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THE SIGNIFICANCE OF ARTIFICIAL BARRIERS TO MIGRATION ACROSS INTERNATIONAL BORDERS

(This document was prepared by Prof. Wim Wolff for consideration by the fifth meeting of the Scientific Council. It is reproduced as an information document of the twelfth meeting of the Council as a reference for its work on barriers to migration)

1. Introduction

1. Migrations of birds are well known. Many species migrate annually between their breeding ranges and wintering areas which, in many cases, are situated thousands of kilometers from each other. In some cases, other types of migrations, e.g. to moulting areas, occur. It is less well known that many other species of animals migrate as well. Many marine mammals migrate from polar environments to temperate waters, terrestrial mammals move across large areas in various continents, bats fly large distances. Marine turtles, marine and freshwater fish, squids, crustaceans such as shrimp and crabs, butterflies and various other insects also migrate, sometimes even over long distances.

2. Migration is not an haphazard process. Of course, the process has to connect suitable areas for breeding and non-breeding periods, but also the migration route itself has to be suitable. For a small songbird living normally in forests, the open sea and the desert are unsuitable habitats which may act as a barrier to migration. For marine organisms, even the smallest isthmus, e.g. those near Suez and in Panama, constitutes an impenetrable barrier. Depending on its habitat requirements and its locomotory capacities, each species experiences its own natural barriers to migration. An icecap will be a barrier to most species, but a forest constitutes a barrier only to grassland species and other animals from very different habitats. Some natural barriers, such as a mountain range or a sea, seem very straightforward. However, much more subtle barriers do occur as well, such as differences in salinity in the sea or the absence of a required food species on the land.

3. In thinking about migration and barriers two concepts are useful, viz. 'resistance' and 'connectivity'. Both concepts have to be defined in relation to a particular type of habitat and in relation to a particular species. A small songbird with a strong affinity to forests usually has no problems moving or migrating through a forested landscape. Hence, the connectivity of this landscape for this species is high and the resistance is low. However, when the forest becomes interrupted by a grassland or a large river, this songbird may hesitate to cross the area of different habitat. This different habitat thus has an higher resistance to this species. In case of a grassland with some scattered trees, the songbird may ultimately decide to cross the unsuitable habitat, but in case of the river it may decide not to do so. Hence, the resistance of the grassland is higher than that of the forest and that of the river is still higher (100%) for this species. Even when the species has no problem crossing different types of habitat, the outcome of the crossing may be different. For example, in one type of habitat the toll taken by predators may be low, whereas in another habitat predators may severely curtail the population.

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4. In conclusion, natural barriers are not absolute features. Their resistance may differ for each migratory species and for many species the resistance will never be 100%. The same will be true for artificial, man-made barriers.

2. Types of artificial barriers and potential consequences

2.1. Altered habitats and landscapes

5. Both on land and in water, humans have profoundly altered the environment in many regions of the world. On land, forests have been cut down, marshes have been drained, and agriculture has claimed large parts of the landscape. The increase of the size of urban areas is another major change. Consequently, for many species the connectivity and resistance of the landscape have changed.

6. In water similar changes have occurred. Some bodies of water have been turned into land, but elsewhere the physical and chemical environment have changed greatly. Discharge of cooling water has increased the temperature of rivers, making them unsuitable for cold-water species. Discharge of sewage and other pollutants has changed the chemical 'landscape'. Hence, also in the aquatic environment, the connectivity and resistance of the landscape have changed.

2.2. In water

2.2.1. Hydroelectric dams and barrages in rivers

7. For the purposes of power generation and irrigation, many rivers all over the world have been provided with large dams. These not only change the aquatic environment upstream and downstream of the dam, but they usually also form an impenetrable barrier to migration of aquatic organisms. Upstream species normally are not able to move across the dam, whereas downstream migration may be possible. However, when the water is discharged from the bottom layers of the lake behind the dam, many species will not be able to move downstream. This type of barrier, therefore, provides a very high resistance to the migration of river dolphins, many species of fish, and several species of crustaceans.

