 1967-68, 18. The highest count was 15 in March 1968.

12. Pintail *Anas acuta.*

In the winter of 1964-65, an aggregate of 18; 1965-66, 5 (in January); 1966-67, 3 (in February).

13. Common Scoter *Melanitta nigra.*
Found regularly but in small numbers, especially in November and December (a maximum of 7 birds on 8.12.63). The predominance of females is striking.

14. Scaup *Aythya marila.*
Only a few birds are regularly recorded, especially in January to February. It is, however, characteristic of this species that larger groups may suddenly turn up (for example in December 1967, 37 birds on sector IV).

15. Long-tailed Duck *Clangula hyemalis.*
Surprisingly, this species is a regular guest on our Danube stretch, with a maximum of 5 birds per winter. The migration period lies between November and December, a very few separate individuals also occur in January, the species being more numerous again during the spring migration, from the end of February to the beginning of April. The striking fact that they are found within the town areas of, among others, Krems, Tulln and Vienna is connected, by Bauer and Glutz (1968), with the mass occurrence of *Dreissena polymorpha* which is not affected by pollution and is stimulated by eutrophication. Some individuals will stay for an extraordinarily long time. The observations refer mainly to females and juveniles.

16. Black-necked Grebe *Podiceps nigricollis.*
The maximum numbers are about 5, mostly in November. They are also found regularly along the Danube in March, especially in the groynes of the Vienna town area.

Group C: species to be found irregularly and in small numbers.

1. Garganey *Anas querquedula.*
It is totally absent in winter and during the counting period it is only found regularly in March. According to other observations, the spring migration in March to the end of April seems quite notable. This agrees with Impekhoven's (1964) supposition that an important spring migration may go through the pannonic part of Austria and Hungary.

2. Shoveler *Anas clypeata.*
It is only recorded irregularly in the area during the counting period, with a maximum of 10 in January 1965. Especially found on the dead river arms along the river.

3. Red-crested Pochard *Netta rufina.*
To be found irregularly during the counting period but also at other times.

4. Ferruginous Duck or White-eyed Pochard *Aythya nyroca.*
This species does not winter on the river. The main migration is during April and the first ten days of May. In autumn, especially the end of October, individuals are seen. Some appear on the Old Danube, a maximum of 6 in mid-December 1964.

5. Eider *Somateria mollissima.*
Almost every year some individuals appear, especially from the beginning of November, being mainly females and juveniles.

6. Red-necked Grebe *Podiceps griseigena.*
This species was recorded almost every year. Maximum in November 1965: 3 birds. Strikingly, it has a preference for the slack water behind the groynes.

7. Slavonian Grebe *Podiceps auritus.*
Usually absent but under special circumstances it reaches a maximum of 5 birds, as in November 1964.

Group D: rare and accidental visitors.

1. Great Northern Diver *Gavia immer*; 2. White-headed Duck *Oxyura leucocephala*; 3. Shelduck *Tadorna tadorna;* 4. Ruddy Shelduck *Tadorna ferruginea*; 5. Pink-footed Goose *Anser brachyrhynchus*; 6. Brent Goose *Branta bernicla;* and 7. Whooper Swan *Cygnus cygnus.*

Group E: temporary visitors

1. Bean Goose *Anser fabalis.*
The winter population is restricted to the two basin landscapes of Eastern Lower Austria, the Tullnerfeld to the west of Vienna and the Marchfeld to the east. Here grazing is available because of the short duration of snow cover, the open water of the river is available for drinking, and roosting sites exist on the large rubble areas resulting from the low water level in winter. As the possibilities for grazing and roosting are also present at the Neusiedlersee but no large winter population of the Bean Goose is found there, the availability of drinking water (at Neusiedlersee the lake and the 'Lacken' freeze completely) seems to be the most important condition for the wintering of

this species (see Leisler 1969). In all, the Austrian winter population is less than 1,000. In the main migration month of October, a spectacular movement takes place along the Danube. In spring, especially in February and March, the species again migrates, more quickly, through the region. The Austrian population is small in comparison with the winter population of the upper sector of the Middle Danube where at least 15,000 could be counted at the Czechoslovakian-Hungarian border sector in the mild winter of 1963-64 (Hudec, Nagy and Randik 1967). The populations of the Marchfeld link with the Slovakian population at the March. Whether the decrease in the formerly impressive winter population in the Tullnerfeld is connected with the general decline of the species in recent times or with a decrease in the growth of buckwheat *Fagopyrum* in the area, as the sportsmen assume, cannot be answered here. As for the choice of roosting sites, the species is rather adaptable, thus in the winter of 1964-65 big flocks passed the night on large ice sheets along the banks of the Danube.

2. White-fronted Goose *Anser albifrons*.
The small population, less than 500 birds, is mainly found on the East section. This species does not show such a striking migration at the Danube. More common, however, are smaller groups which come to the Danube to drink and bathe and which let themselves be drifted downstream.

3. Greylag Goose *Anser anser*.
This species is almost totally absent in winter. However, in autumn, especially in the second half of October, a strong migration occurs in the Tullnerfeld. There seems to be a regular exchange between the population of the southern Mähren and that of the Neusiedlersee, possibly along the March.

PART IV. ECOLOGICAL PROBLEMS OF WATERFOWL ON A RIVER

We shall now try to analyse the river as habitat for waterfowl and to show how it differs from a static lake. The lake district in the Burgenland is of significance in Europe as a breeding and migration area for waterfowl (Festetics and Leisler 1968). In the Seewinkel alone, 12 species of waterfowl breed with a total of 1,200 pairs and during the autumn migration a maximum of 50,000 waterfowl can be observed. However, when the lake area freezes in high winter the Danube in Lower Austria, 20 km. away, is the only large, ice-free water area, forming an important refuge area for the Mallard and the Bean Geese, amongst others. Yet hardly five species of waterfowl breed on the Danube in small numbers, whereas 23 species are found as regular migrants and winter visitors with a winter maximum (January) of 14,200 birds.

A river can be considered an 'open system', in that it has practically no boundaries upstream or downstream. The surroundings, created by the river itself, form a communicating environment. That means that a river, in contrast to a lake, is not only an open system, but also a dependent one, not a self-sufficient habitat in which important nutrients are retained, but one in which they are constantly supplied and carried off.

A. Breeding site

Because of the current, there are no breeding waterfowl on the surface of a river, nor on the banks, especially where it is regulated. Steep banks and a constantly changing water level are also unfavourable. Dead river branches, however, especially when they are silted up, begin to resemble woodland ponds and provide breeding sites for some species (for example Teal, Little Grebe or Coot). The water meadow woods provide nest sites (for example for Mallard and Cormorant). Notwithstanding its relatively short shore line a lake, because of the much more favourable ecology of its shores, produces much larger breeding populations of waterfowl.

B. Feeding site

Flowing water is a permanent source of food, as there is always open water and in addition various substrates are exposed by water level fluctuations, such as rubble, mud or sand. The length of the banks is much greater in relation to water surface in the case of rivers than in almost round lakes, though with very indented shores and transitional vegetation the proportions of a lake can be easily improved (Kalbe 1967). However, the water surface forms the largest feeding area for birds. The strongest unfavourable factor in a river is the current, which often makes it very difficult to reach the food. Only the divers, which are extremely adapted, can hold out here, like the three merganser species, the group of diving ducks, the

Goldeneye and the Cormorant. An adaptable species, like the Mallard, may develop ways of feeding which are specific for these special circumstances ('conveyor belt'). Except for the large schools of fish, the water itself produces very little food. Organic residues, floated into the river from the natural production sites or poured in as sewage, are of importance. Thus in a river outside factors dominate in food production, while a lake produces its own food sources. Therefore lake types (oligotroph, eutroph or dystroph) can only be compared with river sectors (for example the Grayling zone and Barbel zone) in a limited way. Moreover a river, because of its capacity for self-purification, never shows the same degree of pollution over long distances as does a lake. In our middle sector the lack of any inorganic turbidity or organic colouring and the shallowness assists many waterfowl in their search for food. But transparency can decrease in places as a result of industrial effluents. Ice-formation can also be of decisive influence on the intake of food of various species (for example Teal).

Notwithstanding its relative expanse the littoral of a river is not a suitable feeding site. Here the food supply is made up of what is washed ashore and of the few small current-loving animals living among the stone blocks, and also the plant growth with its inhabitants. An important food source are the driftlines (carcasses, rubbish, parts of plants, seeds, grains) yet they can only be reached where the banks are sloping and the water is shallow. Only a few species (Coot and some dabbling ducks) will also feed along dried-out driftlines.

On the bottom of a river it is especially characteristic that vascular plants are absent in contrast to a lake. On the other hand, the animal populations are well developed in places. Of the fishes of the Danube, the endemic fish population is notable and, in comparison with a lake, quantitatively dominant. The bottom, especially the channel being the deepest part, is unsuitable as a feeding site for diving birds because of the strong current and moving pebbles. A moderate food supply is then found only in the dead water spaces and current shadow behind obstacles, such as the groynes.