2.2.2. Weirs, sluices, and locks

8. In slow-flowing rivers and stagnant waters, often weirs, sluices, or locks have been constructed to facilitate shipping and to regulate water supply for agriculture and urban areas. Although these structures may be seen as a barrier to migration of aquatic animals, their resistance is less than 100% for most species. Many species have the capacity to cross the structure unaided and for other species special provisions have been created, such as fish ladders.

2.2.3. Barrages in estuaries

9. Many estuaries have been provided with barrages, either to prevent storm surges from flooding the hinterland, or to save fresh water for agriculture and drinking water, or to facilitate shipping. In many cases, all purposes are served. If barrages are only intended to prevent flooding, they are normally open and do not form a barrier to migration. However, if barrages are closed because of fresh water storage or other reasons, migration may become more difficult. Normally, however, such barrages are open part of the time to discharge excess fresh water, thus enabling fish and other aquatic species to cross the barrage in both directions. This type of barrage certainly increases resistance to passage, but usually it is not 100%. The change of the aquatic environment behind the barrage may be more important.

2.3. On land

2.3.1. Fences

10 Fences are usually constructed to keep cattle or other domestic animals in the place where they are supposed to be. In many cases, such fences do not form serious barriers to migratory wild animals, although exceptions are known. Some fences, however, are constructed for veterinary purposes or to keep out wild animals, and such fences form serious barriers to migration of wild animals.

2.3.2. Major roads, railways

11. In principle, any line-shaped artificial structure in the landscape may form a barrier to migration. Some species simply will not cross the artificial material, but other species will attempt to cross. In that case, they run the risk of injury or death through a collision, a risk which increases with the intensity of the traffic. In some cases, traffic will be so intense that a major road becomes an important barrier.

2.3.3. Canals and ditches

12. Water often forms a barrier for terrestrial animals because they cannot or refuse to swim. However, many terrestrial species are able to swim when they really need to do so. Canals may also form a barrier for these species because the sides are too steep for them to leave the water again.

2.3.4. Other constructions

13. Several other man-made constructions may form a barrier to migration. Surface pipelines sometimes form very long line-shaped structures, as do overhead electric power lines. Both types of structures certainly do not form major barriers although individual animals may experience difficulties in crossing these structures or even are killed in the attempt.

14. Elsewhere, television towers and other large broadcasting antennas are believed to have an effect on migratory birds by disturbing their navigation system. A similar effect on nocturnal migrants is known from lighthouses and gas flares at sea in very dark nights.

3. Some examples

3.1 The Rhine river

15. The Rhine river runs from Switzerland through France, Germany and The Netherlands towards the North Sea. Originally anadromous fish species, such as sturgeon, salmon, houting, and allis shad, migrated annually from the North Sea upstream to spawn in the river and its tributaries. Catadromous species, such as eel and flounder, spent part of their life in the river and went to sea to spawn. Porpoises and harbour seals were regular inhabitants of the lower course of the river.

16. In the 19th and 20th centuries, the river changed drastically. Barrages have been built in many of its tributaries, weirs and locks in the river itself. Three of its four outlets to the sea have been closed by dams or barrages. The temperature of the river has increased, although not very much, and the chemical environment of the river has changed drastically. In the worst period, i.e. in about 1970, oxygen levels dropped to about 50% saturation and innumerable chemical pollutants occurred in the river.

17. This has had far-reaching consequences for migratory animals in the river. Marine mammals no longer occur in the river, probably because of changes in water quality and the barrages in the estuaries. Anadromous species have either disappeared, such as sturgeon, houting, and allis shad, or strongly declined in numbers, such as river lamprey, sea trout, and smelt. In these cases, barrages made their spawning areas

hard to reach, the chemical 'landscape' of the river had changed, and the estuaries were hard to enter because of barrages.

18. At present, the Rhine states are trying to rehabilitate the river system. In the year 2000, salmon has to be returned in the Rhine river. However, the 'landscape' of the river has changed so much that it is still questionable whether a viable population of salmon can ever be accommodated again in the river.

3.2. The Okavango delta

19. The Okavango delta is situated in Botswana and covers roughly 10,000 km². It is mainly fed by the Okavango River which brings water from rains in the highlands of Angola. In addition, local rains support the water balance. The river floods the area usually in March-April, later in the year large areas become dry again. The delta is a wet nucleus in an otherwise rather dry country and in the dry period it is the goal of numerous migrating large terrestrial mammals.