We must refer to the importance of the adjacent dead river branches. As a result of the warm stagnant water, a rich supply of nutritious substance and low turbidity, these become important production sites and thus are, from an ecological point of view, comparable with ponds. Because of a richly developed bottom-rooted, floating and transitional vegetation, because of the rich population of animals living on the bottom, often in the mud, and because of the great quantity of fish (introduced species as well as endemic ones), the dead river arms form an ideal feeding site, for plant- and animal-feeding, swimming and diving species. They can, however, only be used for a short period as, in contrast to a river, they freeze regularly. For short periods also, the further surroundings of the river, such as the stubble fields at Marchfeld, can offer an important feeding site for certain dabbling ducks, especially Mallard (Abensperg-Traun 1960). The feeding conditions at the river are thus favourable, notwithstanding the above-mentioned limitations, so the Danube, together with its accompanying biotopes, could hold a still larger waterfowl population than it does.

The wide range of types of food for the waterfowl at the Danube in wintertime clearly favours the animal-feeders: six species (the three mergansers, two divers and the Great Crested Grebe) are, as pure piscivores, represented in the region with a total of 590 in the high winter population of January. To this group, the 700 to 1,000 Cormorants in spring could be added. A group with seven species (Goldeneye, Velvet Scoter, Common Scoter, Long-tailed Duck, Scaup, Little Grebe and Black-necked Grebe), with 1,548 birds, feeds mainly on animal food. One single species, the Mallard, forms the biggest group, as omnivores, with 11,500 birds. Mixed animal- and plant-feeders are the three species, Pochard, Tufted Duck and Teal, with a total of 595 birds. Finally, five species, which are mainly vegetarian, comprise only 55 birds: Coot, Mute Swan, Pintail, Wigeon and Gadwall. Consequently the Danube shows a clear difference in its winter population from the Neusiedlersee region (breeding and migratory populations), where the plant-eating species very clearly dominate.

C. Resting site

The river itself seldom offers, and then only for short periods, a resting place for those species which will allow themselves to float downstream. Waterfowl will often roost on ice-floes. More often, shallow waters and impoundments are used for resting. At the stagnant dead river branches the roosting possibilities are the same as those at a lake, although their width is restricted in places by the water

meadow woods. Of the hard substrates in the water, sand and rubble banks, and also the groynes, are of the first importance. Along the banks and rarely on stretches of grass and high water dikes there are occasional resting sites. At high water rubble banks and groynes are lost as such. In all, the supply of resting sites at the river, compared with that of a lake, is more varied, but less favourable.

A river has far more disturbances than a lake, although this varies greatly in places. The most permanent but most innocent disturbance is certainly shipping. This is relatively slight on the Danube compared with western European rivers (Rhine, Elbe or Rhône) and is of influence both from the actual disturbance and from the wash of the waves. When a ship comes along the birds can fly away parallel to the river (Goldeneye), move to the dead river arms (Mallard), or wait, while circling high overhead, until the disturbance is past (Cormorants). Mergansers and divers will often get out of the way by submerging. A really notable disturbance is created by the anglers, because they occupy, often for several days, potential resting sites (especially the groynes). Shooting has a much greater influence on the waterfowl of a lake than on those of a river, which is topographically less favourable to the shooter. In the vicinity of towns, recreational pressure is felt strongly along the banks of the Danube, especially at weekends. Finally, in the East section of our counting stretch, the wintering White-tailed Eagles constitute a not insignificant disturbance. In between Vienna and the Czechoslovakian border up to 13 individuals may be found (Spitzer 1966). When they appear they flush the resting waterfowl flocks; if they sit quietly they are accepted. A disturbance is generally greater than on a lake, where there are usually reasonable 'buffer zones'. In the case of a lake, which has a relatively larger water surface in comparison with the length of its shore, the refuge possibilities are, in general, more favourable.

Finally, we would like to point out the various nature conservation problems: human interventions at a river do not fundamentally reduce the water surface, as they do in the case of static water (by drainage). On the contrary, the dams enlarge the water area. The banks, however, have been fundamentally changed by slope improvement. The dead water areas, not only as an important supplement to the river, but also as an independent biotope, are no less in danger than peat bogs, marshes or small lakes. A great part of these environments along the Austrian Danube has been lost and the conservation of those still in existence is the most urgent task of nature conservation along the river.

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Summary

The environment and winter population of the waterfowl of a section of the Danube are discussed in detail, based on co-operative work over five years. In the first part, the course, environments and life of the whole Danube, from its source to its mouth, are sketched. In the second part the breeding and winter populations of the waterfowl (based on three years' mid-winter counts) are mentioned in relation to the characteristics of the whole Austrian stretch. In the third part we describe the 128 km. long counting stretch in Vienna and Lower Austria as a waterfowl biotope and analyse the counting results from five winters. The individual species are discussed in terms of population size, phenology, distribution, feeding and roosting. In the fourth part the river as a waterfowl biotope is contrasted with a lake.

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