20. The Botswana Government has constructed fences to control diseases in commercial cattle herds. In some cases, these veterinary fences also restrict migration of wild animals to water. In dry years, tens of thousands of wild animals have died because of these barriers to migration.

3.3. The badger in The Netherlands

21. The badger is a rather rare species in The Netherlands. It has been heavily persecuted for various reasons, but nowadays it is protected from hunting. However, the species is not really safe, because it experiences the negative impact from motorways and other roads which serve as a barrier to migration. Especially young animals tend to migrate in order to settle elsewhere in a suitable living area. Doing so they have to cross roads and this causes annually a number of collision victims which is of the same order of magnitude as the annual population recruitment.

4. Remedial measures

4.1. General

22. It is not possible to state which form of artificial barrier is most harmful to migratory species. That is not only because we do not know sufficiently what the effects are, but also because the situation is different for each species.

23. In general, however, alteration of the landscape, both on the land and in the water, appears problematic for many species. More specifically, hydroelectric dams and barrages in rivers and large fences on the land appear to have very drastic effects because they almost completely inhibit migration. Other barriers appear to have less of an impact on migratory animals and allow a certain proportion of the migratory population to cross the barrier.

24. Alteration of the landscape is a feature of our society and it cannot always be prevented everywhere. However, a set of instruments is available to mitigate the effects of landscape change. In the first place, we need to have baseline surveys in order to know the characteristics of the original landscape, especially as a place where animal migration may take place. An aspect of this is the determination of the genetic variability of the populations present. This may give information on the possible impact of the construction of barriers in the landscape. With the information thus obtained, Environmental Impact Assessments can be made, preferably also in cases where land is reclaimed for agriculture or in case of town development. These EIAs should make it possible to determine the most sensitive and vulnerable situations for migratory animals. The following physical planning may result in a landscape development which is optimal, or less negative, for migratory animals.

25. For the construction of specific forms of barriers to migration, the same instruments should be employed, but in addition mitigation may be found in the design of the structure.

4.2. Specific measures

4.2.1. Dams, barrages, weirs, sluices, locks

26. When the difference in water level on both sides of a construction across a river, estuary or other water course is not too large, special design features may be helpful to enable migration of fish and other aquatic organisms. Among these are fish ladders, i.e. cascades of series of ponds along which fish can jump from one pond to the next, and fish sewers, i.e. tunnels through which the water always flows unimpeded and which allow the passage of fish.

27. Another way is to operate the constructions in a way which allows passage of aquatic organisms. Barrages can remain slightly opened during the larger part of the year or the most important part of the migration season. Locks can be operated to move fish instead of ships, in periods in which no ship traffic is needed.

4.2.2. Roads, railways

28. To allow migration across barriers formed by roads and railways, one can construct bridges or tunnels for wild animals. Bridges have been constructed successfully for deer ('cerviducts') in The Netherlands; tunnels have been made in many countries for a variety of species. Of course, wild animals can also profit from construction made for human use; in such cases, the construction may be optimized for animal use.

29. Another possibility is to stop traffic in periods with high risks for migrating animals. This is practiced in several places for migratory amphibians.

4.2.3. Canals

30. The bank of canals often is covered by stone, concrete or wooden revetments which are hard for swimming animals to climb. Along such canals the bank can be indented with gentle sloping shores or provided with steps to allow animals to leave the water.

5. Conclusions pertinent to the aims of the Bonn Convention

31. From the preceding paragraphs it becomes clear that many barriers to migration have an impact especially on a regional or national scale. The types of barriers most likely to have an impact on international migration are the alteration of the landscape, both on the land and in the water, and the construction of dams and barrages in rivers and estuaries.

32. The Bonn Convention may be used to prevent, or more often, to mitigate the effects of these and any other type of barrier as long as migratory species can be identified which migrate across international borders and may suffer from such barriers. For example if migratory fish in an international river (and the river fisheries!) will suffer from the construction of a dam, an Agreement under the Bonn Convention may be signed in order to protect the fish populations (and the fisheries!) by preventing the building of a dam or by adapting the design of the barrage.